FOSS4G-ASIA 2021

Dhulikhel, Nepal

PROCEEDINGS of FOSS4G-ASIA 2021

FOSS 4G IN THE ERA OF ARTIFICIAL INTELLIGENCE, IOT FOR LAND MANAGEMENT AND SUSTAINABLE DEVELOPMENT

SEPTEMBER 30, OCTOBER 1 & 2 , 2021

DHULIKHEL, KAVREPALANCHOK, NEPAL

Government of Nepal
Ministry of Land Management, Cooperatives and Poverty Alleviation
LAND MANAGEMENT TRAINING CENTER
Dhulikhel, Kavre, Nepal

Editors

- Venkatesh Raghavan
- Reshma Shresta
- Natraj Vaddadi

FOSS4G-ASIA 2021

KATHMANDU UNIVERSITY, DHULIKHEL, NEPAL

Over the last few decades, Free and Open Source Software (FOSS) has grown tremendously in scope and popularity. FOSS has gained the attention of the Geoinformatics community and created new opportunities for developing local capabilities.

FOSS4G-Asia 2021 is the international gathering of the Asian Free and Open Source Software for Geoinformatics Community. FOSS4G-Asia 2021 aims to support the global agenda of sustainable development goals including land management and contribute to Artificial Intelligence and IoT by bringing researchers, professionals, developers, students, and other stakeholders in Asia on a common platform.

FOSS4G-Asia 2021 was hosted at Kathmandu University by the Department of Geomatics Engineering with support from the Department of Computer Science and Engineering and Land Management Training Centre.

Considering the pandemic situation globally, and the situation in the host country, the conference was organized in a "Hybrid Mode" on 1st and 2nd October 2021 at Kathmandu University, Dhulikhel, Nepal. Pre-conference training workshops were held on 30 September 2021.

The overall theme of the conference was - ***FOSS4G in the era of artificial intelligence and IoT for land management and sustainable development.*** The presentations and papers covered the following nine themes:

- People to Land Relationship and Urban System (PLUS)
- Web, Mobile and Location Based Services (WeMLBS)
- Spatial Land use Planning and Decision Support System (SPDSS)
- Artificial Intelligence for Geospatial Applications (Geo AI)
- Geospatial Technologies in Agriculture, Forest and Environment (GeoAFE)
- Innovative Technologies, Research and Experience Sharing in Geospatial Capacity Development (IRGCD)
- FOSS4G for Disaster and Epidemiology (FOSSDE)
- Geospatial Applications in citizen science (GCS)
- Geospatial Plugins, Packages and platform development (GPPPD).

In all over 50 presentations, 58 abstracts, 24 full papers and 7 workshops were presented as a part of the successful conference.

CONFERENCE CHAIRS

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FOSS4G-ASIA 2021
Dhulikhel, Nepal

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Geo-Information & Earth Observation Services

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PROGRAMME OVERVIEW

DATE	ACTIVITY	TIME
Thursday, September 30th, 2021	Workshops	9:00 to 16:00
Friday, October 1st, 2021	Opening Ceremony Paper Presentations	9:00 to 10:25 11:00 to 18:00
Saturday, October 2nd, 2021	Paper Presentations Closing Ceremony	9:00 to 17:00 17:00 to 18:00

PROGRAMME - WORKSHOPS SCHEDULE

TIME	WORKSHOP ID	TITLE	TUTOR/S & DETAILS
09:00-12:00	WS-01	**Python for geospatial analysis and machine learning**	**Prakash P S** psprakashgis@gmail.com IIT Kharagpur
	WS-02	**Web Mapping Using GeoServer and OpenLayers**	**Shailesh Chaure** chauresk@gmail.com Govt. Holkar Science College, Indore, India
	WS-03	**MS4W: Easy Step-by-Step Serve & Deploy on Windows**	**Jeff McKenna** jmckenna@gatewaygeomatics.com GatewayGeo
	WS-08	**OGC API – The Modern Geospatial data access standard**	Prasong Patheepphoemphong + 2 prasong.p@i-bitz.co.th i-bitz company, Thailand
13:00-16:00	WS-04	**Introduction to Re:Earth – An innovative WebGIS OSS I which uses Cesium**	**Hidemichi Baba** h.baba@eukarya.io Eukarya Inc.
	WS-05	**Spatial Data Collection for Society with Epi-collect5**	**V. Ravi Kumar** ravivundavalli@gmail.com Director (retired), Geological Survey of India and Secretary, OSGEO India
	WS-06	**Deep Learning with the PyTorch Package for High-level Earth Observation Analysis**	**Thomas Y. Chen** thomasyutaochen@gmail.com Academy for Mathematics, Science, and Engineering
	WS-07	**Tethys: A platform for developing and hosting GIS/RS Science applications**	**Rajesh Thapa & Kiran Shakya** rajeshthapa@icimod.org kiranshakya@icimod.org ICIMOD

PROGRAMME - DAY 1 - OPENING SESSION

Time [UTC + 5:45]	Session	Activities Physical Participation: C.V. Raman Auditorium Virtual Participation: https://zoom.us/webinar/register/WN_7BfWiARZRXeJQNyRh20yGQ
08:30	Opening Ceremony	Registration /Tea Coffee (On-site Participants)
09:00		National Anthem of Nepal
09:05		Kathmandu University Anthem
09:10		Delegates Seating
09:15		Welcome Dr. Reshma Shrestha, Conference Coordinator (Kathmandu University)
09:20		Inauguration [Lighting the lamp]
09:25		Opening Remarks: Prof. Dr. Manish Pokharel, Conference Chair (Kathmandu University)
09:35		Remarks: Mr. Ganesh Prasad Bhatta, Executive Director, Land Management Training Center
09:45		Remarks: Dr. Sunil Babu Shrestha, Vice Chancellor, Nepal Academy of Science and Technology
09:55		Remarks: Er. Ganesh Shah, Former Minister of Environment, Science and Technology
10:05		Remarks: Prof. Dr. Bhola Thapa, Vice Chancellor, Kathmandu University
10:15		Remarks: Prof. Dr. Venkatesh Raghavan, Conference Chair (FOSS4G-ASIA)
10:25		Group Photo
Break (1 hour)		
Time [UTC + 5:45]	**Session**	**Moderator: Dr. Bal Krishna Bal Physical Participation: C.V. Raman Auditorium Virtual Participation: https://zoom.us/webinar/register/WN_7BfWiARZRXeJQNyRh20yGQ**
11:30	Keynote Session-1	**Dr. Junho Lee** Data-driven urban problem solving platform : COMPAS
12:15		**Prof. Dr. Xianfeng Song** Development and challenges of open source geospatial technology in China
13:00		**Prof. Dr. Rangajeewa Ratnayake** 4ONSE- Lessons leant from FOSS for climate-based services

PROGRAMME - DAY 1 - THEME 1

Time [UTC + 5:45]	Session	**THEME 1:** **People to Land Relationship and Urban System (PLUS) Physical Participation: Mini Auditorium** **Virtual Participation:** https://zoom.us/webinar/register/WN_W9OIh_N3RcqzC2wLwUSV1w
		Session Chairs: Prof. Rangajeewa Rathnayake, Prof. Venkatesh Raghavan
14:15	Technical Session -1	[Paper ID-44] **Quantum GIS Based Suitability Analysis for Effective Planning Of Solid Waste Management Of Kathmandu Valley** [Prashant Thapaliya]
14:30		[Paper ID-51] **Importance of Land Use Planning in the Management of Urbanization** [Anjali Pathak]
14:45		[Paper ID-68] GIS art as means of urban revitalization - **A case study on Bangalore city of India** [Madhuri Ramamurthy]
15:00		[Paper ID-71] **Examine the effect of the physical characteristics of the Urban Green and Blue Spaces in Heat Mitigation: A case study of Palakkad city** [Vignes H P M]
15:15		[Paper ID-78] **Comparative Study of Mapping Land Parcels with Fit-for-Purpose Tools and Conventional Techniques to Support Tenure Security for All** [Raja Ram Chhatkuli]
15:30		[Paper ID-72] **Geoenabled municipal energy planning (MEP) in new federal context of Nepal** [Hari Krishna Dhonju]

PROGRAMME - DAY 1 - THEME 2

Time [UTC + 5:45]	Session	**THEME 2:** **Web, Mobile and Location Based Services (WMLBS) Physical Participation: Senate Hall** **Virtual Participation:** https://zoom.us/webinar/register/WN_HyISUptESV-hUak0fqBmaA
		Session Chairs Prof. Xianfeng Song, Dr. Upama Ashish Koju
14:15		[Paper ID-47] **Web GIS Application by using open source software - A Case study of Hyderabad Urban rural belt (15-40 kms).** [T.Pratigna]
14:30		[Paper ID-32] **Development and prospects of Re:Earth, an open source GIS web app using Cesium** [Kenya Tamura]
14:45	**Technical Session -1**	[Paper ID-58] **Suitability of OSMAND Mobile App for Mapping and Monitoring of Rural Roads** [H K Solanki]
15:00		[Paper ID-62] **ShinyGeoVA: An Open source Web Application for Geospatial Visualisation and Analytics** [Tin Seon]
15:15		[Paper ID-46] **Introduction to Open Indoor Map** [Sanghee Shin]
15:30		[Paper ID-24] **MapMint: The service-oriented platform [Web]** [Gérald Fenoy]

PROGRAMME - DAY 1 - THEME 6

Time [UTC + 5:45]	Session	**THEME 6:** **Innovative Technologies, Research and Experience Sharing in Geospatial Capacity Development (IRGCD) Physical Participation: Mini Auditorium** **Virtual Participation:** https://zoom.us/webinar/register/WN_W9OIh_N3RcqzC2wLwUSV1w
		Session Chairs: Prof. Ramesh Kr. Maskey, Dr Bharath H Aithal
16:00	**Technical Session -2**	[Paper ID-15] **Potential of Free and Open Source Software for Education in Developing Countries** [Pawan Thapa]
16:15		[Paper ID-50] **Teaching Geographic Information Science concepts with QGIS – lessons from 4 years of distance education** [André Mano]
16:30		[Paper ID-48] **Passport in my shoe: The History of FOSS4G** [Jeff McKenna]
16:45		[Paper ID-38] **MapServer Project Status Report** [Jeff McKenna]
17:00		[Paper ID 80] **Automated Coastal Monitoring using Deep Learning Techniques using UAV images** [Laxmi Thapa]
17:15		[Paper ID-29] **Solutions for monitoring air quality: A proposal of air quality monitoring sensor network based on Internet of Things (IoT)** [Rojina Shakya]

PROGRAMME - DAY 2 - KEYNOTE SESSION 2

Time [UTC + 5:45]	Session	Moderator: Sanghee Shin Physical Participation: Mini Auditorium Virtual Participation: https://zoom.us/webinar/register/WN_fZn8Q86YSYKjXdiYu8lg2A
08:00		**Dr. Sarawut NINSAWAT** From Maps to DSS with Big Data and Machine Learning
08:45	**Keynote Session-2**	**Dr. Nguyen Quang Tuan** Application of open source software to build and deploy SDI system for Thua Thien Hue province
09:30		**Dr. Iwasaki Nobusuke** Where do we come from and where are we going? -15 years progress of OSGeo Japan chapter

PROGRAMME - DAY 2 - KEYNOTE SESSION 3

Time [UTC + 5:45]	Session	Moderator: Dr. Subash Ghimire Physical Participation: Senate Hall Virtual Participation: https://zoom.us/webinar/register/WN_AMXLkXIlQFyZ0HlbZ4Q2Kw
13:15 PM		**Mr. Janak Raj Joshi** Free and Open-Source Software for Land Management in Nepal
14:00 PM	**Keynote Session-3**	**Prof. Dr.-Ing. Franz-Josef Behr** Commons as an inner Habit and the Impact of the OSGeo Foundation
09:30		**Dr. Iwasaki Nobusuke** Where do we come from and where are we going? -15 years progress of OSGeo Japan chapter

PROGRAMME - DAY 1 - THEME 4

Time [UTC + 5:45]	Session	**THEME 4:** **Artificial Intelligence for Geospatial Applications (GeoAI) Physical Participation: Senate Hall** **Virtual Participation:** https://zoom.us/webinar/register/WN_HylSUptESV-hUak0fqBmaA
		Session Chairs: Dr. Arun Pratihast, Prof. K.S. Rajan
16:00	**Technical Session -2**	[Paper ID-19] **Experimentation with Generative Adversarial Networks for Building Extraction from a Very High- Resolution Remote Sensing Imageries** [Prakash PS]
16:15		[Paper ID-37] **Need of Open Spatial Data Infrastructure: Application of Machine Learning Tools in Disaster Management and Mitigation.** [Subash Ghimire]
16:30		[Paper ID-14] **Novel approach to delineate cities and their population based on open source GIS applications, machine learning and open-data** [L.D.C.H.N. Kalpana]
16:45		[Paper ID-45] **Model Land Fragmentation by Using Feed Forward Neural Network and Decision Tree: Case of Western Province, Sri Lanka** [M.N.N. Ranaweera]
17:00		[Paper ID-28] **Object-based Image Classification Using Mask R-CNN and CNN** [Batbold Badamdorj]
17:15		[Paper ID-25] **Multi-layer perceptron - Markov chain based artificial neural network for modelling Urban Expansion in Ulaanbaatar, Mongolia** [Bolorchuluun Chogsom]

PROGRAMME - DAY 2 - THEME 3

Time [UTC + 5:45]	Session	**THEME 3:** **Spatial Landuse Planning and Decision Support System (SPDSS)** **Physical Participation: Senate Hall** **Virtual Participation:** https://zoom.us/webinar/register/WN_ciRtJgHGRmKtSCKO6_Jjlg
		Session Chairs: Raja Ram Chattkuli, Dr. N N Saldhuna
10:30	Technical Session -2	[Paper ID-74] **Web based spatial planning and decision support system** [Suhas S]
10:45		[Paper ID-11] **Future land use land cover scenario simulation using Open Source GIS for the City of Banepa and Dhulikhel Municipality, Nepal** [Sijan Bhandari]
11:00		[Paper ID-73] **AI based Land use Planning for Nepal** [Purna Nepali]
11:15		[Paper ID-55] **Spatiotemporal dynamics of Chamarajanagar region, Karnataka, India** [Rajeshwari N]
11:30		[Paper ID-59] **Impact of land use and land cover changes on the land surface temperature: A case study of Bhokardan, Central Maharashtra, India** [Ajit Jadhav]
11:45		[Paper ID-61] **Envisioning Rural Development in India through Spatial Planning and Decision Support System** [Dr. N.S.R. Prasad]
12:00		[Paper ID-49] **An Open Source Approach To Map Land Use In Urban Areas: Based On Deep Learning Technology** [H.W.A.S Sathsarana]

PROGRAMME - DAY 2 - THEME 5

Time [UTC + 5:45]	Session	**THEME 5:** **Geospatial Technologies in Agriculture, Forest and Environment (GeoAFE) Physical Participation: Mini Auditorium** **Virtual Participation:** https://zoom.us/webinar/register/WN_fZn8Q86YSYKjXdiYu8lg2A
		Session Chairs: Dr. Nobusuke Iwasaki, Dr. Sarawut Ninsawat
10:30	Technical Session -2	[Paper ID-35] **Growth Monitoring and Yield Estimation of Maize field using UAV** [Ganesh Pandey]
10:45		[Paper ID-34] **Multitemporal Unmanned Aerial Vehicle (UAV) data for Quantitative Measurement of Soil Deposition and River Track Change due to Flooding in an Agricultural Watershed** [Sujan Sapkota]
11:00		[Paper ID-30] **Banana Acreage estimation using Sentinel data and Google Earth Engine over Chamarajanagar district, Karnataka, India** [Barsale Sayali Bhagwan]
11:15		[Paper ID-65] **Multi criteria evaluation for potential forest ecosystem resilience** [S. Mira Shivani]
11:30		[Paper ID-69] **Continuous Assessment of Land Degradation and Its Impacts on Land Resources of Sivagangai Block,Tamil Nadu, India** [Himanshu Sharma]
11:45		[Paper ID-79] **A Long-term Assessment of Cropping Intensity using Google Earth Engine : Impact of Asia's Biggest Irrigation Project in India** [Nagaveni Chokkavarapu]
12:00		[Paper ID-17] **A Research on EIA (Environment Impact Assessment) Data Visualization using Open Source** [Sanghee Shin]

PROGRAMME - DAY 2 - THEME 7

Time [UTC + 5:45]	Session	THEME 7: FOSS4G for Disaster and Epidemology (FOSSDE) Physical Participation: Mini Auditorium Virtual Participation: https://zoom.us/webinar/register/WN_AMXLkXIlQFyZ0HIbZ4Q2Kw
		Session Chairs Mr. Birendra Bajracharya, Mr. Sanghee Shin
15:00	Technical Session -4	[Paper ID-26] **Multivariate building damage model for scenario based flood risk assessment** [Aishwarya Narendr]
15:15		[Paper ID-52] **Detection Of Shoreline Change Due To Impact Of Breakwaters At Ariyankuppam River Mouth In Puducherry, India By Using Remote Sensing And GIS** [Nandanaa Naresh Singh]
15:30		[Paper ID-56] **Spatial Modelling of Tamilnadu Economic Crisis During Covid 19** [Saraswathy Rajasekaran]
15:45		[Paper ID-57] **Spatial Modelling On The Incidence With Socioeconomic Aspects During The Pandemic At India** [Rathna Reddy]
16:00		[Paper ID-23] **GIS Modelling to Decentralize Examination Centers to Maintain COVID-19 Protocol** [Biplab Biswas]
16:15		[Paper ID-60] **Lockdown turned 'Farm to Fork' – Dream or Reality! - Agricultural Situation in Thanjavur, India before, during and after COVID-19** [S D Anitha Selvasofia]
16:30		[Paper ID-18] **Surface Runoff Estimation by SCS Curve Number Method in an un- gauged Usri River Basin using GIS** [Biplab Biswas]

PROGRAMME - DAY 2 - THEME 8

Time [UTC + 5:45]	Session	THEME 8: Geospatial Applications in Citizen Science (GCS) Physical Participation: Block No. 9, Virtual Participation: https://ku-edu- np.zoom.us/j/97043371638?pwd=V3BOdC9XT0taa2ZRZTJpTXdRZkZIUT09
		Session Chairs: Dr. Rehana Shrestha, Prof. Shailesh Chaure
15:00	Technical Session 4	[Paper ID-53] **Use of Geographical Information System (GIS) on Public Police Partnership (PPP) in Nepal** [Deepak Raj Awasthi]
15:15		[Paper ID-63] **Integrated PGIS for the Sustainable Development of Tourism in Machhapuchchhre Model Trek Route and Development of Mobile based Application** [D. Bishwakarma]
15:30		[Paper ID-76] Volunteered In- **Situ Data for Agriculture Crop Mapping: A Case Study of Nepal** [Uma Shankar Panday]
15:45		[Paper ID-64] **Rethinking the future of the cities using Geospatial technology – A Pilot study in Perundurai, Erode district, Tamil Nadu, India** [Apoorva Shanthkumar]

PROGRAMME - DAY 2 - THEME 9

Time [UTC + 5:45]	Session	**THEME 9:** **Geospatial Plugins, Packages and platform development (GPPPD)** **Physical Participation: Senate Hall** **Virtual Participation:** https://zoom.us/webinar/register/WN_gTvOdFHmQt6e47n3TVuqZQ
		Session Chairs: Dr. Bhogendra Mishra, Dr. Vinayaraj Poliyapram
15:00	Technical Session 4	[Paper ID-21] **PySLD: An Opensource Python Package for Generating the Symbology of Geospatial Data** [Tek Bahadur Kshetri]
15:15		[Paper ID-54] **Developing spatial data visualization system using open source tools: A case of Mysuru city, Karnataka** [Sushma M N]
15:30		[Paper ID-16] **State of mago3D, An Open Source Based Digital Twin Platform** [Sanghee Shin]
15:45		[Paper ID-36] **Development of Plugin in QGIS Environment for Accuracy Assessment of the Extracted Boundary** [Ganesh Khadanga]
16:00		[Paper ID-31] **Development of enterprise level Spatial Planning and Decision Support..System for Gas Asset Management in City Gas Distribution companies in India using FOSS** [Saurabh Varma]
16:15		[Paper ID-47] **ZOO-Project: from OGC Web Processing Service to OGC API - Processes** [Gérald Fenoy]

PROGRAMME - DAY 2 - CLOSING SESSION

Time [UTC + 5:45]	**Session Senate Hall**	**Session Chair:** **Prof. Dr. Manish Pokharel, Conference Chair (Kathmandu University)** **Physical Participation: Senate Hall** **Virtual Participation:** https://zoom.us/webinar/register/WN_gTvOdFHmQt6e47n3TVuqZQ
17:00	**Closing Ceremony**	Remarks **Associate Professor Brijesh Adhikary** Conference Co-Chair,
17:10		Remarks **Mr. Natraj Vaddadi** Conference Coordinator (FOSS4G)
17:20		Remarks **Mr. Janak Raj Joshi,** Joint Secretary, MoLCPA
17:30		Award Announcement and Remarks **Prof. Dr. Venkatesh Raghavan**
17:40		Vote of Thanks **Dr. Reshma Shrestha** Conference Coordinator (Kathmandu University)
17:50		Closing Remarks **Prof. Dr. Manish Pokharel** Conference Chair (Kathmandu University)

THE SECOND (2021)

DAVID HASTINGS AWARD

The 2021 **DAVID A. HASTINGS AWARD** for outstanding contributions to the Asian FOSS4G communities was awarded to **MARTIN ISENBERG** posthumously at the Kathmandu university, Dhulikhel, Nepal on 2nd October 2021.

A wonderful human being and great fun to be with, Martin is known not only for his revolutionary and single-handed contribution to LIDAR but also for his immense contribution to environmental awareness and education. He successfully launched and supported the **LAStools** product for **LIDAR** processing. He has been a regular participant at FOSS4G-Asia Events and also Member of Committee for selecting FOSS4G-Asia Host since 2014.

Often described as a scientist in the body of a surfer/ environmentalist, he travelled extensively through Asia and helped communities of all sizes, with capacity building and technology transfer.

The David A. Hastings Award is given for exceptional contributions to the Free and Open Source Solutions for Geoinformatics (FOSS4G) communities in Asia. Nominees must have contributed to the spread FOSS4G in academia, government and business and promoted the use of FOSS4G in projects in Asia.

The award has been instituted in the fond memory of David, Hastings, an early pioneer of FOSS4G, having written a ***GRASS GIS How-to***, as well as being actively involved in the first FOSS4G event held in 2004 at Chulalongkorn University in Thailand, where he helped bring the future founders of the annual FOSS4G event Jeff McKenna, Markus Neteler, and Venkatesh Raghavan, together. He also led an "*Installfest*" at that FOSS4G 2004 event, which set the tone for training workshops and software packaging initiatives for subsequent FOSS4G events.

David would later go on to develop the global level measurement of human development and happiness, what he coined as the Human Security Index. Dr. David A. Hastings left for his heavenly abode on the 13th of November, 2017.

KEY NOTE ADDRESSES

COMMONS AS AN INNER HABIT AND THE IMPACT OF THE OSGEO FOUNDATION

Prof. Dr.-Ing. Franz-Josef Behr
Stuttgart University of Applied Sciences

Prof. Behr is a professor of spatial information processing at the Stuttgart University of Applied Sciences since 2002. He is currently working on topics like Interoperability, open standards, disaster mapping and crowdsourcing.& Free and Open Software/standards/data as applied in teaching and research. He is head of the Laboratory for interoperable, and open-source Geospatial Software, Data and Standards (HFT ICA-OSGeo-Lab). He is co-founder and head of the Applied Geoinformatics for Society and Environment conferences. Besides being a member of the German Organisation for Standardization for Kartographie und Geoinformation., he also serves as co-chair of the 'Commission on SDIs and Standards' of the International Cartographic Association (ICA). Since 2016 he is Member of the SDI Advisory Board, State of Baden-Württemberg, Germany. He has published two GIS textbooks, more than 60 scientific papers and gave numerous presentations at international conferences.

WHERE DO WE COME FROM AND WHERE ARE WE GOING? 15 YEARS PROGRESS OF OSGEO JAPAN CHAPTER

Dr. IWASAKI Nobusuke
Board member of the OSGeo Japan chapter

Dr. Nobusuke Iwasaki has been a board member of the OSGeo Japan chapter since 2007, as Vice Representative since 2014 and Representative since 2018. From 2009 to 2015, He participated in projects of the Japanese Ministry of Education to localize FOSS4G Tools, such as GRASS and QGIS, and to create tutorials. Currently, he is working on the utilization of Web Map tiles for deep learning and the development of map algebra tools using Web GL.

FREE AND OPEN-SOURCE SOFTWARE FOR LAND MANAGEMENT IN NEPAL

Mr. Janak Raj JOSHI
Ministry of Land Management, Cooperatives and Poverty Alleviation

Janak Raj Joshi is a land professional with more than 20 years' experience. He is currently Joint Secretary at the Ministry of Land Management, Cooperatives and Poverty Alleviation of Government of Nepal. He was involved in different land reform initiatives on policy, legislation and institutional development under the Ministry. He has led the Ministry team to come up with the Land use policy, National Land Policy, legislation reform and Fit for purpose land administration strategy development in Nepal. He holds a M. Sc. Degree in Geoinformation Science and Earth Observation from ITC/ University of Twente, with Distinction. He is actively involved in various research activities and publication on land and tenure governance in Nepal.

KEY NOTE ADDRESSES

DATA-DRIVEN URBAN PROBLEM SOLVING PLATFORM : COMPASS

Mr. Junho LEE
OSGeo Korean Chapter and OSGeo charter member

Junho Lee is a GIS analyst in LH Corp (Korea Land & Housing Corporation), a partner organization of OSGeo in Korea. He has put much of his efforts to disseminate the open source spirits and technologies around my organization. He has organized a local QGIS group in my city and has led the group. Local policemen, students, professors, and other people regularly gathered there together to learn how to use QGIS for their own jobs. He recently wrote and published a book called 'QGIS Cookbook for Big Data Analysis' in Korean.

APPLICATION OF OPEN SOURCE SOFTWARE TO BUILD AND DEPLOY SDI SYSTEM FOR THUA THIEN HUE PROVINCE

Dr. Nguyen Quang TUAN
Hue University of Sciences

Dr. Nguyen Quang Tuan is currently working as an Associate Professor, Senior lecturer and Vice Dean of GeoSciences Faculty at Hue University of Sciences. He is also the Head of Geodesy and GeoSpatial LAB (GeoLAB), Head of researchers group on Geospatial technologies and Digital transformation, Vice Director of Centre for Coastal Management and Development studies (CMD) and member of the Executive Committee of Vietnam Association of Geodesy, Cartography and Remote Sensing. He has been teaching Soil Sciences, Cartography, GIS and Remote Sensing, Natural Resources Management, Resource and Environment Project management courses to Undergraduate students and Post – graduate students at the Hue University.

4ONSE- LESSONS LEARNT FROM FOSS FOR CLIMATE-BASED SERVICES

Prof. Rangajeewa RATNAYAKE
University of Moratuwa, Katubedda, Moratuwa, Sri Lanka

Rangajeewa Ratnayake is a Professor in Town and Country Planning, University of Moratuwa and a Chartered Town Planner (PhD, MSc, BA Hons) with over 19 years of experience lecturing in international and national universities, providing local level land use planning, managerial, operational, and capacity development support for Local Authorities, supervising the preparation of physical plans. His areas of expertise include research in urban planning, Local Authority Level Strategic and Statutory Planning, Local Governance, Social Planning, Participatory Community Planning and Environmental Information Management System (GIS). The central themes of his research agenda involve unravelling the relationship between human behaviour and the built environment. He has researched the complexity of urban settings and the sense of safety concerns. He has recently commenced studying climate sensitive planning and non-conventional systems for sensing environment.

KEY NOTE ADDRESSES

FROM MAPS TO DSS WITH BIG DATA AND MACHINE LEARNING

Dr. Sarawut NINSAWAT

Remote Sensing and Geographic Information Systems FoS, Asian Institute of Technology, Thailand

Dr. Sarawut Ninsawat received the Doctoral degree at Osaka City University (OCU), Japan. He was a Postdoctoral researcher at National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan. Currently, he is an Assistant Professor and Degree Program Chair Coordinator of Remote Sensing and GIS program, Department of ICT, School of Engineering and technology, Asian Institute of Technology. Currently, he is a Thai OSGeo Chapter Secretary. His research interests are application of Remote Sensing and GIS for natural resource management, developing Web Mapping Application especially focus on the implementation of standard OGC Web services (OWS) framework such as WCS, WFS, WPS and SOS using Open Source Software solutions. Additionally, the various Location-Based Service applications were developed to utilize the location information for agriculture, environment and logistic purpose.

DEVELOPMENT AND CHALLENGES OF OPEN SOURCE GEOSPATIAL TECHNOLOGY IN CHINA

Prof. Dr. Xianfeng SONG

College of Resources and Environment, University of Chinese Academy of Sciences

Xianfeng Song works on geo-informatics with a focus on remote sensing hydrology, GIS and environmental modelling, spatiotemporal analysis and modelling particularly on understanding urban human mobility patterns. He heads the GIS Lab in College of Resources and Environment, which aims to promote open-access geographic data based geo-computing and web mapping using the state-of-the-art open source geospatial technologies. His research has been funded by various agencies, including the National Science Foundation of China, National Science and Technology Major Project, and National Key Research and Development Program. He was awarded JSPS Fellowships (2000-2002), Osaka City University Fellowship for Inviting Foreign Researcher (2008), and CSEAS Fellowship for Visiting Research Scholars of Kyoto University (2012). Before joining UCAS, he worked as a postdoctoral fellow (2 years) and assistant Professor (3 years) at the Center for Southeast Asian Studies at Kyoto University from 2000-2005.

EDITORIAL

Prof. Dr. Manish Pokharel
Dean, School of Engineering,
Kathmandu University, Nepal

Prof. Venkatesh Raghavan
Graduate School of Engineering
Osaka City University, Japan

Associate Prof. Brijesh Adhikary
(Co-Chair)
Associate Dean, School of Engineering
Kathmandu University, Nepal

On behalf of the FOSS4G Asia 2021 conference organizing committee, we would like to thank you all for your presence at the FOSS4G Asia 2021 held in Dhulikhel, Nepal. It was indeed a pleasure to have you at the conference. Due to the ongoing pandemic, and restrictions on international travel, we had to conduct the conference in a hybrid mode – a first for us and for FOSS4G Asia conferences.

The theme of '*Free and Open-Source Software for Geospatial in the era of Artificial Intelligence and IoT for Land Management & Sustainable development* ' was well received. The conference received over fifty-eight abstracts and twenty-four full papers. Seven workshops were hosted online as a pre-conference event

We were also privileged for this event to attract eminent keynote presenters as Prof. Dr.-Ing. Franz-Josef Behr, Dr. IWASAKI Nobusuke, Mr. Janak Raj Joshi, Dr. Nguyen Quang Tuan, Prof. Rangajeewa RATNAYAKE, Dr. Sarawut Ninsawat and Prof. Dr. Xianfeng Song.

Organized by the Department of Geomatics Engineering, Kathmandu University with support Department of Computer Science and Engineering and Land Management Training Centre. Nepal, the Local Organizing Committee received the support of many entities. Kathmandu University provided the infra-structure, administrative and financial support. The support from our sponsors for their invaluable financial assistance and other supporters for their assistance is highly appreciated.

Organising this event would have been impossible without the motivation and support of Prof. Dr. Bhola THAPA, Vice Chancellor, Kathmandu University and Dr. Sunil Babu Shrestha, Vice Chancellor, Nepal Academy of Science and Technology (NAST). We express our gratitude to all conference committee members and university staff who have assisted us at every stage of organization, and we greatly appreciate their willingness to take part in so many difficult tasks. Finally, a big heartfelt thanks to all the student volunteers for their assistance throughout the event

It now gives us great pleasure to present to you the proceedings of the conference. The proceedings contain both full papers and the abstract received and presented at the conference.

Thank you once again for the participation and support to the FOSS4G Asia movement

Conference Chairs
FOSS4G-Asia, 2021

Section 2

Proceedings

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THEME 1

People to Land Relationship and Urban Systems (PLUS)

Quantum GIS based suitability analysis for effective Planning of Solid Waste management of Kathmandu Valley.

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Abstract

Due to unplanned urbanization and rapid increase in population, solid waste management has become a global problem. Improper site selection for waste disposal can cause various economical, morphological and environmental losses as well as adversely impacting human habitat. Waste disposal sites are an easier and economical solution for the solid waste management of urban places. Kathmandu valley has been generating thousand metric tons of garbage on a daily basis which will overtake the carrying capacity of current disposal site in the near future. So, Kathmandu valley was selected as the study area to assess alternative waste disposal site here. Among many methods, Geographic Information System (GIS) in integration with Multi-Criteria Decision Analysis (MCDA)–based Analytic Hierarchy Process (AHP) method has proven to be one of the effective ways. MCDA based AHP method in QGIS was done for the determination of waste disposal sites. Quantum GIS software is a free and open-source GIS software. QGIS permits free modification to carry out complex and specialized operations. The study aims to identify the suitable site for waste disposal such that effective management of waste can be obtained using FOSS-Geo QGIS. In this study, eight criteria were considered, among them seven were factors and one was constraint. The factors included distance to water bodies, distance to road, distance to settlement area, slope percentage, soil type, geology and land-use and the constraint included national park. The standardization of the criteria was done by reclassification in order to use a common scale of measurement. The weight for each criteria was obtained from the AHP pairwise comparison matrix. The normalization of the weightage was performed and the consistency ratio of 0.064 was obtained which validated the consistency of the matrix. The result of the study is suitability map indicating low-suitable to high-suitable areas with restricted areas included. 8% of the total study area lies in the restricted area and about 1% of the total area was found to be suitable for waste disposal. Almost all of the study area has been found to be unsuitable for waste disposal so, waste disposal site for Kathmandu valley must lie outside the valley. The use of QGIS in spatial analysis for the effective identification of the suitable waste disposal site minimizes the environmental risk and aid in a better world for the future generation. Such analysis helps to advocate the use of FOSS in geoinformatics.

Keywords: GIS, MCDA, Waste Disposal, QGIS, Geospatial Technology, FOSS

Introduction

Lack of appropriate solid waste management system, unplanned and increasing urbanization and increase in population has resulted in problems in selection and management of proper solid waste dumping sites in developing countries (Zehra et al., 2019). Land filling of the waste without applying any particular techniques is a traditional method for the solid waste management which is still prevalent in developing countries (Kumar et al., 2014).

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Municipal solid waste management has been a major global problem. In the UK, out of 400 million tonnes of waste each year, 35 million tonnes is municipal waste (Koshy et al., 2007). As per an article published in The Himalayan Times on July 17, 2016, Kathmandu Metropolitan City transported 300 tonnes of garbage daily to the landfill located at Okharpauwa.

Kathmandu valley has an approximate population of 2.54 million and has population growth rate of 6.5% per year which imples that it is one of the rapidly growing metropolitan cities in South Asia (Timsina et al., 2020). Kathmandu valley consists of three districts of Nepal i.e. Kathmandu, Bhaktapur and Lalitpur. Bhaktapur Municipality has satisfactory results in the city's sanitation however, dumping and spreading of waste and covering with a thin layer of soil in several locations is common practice there (Ranjit et al., 2019). For Lalitpur and Kathmandu, all waste is disposed at Okharpauwa landfill site which is located 43km from Kathmandu according to Solid Waste Management Service Improvement Plan (SWM SIP).

Improper ways of waste disposal may cause serious damage in human health and deterioration of environmental constituents. Selection of appropriate solid waste disposal sites should take many considerations such as cultural, environmental, social, spatial, etc. For the manipulation of such data, GIS technology can be useful which allows users to store, process, analyze and handle big data both spatial and non-spatial (Kumar et al., 2014). Use of GIS along with Multi criteria evaluation (MCE) enhances the decision making process as it provides environment for collecting, managing and organizing large number of spatial and attribute data (Malczewsku, 2004). MCE allows users to make best choice among several criteria which makes it a widely accepted tool. GIS helps to perform operations such as buffer, overlay, reclassification, etc. and MCE helps to weight criteria based on their priority and subjective values (Christian & Macwan, 2017). Analytical Hierarchy Process (AHP) can be an effective and practical method while making decisions where different criteria with different units need to be considered (Triantaphyllou & Mann, 1995). This research will use Free and open source GIS software i.e. Quantum GIS for analysis, manipulation and display of spatial and attribute data and AHP for determining the suitable waste disposal site for the Kathmandu Valley of Nepal. Free and Open Source Software (FOSS) are those kinds of software which provide users freedom to run, program, study about the mechanism of the process, share the copies and edit and modify the program as per their needs and requirements (Free Software Foundation, 2021).

Literature review

Most number of world population resides in urban areas. To accommodate growing population, the infrastructures of urban areas should be suitable for a healthy living (Ramaswamy & Madakam, 2013). Waste management has influence on social, economic and environmental factors. Migration of people from rural to urban areas has caused increase in solid waste generation. Various factors such as population demographics, amount of waste produced, and related stakeholders should be considered by authorities for solid waste management (Ahmad & Kim, 2020). It is necessary to manage waste in smart manner, be up to date about situation about waste collection and provide timely information about waste data to concerned authority. The waste management should be efficient and smart so that there is real time notification to the stakeholders about when to collect waste, type and amount of waste generated by population. Considering this factors, a cloud based waste management system was suggested by Aazam et al. (2016) in their study. They have suggested to equipp waste bins with sensors, which keep track about level of waste in them and update the status to cloud. This helps in easy access to data and plan for optimum route for waste collection.

Ravi & Jawahar (2017) had incorporated the idea of big data management by using technologies like Internet of Things (IoT) for solid waste management. They suggested developing portals for solid waste processing which takes classified information about solid waste. They had proposed algorithm for classification of the waste in which waste are classified into dry, wet and hazardous categories. This helps concerned stakeholder to determine if the waste are to be reused, recycled or disposed.

Akther et al., (2016) proposed solid waste generation, collection, separation and reduction handling model through their study. They identified all the waste generation sites within their study area i.e. area under the jurisdiction of Rajhdhani Unnayan Kartipokkho of Dhaka. They scored the waste sites based on their proximity to various sites such as hospitals, mosques, residential areas, etc and performed the data management, analysis and display using ESRI ArcGIS 10 software.

In the Indian socio-economic and regulatory condition, a GIS based environmental decision support system for solid waste management was developed by (Yadav, 2013). He considered geology, groundwaret depth, water supply well points, hydraulic conductivity, land-use/land-cover, slope, drainage pattern, roads and airport locations as criteria and AHP for weighing them. He used suitability index 0-10 which was generated using weighted linear combination and classified that into excluded, less preferable, suitable and best suitable categories. The study helped to identify suitable solid waste disposal sites which helped in minimun negative effects on enviroment and public health.

Using GIS and Remote Sensing (RS) technique, Zehra et al., (2019) investigated for suitable site for municipal solid waste management in Jacobabad city in 2019. They considered environmental, social and technical factors such as land use/ land cover, distance from residences, proximity to road, school, health facilities, reservoirs, railways, parks and flood susceptible areas as factors for determining suitable sites. They used Landsat 8 image to create land use/ land cover map. They further suggested to conduct geotechnical and hydro-ecological analyses to finalize suitable site obtained from study.

For the purpose of providing alternative solid waste disposal site in the Guwahati Metropolitan Area, India, in 2020, Hazarika & Saikia used GIS based MCDA-AHP method. They considered seven criteria namely land use, slope, elevation and proximity to wetlands, rivers, road and airports and categorized the area into most suitable, highly suitable and moderate, low and least suitable for waste disposal. In this research, they had emphasized on problem faced by low and middle income cities for proper waste management waste.

Kumar et al. (2014) integrated RS with GIS based MCDA with AHP for selection of suitable solid waste disposal site in Lucknow, India. They used India topographical map sheets, satellite images of IRS-1C/1D LISS-III 23.5 m resolution and IKONOS satellite's 1m resolution data. For multicriterion layers praperation, landuse/ landcover, geomorphology, soil texture, surface water bodies, habitation, transport network, slope and ground water were considered. They illustrated the capacity of Remote Sensing data for the preparation of multi criteria layers and thematic map and their analysis through their research.

Since Nigeria was having serious issues regarding improper dumping of solid waste, in 2015, Ngumom & Terseer used Spot5 satellite image, DEM, ground control points collected by GPS and topographic map to identify suitable sites for waste disposal. They used RS technique, Arc GIS along with MCA for the study. The study suggested very low, low, moderate and highly suitable areas for solid waste disposal considering drainage, river, elevation, settlements, important places and roads as factors.

Sindhu & Manickam (2018) performed raster analysis in Quantum GIS using several data like land-use, land cover, distance from road, lake, river, urban and rural settlement to identify suitable waste disposal site in Thiruwallur District, Tamilnadu. After assigning weights and ranks to all factors they prepared final suitability map for waste disposal site categorized into highly suitable, moderately suitable, least suitable and not suitable area.

Randazzo, et al. (2018) researched in Sicily of Italy to test a methodology of GIS based MCDA to identify suitable landfills for Municipal solid wastes. They divided the study area into restricted and potential sites for landfill and later reevaluated the potential sited by MCDA method as per eight criteria i.e. geology, hydrogeology, land use, land slope, distance from road, residential areas, protected areas and wind direction as per weight estimated by AHP. They concluded that GIS based MCDA provides powerful tool in order to identify suitable areas for landfill.

METHOD AND MATERIALS

Study area

Kathmandu Valley (Kathmandu, Bhaktapur, Lalitpur) extends from 85° 11′ E to 85° 33′ E longitude and 27° 24′ N to 27° 49′ N with an area of 933.18 km^2 as shown in figure 1. It is a bowl-shaped valley surrounded by Nagarjun, Phulchowki, Shivapuri and Chandragiri Hills. The total population of Kathmandu valley is 2,517,023 (CBS, 2014). The centralization of various facilities such as education, medical, governance, economy and other productive activities has led to rapid population growth in Kathmandu valley (Dong & Karmacharya, 2018). The altitude of the study area varies from 420m to 2828m from the mean sea level (m.s.l).

Software used

Various software is available for collection, management, analyzing, presenting and dissemination of geospatial data. In this study, Quantum GIS was used. QGIS is a free and open source software (FOSS). Although both proprietary commercial software and open source GIS software are available, use of FOSS-Geo in researches seems to be comparatively less. Use of FOSSs can solve the problem of

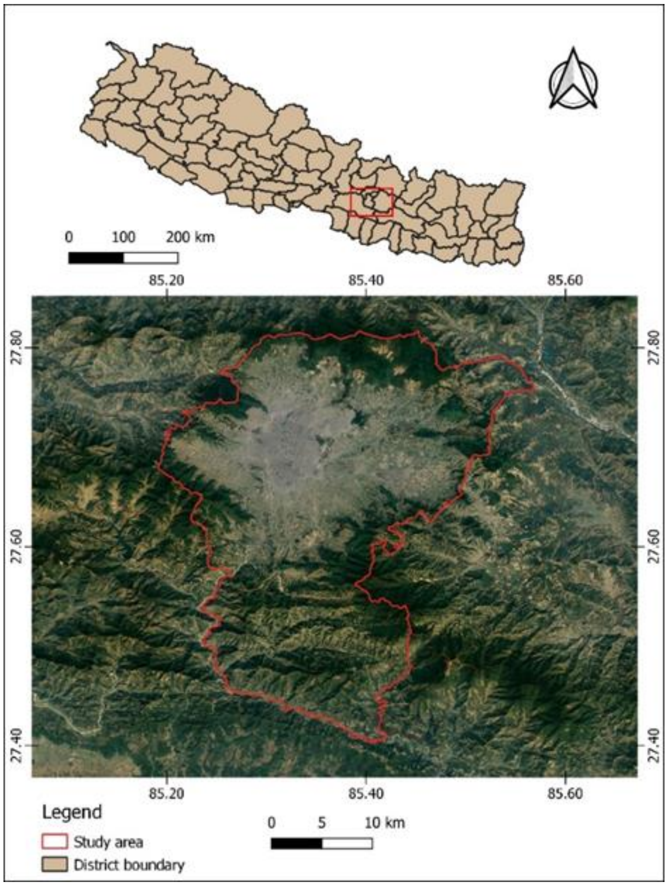

Figure 1: Location of the study area

copyright licensing and purchase cost. QGIS allows viewing, editing and analysis of geodata as well as preparation and export of maps. Being an open source software, it permits modification freely to carry out complex and specialized operations.

Different kinds of spatial operations such as raster to vector conversion, vector to raster conversion, buffer, Euclidean distance, reclassification, union, weighted summation were performed on QGIS.

Data and sources

In order to generate the criteria layers in QGIS, data from various sources were sought (Table 2). For the evaluation, eight criteria were considered, among them seven were factors (road network, water body proximity, settlement proximity, slope, geology, soil and landcover) and one was constraint (national park). The data were projected into EPSG:32645 - WGS 1984 UTM Zone 45N. The vector criteria layers were transformed into raster data and all the raster data were resampled with 30m spatial resolution.

Table 1: Geospatial data used in the study

Criteria description

Road network

The proximity to road should be taken into consideration as it represents the accessibility to the disposal site itself. According to Kazuva et al. (2020), the waste disposal site should neither be too far as it will result in excessive transportation costs, nor it should be at the site where

Factor	Description	Type	Source
Road	Transportation facilities e.g.: Main highway, roads	Vector	ICIMOD
Water	Drainage system which includes streams, rivers	Vector	Humanitarian Data Exchange
Settlement	Residential sites	Vector	Open Street Map
Slope	Rising or falling surface in percent	Raster	Humanitarian Data Exchange
Geology	Physical structure of the earth based on water absorptivity	Vector	ICIMOD
Soil	Fertility of the surface	Vector	SOTER
Land-cover	Type of land covered by surface e.g.: forest, barren area, grassland and so on	Raster	ICIMOD
Protected area	Conserved area for natural and ecological values	Vector	ICIMOD

landfill vehicles interfere with the normal vehicular traffic. Thus, a low suitable score was assigned at a distance less than 500m and it was followed by high suitable score at a distance greater than 500m.

Water body proximity
The waste disposal site near the water bodies should be avoided in order to prevent from contamination (Hazarika et al., 2020). Considering the environmental health of the water body, the site which is at a distance more than 2000m was assigned to be highly suitable.

Settlement proximity
High importance is attributed to settlement proximity for the waste disposal site. Various problems to human health may arise if the waste disposal site is located near settlement area or at least there will certainly be presence of unpleasant odors. Hence, direct distance of settlement proximity was taken into account, assigning distance less than 2500m to be unsuitable.

Slope
Slope is one of a crucial factor for selecting the waste disposal site because very steep slopes will result in high excavation costs. Digital Elevation Model (DEM) was used to compute slope percentage of the study area on the pixel basis. The slope of less than 10% was assigned to be highly suitable.

Geology
The geological map of the study area has various rock formations. It was categorized on the basis of permeability to determine the regions which would make the groundwater more susceptible to defilement by leachate. The geological feature having less permeability was considered to be highly suitable.

Soil
Global Action Programme (GAP) states that the fertile soils ought to be maintained a strategic distance in any engineering projects to be carried out to develop land and water resources (Yesilnacar & Cetin, 2005). Therefore, the soils were classified in terms of fertility where high fertility was assigned as unsuitable for waste disposal site.

Landcover/Landuse
The land cover and use includes the natural and human landscape which may be effected by the menaces imposed by landfill adjacency (Ebistu & Minale, 2013). Examining the characteristics of land coverage, barelands and grasslands were considered as suitable sites.

Table 2:Factors for selection of waste disposal and their rank

Factors	Classes	Rank
Distance from road (m)	<500	1
	>1500	2
	1000-1500	3
	500-1000	4
Distance from water body (m)	<1000	1
	1000-1500	2
	1500-2000	3
	>2000	4
Distance from settlement area (m)	<1500	1
	1500-2500	2
	2500-3500	3
	>3500	4
Slope (%)	>20%	1
	15-20%	2
	10-15%	3
	0-10%	4
Geology	High permeability	1
	Moderate permeability	2
	Low permeability	3
	Least permeability	4
Soil Type	Eutric REGOSOLS/ CAMBISOLS, Chromic LUVISOLS	1
	Humic/Chromic/Ferralic CAMBISOLS	2
	Gleyic CAMBISOLS	3
	Dystric REGOSOLS	4
Landcover	Water bodies	1
	Built up area	2
	Agriculture area/forest/ shrubland	3
	Barren area, grasslands	4

Protected area

The protected area is the constraint in this study which includes Shivapuri National Park. The waste disposal site located within 750m buffer from its surrounding was taken as restriction.

AHP for factors organization and analysis

The factors were superimposed with AHP, which is one of the widely used MCDM tool for processing multiple important objectives and weighting the criteria (Ozkan et al., 2019). The AHP allows to assign a priority among various alternatives and integrating multidimensional measures into a single scale of priorities (Saaty, 1980).

The pair-wise comparison was carried out with nine-point scale value which includes values 9, 8, 7, 6...., 1/7, 1/8, 1/9, which indicates 9 as extreme preference, 7 as very strong preference, 5 as strong preference and so on down to 1 which represents no preference. The preference data were collected from various literatures corresponding to the hierarchical structure. Thus, the pair-wise comparison aids to simplify the criteria by evaluating the independent contribution of each criterion with each other. The square matrix was organized for pairwise comparisons of various criteria (Bhushan & Rai, 2004).

The principal eigenvalue and their corresponding eigenvector was developed among the relative importance within the criteria from the comparison matrix. The weights for each element were generated from the normalized eigenvector. The subjective judgment from AHP were checked via consistency index. The consistency index (CI) was calculated as:

$$CI = (\lambda_{max} - n) / (n - 1) \qquad (1)$$

Where CI = Consistency Index

λ_{max} = maximum eigenvector of the matrix

n = order of the matrix

After comparing CI with random index, Consistency Ratio (CR) was derived from their ratio. The consistency ratio should be ≤ 0.1 (Saaty, 1990). The pairwise comparison is assumed to be inconsistent if the CR exceeds the threshold, the process has to be reviewed in such case. The random index for this study was 1.32 for 7 order of matrix and the computed λ_{max} was 7.511, generating the consistency index of 0.085. The matrix was found to be consistent as the CR was 0.064. However, the different experts might have distinct judgment when the factors are compared in pairs.

The final step involved multiplying each factors by weight and aggregating them to determine global rating. In this regard, the rating scale of 1 to 4 was considered that indicates 1 as unsuitable, 2 as least suitable, 3 as suitable and 4 as highly suitable. The suitability was evaluated by weighted summation of factors which is expressed by given formula (Hwang & Yoon, 1981).

$$S = \Sigma\, Wi\, Ci \qquad (2)$$

Where, Wi = relative importance of weight given to the factors

Ci = criteria

The restriction model was prepared for the national park. The national park and its surrounding up to 750m was taken as a restricted site which was indicated by Boolean expression where 1 was taken as non-restricted site and 0 as restricted site. Eventually, the application of FOSS-Quantum GIS aided in overlay analysis of suitable factors and constraint to produce the final suitability map with various suitability levels.

Result and findings

Generation of criteria maps

Data were obtained from different sources as shown in table 1. Spatial operations such as clip, buffer, euclidean distance and reclassification were performed to obtain the criteria maps. Area of high suitable, suitable, least suitable and unsuitable as per each criteria is illustrated in Table 3.

Out of total study area, about 56% area fall under unsuitable category in regards to water body because there are rivers like Bagmati, Bishnumati, Dhobi khola, Hanumante khola, Manohara khola which dissect the Kathmandu valley. 21% of the study area was found to be highly suitable for water body proximity factor. Similarly, most of the area in terms of road proximity and settlement proximity was found to be unsuitable for waste disposal because with the rapid increase in population growth, the settlement and road infrastructure have been tremendously established. Only 2% of the total study area lie under suitable and highly suitable in settlement proximity for waste disposal. Considering the slope factor, 34% of the total area fall under highly suitable category as Kathmandu valley is a valley itself which means there is low area land between hills. There is very less area that has highly suitable site for waste disposal based on soil type because most of the area of Kathmandu valley has Silty Clay soil which are composed of intermediate sized particles that makes it fertile (KC & Dahal, 2020). Likewise, only 8% of the extend of study area is highly suitable, followed by

12%, 24% and 54% as suitable, least suitable and unsuitable respectively. In the context of land cover, most of the area was found to be suitable for the waste disposal site.

Generation of suitability map

The final suitability map was analyzed by overlaying suitability factors and restriction factor. As a result, about 48% of the total study area was found to be restricted and unsuitable in which restricted area lie on the northern part, whereas unsuitable area lies on the center and its surrounding part of the valley. There regions are mainly comprised of built-up areas with dense population and industrial sites. Thus, such areas should be excluded from the waste disposal site as it may lead to serious environmental and health problems. The least suitable site is about 51% of the total area and suitable site is about 1%. This means there are no highly suitable area for the waste disposal in Kathmandu valley from our study.

Conclusion and discussion

The linkage of FOSS with geospatial theme has a great potential for solving the real-world issues like solid waste management. Solid waste management is one of the many problems that both developed and developing countries face

Table 3: Area coverage of different factors

Factors	**Unsui table**	**Least suitable**	**Suit able**	**Highly suitabl e**
Distance from water body	56%	14%	9%	21%
Distance from road	39%	18%	17%	27%
Distance from settlement area	96%	2%	1%	1%
Slope	53%	6%	7%	34%
Soil	47%	32%	20%	1%
Geology	54%	24%	14%	8%
Land cover	1%	18%	78%	2%

due to the growing population. Kathmandu valley has a population growth of 6.5% per annum. More population produces more waste which needs to be managed by authorities. Determination of a proper solid waste disposal site facilitates monitoring of environmental factors and proper operations of the site. Several environmental, economic and social factors need to be considered while selecting a waste disposal site. Due to several considerations, there is a big volume of data which needs to be collected, managed, stored, analyzed and displayed. Use of the GIS based MCDA method for suitability analysis of waste disposal sites is an ideal solution for this problem.

This study was based on data from Kathmandu Valley, Nepal. Kathmandu valley is one of the most populated places of Nepal. The current solid waste disposal site of Kathmandu Valley sometimes become inoperable due to different reasons like protest by locals and damage of road

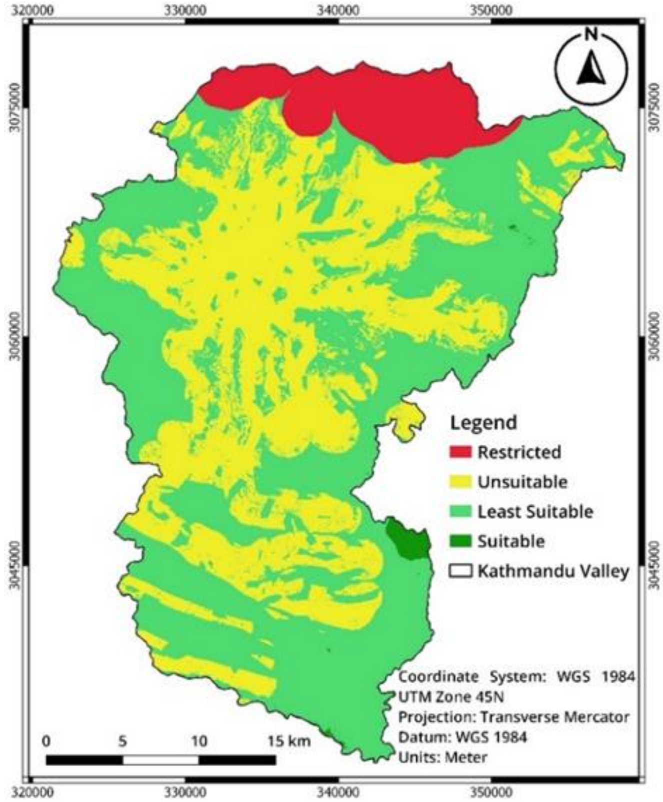

Figure 2: Final suitability map

networks during monsoon. In this study, GIS was integrated with AHP-MCDA for identifying suitable sites for solid waste disposal in Kathmandu Valley which integrated various features which influences the selection of suitable waste disposal sites. AHP was done to determine weight for all the factors considered which were land-use/land-cover, geology, soil, and distance from road network, water bodies and settlement. The method helped to rank and weight the several factors which were considered during the study.

The study showed that there is inadequate land for the establishing the waste disposal site in Kathmandu valley. There should be adaptation of incisive planning for the waste reduction policies. The findings of this study could provide an important statistic to the concerned authorities for the planning, maintenance and development of the waste disposal sites.

It is necessary to plan for a sustainable solution for waste disposal sites. All the landfill sites will be full in future. To increase the longevity of such sites, the waste materials should be categorized into decomposable and non-decomposable wastes. Those waste which can be decomposed should be turned into compost and can be used in vertical or horizontal farming. Also non-decomposable wastes can be categorized so that they can be recycled and reused. Concerned authorities should inform and guide the general public to manage solid wastes in their home by making composts from decomposable waste.

Table 4: Area-wise suitability levels

Suitability Level	Area coverage (ha)	Percentage of total area
Restricted	7488.74	8%
Unsuitable	37439.33	40%
Least suitable	47311.36	51%
Suitable	540.53	1%

Quantum GIS can be used for spatial database management, analysis and dissemination through maps. FOSS can be a powerful instrument for performing scientific and systematic researches, assisting to a fruitful result for decision making process. The use of FOSS should be encouraged at different sectors and its user community should be supported in order to develop more tools/plugins.

The main limitation of this study is that all the data used were obtained from secondary data sources. So, the data used may not be accurate and relevant to the current date. It is recommended that assessment of suitable sites for waste disposal can be improved by incorporating more detailed, robust and reliable data and methodology. Furthermore, optimal site should be selected considering further field investigation, geotechnical and hydrological aspects, site lifespan and other minuscule factors.

Acknowledgements

The authors would like to thank all those who have supported and guided them throughout this research. They appreciate the help of Mr. Hem Sagar Devkota for his valuable input in this work

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Comparative Study of Mapping Land Parcels with Fit-for-Purpose Tools and Conventional Techniques to Support Tenure Security for All

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Abstract

Land Administration is defined as a procedural legal and administrative task which involves determining, recording, and dissemination of information related to land ownership, value and use when implementing land management policy. FFPLA is the system which was developed to support the tenure security of land for vulnerable and economically marginalized communities based on necessity of people and their relation to land. Under the spatial framework of the FFPLA approach, data collection can be done using Social Tenure Domain Model (STDM) plugin which contains free and open source components. This paper defines conventional technique as a method of land information development adopted by cadastral survey division of survey department, Nepal. Insecurity of land tenure is still one of the major issues in land administration of Nepal. It is estimated that 25% of land occupied in Nepal are not recorded in Nepalese formal land information system. The main objective of this study is to compare the unregistered parcel mapping methods via widely used Fit-for-Purpose Land Administration (FFPLA) tools and conventional techniques in an allocated study area. The study area lies in eastern terai of Nepal in ward-7 of Kanakai Municipality of Jhapa district of Province 1. Within this Municipality, 73 parcels covering nearly an area of 6.8 ha of three different places (Redcross tole, Pathivara tole, and Kalinag tole) has been selected. The methodology of this study was divided into 3 parts. In the first part, different literature review was conducted via reports, journal articles etc. Similarly, in the second part necessary data acquisition and processing was conducted. In last phase, comparative analysis on the basis of area, time and cost was done. This study demonstrates that the root mean square error of FFPLA approach compared to the conventional total station survey is ± 8.62 % and more than 86 % of parcels mapped are within 10% of deviation. It also depicts FFPLA strategy is much faster and cheaper compared to conventional techniques. Considering the need for fast, cheap and good solution for tenure security for all, the FFPLA approach is recommended.

Keywords: QGIS, Open Source, STDM, Satellite imageries

Introduction

Background

Land Administration is defined as a procedural legal and administrative task which involves determining, recording, and dissemination of information related to land ownership, value and use when implementing land management policy (UN/ECE, 1996). Different types of land administration system are developed by various countries in the world based on their economy, available resources, infrastructure, legal requisite etc. (Ventura, 2000). Among various approaches of land administration adopted in different countries, one emerges concept is Fit-for-Purpose Land Administration (FFPLA).

FFPLA is the system which was developed to support the tenure security of land for vulnerable and economically marginalized communities based on necessity of people and their relation to land. It primarily contains major three

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framework; Institutional, Legal, and spatial framework (Enemark, Bell, Lemmen, & McLaren, 2014). It was developed mainly focusing for pro-poor land management in most of the developing countries throughout the world (UN-Habitat, 2004). Flexible, inclusive, participatory, affordable, reliable, attainable, upgradable are the key elements of FFPLA. Similarly, general boundaries rather than fixed boundaries, aerial imageries rather than field survey, accuracy related to the purpose rather than standards and opportunities for updating, upgrading and improvement are key principles of FFPLA (Enemark , Bell, Lemmen, & McLaren, 2014). Under the spatial framework of the FFPLA approach, data collection can be done using Social Tenure Domain Model (STDM) plugin (Panday, et al., 2019). STDM plugin contains free and open source components such as; Quantum GIS, Post GIS, Postgres SQL. (UN-Habitat & GLTN , 2013). Since it is free of cost, and the source code can be modified for specific software, it is widely adopted in FFPLA approach (Gertrude , 2008). Thus, FFPLA is the method which primarily focuses surveying and mapping for vulnerable and landless people with less time and low cost with desirable rather than standards.

This paper defined the conventional technique as method of land information development adopted by cadastral survey division of survey department, Nepal. It primarily includes one field works; planning, reconnaissance and monumentation of the control points, establishment of control points via traverse method, detail survey of parcel boundaries and another office works; data processing, digitization and development of parcel information using perpetual GIS software i.e., *Parcel Editor (Survey Department, 2021).* Survey department has initiated this method since 2006 from Banepa, Kavre district in order to develop the digital land information system of the registered parcel boundaries due growing value of land (Pudyal, 2007). This method primarily focusses surveying and mapping activities for registered parcels with defined accuracy rather than time and cost.

The main objective of this study is to compare the unregistered parcel mapping methods via widely used Fit-for-Purpose Land Administration (FFPLA) tools and conventional techniques in an allocated study area. This study will depict the comparison of parcel area, time taken and cost expenses for surveying and mapping of the parcel boundaries using two approaches. Results generated from this study will also demonstrate the possible applicability of respective methods for respective geographical areas.

Literature Review

Status of Land Tenure in Nepal

Nepal is a country with geographical regions extent from Himalayan, Hilly, and Terai and consist of various ethnic groups (Mishara, 2009). All these ethnic groups considered land as key source from social, economic and religious perspective (Adhikari, 2008). Land being key source to each individual insecurity of land tenure is still one of the major issues in land administration of Nepal (Paudyal, 2008). During and after the civil war, forest land of terai regions of Nepal were exploited into arable and built up areas and still most of it is unregistered in Nepalese formal land information system (Nepal & Marasini, 2017). A joint report published by (MOLMCPA,GLTN,UN-HABITAT,CSRC, 2018) reveals that, still about 25% of land occupied in Nepal are not recorded in Nepalese formal land information system which approximately covers 10 million spatial units (parcels).

Security of land tenure is one of the major concerns of government in Nepal but still fails in providing the land access for all (Dhakal , 2011). Different government entities were formed to solve this problem of unregistered land time and again till date but were unable to solve the issues comprehensively due to political instability of government (Adhikari, 2008). Moreover, no any entities could generate the precise information of the unregistered parcels over country. Despite the successive failure of government entities for solving unregistered land issues, various national and international organization are actively involving to provide land rights for vulnerable and pro-poor communities (Adhikari, 2008). Another major problem for failure of the government for not addressing these issues is adopting the existing time consuming and costly conventional techniques. Thus, government has to adopt another alternative for solving such issues which is affordable, desirable accurate and consumes less time such as FFPLA tools.

Method and Materials

Study Area

The figure (1) illustrates the area chosen for this study. It lies in eastern terai of Nepal in ward-7 of Kanakai Municipality of Jhapa district of Province 1. The different places; *Redcross tole, Pathivara tole, and Kalinag tole* of ward 7 were chosen. These three places approximately covers 73 parcel units with an area of 6.8 hectare. This study area is geographically flat and open which extends from 87° 53'58.08"E to 87°56'13.17"E and 26°37'24.09"N to 26° 38'15.18"N. The places chosen for study area mostly consists of the arable land with few build-up areas.

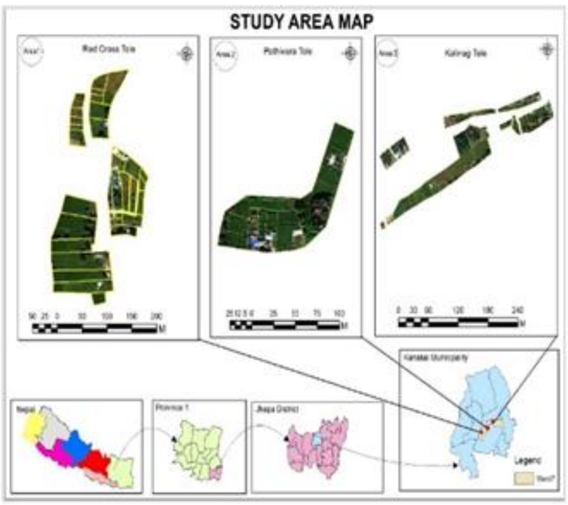
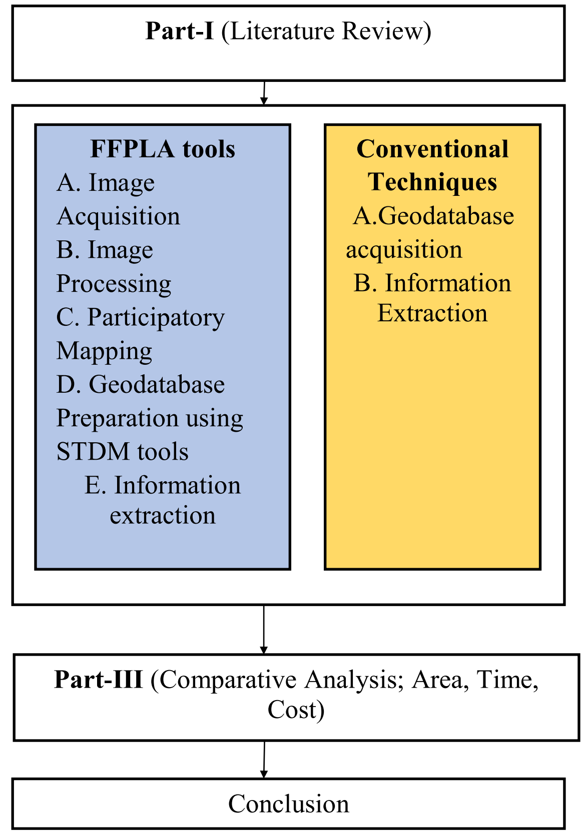


Figure 3: Study Area



Methodological Framework

The methodological framework of this study was divided into 3 parts. In the first part, different literature review was conducted via reports, journal articles and other related documents. Similarly, in the second part of this study necessary data acquisition and processing were conducted. Finally, in the third part, database preparation and analysis focusing on the data quality, time, and cost was done.

3.2.1 Part-I (Literature Review)

Desk study using various journal articles, reports, and related documents was done to conceptualize the methodological framework of the study.

3.2.2 Part-II (Data Acquisition and Processing)

a. FFPLA tools

i. Image Acquisition and Processing

Acquisition of high-resolution satellite image was the initial task done for surveying and mapping via FFPLA tools. The major specifications of the satellite image are illustrated in table (1). Image used in this study was acquired via municipality.

After the acquisition of the satellite image, mosaicking and geometric correction was done. Due to the limitation in the study, geometric correction of images was done using 'image-image' georeferencing technique. The geometrically corrected topographical map of survey department was used for 'image-image' georeferenced technique.

ii. Participatory Mapping

After the acquisition and processing of the high-resolution satellite images, the enumerators were provided with the

Parameters	Description
Sensor	GeoEye-1
Acquisition date	2018-10-18
Spatial Resolution	0.5 m
Data Source	Digital Globe, USA

Table 1: Specification of Image

print of the images. The enumerators along with the representatives from the ward were involved in the mapping. The mapping was done with the participation of respective household members. During the adjudication (identification and demarcation of boundaries), all the respective land owners along with their adjacent parcel owners were present in order to resolve any disputes and conflicts in the parcels boundaries.

iii. Geodatabase Preparation and Information Extraction

During the geodatabase preparation, new configuration file was created in STDM on the basis of questionnaire survey form used for data collection. After creating the configuration file, non-spatial information and boundary digitization on satellite images was done parallelly using STDM tool. The digitization was done based on the print maps used for adjudication. After the digitization of the land parcels area, information was extracted whereas time and cost information were extracted through concerned authorities (project members).

b. Conventional Techniques

i. Geodatabase Acquisition and Information Extraction

The data of conventional techniques were acquired from the Kankai Municipality. Acquired geodatabase was in *.mdb* extension prepared using total station survey and perpetual software parcelEditor in ArcGIS. Since, it wasn't supported by STDM plugin of QGIS, necessary data were converted in *.shp* via ArcGIS software. Then, all *.shp* were added in STDM plugin for further procedure. The acquired geodatabase consists of lots of information related to parcel and owner. Only the area of necessary parcels (73) were extracted from geodatabase acquired from municipality, while time taken and cost required to accomplished the surveying and mapping of 73 parcels was retrieved through involvement with the surveyors of the municipality.

3.2.3 Comparative Analysis

Comparative charts in terms of Area, Time, and Cost of both methods (FFPLA tools &Conventional techniques) were prepared for further analysis. Area Comparison was done based on the relative difference of parcel area generated via two different methods. While comparing the area of two different methods, root mean square error (RMSE) along with error percentage was also computed. Then, the deviation range of the area with respect to the parcel quantity was also analyzed. Similarly, for time and cost comparison of the both methods, comparative charts were prepared and analyzed in excel sheets based on the information retrieve from the concerned authorities.

Results and findings

4.1 Area Comparison

The figure (3) illustrated the comparison graph of the parcels area measured using conventional techniques (ground survey) and FFPLA tools (satellite Images). The selected parcels (73) cover an area of 68087.61 and 68151.75 sqm while measuring area from ground survey and satellite images respectively. This study shows ± 52.19 sq. m root mean square error (RMSE) i.e. ± 8.62 % of RMSE. It reveals that more than 86 % of parcels mapped are within 10% of deviation of area. This study also shows that the deviation range gradually decreases with the increase in the area of parcels. The deviation ranges from 0.1- 33 % where parcels having area up to 1000 sq. m while the deviation is larger when compared to parcels having area more than 1000 sq. m. Moreover, figure (4) depicts the deviation range of the measured area of selected parcels. It shows that out of 73 parcels, 8 were found to have deviation less than 1%. Similarly, 37, 18, and 10 parcels were found to have deviation range between 1-5 %, 6-10% and >10% respectively.

4.2 Time Comparison

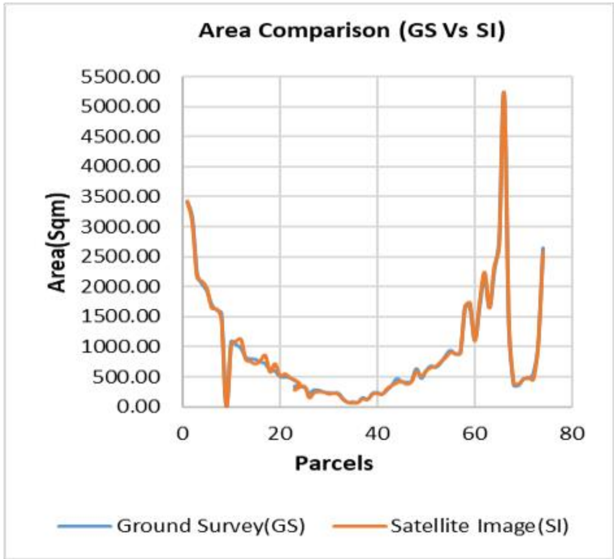


Figure 5: Area Comparison

The comparative table between major activities of the conventional techniques and FFPLA tools is illustrated in the table (2). It reveals that the conventional technique requires almost 3 times more time than the FFPLA tools while examining sample of 73 parcels. While adopting the conventional techniques for mapping 73 parcels, it consumes more time in reconnaissance and monumentation of control points due to larger distance of the traverse leg and time for monumentation of concrete pillars respectively. Similarly, while adopting FFPLA tools; boundary Identification and

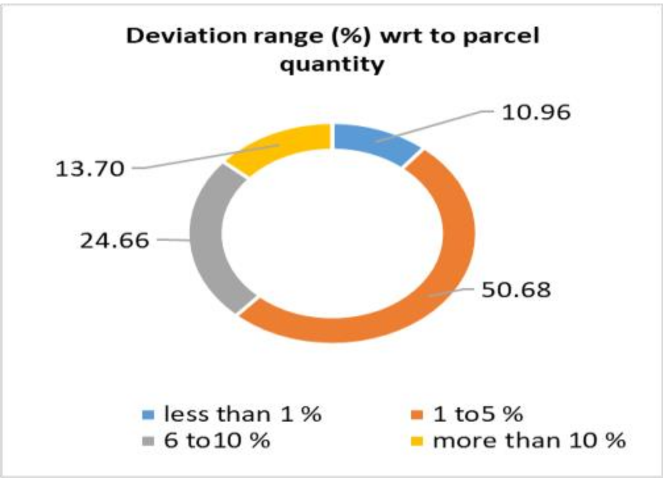


Figure 6: Deviation Range

demarcation via participatory mapping consumes more time while compared to other activities due to difficulty in identifying the parcels on the print maps. Besides, this study also reveals conventional technique requires more field activities when compared to the FFPLA tools. Finally, this study yields, if the surveying and mapping is to be done on the larger area with difficult topography, then it is difficult to accomplish the task in short period of time using conventional techniques.

4.3 Cost Comparison

The table (3) and (4) illustrate the cost required for surveying and mapping using conventional techniques and FFPLA tools respectively. While comparing for sample parcels, it shows large difference of Rs 61,812 which rationalize conventional technique takes 6 times more resources than that of FFPLA tools. This study also reveals that an average of Rs 170 and Rs 1016 per parcel is spent using FFPLA tools and conventional techniques respectively. Similarly, this result

Major Mapping Activities (Time; days)	
Conventional Techniques	FFPLA tools
Planning of the Field Survey (1)	Image to Image Georeferencing of satellite images (1)
Reconnaissance of Control Points (3)	Boundary Identification and demarcation via participatory mapping (3)
Monumentation of control points via concrete pillar (5)	Digitization of the demarcated boundary via SDTM tool (1)
Control Survey using Traverse (3)	Field Verification and Necessary Correction (1)
Detail Survey (3)	-
Data Processing and digitization (1)	
Field Verification and Necessary Correction (1)	-
17 days	**6 days**

Table 2: Mapping activities

also examines that, major cost is spent on human resources when compared to other resources in both the methods.

Results generated from this study illustrates that, adopting conventional techniques requires large amount of cost and time while comparing FFPLA tools. This study also reveals that desirable accuracy with low cost and less time can be accomplished using FFPLA tools. Adopting the conventional techniques only involve (black box) the

Major Resources	**Unit (Rs)** Per day	**Quantity**	**Time (days)**	**Total Cost (Rs)**
Total Station	2000	1	8	16,000
Software Cost	360	1	8	2,880
Surveyor	940	1	17	15,980
Asst. Surveyor	887	2	17	30,158
Chainman/ Helper	500	1	17	8,500
Laptop	90	1	8	720
Total				**74,238**

Table 3: Cost Comparison of FFPLA Tools

communities during adjudication of boundaries whereas FFPLA approach empower the vulnerable and indigenous people in mapping activities and land rights through active local participation. This study also reveals while surveying and mapping over larger area, conventional techniques needs to be used for areas where land value is too high, whereas less densely populated areas (rural areas) can be mapped using the FFPLA approach. Otherwise, huge amount of budget should be allocated, which is difficult for a developing country like Nepal.

Discussion & conclusion

FFPLA tools is recognized throughout the world, since

Major Resources	Unit (Rs) Per day/ sqkm	Quantity	Time (days)	Total Cost (Rs)
Satellite Image	2250 per sqkm	1 sqkm (approx.)	-	2,250
GIS related person	940	1 person	6	5,640
Laptop	90	1	6	540
Digitizer	666	1 person	6	3,996
Total				**12,426**

Table 4: Cost Comparison of Conventional Tools

surveying and mapping activities can be done with low cost and time. The primary objective of this study was to compare the two methods; FFPLA tools and conventional techniques for surveying and mapping of selected 73 parcels in an allocated study area. It demonstrates that the root means square error of FFPLA approach compared to the conventional techniques is ± 8.62 %. In addition to this, it also reveals more than 86 % of parcels mapped are within 10% of deviation of area. This study also depicts FFPLA strategy is 3 times faster and 6 times cheaper when compared to conventional techniques while implementing for 73 parcels. Results generated from this study shows satellite images with high spatial resolution can be faster and cheaper with desirable accuracy on open and flat areas. Similarly, drone imageries can also be also used if higher spatial resolution is needed for delineating the parcel boundaries. The conventional technique can be used in urban areas where land value is high and have obstructed areas from satellite images/drone imageries etc. Based on the results generated from this study it can be said that adopting the conventional techniques over all the country surveying and mapping of approximately 13,60,000 unregistered land parcels is almost impossible in short period of time. Thus, considering the need for fast, cheap and good solution for tenure security for all, the FFPLA approach is recommended.

Acknowledgements

Authors like to thanks Kanakai municipality and Land Issues Resolving Commission for accessing giving the necessary datasets used for this study.

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Geo-enabled Municipal Energy Planning (MEP) in New Federal Context of Nepal

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Abstract

Energy is a fundamental need of modern society and is a basis for economic and social development. In 2019, Nepal has total electricity access of 87.55%, grid energy by 77.80% and with no access by 12.45%. In terms of electricity access remarkable progress has been made in Nepal, however, people residing in remote rural areas are still not benefiting from the grid electricity. The reasons behinds this might be expensive cost incurring for grid extension to those areas due to poor proximity to a settlement with difficult terrain and topographic diversity. On the other hand, Nepal is also blessed with abundant water resources and solar potential, harnessing a mix of decentralized technologies such as mini/micro hydro power (MHP) and solar energy systems comes to the fore to reach universal access a reality where connections to the national gird are nearly impossible. For this, an integrated planning approach that encompasses the best available technologies are explored in terms of 1) Life Cycle Cost and 2) Levelized Cost of Energy among which a) extension of grid electricity, b) installation of solar home system and c) installation of min-grid (MHP or solar) are assessed that is best suited for a given catchment area for electrification. To do so, an energy assessment is conducted with the exploitation of energy related geospatial and socio-economic data that are coupled with a mobile survey app by collecting data on households, businesses, communities in order to garner energy status-quo and enables local governments to assess the existing energy situation. Recently, Nepal's Constitution 2015 incorporated a federal system under the purview of a municipality as the local government. In this context, this paper aims to examine geo-enabled municipal energy planning (MEP) processes to ensure sustainable energy access to the people. The process is presented in a data-driven approach for renewable energy planning at the local level. In the end, FOSS4G based MEP tool is demonstrated with an automatic generation of a comprehensive municipal energy plan from primary and secondary data sources.

Keywords: Geospatial, Grid Sampling, Baseline Energy, Best Available Technology, Decentralized Renewable Energy, Integrated Municipal Energy Planning

INTRODUCTION

From the very beginning of the agrarian society, energy is becoming a basic need of human beings for cooking foods. Nowadays, the use of energy varies from cooking, lighting, heating, communication, to operate home appliances, and running institutions, enterprises and industries that improve the quality of life (Goldemberg et al., 1988). Therefore, energy is crucial to perform the daily socio-economic activities of modern society and its consumption is one of the key indexes of human development as per capita energy consumption of the developed countries outweighs the under -developed countries like Nepal (*Key World Energy Statistics*, 2020).

Nepal is a mountainous landlocked country that extends from east to west ranging from the plain area (17%) in the south, mid hills (68%) is in between and high mountains

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(15%) in the north with more undulating high and low elevations representing complex geography. Nepal has a population of 30.40 million with an annual growth rate of 1.35% with more than 6 million households (CBS, 2021), with a GDP per capita income of USD 1155("The World Bank," 2020).

The Constitution of Nepal 2015 has incorporated a federal structure and devolves power from central to the local governments with 753 municipalities. The newly formed local governments are now empowered to design policies and support programmes, and deliver public goods and services in regards to decentralized renewable energy (RE) ("Constitution of Nepal," 2015). Due to rapid urbanization and merging of municipalities to form 293 urban and 460 rural municipalities, only 37.8% of the population resides in remote areas. In 2019, NEA and RERA claimed that Nepal has total electricity access (87.55%), grid access (77.80%), RE (9.75%) and 12.45% with no access (RERA, 2019). The disconnected households corresponding to villages or settlements are sparsely distributed or isolated with a small household cluster in rural areas. Poor accessibility to these locations, difficult terrain and topographic diversity could be some of the reasons behind hindrance to penetration of grid electricity in such areas. And also, 69% of households still relying on solid biomass for cooking and a majority of the households (68.6%) use traditional fuels as their primary stove for cooking and heating purposes (RERA, 2019). Alongside the negative effects on health and gender, the climate is adversely impacted by traditional cooking practices. This also means that Nepal remains far off track from achieving the 2030 target for United Nations Sustainable Development Goal, 7.1: ensuring universal access to affordable, reliable, and modern energy cooking services. To address this issue, possible best available RE has to be assessed and the municipalities are strengthened through improving evidence-based planning, informed decision making and better allocation of local resources. At the same time, the Alternative Energy Promotion Centre (AEPC) is the government's nodal agency for the scaling-up decentralized RE. The promotion of decentralized RE builds strongly on subsidies and has so far been unable to build sustainable markets for these technologies ("Alternative Energy Promotion Centre," 2021). Moreover, coordination between local governments and federal governments is essential to adopt an integrated planning approach to achieve universal access to energy for the citizens of Nepal.

The RE is referred to as a clean form of energy that comes from natural sources or processes that are constantly replenished. The major RE sources are hydropower, solar, wind and biomass which are substantially available in Nepal and harnessing a mix of technologies is the key determinant to provide energy access in the far-flung communities of Nepal.

Surendra et al. (2011) present the current status of RE and which helps to identify major RE sources for the promotion as well as the adoption of the RET. H. Shrestha (1966) claims Nepal has about 42,000 MW economically exploitable hydropower potential out of which only 2% has been installed yet and micro-hydropower plants (<100KW) whose potential installation capacity has been estimated to 50MW, can be installed at the vicinity of the local level.

For more than two decades, the AEPC together with various development partners, has been using subsidies as a tool to stimulate demand for off-grid renewable energy in the country. This fiscal tool coupled with community mobilization practices helped the uptake of various RETs that has transformed the lives of millions of poor households by providing them cooking, lighting and other energy-induced income-generating solutions. Specifically, MHPs are contributing to uplift the livelihoods of rural people and opening up other avenues for economic activities. With the support of the AEPC, more than 32.159 MW of micro/mini hydropower plants have been providing off-grid electricity to more than 3.5% of the population of Nepal(RERA, 2019). Moreover, reaching universal electricity access to all is still a major challenge as the grid networks are expensive for a hilly country like Nepal due to its undulated topography and scattered rural settlements with a lack of access roads and adequate transmission networks (Surendra et al., 2011). Additionally, Nepal has high a potential for solar energy and experiences an average of 6.8 sunshine hours per day with an average intensity of solar energy of 4.7kW/m2 (ranging from 3.9 to 5.1 kWh/m2)(J. Shrestha, 2006). In these consequences, the locations where extending the grid is not feasible, mini-grids are to be promoted where feasible with consideration of affordability of the technology and its sustainability. Hence, it is a paramount to have a comprehensive energy plan with the exploitation of decentralized RETs to electrify rural areas and to improve the quality of life of the population residing in far-flung communities.

Nowadays, numerous free geospatial datasets, such as administrative municipal boundaries, SRTM are landcover are becoming readily available in the public domains (Kabir, 2015; Survey Department, 2015; Van Zyl, 2001). At the same time, recent development in FOSS-based geospatial information and communication technology (GeoICT) offers a historic opportunity to enable a fast-changing and knowledge-driven society. The GeoICT and tools are capable to collate, analyse, visualize and even online processing of complex algorithms compared to traditional data management and processing approach(Anderson et al., 2007; Cross Compare, 2012; GDAL, 2013). Application of these tools and technology is awarding for assessing energy among various RE alternatives.

This paper aims to present the municipal energy planning (MEP) process and proposes a geo-embedded tool in the federal context of Nepal. The planning process is discussed in the multi-tier framework (MTF) for energy access measurements. The main purpose of the MEP tool was facilitating the generation of a comprehensive energy planning report in a data-driven and evidence-based approach with utilizing geospatial datasets, geospatial tools and technologies, as well as established energy-proven technologies. The MEP tool devises major three base tools viz a) spatial grid sampling and energy baseline survey, b) best available technology (BAT) and c) explore tool to check micro-hydropower potential (MHP) plant underlying to generate the comprehensive municipal energy plan.

LITERATURE REVIEW

In recent days, energy planning is accomplished with the use of energy models. An energy model can defined as a simplified representation of real system which can be used to conduct complex analysis and or calculations. Hourcade et al. (1996) and Grubb et al. (1993) classified different energy models in terms of purpose, structure, optimization, aggregation, geographical coverage and so forth. Energy optimization models which are used to identify the best among the available alternatives for promoting the use of RE sources, are presented by (Cormio et al., 2003; Luhanga et al., 1993). These studies demonstrated the use of energy plan developed based on supply and demand at cluster to municipal levels.

Generally, energy planning is carried out at centralized level in view of grid electricity and its distribution which triggers remote villages remain isolated due to incurring high capital cost of generation and transmission. However, it fails to solve the problems of rural areas where population is scattered and village settlements are isolated. To address this sort of problems, Das et al. (1990) studied in selecting an appropriate alternative energy technology with a priority which can harness RE sources for rural areas of India. With use of dynamic programming, the study was carried out based on a field survey. Similarly, Van Beeck et al. (2000) proposed a method for local energy planning, a village level, which focuses to prepare energy plan based on data availability and renewable energy options. Although, the method uses a decision support tool, it does not help energy planner to take actions.

On the other hand, energy inputs are important parameters for comprehensive analysis of energy scenarios of a rural system which shall totally depends on primary and secondary data sources (Devadas, 2001). In view of current pattern of centralized electricity planning, Hiremath et al. (2007) reviewed on different decentralised energy planning models and approaches with respect to available energy locally available energy sources. The review emphases local level and decentralised energy planning models to adopt bottom-up approach using fragmented and isolated data to solve the problems of rural areas regarding access to energy. The emphasis is given the fact that large proportions of rural population depend on low-quality energy sources leading to a low quality of life which led to environmental degradation. Thus, the review highlights a need for an alternate approach of renewable energy planning for sustainable economic development.

In context of Nepal, a majority of Nepalese population resides in rural areas where they are using conventional energy sources e.g., fossil fuel and biomass, for lighting and cooking. These energy sources are not clean, sustainable and even not techno-economically feasible which lead to keep female and children are in danger (Zhongming et al., 2017). Inconsequence, active working hour per day is limited to them (N. Shrestha, 2017) for performing better economic activities.

Where grid-energy is inaccessible or costly while extending it to rural areas, solar energy can be a major source. The solar energy can be exploited for a targeted single house (Solar Home System) or a group of houses (Solar-Mini Grid). Moreover, Nepal is blessed with snow-fed and natural river systems which has potential for micro-hydro power installations locally. Normally, energy planning is explicitly spatial in nature as Herrmann et al. (1999) presented decentralised planning concepts for examining at regional and local level (a settlement as a community) using Geographic Information System (GIS) and modelling approach. On the other hand, geospatial data related to energy and topography (Kabir, 2015; Van Zyl, 2001) are readily available and the data gaps related to ground reality can be acquired with the exploitation of latest geospatial tools and technologies (Hartung et al., 2010). These datasets can be utilised to conduct comprehensive energy planning to choose the best energy planning among the available alternative RE sources at local level. At the same time, a comprehensive municipal energy planning report is generated for short term energy planning.

Thus, energy assessment is feasible even at small village community with proper data collation from various sources. The energy assessment is performed at settlement or community level with use of available energy and topographic geospatial datasets along with complementary insitu data collection using latest FOSS based geospatial tools and technologies. The energy assessments at geographically isolated communities are aggregated at the municipal level. At the end, this study presents a novel method to develop a comprehensive municipal energy plan and maps automatically.

METHOD AND MATERIALS

Data-Driven Approach

Various fragmented and segregated data are compiled and integrated from different sources into a single gateway. It includes a) population and demographic, b) topographic, c) energy infrastructure, d) crowd sourcing, and e) field-based survey data. Population and demographic data are used to study trend of population growth and enumeration of households. Topographic data comprises of administrative boundary, elevation, landcover, river and road networks and settlements.

Administrative boundary is used to discriminate municipal boundaries and limiting the energy assessment withing a municipality. Elevation data is important for understanding topography of the location in terms of altitude, slope and aspect of the terrain where energy assessment is to be conducted. Moreover, solar potential areas are derived using the elevation data. Landcover data helps to understand ground situation such as from forest, agriculture and built-up areas. Potential micro-hydro power can be explored based on availability of river networks within a municipality. Accessibility of municipality is assessed with use of road networks and settlement's locations provide information on where the people being reside. Energy infrastructure consists of locations of sub-stations, distribution lines and location of transformers are used to understand and assess the accessibility of grid-energy and possibility of its extension. Crowd sourced data such as building foot prints or locations of households are most essential for delineating the settlement or to know where do people live. Such data can be used to estimate the service area if an energy plant (Solar mini-grid or micro-hydro power) is installed locally. The data gaps from these secondary sources are complimented from field-based survey, for example, energy baseline.

Thus, these datasets can assist to get preliminary energy related information of any municipality. Further, this will enable to explore, visualize and acquainting on energy situation and available energy resources at a particular interest area, even at a community level. Moreover, energy assessment can be performed in data-driven approach specific to the spatial location and available contextual information.

Energy Planning Process

Basically, municipal energy plan is prepared for a period of five years. The plan encompasses of a) current energy profile including households, industries/enterprises, and institutional energy supply and demand scenario, b) vision of desired energy future, c) measurable and achievable goals and objectives to meet future energy demand, d) prioritize actions to meet goals and objectives, e) estimation of funding requirement and identification of potentials financing and funding mechanisms and as well as f) monitoring and quality assurance of energy plan. The plan is an outcome of an energy planning process. The process is a cyclic process comprising of a nine-step planning process (Figure 7**Error! Reference source not found.**), jointly developed by AEPC, RERA and RERL.

Step 1 Identify Stakeholders: Stakeholders play roles of generating, controlling sales of, and sells or uses energy. The stakeholders are categorised into three levels viz a) key, b) primary and c) secondary. Key stakeholders are the ones without whom the energy measures identified in the MEP cannot be implemented. The primary stakeholders those who directly (positively/negatively) affects by the energy activities of the municipality and the secondary stakeholders are those indirectly or temporarily affects the energy measures.

Step 2: Establish Energy Development Sub-Committee (EDSC): EDSC is established for execution and implementation of the energy plan and play leading roles to take necessary decisions and actions regarding allocating funding resources and promoting the energy project.

Step 3: Develop Energy Baseline: Understanding of energy baseline conditions provide a basis for planning. The energy baseline study is carried out to gather information on current energy access scenario. Further, this will use three major technologies and tools to assess the energy baseline. The development of energy assessment tools is presented and discussed separately in implementation section.

Step 4: Development: In this step, energy vision, mission, goal, objective and strategy will be formulated, which will facilitate to provide an aim and direction for a municipality on way forward to improve energy access situation.

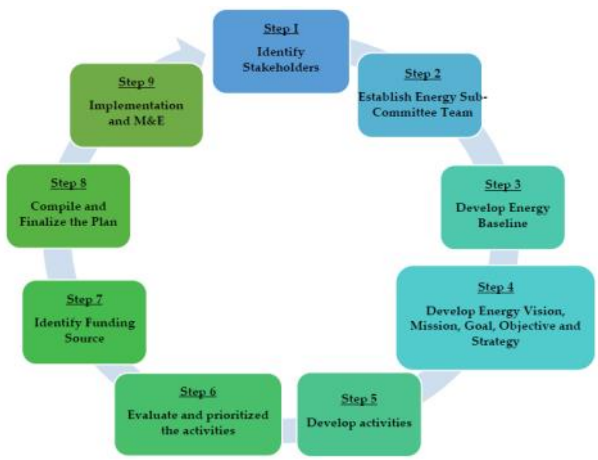

Figure 7: A nine-step planning process

Step 5: Develop Activities: A broad range of activities are identified based on the formulated vision, goals and objective, and energy base line of the energy plan to be developed.

Step 6: Evaluate and Prioritize Activities: Each activity is evaluated and prioritized based on the results achieved from the energy assessment tools.

Step 7: Identify Funding Sources: The total fund required for the implementation of prioritized activities and possible funding sources will be identified from various organizations: within municipality, federal government, development partners, community and others.

Step 8: Compile and Finalize Plan: The information gathered from the above steps will be summarised and consolidated into a periodic municipal energy plan with illustrative facts, figures and maps.

Step 9 Implementation and Monitoring & Evaluation: During actual execution of the plan, the progress of each activity is periodically monitored against the pre-defined indicators to ascertaining the successful implementation of the plan

Clean Cooking Framework

In line with energy planning process, RERA developed a simplified clean cooking access measurement framework towards clean cooking solutions which defines criteria to categorise fuels and stoves. The framework classifies cooking fuel as into three categories: a) basic fuels (e.g., coal and kerosene), b) intermediate fuels (e.g., biomass products), c) modern fuels (e.g., BLEN: Biogas, LPG, Electricity and Natural gas). Similarly, it categorizes household cookstoves into basic, intermediate and modern cookstoves. Further, access levels are defined as a) tier 0: low, b) tier 1-2: partial, c) tier 2-3: intermedia, and d) tier 4: modern and advance following the Multi-Tier Framework (MTF) as in Annex-I. This has been implemented to conduct field-based survey as well as establishing energy baseline of the given municipality.

Energy Assessment Methods

Most of the household in the country receive electricity from the national grid and about 9.75% from off-grid RE sources (RERA, 2019) such as Pico Hydro (<10KW), Micro Hydro (10-100KW) and Solar Home System (SHS). Although there is a huge potential for Mini-Hydro (>100KW), very few projects have been developed in the country in recent years due to technical and operational challenges. The most appropriate technology depends on specific circumstances. Therefore, exploration and assessment of various energy alternatives are required to choose a best available technology (BAT) in terms of investment and cost of energy.

To assess the cost-effectiveness of the technological options, two energy cost assessment methods; a) 'Life-Cycle Cost' (LCC) (Ren et al., 2019) and 'Levelized Cost of Energy' (LCOE) (Raikar et al., 2020) are devised. The LCC of a project is defined as the total amount of all costs incurred in the project from its initial design stages to its decommissioning. It is calculated as the present value of the total cost of purchasing, installing, operating, maintaining and repairing energy generating and or distributing system over its economic life and is given equation (1). The life-cycle cost analysis (LCCA) takes all costs into accounts, all from the cost of construction, fuel cost, repair cost to the cost imposed by emission from the project. The LCCA of a project helps to compare different technical options to determine which technology is the cheapest in the long run.

$$LCC = CC + \sum_{i=0}^{n} \frac{(OMC + RC + FC)}{(1 + DR)^i} \#(1)$$

Where;

LCC= Life Cycle Cost
CC= Capital Cost
OMC = Operation and Maintenance Cost
FC = Fuel Cost
DR = Discount Rate factor
n = No. of years

The LCCA is usually presented in the form of the levelized cost of energy (LCOE) of the project. LCOE is defined as a measure of a power source that allows the comparison of different methods of electricity generation consistently. It is an economic assessment of the average total cost to build and operate a power-generating asset over its lifetime divided by the total energy output of the asset that life time and can be calculated using equation (2).

$$\boldsymbol{LCOE = \frac{LCC_i}{\sum_{i=0}^{n} \frac{EG_i}{(1 + DR)^i}}} \#(2)$$

Where;

LCC=Life Cycle Cost
EG=Electricity Generation
DR=Discount Rate factor
n= No. of service years

The LCOE measures the costs over the lifetime of the proposed energy project and determines how much it costs to produce an amount of energy per kWh. The LCCA and LCOE of the project can be used to compare the lifetime costs of one energy option to another to identify the best available technology (BAT). How BAT has been implemented is discussed separately in section 0.

In the context of Nepal and in accordance with sustainable development goal (SDG), energy access should be with provision of tier-2 energy access option in line with multi-tier framework (MTF) and hence it is considered as the baseline and needs to be adopted. The amount of energy within tier-2 will be adequate for various appliances such as electrical lighting, air circulation, television, and phone charging. The energy consumption will be minimum of 50W and 200Wh with duration of min 4 hours per day and min 2 hrs in the evening to meet this tier. To assess the energy options and to identify, major three RE were considered, namely, a) grid-extension, b) min-grid (MHP or Solar Mini-grid) and c) solar home system (SHS). To check the potentiality and possibility of these energy options, the following criteria have been set to check the potentiality of a particular energy under assessment.

Grid-Extension (GE): Grid extension shall be evaluated with an estimation of LCC and LCOE based on 11kVA gridline, finding nearest transformer from the service centre such as centroid of a settlement cluster and aerial distance between them targeting to tier-3 energy by default.

Mini-grid: (Micro-Hydro power or Solar Mini-grid): Firstly, for the given location, it needs to be checked whether there is already a mini-grid (MG) or provision for the near future for development. Else, assess the possibility and development of a potential mini-grid in the vicinity of the area or its surrounding within a municipality.

Solar Home System: The calculation also provides LCC and LCOE for solar home system (SHS) for a single household. The solar potential of the area is determined with a criterion of minimum peak sunshine of 4 hours assuming annual sunshine days of greater than 300 days.

Decision Tree

Just looking at the technological aspect of each energy option and associated costs shall not be sufficient to decide which energy type is best to choose among the available energy options for a particular are of interest. For deciding the best available technology (BAT), a decision tree (Figure 8) developed by RERL, AEPC was adopted. According to this decision tree, at first, energy demand (kWh/Year) is estimated for a given location or of a settlement cluster. Then, the possibility of gird extension from nearest grid (distribution line or a transformer) is checked. If grid extension limit is greater than the allowable distance from the grid, a plan for future plan for grid extension is checked and if future grid extension period is less than five years, it is recommended to go for SHS or MG. If not, energy assessment for each option is evaluated in terms of LCC and LCOE and technology with the least LCC and LOCE is selected as the feasible BAT.

IMPLEMENTATION

Deriving Energy Datasets

To check the potentiality of each available RE options: grid extension, MG and SHS, different energy datasets are developed with use of energy criteria defined in section 0.

Household Clusters: Building footprints from OpenStreetMap (OSM) (Mooney et al., 2017) was used to discriminate a contagious household cluster as an isolated settlement. Generally, the size of the individual building footprint, a household ranges from 3 to 4 meters in hilly terrains of rural Nepal. If two building footprints are separated within 100 meters of aerial distance, justifiable in hilly geography, both footprints are treated as lie in the same cluster. Thus, formed household clusters help to visualise and understand where do people live with or without access to energy, for example, the national grid.

River Networks: River networks of whole Nepal was generated from 30 meters SRTM data (Van Zyl, 2001). The dataset was topologically corrected and river order is calculated for each of the river lines with elevation nodes assigned. Thus, the created dataset was used to explore whether micro-hydro power can be installed for a given river stream at the municipality level.

Figure 8: Decision Tree from RERL, AEPC

Grid Extension Potential: Grid electricity distribution lines (33kV and 11kV) were topologically corrected. Topographic cost distance was computed for these electricity distribution lines. A 1000-meter cut-off cost distance was used to define the potential grid extension area which helps to check whether grid electricity is extensible or not to a given nearest settlement cluster. The decision is made as if a given point is within this region is marked as grid extensible otherwise not.

Micro-Hydro Potential: For existing micro hydropower, a 1000-meter aerial radial distance was used as a service area of the micro hydro power. If a point lies within this area, it is marked as accessible to micro-hydro power otherwise not accessible.

Solar Potential: A 90-meter SRTM data (Van Zyl, 2001) was used for solar potential mapping. Solar radiation was calculated at pixel level and flagged as solar potential if it meets the criteria of at least 4 sunshine hours and has annual sunshine days with greater than 300 days. This dataset helps to check whether there is solar potential for a given point or not for installing SHM or SMG.

Energy Assessment Tools

The energy planning process constitutes of a set of energy assessment tools, in other words, Municipal Energy Plan (MEP) tools. The tools ranges from a) dashboard for exploring geospatial data and infographics, b) grid-sampling and survey toolkit for conducting household survey, c) BAT for identifying the best technology among available renewable energy options, d) micro-hydropower potential exploring tool and finally, e) report generation module (RGM) that compiles all information and results into a comprehensive period municipal energy plan.

Dashboard: A platform that facilitates to exploration of different geospatial datasets and other information related to population, energy and physical infrastructure, landcover and field survey-based baseline energy information including clean cooking infographics. The tool can be used to explore and visualize data and supports evidence-based energy planning for three-tiers of governments.

Grid-Sampling and Survey Toolkit: While conducting a field-level household survey, visiting every household might not be practical as it can be resourceful, time-consuming and costly. In this case, a sample-based survey can be handy and efficient, and GridSample (Thomson et al., 2017) tool has been devised to conduct field surveys for representative households only. From this method, grid samples are generated at the municipal level ensuring that each ward has at least one grid sample. Thus, a household survey is carried out in each of these grid samples and later aggregated the information at the municipality level (Pelz, 2020). Survey forms were designed with ODK platform (Hartung et al., 2010) and were integrated with the MEP tool to conduct field surveys to capture data of a) households, b) focus group discussion at ward level, c) energy infrastructures and d) enterprises.

Best Available Technology: Identifying the best energy technology among the available renewable energy options is termed as Best Available Technology (BAT). The most appropriate technology is evaluated based on energy demand, availability of energy resources, minimal life cycle cost (LCC) and minimal levelized cost of energy (LCOE), and access to the energy for a specific geographic location. The LCC and LCOE are being calculated by using equations (1) and (2) respectively.

Micro-Hydropower Potential: If net head, discharge, turbine/generator efficiency is given, power generation can be estimated using potential energy of water using equation (3) (Calisal, 1983). Reversely, for a given geolocation of intake of a specified river, discharge and required power, downstream location can be estimated with a promising head availability calculated by using equation (4) following the river creek line from intake to the location of the head.

$$H = \frac{P}{6867Q} \#(4)$$

Where;

P = the power output, measured in Watts.
h = the efficiency of the turbine
r = the density of water, taken as 1000 kg/m^3
g = the acceleration of gravity, equal to 9.81 m/s^2
H = the head, or the usable fall height expressed in meters
Q = the discharge, also called the flow rate, calculated in m^3/s

With values of h=0.7 (70% efficiency) for instance, r and g used, the equation can be generalized as in equation (3).

$$P = \eta\rho gHQ \#(3)$$

Additionally, this tool can be used to calculate a circular service area that encompasses the number of underlying households which can be served from the generated energy.

Report Generation Module: All the information and results generated during the energy process are compiled automatically into a printable report, a periodic municipal energy plan. The report consists of a) characteristics of a planned municipality, b) baseline energy profile, c) energy assessment results, d) comprehensive maps, e) an executable plan with prioritised activities, and f) monitoring and evaluation framework.

Characteristics of municipality contains information on demography, physical and energy infrastructures, and topography. Infographics including clean cooking generated from the field survey are presented in baseline energy profile. BAT results are summarised in energy assessment section of the report. A list of automatically generated illustrative maps are presented in relevant sections. Activities are prioritised based on ranking and availability funding resources and presented in the form of plan. For implementation of thus generated plan, monitoring and evaluation framework is added a part of the energy planning report.

Development Framework

FOSS based development framework with exploitation of geospatial tools and technologies, has been proposed for the development of the Municipal Energy Planning Tool. Frontend tools and technologies are Openlayers for client-side mapping and Vue.js with HTML, JavaScript and CSS. Backend tools and technologies are Postgres/PostGIS for geospatial database handling, GeoServer for mapping and geospatial data abstraction library (GDA) for geospatial data process in Linux environment with nginx web server (Anderson et al., 2007; Cross Compare, 2012; GDAL, 2013; Schmidt, 2008).

An Illustrating Example

This paper presents an illustrating example for the process of municipal energy planning in the case of Khanikhola rural municipality, Kabhrepalanchowk district, Bagmati province, specifically for running tools viz grid sampling, best available technology and micro hydropower potential. Initially, settlement clusters will be identified with no or less access to national grid. Then, these tools are executed repeatedly at different settlement clusters to cover the municipality. The proposed municipal energy planning (MEP) tool can be accessed via http://mep.pathway.com.np/.

Grid Sampling Tool (GST): For implementing the grid sample tool, a 100-meter grided WorldPop (Tatem, 2017), rural and urban areas (municipalities) based on current federal structure of Nepal, and municipal boundaries have been used. The size of a grid sample used is 500 meters which constitutes 100 people and 10 households in each of 40 grid samples as the clusters, i.e., representing whole municipality by 400 households, suggested by Pelz (2020). A sample grids generated with these parameters for the municipality has been depicted in Figure 9. Municipal boundary and grid samples are displayed respectively in green and yellow colours.

Best Available Tool: For a digitized polygon or a settlement cluster as shown in Figure 10, BAT is executed in the server-side. The settlement cluster is represented by red household cluster encompassed by digitised cyan colour boundary. With a successful run of the BAT presents graphical scenarios for LCCs and LCOEs for all available renewable energy options and recommends a best available technology for tier-3 electricity access based on the inbuilt algorithm. In this case, the tool recommends SHS as a feasible technology for electricity access for the given settlement.

Micro Hydropower Potential: Micro hydropower potential was explored for a settlement of Mahadevtar along Mul khola (stream) with a parameter of discharge (0.02 m3/s) and at an interval of 5 kW at three consecutive locations. Circle represents service area with indicated capacity for underlying households targeting to tier-3 energy.

Discussion

The municipal energy planning (MEP) tool has been developed using FOSS based latest geospatial tools and technologies along with exploitation of various geospatial datasets. Municipal energy planning, primarily uses secondary and then primary data as a complementary in energy assessment process. Since the process has adopted a driven-approach, the beauty of the method is that results are

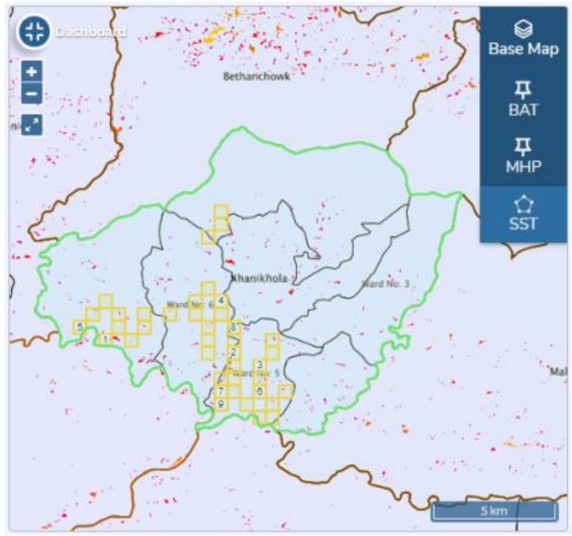

Figure 9: Distribution of grid samples

received with available facts and evidence. However, if the secondary data is raw or incomplete, this may mislead the results achieved. Therefore, the secondary data has to be accomplished with field survey data towards realistic results. While collecting field data, challenges due to poor road accessibility and proximity, topographic difficulties due to hilly terrains, and isolated and sparsely distributed population clusters should not be ignored.

A number of assumptions have been made while deriving the energy datasets and formulating methods. For example,

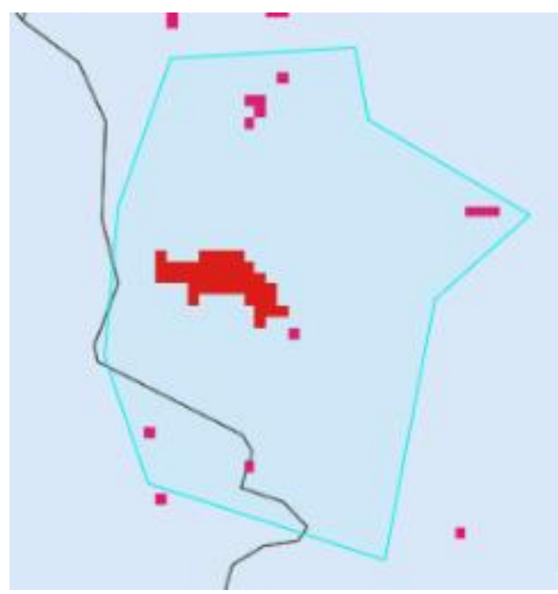

Figure 10: A settlement cluster

some isolated and parsley distributed rural settlements can't be identified for energy assessment as these settlements are visually inspected based on OSM based crowed sourced building footprints and census household data of 2011 (CBS, 2021). The reason behind might be a) incomplete OSM data in rural areas and b) old data household census data, outdated for current use. Similarly, incomplete or outdated electrical distribution lines can falsify for analysing the possibility of grid extension. Moreover, for

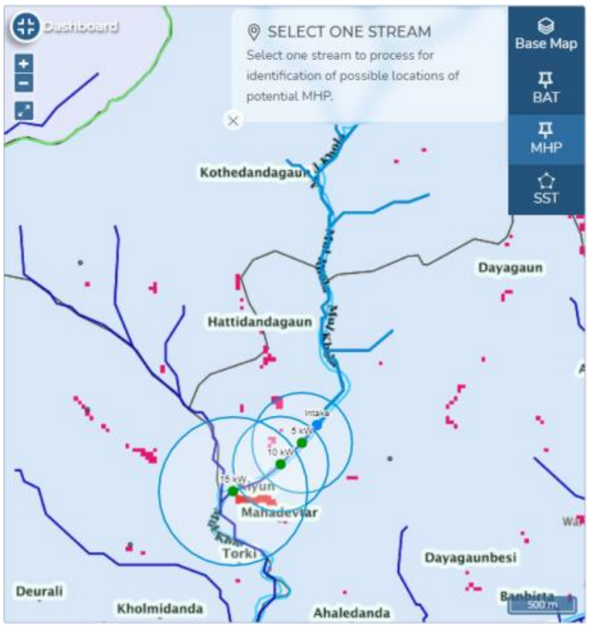

Figure 11: Exploring Micro Hydropower

solar potential mapping, spatial resolution of 100 meters has been used and solar radiation is calculated based on slope, aspect and sun angles. 100 meters represents a big area, can generalize ground reality in a very undulated hilly terrain and may not be feasible for installing SHS. However, this tool can be handy for rapid energy assessments and energy planning at the municipality level.

CONCLUSION

In this paper, we have presented a novel method for the geoenabled municipal energy planning process in the new federal context of Nepal to ascertain sustainable energy access to the people. The backbone of the approach is an automatized routine-based optimization on geospatial data and techno-economic input parameter. The process has been presented in a data-driven approach in conducting renewable energy assessment. In this process, best available energy technologies are explored with the devices: a) Life Cycle Cost (LCC) and 2) Levelized Cost of Energy (LCOE) for selecting the best technology among a) grid extension, b) micro hydropower and c) solar energy. In this context, a FOSS based municipal energy planning process has been demonstrated with the automatic generation of a comprehensive municipal energy plan using primary and secondary data sources. This study should contribute producing publicly available a number of energy datasets and opens up a new horizon for municipal energy planning. Knowing status of energy access and gaps is a very important piece of information in energy planning process. Based on that, energy assessment is conducted to municipal energy planning in order to help energy planners, decision and policy makers in energy area at the local level and beyond. This is initial step in for a municipal energy planning in bottom-up approach where energy assessment is performed at a village or settlement/population cluster level and aggregated at municipal or local level. The next step shall be operationalization of the energy planning process and scaling to whole Nepal.

Acknowledgements

The authors gratefully acknowledge the RERA-II. RERA-II is a German-Nepali technical cooperation that is jointly implemented by the AEPC and Deutche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The German contribution to RERA II is provided by the Federal Ministry for Economic Cooperation and Development (BMZ) for funding and supporting the development of the municipal energy plan tool. This paper reflects only the author's views and the public community is not liable for any use that may be made of the information contained therein. The contributions from colleagues, specifically Diwas Tamang and Suman Sanjel are hereby duly acknowledged for their assistance during system development.

Conflict of Interest: The authors declare no conflict of interest.

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Annex-I: Multi-Tier Framework

ATTRIBUTES		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
1. Capacity	Power[1]		Very Low Power Min 3 W	Low Power Min 50 W	Medium Power Min 200 W	High Power Min 800 W	Very High Power Min 2 kW
	AND Daily Capacity		Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
	OR Services		Lighting of 1,000 lmhrs per day and phone charging	Electrical lighting, air circulation, television, and phone charging are possible			
2. Duration	Hours per day		Min 4 hrs	Min 4 hrs	Min 8 hrs	Min 16 hrs	Min 23 hrs
	Hours per evening		Min 1 hrs	Min 2 hrs	Min 3 hrs	Min 4 hrs	Min 4 hrs
3. Reliability						Max 14 disruptions per week	Max 3 disruptions per week of total duration < 2 hours
4. Quality						Voltage problems do not affect the use of desired appliances	
5. Affordability					Cost of a standard consumption package of 365 kWh per annum is less than 5% of household income		
6. Legality						Bill is paid to the utility, prepaid card seller, or authorized representative	
7. Health and Safety						Absence of past accidents and perception of high risk in the future	

[1] *The minimum power capacity ratings in watts are indicative, particularly for Tier 1 and Tier 2, as the efficiency of end-user appliances is critical to determining the real level of capacity, and thus the type of electricity services that can be performed.*

Importance of Land Use Planning in the Management of Urbanization

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Abstract

Land Use Planning is a crucial tool for governing the growth of the city. This technique in master plan is ideal to allocate and reallocate land as a resource by effectively optimizing its use in the development of cities. It is certainly true in the case of achieving sustainable development purposes. This study was conducted to understand the master plans or planning efforts being made in the capital city of Bihar, Patna. The purpose of the study is to assess how the land-use planning approach has changed the urban environment through a track record of the plans being implemented in the city? How these plans ensured regulated or orderly growth of the cityt? What are the externalities imposed due to land use planning approach adopted for the city? A combined approach of open-source software's such as GIS, google earth and secondary data sources are studied to analyze the spatial growth direction of the city. This study indicates the significant importance of land use planning in the long term to spatially explicit land aptness for proposed uses. The land-use planning approach has been described majorly on land demarcation for various uses. However, it has not been appropriately explored in a comprehensive knowledge of land opportunities and constraints that city planners can correlates with urban environment.

Keywords: Land Use Planning, Master Plan, Urban Environment, Spatial Growth, Patna, India

Introduction

By 2050, the world's urban population is expected to nearly double, making urbanization one of the twenty-first century's most transformative trends (Nation, 2017). Around 3.3 billion people will live in towns and cities for the first time; a number is expected to swell to almost 5 billion by 2030, i.e., 60 percent of the total world population (UN-Habitat, 2015).

The spread of urbanization is on the net, an immensely beneficial process. Urbanization led to series of changes in the urban population and urban scale. It is also considered an inevitable trend of human social development. However, rapid urbanization poses several problems, including affordable housing, essential services, transport, opportunities, etc. Nearly 1 billion urban poor live in informal settlements to be near opportunities.

Of course, the substantial outward migration of people has caused problems, just as migration to the cities did. As more efficient agriculture has reduced the number of people needed in the field, the rise of the new push-pull phenomenon has shifted into high gear, imposing several ill-effects. Serviced urbanized land will be required to accommodate this new growth and land with adequate infrastructure to promote new industries and trade facilities.

The way United Nations and most economists look at it, a city encompasses not just the political geography that lies at the heart of an urban region but the entire surrounding metropolitan area. Once a city is built, its physical form and land use patterns can be locked in for generations, leading to unsustainable sprawl.

The land is a finite resource and is put to multiple uses. To manage the increasing demand for urbanized land or the supply of services requires efficient allocation of land resources. Therefore, land-use planning can be used to balance competing and sometimes contradictory uses while promoting sustainable land use options. This systematic assessment of land has been shown as best practices by research and experience to produce the best land-use

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options. Its purpose is to select and put into practice the land uses that will best meet the needs of the people while safeguarding the urban environment.

The challenges brought by rapid urbanization in different Indian cities are intensified by a lack of control and adherence to existing regulations. The spatial growth of the city with the master plan overlooked the sustainable urban development and exacerbated the degradation of the city environment. Like other developing nations, the Government of India determines that the growth and transformation of the Indian cities be rapid, well planned, sustainable, and equitable. It is also committed to managing this growth and change. To this end, the state government of Bihar, proposed master pan 2031 for the capital city, Patna, situated on the bank of river Ganga. This is to augment its urban land and urban environment more efficiently (Master Plan 2031).

The discussion below, divided into five sections, focuses on the following dimensions. Section two, literature review, explores the nexus of land use planning and interdisciplinary factor which influence land-use planning. Section three briefly describes the methodology adopted to the study and city profile and the track record of development plans implemented in Patna city. Section four presents result of the study. The concluding Section five highlights importance of land use planning in management of the Patna city..

Literature review

Nexus of land use planning and urban environment

The implementation of the master plan was an attempt to control strictly the settlement of urban areas, which enabled an insignificant measure of effective control over urban development.

There was no constitutional intervention after the (1962-81) master plan. The subsequent masters were only partially successful owing to varying socio-economic forces and statutory compliance. Further, to control unplanned development, master plan 1961-81 for 20 years. Nevertheless, Bihar Town Planning and Improvement Trust Act 1951 did not have adequate infrastructure and legal support to implement the plan. To overcome this, in 1982, PRDA was constituted. PRDA updated the development plan 1981-2001 (Master Plan 2031).

In the process of urbanization, the city experienced excessive population due to intra-state and inter-state migration. However, the planning agency's absence of planning interventions since 1981 did not match the rapid urban expansion and transition, which led to unplanned development, haphazard growth, and a dramatic boom in informal settlements in the city. It is common to observe that most of the city's population is in informal settlements, substandard housing, infrastructure, and inadequate basic amenities and utilities due to a lack of investment in infrastructure facilities and unchecked byelaws.

The city was under rapid urbanization and pertaining organic growth in the sub-urban. In parallel, the city was also facing significant problems related to high density built -up, abject poverty, dilapidated housing, traffic gridlock, dirty air, congestion, inadequate water supply, etc. It compelled the urban development of Bihar to take immediate action to re-orient the whole land-use system of the area to enhance the quality of the urban environment.

PRDA took immediate action to restrict the unplanned and haphazard development in and around the city. The uncontrolled growth beyond the formal jurisdiction of the urban development authority. This master plan incorporated all urban areas under its jurisdiction, i.e., PUA, Fatuha, Maner, Hajipur, and Sonepur. Further, PRDA took the initiative to prepare Master Plan 2001-2021. There was an urgent need to augment the city infrastructure such as sewerage, drainage, water supply, and solid waste management. But PRDA got dissolved after the repeal of the Bihar regulation development trust act 1981. Hence, Patna Municipal Corporation submitted the proposal in the year 2008. There was a lack of legal framework, and geospatial reference of master plan result in its disapproval.

The early master plans are rather ineffectual in guiding city growth and population project. It resulted in an unsuccessful and unstructured urban form. The approved plans were implemented to a limited extent and could not guide development, especially ineffective land use, physical and social infrastructures.

For example, there was a massive change in population characteristics, socio-economic conditions, economy, land utilization, density, migration, and employment rate. Moreover, in the year 2000, a new state, Jharkhand, was formed after the reorganization of states. The existing master plans though not implemented but were quick exercises. These plans inherent weakness to address the deviation on population, economy, employment, and other related matters. There is a disconnection between spatial planning, investment prospects, sector development, and lack of or ineffective development control. Etc. The city and surrounding area were facing distress due to inefficient planning procedures and negligence in the region's development. Moreover, the government had some degree of capacity and resource enforcement.

The pragmatic solution needs compatible land and appropriate density standards. The city experienced amplified fragmentation and dispersion, with the urban expansion process linear to major roads, forming ribbon development or leapfrogged islands, pronounced in outgrowth areas. Further, the city requires a land-use zone, zoning, phasing, and land development mechanism to assert the growth pattern. Hence, master plan 2031 proceeded to minimize the ill effects of haphazard development in the capital city.

Methodology

Methods and Techniques

The methodological approach incorporated mixed method. The study conducted the review of secondary data sources and the application of Geographical Information System (GIS) mapping to understand the city dynamic through

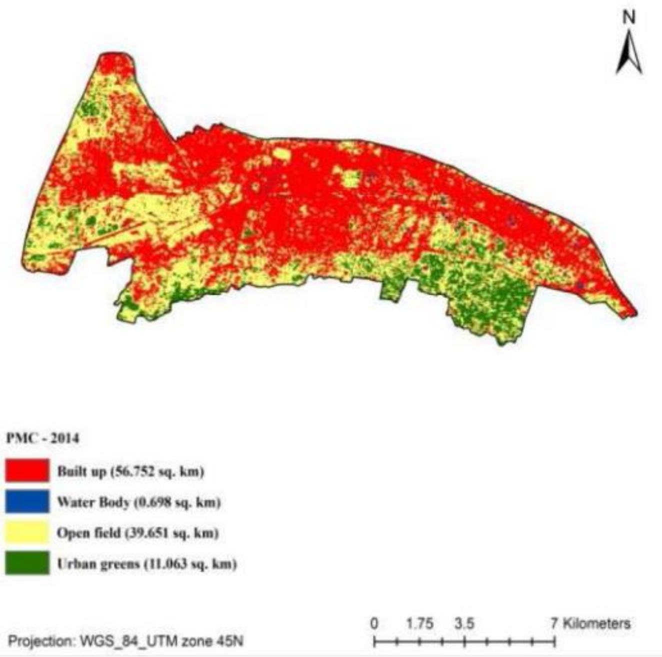

Figure 1 The Maps below show increase in built-up spaces within Municipal Boundaries of PMC from years 1989 to 2014 (M. & Sarkar, 2015)

spatial growth patterns and land use changes. The data was collected from 1961 to 2031 master plans of Patna city through official documents, census of India, legal and policy frameworks, previous published and unpublished manuscripts, news reports, books, and journal articles. The GIS combined the dataset of land use and spatial growth trends. The digital software mapping created a layered map to overlay different data and better analysed the complexity of the city dynamics. the other open-access software such as google earth, Global positioning system (GPS), georeferencing application was instrumental in featuring the timeline of expansion of the city and account for the change in urban planning and management of Patna. Examining the sequence of master plans 1981-2031 exhibits the deficit in planning theory and reality in its approach and implementation to attain a sustainable and well-planned city. The study analysed the settlement pattern, existing and proposed land use change, and spatial growth with available free open access software.

City Profile and track records of master plan

Patna is a metropolitan and the capital city of Bihar state of India. The city lies on the southern bank of the river Ganga, and Sone and Punpun rivers surround it from the other two sides. Patna occupied a significant place in Indian history, being an erstwhile city of Pataliputra in ancient times. The city is rich in history and attracts many tourists to the Hindu, Buddhist, and Jain pilgrimage centers of Vaishali, Rajgir, Nalanda, Bodh Gaya, and Pawapuri. It's a sacred city for Sikhs because the tenth Sikh guru, Guru Gobind Singh, was born. It has gradually developed its own unique culture and lifestyle as an outcome of the fusion of different cultures, people from other regions. The geographical condition and climate also played a vital role in giving the city its own identity.

Patna has emerged as a primate city in the state of Bihar. As per census 2011, the city had an estimated population of 3.7 million and 136 km sq (Census of India, 2011). Patna Municipal Corporation (PMC) is the nodal agency in the state. PMC is the largest corporation with a 44.1 percent share of the population of 7 corporations of the state and 20 percent of the total urban population of Bihar state (Master Plan 2031). The vast population is the resultant of the migration and internal growth of Patna.

As per census 2001, Patna Urban Agglomeration (PUA) had a population of 1.6 million, whereas the PMC population was 1.3 million. The total area of Patna Agglomeration as per the 2001 census extract was 135.79 square kilometres comprising Patna Municipal Corporation (PMC) and the outgrowth of PMC. PUA witnessed repaid growth in the decade 1991-2001. Thus, this growth rate is used as an indicator to project the future population PUA as 2.25 million and 2.8 million in 2011 and 2021, respectively (Master Plan 2031).

To tackle the existing situation, the state government had initiated the formulation of master plans. The first master plan was in 1961-1981 for Patna city. The plan got approval from the state government in 1967. The second master plan was prepared next twenty-year 1982-2001 by Patna Regional Development Authority (PRDA), but the plan did not get approval from the state. The third master plan was formulated for 2001-2021 again by PRDA for all urban centers. In (2006-2007) after the dissolution of PRDA, the plan was not approved. The fourth recent exercise of master plan 2031 got approval for implementation. Master plan 2031 is the second approved master plan after 1981.

Results

Land use and regulated city growth

The master plan ensures the provision of infrastructure by bridging the gap and catering to future demand. With proper zoning, it's easier to segregate residential, industrial, and commercial areas with desired buffer zones between them.

The city had already witnessed rapid growth leading to uncontrolled expansion beyond urban jurisdiction. The metropolitan area located around the city and urban settlements have developed along the transportation axis. Urban fabric engulfed approximately 55 villages, which have a population of roughly 5000 (Master Plan 2031).

Patna Planning Area was delineated to ascertain future growth and to tackle the externalities. The proposed Patna Planning area (PPA) comprises 13 community blocks of Patna District, 575 revenue villages, and six urban administration units, namely PMC, Danapur Nagar Parishad, Khagaul Nagarparishad, Phulwari Nagar Parishad, Maner Nagar Panchayat, and Fatuha Nagar Panchayat. The total proposed area of PPA is 1,167.04 square kilometers with an projected urban population of 60.25 lakhs by 2031. The vision statement arrived at "To develop Patna Planning Area as a modern economic region with locally competitive infrastructure and social amenities to address future requirements in harmony with its ecological resources" (Master Plan 2031).

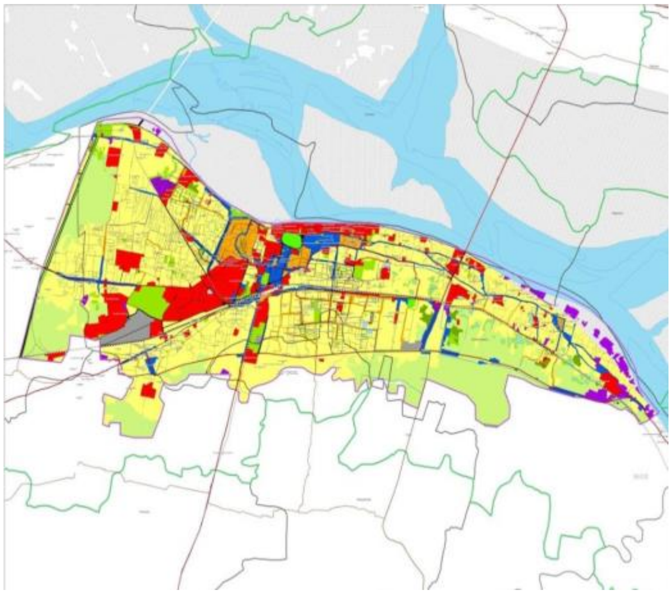

Figure 2 Existing Land use map (Master Plan 2031)

The master plan concept took demographic characteristics, socio-economic aspects, land utilization, migration, and employment. To predict the future population has been estimated based on the past trend. The share and shift method were adopted for the region, the CD block, and the village level (Master Plan 2031).

The following vital parameters were needed to plot ahead of the urban-economic growth and identify urban centers. It includes spatial variation in population growth, distribution of occupied structure, workforce participation rate, settlement hierarchy in rural and urban settlements, potential area for development under different use, gap analysis of infrastructure by assessing the demand-supply scenario, identification of natural resources to determine the spatial extent.

The vision of Master Plan 2031 is to developed strategies for regulated and planned growth. It is likely to control the infinite expansion along the transport axis and create a compact city to achieve sustainable development. Such a compact urban form saves resources and energy along with the revitalization of the inner city. Compact forms do impart advantages. These include lower land consumption, cheaper infrastructure and utility costs, and resource protection (Neuman, 2005). In his significant work Compact City Fallacy, Neuman elaborated a preliminary and not exhaustive list of variables associated with contemporary compact city characteristics. The table below presents a few of the first-cut distinctive.

1.	High residential density
2.	Mixed land use
3.	Fine grain of land use
4.	Increased social and economic interaction
5.	Contiguous development
6.	Demarcated by legible limits
7.	Urban infrastructure
8.	Multimodal transportation
9.	The high degree of accessibility
10.	Street connectivity
11.	The high degree of impervious coverage
12.	Low open-space ratio
13.	Coordinated control of the planning of land development
14.	Sufficient government fiscal capacity

Surprisingly, the first characteristics for planners and designers to define compact cities based on population density are mixed-use and multimodal transportation despite many features that can be used while planning for the city and will equip the degree of functionality.

Henceforth, the intensification led to occur heavy traffic, and this degrades the local environmental conditions. The Planners and policymakers concluded the misconception about the compact city. Urban intensification should be accompanied by more radical measures to constrain traffic generation within intensified areas *(Melia, Parkhurst, & Barton, 2011).*

The concept of Transit Oriented Development (TOD) along the major corridor will accentuate the public transport movement and will integrate periphery areas with core and intermediate regions. This model will tie Patna Planning Area as one entity. It's the creation of compact, walkable, pedestrian-oriented, mixed-use communities (INSTITUTE, 2021). Multi-functional urban land use is commonly observed in high-density urban environments, especially at nodes of high accessibility such as metro stations or railway stations and nearby public transport modes.

A compromise concerning limited intensification would merely redistribute the balance in the allocation of different land use. The proposal of multi-nuclei centers was necessary to reduce the pressure from the urban core and maintain the open-space ratio for a better quality of life. The concept illustrated by Harris-Ullman depicts each center as a self-contained zone. These multi nucleus developed from the city core would add valuable housing areas close to work. In the master plan, these nuclei are a cluster of activities, not the absolute population in a particular area but the services population with different sizes or scales of the nodes *(Master Plan 2031).* Urban nodes include commercial, transportation, industrial nodes, etc., based on specialization.

Master Plan 2031 studies the nature of the settlement, rural-urban dichotomy, or continuity *(Master Plan 2031).* The city core areas are saturated and will no longer absorb the influx

Figure 3 Growth Analysis (Master Plan 2031)

of population. Hence, the city expands physically and slows encroachment seen outside the city limit. Gradually, the rural-urban fringe observes land exploitation and change in population characteristics under direct contact with the city.

The local government demarcates the growth boundary as a guide to zoning and land-use decisions. This boundary circumscribes an entire area having future growth potential. It accommodates future predicted population, their needs for housing, infrastructure, livelihood in an orderly manner. The proposed development on the fringe area already considers ensuring compatibility and synchronization in the land use. It helps to promote compact and contiguous development defined within the boundaries.

Planning of Peri-urban is crucial in the master plan because it protects rural livelihood and caters to the population's food and other products. The Van Thunen Model (1826), also known as Location Theory, though created before industrialization, still illustrate the balance between market, production, and distance (Alonso, 1960). UNDP (1996) defines Peri-urban as an activity that produces, processes, and markets food and other products on land and water in urban and peri-urban areas, applying intensive production methods and reusing natural resources and urban wastes to yield a diversity of crops and livestock. Therefore, the arrangements of agricultural commodities are in circumscribing rings to the central market in the city. Dairying and farming activities (vegetables, fruits, milk, and dairy products) occur in the ring closest to the city to get to the market quickly; they would be produced close to the city. Likewise, other, non-perishable agricultural commodities are produced in subsequent rings.

Discussion and conclusion

Different levels of interventions in master planning in Patna city and metropolitan region influenced the urban form and functions and did so differently. Even the unimplemented or obsolete master plans have an impact on the city by becoming an obstacle to sustainable and integrated development. The several dimensions, including spatial, institutional and financial, execute iterative processes over various time frames grounded in enforceable regulations. The aim is to promote a more compact city and synergies in the region.

The International Guidelines on Urban and Territorial Planning, 2015, highlights the importance of facilitating and articulating political decisions based on different scenarios. The master plan 2031 translates those decisions of multiple stakeholders into actions. It includes flexible mechanisms rather than rigid blueprints, raising public awareness and participation, establishing information databases, monitoring and evaluation systems, etc.

The ineffective strategies and the political will led to unstructured visions and inadequate resources to support urban development. Later, to cope with the damage to the urban environment requires adequate implementation in all dimensions with the appropriate institutional framework, efficient management at the city level, technological interventions, coordination among authorities, and capacity building at all levels to understand the city's needs. The formulation of the plan transforms the physical and social spaces in the city.

A planning professional is also necessary for technical assistance, conceptualizing plans, data collections, analysis, and dissemination. Capacity-building programs for policymakers and leaders sensitize the city's challenges, mainly by providing decision-makers with substantive knowledge and long-term accountability. Thus, land use planning is intended to be an approach in planning and designing cities that will be compact, inclusive, integrated, and resilient.

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The Role of Land Use Planning on Urban Environment in Patna City, India

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Abstract

Land Use Planning is a crucial tool for governing the growth of the city. This technique in the master plan is ideal to allocate and reallocate land as a resource by effectively optimizing its use in the development of cities. It is certainly true in the case of achieving sustainable development purposes. This study was conducted to understand the master plans or planning efforts being made in the capital city of Bihar, Patna. The purpose of the study is to assess how the land-use planning approach has changed the urban environment through a track record of the plans being implemented in the city? How these plans ensured the regulated or orderly growth of the city? What are the externalities imposed due to the land use planning approach adopted for the city? A combined approach of open-source software's such as GIS, google earth and secondary data sources are studied to analyze the spatial growth direction of the city. This study indicates the significant importance of land use planning in the long term to spatially explicit land aptness for proposed uses. The land-use planning approach has been described majorly on land demarcation for various uses. However, it has not been appropriately explored in a comprehensive knowledge of land opportunities and constraints that city planners can correlate with the urban environment.

Keywords : Land Use Planning, Master Plan, Urban Environment, Spatial Growth, Patna, India

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GIS art as means of urban revitalization - A case study on Bangalore city of India

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Abstract

The ability to make people feel safe, relaxed and comfortable in any space can influence positivity and good health in a community and thus a city." With the onslaught of unforeseen social, political, economic, developmental, and emotional challenges faced by our world today, we, as architects, artists, and urban designers, possess a unique opportunity in history to transform and activate a generation through opportunities, experiences, and skills offered by fostering creativity. The creative process acts as a key element in generating positive social change and creating awareness amongst communities. In order to best utilize this process, one must understand the role of art and architecture in positively shaping environments that inspire to change one's behavior for the greater good and different processes and techniques to handle conscious and subconscious creative thought and production. Public art refers to art forms like murals, sculptures, photographs, installations, earth structures including street performances displayed in the public realm. It is thus, a combination of collective creative expression, reflection of the world we dwell in, aspirations of the public, and ever-changing definitions of the same. Through exploration of the definitions and importance of public art in the public domain, this study intends to showcase that public art plays a vital role in altering society by initiating shifts in consciousness for the holistic growth of humanity in ways that leads to a sustainable future. Public spaces such as historical landmarks, parks, playgrounds, beaches, religious institutions, transit stations, town squares, sidewalks, and others ranging in scale act as community ties within any city, town, or village and is open and made accessible to everyone alike. These spaces not only create an identity but also define the quality of the neighborhood or a city collectively. The quality of public space is determined by several parameters including access and networks, sociability, programs and amenities, and image and safety. Therefore, place-making refers to strengthening the ties of the community by building a healthy relationship between its people and their surroundings and in achieving the quality determining aspects of any place belonging to the public. Owing to various dynamic factors of city life, accomplishing the goal of creating a positively functioning public space meeting all the parameters, for the most part, remains ambitious leaving certain loose ends due to changing times that are required to be addressed in a timely manner. It is evident today in India that, the conventional approach to urban planning has not changed greatly since the post-Independence era. We are facing several challenges due to the rapidly changing dynamics of a city that do not match up to the pace of addressing these varying factors through planning as it is a meticulous and time-consuming process that has to not only manage the available resources in an optimal manner but also cater to the upcoming needs of the population in an equitable fashion by attaining the visions politically, economically and socially alike for sustainable growth. The concept of tactical-urbanism is gaining popularity in today's world as it is a temporal strategy that fills the voids in the formal urban planning process. It deals with the most challenging factor that is time for any development project by focusing on context-sensitivity and addressing concerns at hand in a deliberate manner with short-term implementation being its key. It promotes community engagement by actively using readily available scarce resources that behave as temporal solutions that could guide the behavior of the citizens leading to a positive impact on public health and well-being. Tactical-urbanism interventions also act as a great experimentation design tool to instantly test the solutions for problems through design, incurring considerable minimal losses in terms of resources that is temporal, economic,

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and social, and others. Public art and place-making in both Indian and International contexts fit into the idea of tactical-urbanism as it addresses the concerns of today's generation in remaining relevant to the prevailing culture due to the speedy progression in technology and demands of wanting to stand out in expressing individual and collective identity. Its role in shaping cities through architectural and sculptural syntheses sorting out space of squares and boulevards, ruled via landforms or dominant objects and urban subtleties allow to create awareness and facilitate freedom of creative expression and carry relevant and historic messages. The potential of towns and cities that accommodate public art will be contemplated through researching its role as a device for improving the nature of urban squares and streets in urban communities and as a vehicle in the transformation of urban spaces for creating a better world In this context, the study aims at achieving conviviality through identifying the potential sites and desirable locations for Tactical urbanism and public art respectively in view of the creation of identity, economic revitalization, public health and safety, recommendation of design considerations and policies that can be included, aiding informed decision making in the planning process for future developments and arriving at a successful network system resulting in the quality of the urban space in the context of Bangalore using geospatial tools.

Keywords : Public Art, Public space, Place-making, Tactical urbanism

Examine the effect of the physical characteristics of the Urban Green and Blue Spaces in Heat Mitigation: A case study of Palakkad city

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Abstract

Urban areas generally are found to exhibit surface and atmospheric temperatures slightly more than the surrounding rural areas. This phenomenon is known as the urban heat island (UHI) effect and the difference in the temperature is known as the urban heat island intensity (UHII).The climate of Palakkad has changed during the past 3 decades, mainly due to the increased rate of urbanization and expansion of the industries and built up areas. The blue and green spaces are considered as one of the most important passive strategies to reduce the UHII. Through my study I want to find out how effective are the urban green and blue spaces in the Palakkad city in reducing the UHII. The main objective of the study would be to evaluate the cooling intensity created by the blue and green spaces and to estimate the distance up to which the cooling effect is encountered. Further, the study also aims to understand the pattern of cooling island created by the selected green and blue spaces. The parameters of the study will be land use land cover, normalized difference vegetation index (NDVI), land surface temperature (LST), physical characteristics of green and blue spaces such as land shape index (LSI), size and perimeter-area ratio (PAR). LST will be calculated from the LANDSAT4,5 and Landsat 8(OLI) data with the help of QGIS tools and techniques. Apart from the LANDSAT data numerous other data has been collected through the online sources, which would be useful to evaluate the selected green and blue spaces in terms of the selected parameters and variables. The expected outcome of this study will be in the form of strategies, which would be in a application for the present planning guidelines. These strategies may be helpful in the process of expansion of Palakkad city in coming future.

Keywords : UHI, UHII, NDVI, Landsat 4.5., Landsat 8(OLI), LST, Land shape Index (LSI)

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THEME 2

Web, Mobile and Location Based Services (WeMLBS)

Suitability of OSMAND Mobile App for Mapping and Monitoring of Rural Roads

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Abstract

In India, most of the Government flagship programmes for Rural Infrastructure development are having dedicated mobile applications for mapping and monitoring of the assets. Mapping of the assets is also useful in day-to-day work during planning, execution, and monitoring phases. Many free and open-source mobile mapping and navigation apps are available for use with the help of free Course Acquisition (C/A) signals provided by the operators of Global Navigation Satellite Systems (GNSS), but the suitability of these applications and comparative analysis in various domains is a concern. The study analysed the application of OSMAND mobile mapping and navigation app, in rural road data collection as tracks in various parts of the country in different terrain conditions. The study was performed as part of training and capacity-building programmes on applications of Geo-informatics in rural roads, conducted for engineers and officials working for management and execution of rural roads. During training programmes under field visits, the participants collected tracks in OSMAND mobile app of the selected road while sitting in a vehicle or walking on the road during onward and return travel. Later data of all mobiles for the particular road visited during training were downloaded and analysed in the combined manner for the proximity and separation from each other along the length of road, in QGIS and Google Earth Pro software. Total eight roads in seven states of the country were analysed situated in hilly areas to the plain lands. Additionally, one path also was analysed which was tracked on lake water during boating by participants. Participants along with the author in each training participated in data collection. It was found that the data were more in proximity and had less variation in distance from each other in plain terrains with fewer trees and buildings along the roads. For most of the roads data on length were within a range of about 5 meters to 50 meters from each other in the walk or in the move, irrespective of bus width, speed and sitting position of participants, terrain conditions, weather condition, and time of measurement, barring few outliers. The one side variation for such data can be considered as 2.5 meters to 25 meters from the centre line of the road. Having data within 5-50 meters for rural infrastructure assets like roads in all conditions can be a good deal for mapping and monitoring of assets in day to day manner, during planning, execution, and monitoring phases. For plain areas with less disturbances and in walking mode the data remains within 5- 10 meters in variation and error may be considered as 2.5 to 5 meters from the centre line in plain areas with less disturbances along the roads. However, as the data variation was more in hilly terrains with dense tree covers, dedicated GPS instruments with better signals can be used, and data gathered from mobiles can be used as reference when no better location data is available. In the future with better signals availability in the public domain and availability of more GNSS signals on mobiles, and continuous up-gradation of open apps based on users' feedback, can enhance the usability of mobile mapping apps.

Keywords: OSMAND, Open Source GIS, rural roads, QGIS, GNSS, mobile mapping, PMGSY, MGNREGA

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Introduction

"Mobile communications technology has become the world's most common way of transmitting voice, data, and services, and no technology has ever spread faster" (Qiang et al., 2012, p. 1). Open Source Mobile applications are being used nowadays for many purposes by the academia, Government and community for location data collection and navigation etc. In addition to these customised mobile mapping and navigation applications of departments, other applications are also there for location data collection on large scale in predefined survey forms. These applications are more prone to point data collection, however some applications give facility to collect data line features also. The data collected in traditional methods on the road for many variables and mobile mapping can support some of the data requirements well. In a

study the results showed that mobile data compared reasonably well to manual data for most of the desired variables (Findley et al., 2011). In mobile data collection the integration and actual application of data in the overall workflow of an organisation with supporting other than locational requirements are also the factors for evaluating any mobile application. A systematic approach and research are required for standardising the application of mobile based technologies in low income countries (DeRenzi et al., 2011).

Under rural infrastructure or community assets roads are the major infrastructure which consumes the large share of public money and facilitates the common man in various ways for personal or commercial transportation of persons and goods. In India Pradhan Mantri Gram Sadak Yojana (PMGSY) which means for rural roads is the major flagship of Government of India (National Rural Infrastructure Development Agency (NRIDA), 2014).

National Institute of Rural Development and Panchayati Raj, Hyderabad, India is an apex institute of Government of India which caters for Training, Research and Consultancy in Rural Development and Panchayati Raj. One of the divisions of the institute called Centre for Geoinformatics Applications in Rural Development (CGARD) is associated with Training, Research and Consultancy requirements of the Rural sector in the field of Geoinformatics applications in Rural Development. Institute was provided the mandate of training to the functionaries working at State and District level under the PMGSY scheme and author was working in CGARD during mentioned training programmes under study.

Since 2009 Author has conducted more than 100 practical trainings on various themes for Rural Development functionaries on Geoinformatics applications with using QGIS as main tool for practical exercises. Author conducted a total 8 training programmes to the functionaries of rural development working for PMGSY roads on Geospatial applications during the year 2018-2020. In training the author initiated testing the free OSMAND mobile mapping app (OsmAnd B.V., n.d.) on rural roads constructed under PMGSY. The app was tested on a total eight roads and one boating path during eight training programmes in seven states of India for accuracy and utility of OSMAND application for rural roads assets monitoring. For static point data the OSMAND was tested in NIRDPR by a masters student under the guidance of the author, against DGPS single point along with two other applications with three different makes of mobiles in various modes (high accuracy, device only and battery saving). The high accuracy data was found within 3 meters of each other and in the proximity of DGPS point (Fayaz A Kareem, 2018).

The roads are monitored by customised state specific mandatory applications including a dedicated portal and mobile application for submitting the field data. In addition to these applications there is a need always to have solutions for monitoring of road data in public domain or in Government also to have quick monitoring of roads or any length feature or other assets also. However the same may be used for individual purposes also apart from official uses. As the overall accuracy and application potential is not known to the users, they remain hesitated to use these applications available in open domain in day to day purposes. Mostly they want to associate themselves with the customised applications provided by the departments.

In this article the free version of OSMAND mobile application has been tested on various roads constructed under the PMGSY scheme in the seven states of India under different terrain conditions in the country. The application had been used for track data collection by the training participants while sitting in the bus or on walk in onwards and return journey on the road. The data exported to the desktop were analysed using Free and Open Source QGIS Software (OSGeo Foundation, 2021). The OSMAND has been used in the study for familiarity and well tested by the author for ease of use and data handling. However many other applications are also available in Free and Open Source domain for use and tested by the participants for ease of use and suitability in their domain (*Android - OpenStreetMap Wiki*, n.d.). Hence the broad purpose of the article is to give confidence to the users about line data proximity and spread along the roads in various terrain conditions and application potential of the mobile apps for day to day professional use in rural development works in general and rural roads in particular.

Methods and Materials

For monitoring of development works, use of Geo-spatial technology is prevalent in Government. Most of the tools are predesigned and defined based on user requirement. However, for real time execution and monitoring, the available open source mobile mapping and navigation tools are supportive and give freedom to use them at the pace of work and requirement of the user. Many tools are available in the open source domain but some are having better features and user friendly interface. OSMAND is one of its kind and supports mapping, data collection and navigation in Android and iOS. The tool was applied in the study during training programmes for geospatial technology applications in rural roads. In the study the tool was tested for variation between the tracks from each other while used on the same road with many participants with different kinds of mobile makes and settings. It was tested for eight roads and one on the water surface also in the boat. The result section has described the details of all nine cases and data variation within mobiles.

The study was conducted in seven states of India on rural roads during the training programmes with the help of training participants. Out of the eight roads constructed, one was under the Forest Department of Government of Rajasthan, one under MGNREGA (Department of Rural Development, Ministry of Rural Development, GOI, 2021) and six were under PMGSY. These roads were studied in the field and analysed for data consistency in width and accuracy for

OSMAND mobile application. The OSMAND application was also used by the author in research, training and personal uses, mostly for point and line data collection. For dispersion and proximity of data, with the help of participants, the testing was made for the first time during the study. In the study Google Earth and QGIS were used for visualisation and analysis of data in desktop environments.

These training were conducted at State Institute of Rural Development (SIRDs) which functions under administrative control of respective State Governments and National Institute of Rural Development Panchayati Raj (NIRDPR) provides off-campus training to these locations in a collaborative manner. These training were sponsored by the Ministry of Rural Development (MoRD), Government of India and no fee and other charges are taken from the participants except their travel to the training venue. The travel also remains reimbursable from the respective sponsoring departments to the training participants.

The eight roads and one boating tack were analysed in the study during eight training programmes. The Participants for six PMGSY training were mostly graduate civil engineers working in the respective states and responsible for PMGSY roads construction aspects. One forest training participants were State Forest Officers and Indian Forest Services Officers, responsible for forest area monitoring and execution aspects in Rajasthan. Participants of one Training of Integrated Natural Resources Management were mostly related to the MGNREGA scheme. The roads were studied during the financial year 2018-2020. In all the training programmes, one day field visits were held for half a day for road data collection and understanding the location data collection in mobiles in a practical manner. The remaining half day used to be spent for visits to State Remote Sensing Application Centres of the respective state or other reputed relevant institute based on time availability after road visit. All the programmes were of five days duration and full time and residential in nature. In rest of the four days mostly basics of Geoinformatics and cases of applications of Geoinformatics technologies were discussed with the participants and hands-on georeferencing and data creation were usually taught in QGIS environment.

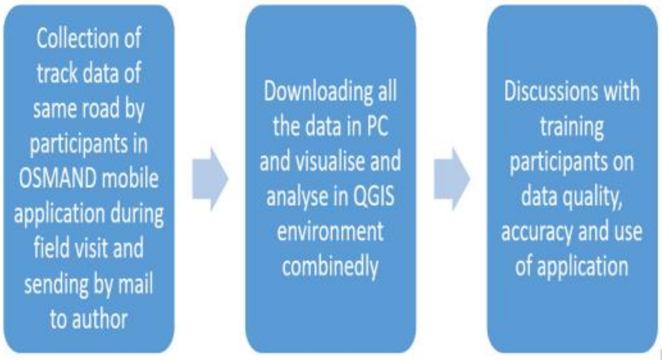

Figure1: Flow diagram

Methodology

The training participants of the training programme mentioned in table used to be taken to the field visit for one day out of five days training programmes to try the learnings of GIS on actual roads under schemes. Each programme one road was covered and as mentioned in the table. Participants collected point data mostly on start and end point of roads and track data during travel on the road in bus. As the participants were not assigned a fixed seat in the bus every time hence, it was always encouraged to take track data in

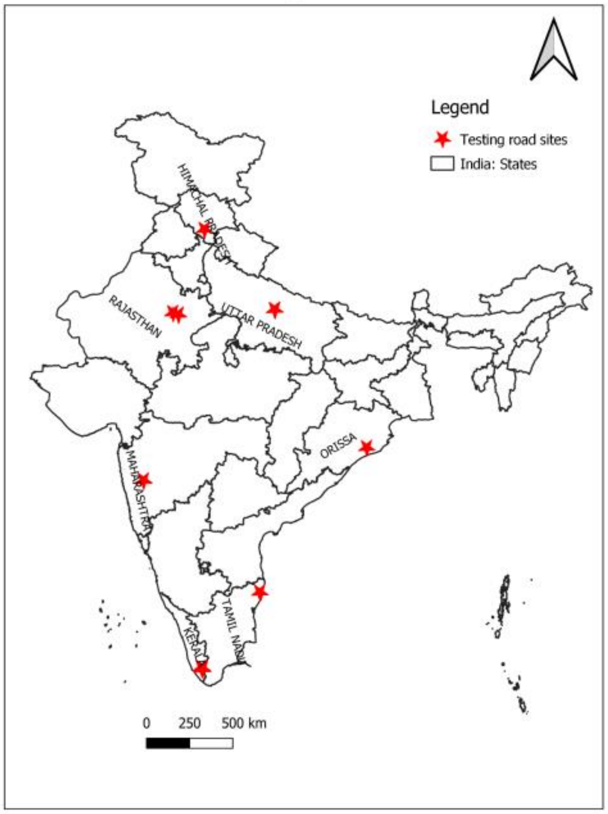

Figure 2: Area of study

return journey also on the same road by all participants so the data may not skew geographically to any side and proper spread and symmetry may be there in data along the road. The buses hired were having width of around 2.5 meters for general buses (*Coach Buses Dimensions & Drawings | Dimensions.Com*, n.d.). Hence, around two meters may be considered as additional random error in the study and can be reduced from overall error.

Most of the mobiles in current time have three kinds of location settings, irrespective of applications used. Those are High Accuracy which uses GPS Wi-Fi, mobile networks and sensors to help estimating the location, Device Only which uses GPS for estimating location and Battery Saving which uses only mobile networks for location. It was instructed to the participants to use High Accuracy mode and participants followed similarity on these aspects, except few due to lack of understanding and, differences in location settings among mobiles. During tracking the data the option for logging interval within OSMAND was also instructed to the participants to keep as per bus speed and it was mostly kept as 2-3 seconds or 'continuous' mode which is an option to log the data during tracking in OSMAND. How to track the line data in OSMAND is explained in the YouTube video of the author (H K Solanki, 2019). No other conditions and settings available in OSMAND tracking were used to keep all the data collection on the same pattern. Point data which is called waypoints in OSMAND were also collected during visits, however not analysed in this article as out of scope of the study. However the accuracy of point data collection were analysed in a separate study for different mobiles previously by the author in which it was found that average variation from a fix DGPS rover point was 2.50 meters of three different mobile makes with three different applications including OSMAND (Solanki, H. K., 2016). In this study the main focus is to check suitability of mobile apps specially OSMAND for monitoring of line features, starting with road but not limited to, and may be applicable to any other linear feature also.

Lines created by mistake of very small length by participants were not used in the analysis. Author also collected data of roads during the study for all roads onward and return journeys. Some tracks were made by individual participants on other roads or during return journeys were also sent to the author by mail but those data also not included in analysis as not relevant to the study. Some mobiles had kept the logging interval more, and on turns the data were found not in consistency with each other, hence data on the part of the road without turns were mostly analysed and considered for checking the width variation. This can be understood by the fact that if the bus is taking a turn at the speed of 40-60 km per hour and mobile is having 5 seconds or logging interval and if the bus is taking the turn in less than 5 seconds the data node points will not have proper curve on turns. The function of using the distance for data logging was not either available in previous versions of OSMAND during study, or not taken, if available for the similarity of operations among mobiles. It was ensured by instructions before the start of bus or during walk that data collection should remain at the same pace among mobiles and vehicle or walk should not be stopped in between to avoid excess data logging along the roads. Few data lines showed extraordinary deviation from the centre of the road and left from analysis, as inexplicable and may require further examination which was beyond the scope of the study. As the study purpose was limited to check the data not showing extraordinary behaviour visually in the first instance. In this way data samples of each road were cleaned or sifted first and remaining data lines were used for the analysis of each road.

In Tamil Nadu, Kerala and Odisha States, the road tracks were taken by foot and vehicles were not used for tracking the road data seeing the short length and/or non motorable. The bus speed during the travel was kept less than 60 kilometres per hour and participants used their own mobile handsets of different makes during the data collection.

The terrain conditions and tree covers were different for all the roads and data collection timings, seasons were also different for different roads and it was assumed that these factors were constant for a particular road among all mobiles.

After the completion of field visit and collecting the road and points' data in mobiles on a particular road, the whole team including participants and course team used to come back to the training venue i.e. State Institute of Rural Developments of particular states, in the evening.

The data were mailed to the author in the GPS eXchange format (.GPX) from mobiles of the participants on the same day or next day during the class. Next day the first session was always kept on data visualisation and analysis in Google Earth and QGIS, where participants were watching their data displayed on Google Earth and in QGIS by the author. As all training were practical in nature, and mostly the visits were taken on the third or fourth day of training, participants could easily repeat the process of data display and analysis on their own systems (available at SIRDs in their computer labs) or on their laptops. Participants used to visualise the track data overlaid on Survey of India geo-referenced Topo-sheets also which were geo-referenced by the participants using QGIS as part of the training. Participants were always encouraged to use the same system throughout the training programmes.

Discussions with training participants were made in each training on data quality, accuracy and use of application in their professional life. The average width variations along the visited roads were checked. The width of data spread used to be checked at four to five points along the road at the middle of road segments excluding the turns. The Lat Lon Tools plugin of QGIS was used for capturing the central coordinate of roads and Digitizing and Advanced Digitizing Toolbar tools were used for creating parallel lines and point features on the road at selected test point sites for recording the measurements. All measurements were recorded with road codes in Shape files (Environmental Systems Research Institute, Inc., 1998). Roads were given codes numerically in chronological order and testing point sites were given numerical coding from south to north direction or left to right direction with approximation of directions. For example the first testing point on the first road was given code as 1-1 and the third testing point on fifth road was given code as 5-3 in the attribute table of combined shape file created for recording the test point sites. During the boating track which was like a closed loop the testing points were given numbers 1,2,3,4 in clockwise direction starting from the left direction. An attribute with the name Spread was also added in the point shape file for recording measurement of spread of track lines along the road on the particular test point sites. The clearly visible deviating data lines from the centre of road were excluded from the analysis. The data spread in width at these road points were checked using Measure Line tool in QGIS and finally fair estimates were drawn that under a particular terrain conditions using mobiles how much width deviation is possible in data while tracking and collecting data for road, and is that tolerable in general rural road conditions in India. The fair discussions were made with the participants of training for acceptance or rejection of the deviation of data along the road. The checking points along the roads were selected in small scales of map in the middle of road segments to remove the bias of selecting the portion where data is more consistent or closer to each other. Data spread widths were checked after drawing perpendicular lines along the roads on those selected locations. The best zoom levels possible in canvas were used while measuring the spread of track data along the road at the particular points of road. The spread was calculated in the GIS environment in WGS1984 Long/Lat Geographic Coordinate Systems.

Results and Findings

The analysis of all the roads and findings are described in further sections with taking the data and case of each road separately. The analysis for eight roads has been arranged in chronological order in time.

3.1. Case-1 - Road -1

Training Title: Geospatial technologies for Planning and Management of PMGSY Roads

Duration: 25-29 June, 2018

Total training participants: 23

Training Venue: SIRD (Indira Gandhi Gramin Vikas evam Panchayati Raj Sansthan), Jaipur, Rajasthan

Road Name: Kapadiyawas to Govinda ki Dhani

Location: Village Kapadiyawas, Block Jhotwara, District Jaipur, Rajasthan

Length: Approximately three kms

Date of road visit: 27.06.2018

Approximate central coordinates of road: 24.94552 Latitude, 75.55362 Longitude

Mode of travel on road during tracking: Bus

Tracks taken and included for return journey also: Yes

Tracks showed clearly visible deviations (not included in analysis): 2

Total tracks considered for analysis: 15

Number of points used for checking track data width spread along road: 4

The terrain was plain, having scattered vegetation and habitations along the road. The track data spread was checked in QGIS environment at four places (Figure-3) and spread in width was observed between 7.02 to 11.34 meters (Table-1).

3.2. Case-2 - Road-2

Training Title: Geospatial technologies for Planning and Management of PMGSY Roads

Duration: 24-28 Sep, 2018

Total training participants: 31

Training venue: SIRD (YASHADA), Pune, Maharashtra

Road Name: Lonikalbhor to Ramdhara

Location: District Pune, Maharashtra

Length: Approximately six kms

Date of road visit: 26.09.2018

Approximate central coordinates of road: 18.46587 Latitude, 74.02071 Longitude

Mode of travel on road during tracking: Bus

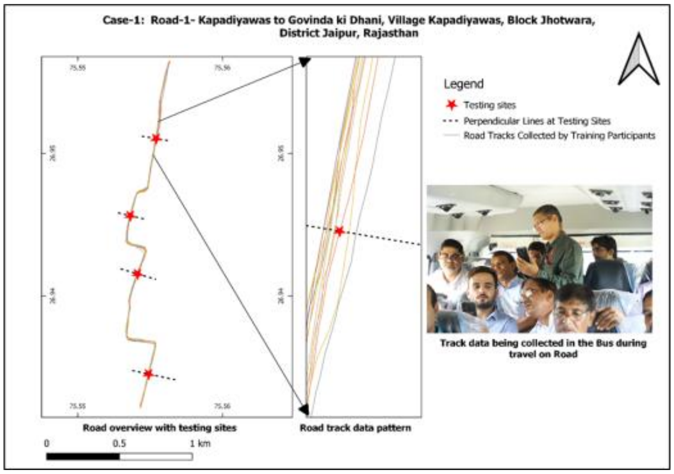

Figure 3: Road overview and track data pattern for case-1

Tracks taken and included for return journey also: Yes

Tracks showed clearly visible deviations (not included in analysis): 11

Total tracks considered for analysis: 37

Number of points used for checking track data width spread along road: 4

The terrain was plain but the bus passed from the vicinity of a small hill, villages and closely spaced habitations. Along the road scattered and somewhere closely spaced vegetation was there. The track data spread was checked in the QGIS environment at four places (Figure-4) and spread in data was observed between 8.75 to 22.08 meters (Table-1).

3.3. Case-3 - Road serial number-3

Training Title: Geospatial technologies for Planning and Management of PMGSY Roads

Duration: 22-26 Oct, 2018

Total training participants: 23

Training venue: KILA, CHRD, Kottarkakkara, Kerala

Road Name: Nedumpara to Mampazhathara

Location: Thenmala Panchayat, Anchal Block, District Kolam, Kerala

Length: Approximately 10 kms

Date of road visit: 26.09.2018

Approximate central coordinates of road: 8.99796 Latitude, 77.05283 Longitude

Mode of travel on road during tracking: Bus

Tracks taken and included for return journey also: No

Tracks showed clearly visible deviations (not included in analysis): 3

Total tracks considered for analysis: 15

Number of points used for checking track data width spread along road: 4

The terrain had a high hill on one side and dense vegetation along the road. However, the start and end segments of the road were having less undulation and vegetation along the

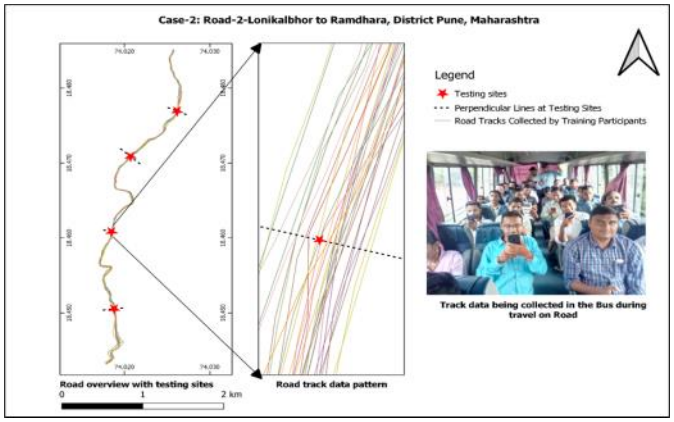

Figure 4: Road overview and track data pattern for case-2 road. The track data spread was checked in the QGIS environment at four places (Figure-5) and spread in track data along the road was observed between 12.67 to 47.91 meters (Table-1).

3.4. Case-4m – Track serial number-4

Training Title: Geospatial technologies for Planning and Management of PMGSY Roads

Duration: 22-26 Oct, 2018

Total training participants: 23

Training venue: KILA, CHRD, Kottarkakkara, Kerala

Track Name: Boat travel in Thenmala Reservoir, District Kolam, Kerala

Tracks taken and included for return journey also: No (it was almost a closed loop)

Travel Length: Approximately 11 kms

Date of road visit: 24.10.2018

Approximate central coordinates of road: 8.94020 Latitude, 77.08763 Longitude

Mode of travel on road during tracking: Top covered Boat (partially open)

Tracks showed clearly visible deviations (not included in analysis): 1

Total tracks considered for analysis: 6

Number of points used for checking track data width spread along road: 4

It was a journey on a calm water surface in a partially covered boat (top covered). The track data spread was checked in QGIS environment at four places (Figure-6) and spread in track data was observed within 2.36 to 3.68 meters from each other (Table-1).

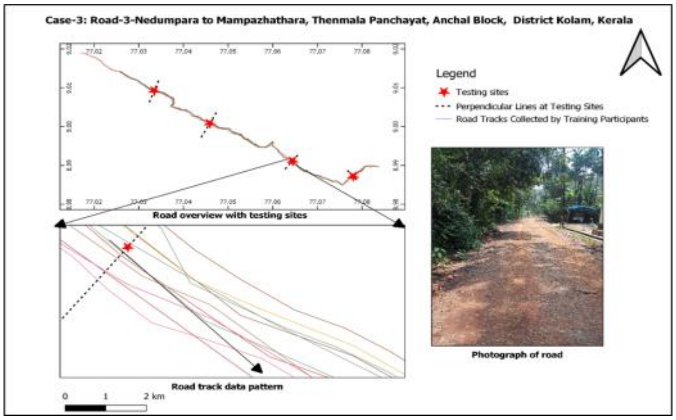

Figure 5: Road overview and track data pattern for case-3

3.5. Case-5 - Road serial number-5

Training Title: Geospatial technologies for Planning and Management of PMGSY Roads

Duration: 28 Jan-1 Feb, 2019

Total training participants: 28 (Indian Forest Service and State Forest Service Officers)

Training venue: Birla Institute of Scientific Research, Jaipur, Rajasthan

Road Name: Anonymous forest track in Jhalana Wildlife Reserve area, Jaipur, Rajasthan

Location: Jahalana Wildlife Reserve, Jaipur, Rajasthan

Length: Approximately 01 km

Date of road visit: 30.01.2019

Approximate central coordinates of road: 26.85647 Latitude, 75.83946 Longitude

Mode of travel on road during tracking: Walk

Tracks taken and included for return journey also: No

Tracks showed clearly visible deviations (not included in analysis): 1

Total tracks considered for analysis: 19

Number of points used for checking track data width spread along road: 4

The tracks were taken by walking in a reserve forest area

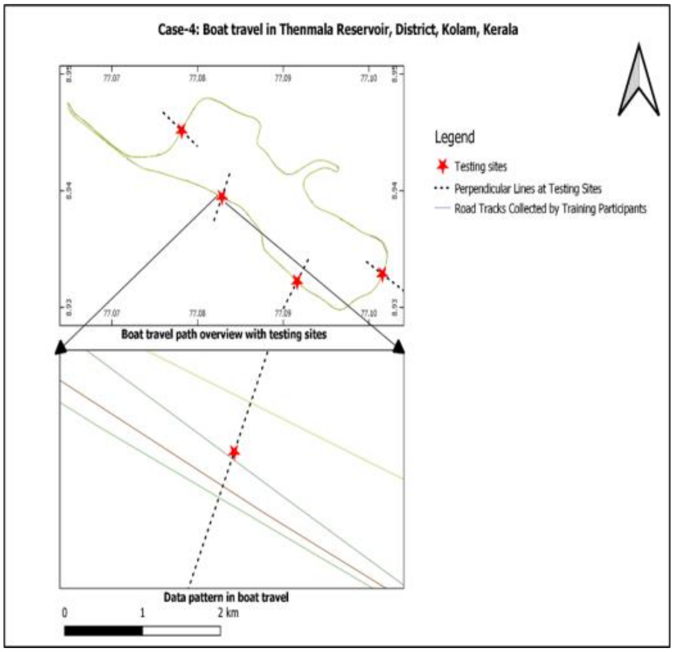

Figure 6: Road overview and track data pattern for case-4

along a forest track. Along the distance the sparse vegetation was there. The track data spread was checked in QGIS environment at four places (Figure-7) and spread in data width was observed between 6.80 to 10.10 meters (Table-1).

3.6. Case-6

Training Title: Geospatial technologies for Planning and Management of PMGSY Roads

Duration: 04-08 Feb, 2019

Total training participants: 33

Training venue: DDU, SIRD, Bakshi ka Talab, Lucknow, Uttar Pradesh

Road Name: NH 24 to Jamkhanwa village

Location: Block Bakshi ka Talab, Lucknow, Uttar Pradesh

Length: Approximately 05 km

Date of road visit: 06.02.2019

Approximate central coordinates of road: 27.10804 Latitude, 80.86681 Longitude

Mode of travel on road during tracking: Bus

Tracks taken and included for return journey also: Yes

Tracks showed clearly visible deviations (not included in analysis): 5

Total tracks considered for analysis: 32

Number of points used for checking track data width spread along road: 5

The terrain was plain but the bus passed from two villages and the path was having scattered trees along the road. The track data spread was checked in the QGIS environment at five places (Figure-8) and data spread in width was observed between 10.47 to 16.52 meters (Table-1).

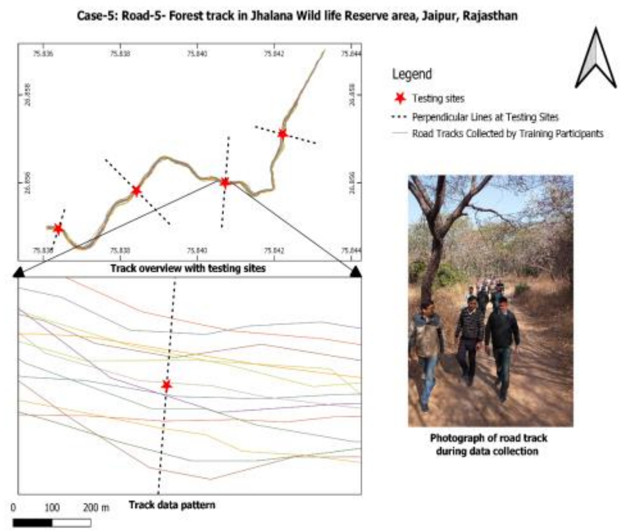

Figure 7: Road overview and track data pattern for case-5

3.7. Case-7

Training Title: Geospatial technologies for Planning and Management of PMGSY Roads.

Duration: 15-19 July, 2019

Total training participants: 24

Training venue: SIRD (HIPA), Shimla, Himachal Pradesh

Road Name: Sadhoda to Kyarkot (Mohanpur) Link Road

Location: Block Basantpur, District Shimla, Himachal Pradesh

Length: Approximately 06 kms

Date of road visit: 18.07.2019

Approximate central coordinates of road: 27.10804 Latitude, 80.86681 Longitude

Mode of travel on road during tracking: Bus

Tracks taken and included for return journey also: Yes

Tracks showed clearly visible deviations (not included in analysis): 1

Total tracks considered for analysis: 16

Number of points used for checking track data width spread along road: 4

The terrain was hilly with sharp slopes, turns and dense vegetation along some length. The track data spread was checked in the QGIS environment at four places (Figure-9) and the spread in data width was observed between 10.26 to 22.25 meters (Table-1).

3.8. Case-8

Training Title: Geospatial technologies for Planning and Management of PMGSY Roads

Duration: 23-27 Sep, 2019

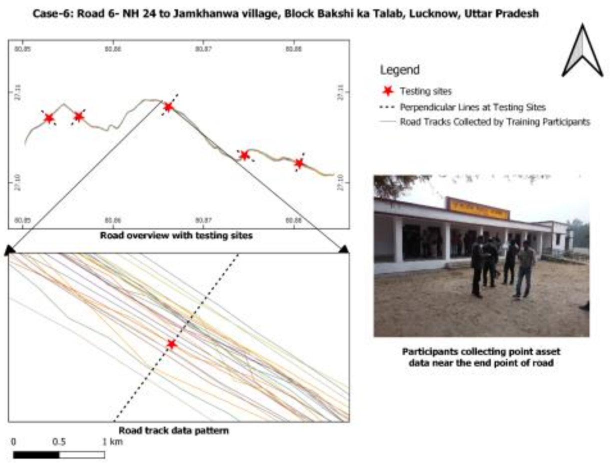

Figure 8: Road overview and track data pattern for case-6

Total training participants: 20

Training venue: SIRD&PR, Maraimalainagar, Tamil Nadu

Road Name: Anonymous PMGSY road

Location: Maraimalainagar, Tamilnadu

Length: Approximately 01 km

Date of road visit: 26.09.2019

Approximate central coordinates of road: 12.81565 Latitude, 80.08732 Longitude

Mode of travel on road during tracking: Walk

Tracks taken and included for return journey also: Yes

Tracks showed clearly visible deviations (not included in analysis): 3

Total tracks considered for analysis: 29

Number of points used for checking track data width spread along road: 4

The terrain was a plain area of semi urban environment and scattered house constructions were there along the road. The road was small in length and travelled by walk. The track data spread was checked in the QGIS environment at four places (Figure-10) and the spread in data width was observed between 5.54 to 8.38 meters (Table-1).

3.9. Case-9

Training Title: Applications of Geo-Spatial Technology for Integrated Natural Resource Management (INRM) Plan under Mission Water Conservation

Duration: 29 Feb-04 Mar, 2020

Total training participants: 31

Training venue: SIRD Odisha, Bhubaneshwar

Road Name: MGNREGS Road, Gram Panchayat Taraboi

Location: Grampanchayat Taraboi, Block Jatni, District Khorda, Odisha

Length: Approximately 100 mts

Date of road visit: 03.03.2020

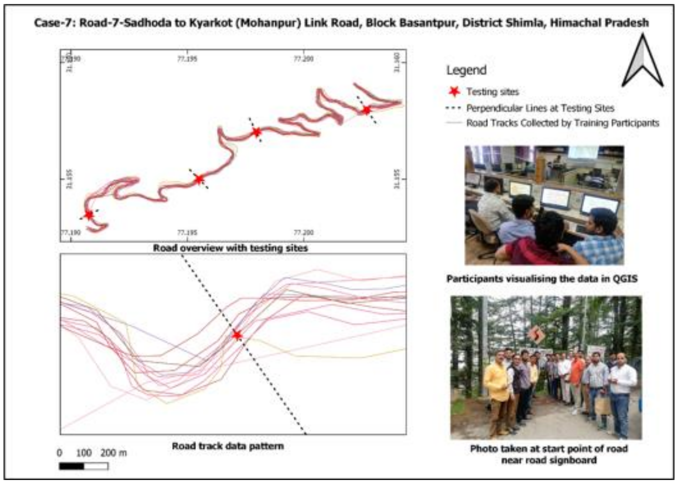

Figure 9: Road overview and track data pattern for case-7

Approximate central coordinates of road: 20.12679 Latitude, 85.66169 Longitude

Mode of travel on road during tracking: Walk

Tracks taken and included for return journey also: No

Tracks showed clearly visible deviations (not included in analysis): 1

Total tracks considered for analysis: 16

Number of points used for checking track data width spread along road: 2

The terrain was plain and travelled by walk. No GPS signal hindrances were there, except the crowd of participants walking along the road. The path was of small length of about 100 meters. The track data spread was checked in the QGIS environment at two places (Figure-11) and the spread in data width was observed as 4.86 to 5.64 meters at these points (Table-1).

3.10. General findings

It was observed during the study that the same mobile set with the same person were behaving differently in onward and return journeys. Mostly the return journey tracks were

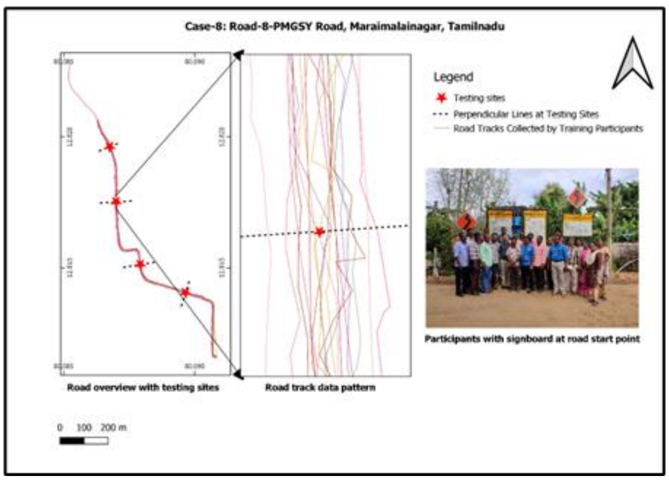

Figure 10:. Road overview and track data pattern for Case-8

more stable and smooth in comparison to onward journeys with the same mobile handset and settings.

It was observed that at the end of roads the data were more stable and close together. The variation in terrain conditions was a majorly associated cause for variations between observations. On calm water surfaces without disturbances, even with partially covered boats, the proximity was coming within data from 2.36 to 3.68 (Table-1) meters only irrespective of the sitting of participants in the boat.

In the areas where only GPS signals in tree covers and sloppy lands were present the spread between the track data was more. The augmentation of signals due to internet connectivity and Wi-Fi etc was also not present in these areas due to unavailability of mobile data.

It has been observed that speed of travel was also a factor in data spread and walking gave better results in comparison to bus travel, due to less signal disturbances and more stability of signals during travel.

It was observed from the data in Table-1 that all tracks generated from mobiles remained within around 5-50 meters proximity of each other. For plain areas with less disturbances and in walking mode the data remains within 5 - 10 meters in variation and error may be considered as 2.5 to 5 meters from the centre line in plain areas with less disturbances along the roads. The data variation was more in hilly terrains with dense tree covers.

Training feedback was invariably taken in the online training feedback system of the Institute and participants gave positive feedback about the tool and the field session. They were confident with the tool by observing and practicing themselves.

4. Discussion and Conclusion

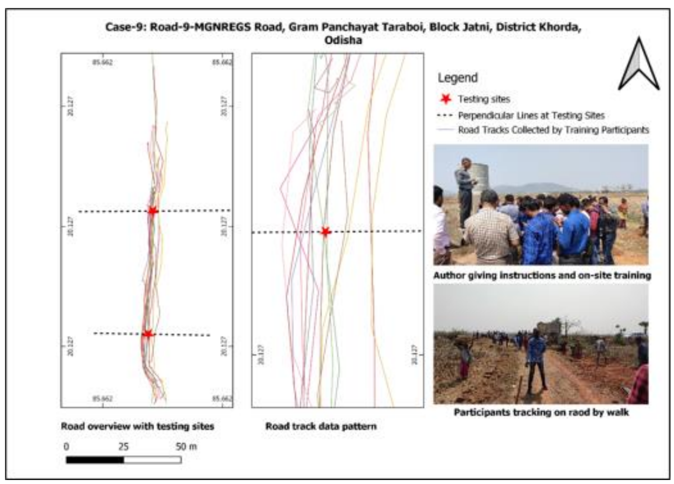

Figure 11 : Road overview and track data pattern for case-9

For most of the roads data on length were within a range of about 5 meters to 50 meters from each other in walk or in move, irrespective of bus width, speed and sitting position of participants, terrain conditions, weather condition and time of measurement, barring few outliers. The one side variation for such data can be considered as 2.5 meters to 25 meters. Having road data within 5-50 meters of each

Table 1: Comparative statements of roads/tracks data

Case no.	Mode of Travel	Terrain condition	Approximate Travel length (Kms)	Number of sites considered at map for width variation	Road tracks width variation at points (Meters)				
					1	2	3	4	5
1	Bus	Plain	3	4	7.02	8.50	7.36	11.34	-
2	Bus	Plain with houses along the roads	6	4	15.68	8.75	22.08	17.41	-
3	Bus	Hilly with tree cover	10	4	28.82	47.91	12.67	30.82	-
4	Boat	Calm Water surface	11	4	2.39	3.12	3.68	2.36	-
5	Walk	Undulated with scattered forest	1	4	7.69	8.05	6.80	10.10	-
6	Bus	Plain with habitations along the road	5	5	10.47	10.67	12.50	11.72	16.52
7	Bus	Hilly with steep slopes	6	4	16.82	14.66	10.26	22.25	-
8	Walk	Plain with habitations along the road	1	4	5.54	5.79	8.38	5.99	-
9	Walk	Plain	0.10	2	5.64	4.86	-	-	-

other in all conditions can be a good deal for mapping and monitoring of assets in day to day manner, during planning, execution and monitoring phases. However, as the data variation was more in hilly terrains with dense tree covers, dedicated GPS instruments with better signals can be used, and data gathered from mobiles can be used as reference when no better location data is available.

This is good for rural development settings and work environments, where we do not have any higher quality of data. This can be used in initial planning and mapping, during execution and monitoring of works. In developing countries having such kinds of utilities at low cost or even at no cost is a boon to the government, officials and even suitable for personal uses also. In future with better signal availability in public domain on mobiles, and continuous upgradation of open apps based on users' feedback, can enhance the usability of mobile mapping apps. Open Source tools like QGIS are always available to support the further process of data and analysis for putting the data in real use. During discussions with participants the application and availability of such a kind of application in a free and open environment was considered useful in the day to day professional life of training participants.

The OSMAND mobile application is used in experiment as found better by the author among other available applications in free and open source domain. Moreover it works without the internet also with the GPS signals only. Hence it can be used in difficult terrains and in the regions where data connection is not available. It gives the facility to download base maps derived from OpenStreetMap (OSM) to download and use without internet (*Android - OpenStreetMap Wiki*, n.d.). However, the same experiment can be repeated with the other applications also on which users are more convenient.

4.1. Limitations

It was assumed that except for common factors like differences in mobile makes, other factors will remain common in the study. However the participants had varying degrees of understanding with the mobile tools and the internal settings of the app like logging interval might be varying unnoticed to the author.

The study was undertaken in different time settings and different areas and weather conditions which is having influence on satellite positions and Dilution of Precision (DOP) and can cause the overall accuracies of data among different roads. However for the same road these factors were constant among mobiles.

The findings that the onward and return journey data pattern may be different in the same mobile with the same setting was inexplicable and may require future studies.

Some data deviated from the average centre line of data for that the author was not able to understand the cause and may require further examination in other research settings.

The effect of GPS chip quality according to mobile makes were not part of study consideration due to scope and type of study. However such studies may be done to recommend mobile makes for better quality of data according to the quality of the GPS chip inside.

4.2. Conclusion

For the countries especially the developing countries field mapping and data collections in GIS environment is the need of the hour. The application of Geo-informatics is mandated by the respective Governments in various ways including deployment of customised tools associated with the schemes. In addition to mandated arrangements, there is a need to have flexible tools and techniques in an open source environment to support the officials in day to day basis real time monitoring of works. Mobile mapping tools which are using Open Street Map (OSM) as base map in offline and online mode and able to use freely available GPS signals without internet dependencies are the boon to the developing countries. OSMAND is one such kind of application and others are also there to use and test. The study indicates that in the Indian terrain conditions the road data may be collected with 2.5-25 meters variations from the centre line of data observations, which can be a good proposition for mapping, planning, execution and monitoring of development works in general and rural infrastructure in particular. Hence the use of these tools may be encouraged along with proper capacity building of users. Governments and institutions can have tie-ups also with the developers and organisations related to these applications for further strengthening and flexible incorporations of strength of these tools in the customised applications. In future with better signal availability in public domain on mobiles, and continuous upgradation of open apps based on users' feedback, can enhance the usability of mobile mapping apps.

Further research may also be taken up on these tools to standardise the uses and understanding the differences in patterns of data among the mobiles.

5. Acknowledgements

The training programmes on PMGSY were sponsored by the Ministry of Rural Development, Government of India. I thank the Centre Head, Centre for Geoinformatics Applications in Rural Development (CGARD), and Administration of NIRDPR for providing support from time to time in conducting the programmes. Author acknowledges the support of the faculty members, staff and administration of the respective State Institute of Rural Development in successful conduct of training programmes.

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Mr. H K Solanki has worked 12 years in the field of Watershed Management at Government of Rajasthan, India as an Engineer. He prepared numerous Detailed Project Report Reports of Watershed projects and was involved in the execution and monitoring of Rural Development works at field level in various Blocks of Rajasthan State. He has been working for the last 13 years on Training/Research and Consultancy projects in Geo-informatics Applications in various thematic areas of Rural Development and Infrastructure. He has conducted about 100 training to Rural Development functionaries of 2-5 days duration on applications of GIS in thematic areas of Rural Development using Open Source GIS and Mobile Mapping tools. He has delivered 85 expert sessions in reputed organizations. He is a charter member of OSGeo. He is a constant learner.

Web GIS Application by using open source software -A Case study of Hyderabad Urban rural belt (15-40 kms).

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Telangana University

Abstract

The study area falls in Hyderabad Urban and rural belt (15-40 kms), which is part of peripheral areas of the city of Hyderabad which is the capital of Telangana state. The area includes parts of erstwhile Rangareddy, Mahaboobnagar, Nalgonda, Medak districts of Telangana. Telangana state is one of the youngest states in India. The study area is about 4323.75 Sq km i.e Urban-Rural belt (15-40 kms) of Hyderabad Metropolis. . Administratively it comprises of 38 mandals with 611 revenue villages. Land and its concerns are universal in nature. Land with all its natural attributes very -rarely gets unchanged as the time progresses. This is inevitable as land-man relations are so intricate and so inter dependant that as the man develops technologically and increases his needs, there is bound to be an alteration in the nature of the land, the land gets transformed. In a way, the natural land cover under unaltered condition switches over to altered land use suiting to the environs. Slowly, with more technological advances and increasing human demands on the land, the land transforms itself at various levels. This type of land transformation is more evidenced where there is dwindling land man ratios, which are conspicuous in urban and peri urban areas. Land Transformation manifests itself in many ways culminating into fragmentation and complex land breakup. Land Transformation is the transformation in Land use and Land cover. LULCC is also known as land change (LULCC by Else Ellis; 18th April 2010) which is a general term for the human modification of Earth's terrestrial surface, i.e. Land Transformation is a subset of LULCC. Literally it is the transformation of the Land in a Spatio-Temporal context. It is the process of identifying differences between the objects or state of any phenomena by observing it at different time periods. In this paper an attempt has been made to provide the Web GIS Application by using open source software for the above study area which aids in better understanding of the land transformation and also helpful to take appropriate decisions by the administrators.

Keywords : Land Use, Land Cover, Land Transformation, Web GIS, Urban Rural belt

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Development and prospects of Re:Earth, an open source GIS web app using Cesium

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Eukarya Inc.

Abstract

This year we released Re:Earth, our no-code web GIS tool that uses Cesium under the hood, to the OSS community. Re:Earth's aim is not to rewrite the wheel, but rather to harness the power of the 3D globe and allow absolutely anyone to visualize and share their geospatial data. Users are able to import preexisting data and build projects off of that, or start from scratch and then easily publish the project or export the data in a variety of supported formats. All without the need of an engineering team. The Re:Earth team is currently recruiting OSS committers and plug-in developers to help expand Re:Earth's potential and build a digital earth community of users and developers. The Re:Earth project grew from the idea of, "What would be possible if anyone, anywhere could access the digital Earth's potential?". To make this a reality, we knew Re:Earth needed to be no-code, but more than that we needed to make sure hardware or OS requirements wouldn't get in the way either, so that is why it is a fully web-based application. We also knew projects as well as data would need to be shareable so we have both project publishing and data exporting. Publishing a project is easy and gives users the chance to opt-in or out of SEO, change their URL and setup publishing to their own domain. Exporting data is easy and supports many of the most common file formats seen in GIS. Our hope has always been to open Re:Earth up to the OSS community and build a global community around it and what it stands for. The first step to making this happen was Resium, a popular OSS package that allows developers to use Cesium with React. With Resium we have been able to write Re:Earth's codebase with React and Typescript on the front end. As the main backend language we chose Go. By using these modern languages we have kept Re:Earth highly maintainable and scalable and hope that other developers will find contributing to it easy. Beyond the code, we have already begun our global community with the core Re:Earth team coming from around the globe. We especially want to help lift talented people up from areas of the world with less opportunities locally, and that is why we have been focusing on finding talent in Syria. At the very least, we hope this project can bring some hope to the people around the world facing difficult times and let them know that there are opportunities out there.

Keywords : Cesium, WebGIS, Resium, no-code

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ShinyGeoVA: An Open source Web Application for Geospatial Visualisation and Analytics

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Singapore Management University

Abstract

With the rapid development of open source technologies, a wide variety of data visualisation and geospatial analytics packages have been developed. Despite their usefulness in transforming data into decision support information, these tools have yet to be widely adopted by partitionists from both the public and private sections. To a large extent, this is due to the general lack of programming skills among the partitionists to put these tools into effective uses. In view of this limitation, we have designed and developed ShinyGeoVA, a web-enabled client-based geovisual analytics tool based on Shiny. It aims to democratise geospatial data and analytics by supporting the analysis and visualisation needs of partitionists without having them to learn programming. This is achieved by wrapping the complex R functions with user interaction and reactive feature of Shiny. This paper reports on our research and development efforts to design and implement ShinyGeoVA. The successful use of ShinyGeoVA to discover the spatio-temporal patterns COVID-19 at the sub-district level (i.e. kelurahan) is then demonstrated.

Keywords : Geospatial Analytics, Geospatio-temporal analysis, Web application, Shiny, COVID-19

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Introduction to Open Indoor Map

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Gaia3D, Inc.

Abstract

Have you ever heard about Open Indoor Map project? No? Don't worry about that you don't know the OIM(Open Indoor Map) project, because OIM is quite new project and not publicly well-known. OIM project got many inspiration from Open Street Map. OIM is a project to let users upload & share their indoor related data. Users can upload their IFC, CityGML, IndoorGML, 3DS data that represent indoor space to the OIM server and OIM server service those data through web in 3D. OIM project makes use of many open source project including mago3D, assimp, and others. We expect OIM project could expand crowd-sourced map to indoor space as well by complementing Open Street Map.

Keywords : Crowd-sourced Map, VGI, mago3D, Open Indoor Map

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MapMint: The service-oriented platform

Gerald Fenoy

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Abstract

MapMint is a comprehensive task manager for publishing web mapping applications. It is a robust open-source geospatial platform allowing the user to organize, edit, process and publish spatial data to the Internet. MapMint includes a complete administration tool for MapServer and simple user interfaces to create Mapfiles visually. MapMint is based on the extensive use of OGC standards and automates WMS, WFS, WMT-S, and WPS. All the MapMint functions run through WPS requests calling general or geospatial web services vector and raster operations, Mapfiles creation, spatial analysis and queries, and much more. MapMint server-side is build on top of ZOO-Project, MapServer, GDAL, and numerous WPS services written in C, Python, and JavaScript. MapMint client-side is based on OpenLayers and Jquery and provides user-friendly tools to create, publish and view maps. In this presentation, MapMint architecture and main features will be presented, and its modules: Dashboard, Distiller, Manager, and Publisher described with an emphasis on the OGC standards and OSGeo softwares they are using. Some case studies and examples will finally illustrate some of the MapMint functionalities.

Keywords: OGC,WPS,FOSS4G,MapServer,GDAL,MapMint,Standards

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THEME 3

Spatial Landuse Planning and Decision Support System (SPDSS)

Web Based Spatial Planning and Decision Support System

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Abstract

With the rapid onset of technological advancement, Geographic Information System (GIS) today is no longer restricted to desktop, rather a person can access analyse and visualize GIS data sets from anywhere around the world without having installed the software. Although, there is huge repository of spatial information existing in the internet under various domains and sources, it is difficult to use web browser to seamlessly access, view and exploit the vast, diverse and widely distributed geo-spatial data, which makes it hard to develop GIS based application and to provide enough support for spatial decision-making. Recently, web-based GIS application have become important tool for disseminating geographical information in digital map format on the internet because of their platform independence, interactivity, and wide accessibility. Web based GIS have evolved from various web maps using client server architecture to distributed ones. Integration of advanced web mapping technologies have lead a way to meet the needs of urban and regional planning tool based on information expertise, accelerating the decision making process and enhancing the process of spatial planning.

Literature survey reveals GIS and allied web based technology is an effective tool for planning and management of cities globally. In recent years, many municipalities in the World have switched from stand-alone GIS systems to integrated approaches that share resources and applications. In developing countries like India, Governments and planning authorities have executed GIS projects independently. Integration of both spatial and non-spatial data with technology helps in effective planning, governance and better management of a city. This paper presents experiences of GIS implementation in Mysuru City in Karnataka, Southern India and suggests a conceptual Web-GIS model for Mysuru. An attempt was made to develop a Web enabled geo-information system for the Mysuru District. Three specific areas of interaction between information technology and urban planning were examined. First; the structure of computer systems used for urban planning, second; the modeling of urban planning data using open source QGIS software and, third; the models as the major components of spatial decision support system (SDSS). Various raster and vector layers were integrated to Geoserver, which acts as a bridge to link between the spatial database and web interface to allow the user to easily query spatial data. After gathering all the required layers, a web portal was developed using the Hyper Text Markup Language (HTML), Cascading Style Sheets (CSS) and scripting language Java Script, which describes the structure of a web page and it also includes all cues for the appearance of the document. These open technologies combined aids in decision making effectively and realized to achieve the process of SDSS. The results thus displayed on web portal helps users to obtain the data of a particular region and these information can be used for further theme based applications. Urban planners and civic authorities can make use of the web based map visualization and SDSS to effectively handle current situation of urban management.

Keywords: Web based GIS, Web mapping, SDSS, Open source, Geoserver, Urban management.

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Introduction

Recent years have witnessed rapid advances in Web-based geographic information systems (Web GIS), which aim at providing geospatial functionalities (e.g., web mapping and spatial analysis) to users through a web browser. Web technologies have a profound effect on how Web GIS are developed. While the first browsers often acted as a renderer of simple web pages, current web browsers behave like “a runtime environment capable of delivering rich interactive applications across many application domains”. Despite these advances, current Web GIS are still rather poor in terms of interface and functionality, compared to their desktop counter parts. This is probably due to the poor functionality support in the current web standard HTML4. HTML5 is being developed as the next web standard (Qui & Huang, 2015). HTML5 is a response to the observation that current web documents are a mixture of features introduced by various specifications and web browsers, and contain many syntax errors, which can be attributed to the limitations of the current HTML4. These new features are designed to make it easy to include multimedia and graphical content on the web in a plug in - free manner. Current research in Web GIS mainly focuses on spatial data visualization using the canvas element and the web socket of HTML5 (Qui & Huang, 2015).The feasibility of HTML5 in developing highly interactive Web GIS with true vector graphic capabilities and enhanced functionality. Spatial data can be classified into raster data and vector data. Raster data, such as satellite images, represent the world as a surface divided into a regular grid of cells. In contrast, vector data model the world as a surface littered with recognizable spatial objects, which can be represented as points, lines or polygons.

GIS (Geospatial Information System) is the main important tool in present days to analyze the spatial alignment and understanding of different informative system of a particular region. Recently, in Karnataka many cities are developing in faster rate, therefore identification and searching of many different locations (e.g., roads, hospitals) has become difficult for people. Thus by collecting the spatial data of a city, GIS is used for capturing, storing, checking, displaying, and understanding of all the data layers. Web GIS is an advanced form of GIS commonly available in the web platforms. The exchange of information takes place between the user (client) and the server. The server has a Unique Resource Locator (URL) so that, the clients can find out the information in the website easily.

In earlier days spatial data has to be edited, modified, and extracted to a particular pre -determined set of questions. Now all the data is transferred into web maps that are having many layers in web GIS. Geoserver is the interface to compile the data obtained from the GIS that will be modified in QGIS system application that is map and point data (vector and raster). QGIS known as Quantum GIS is a free and open source platform geographic information system (GIS) application that supports viewing, editing and analysis of geospatial data. QGIS functions as geographic information system (GIS) software, allowing users to analyze and edit spatial information, in addition to composing and exporting graphical map (Hetland, Thyng, DJ, & Qu, 2017). QGIS supports shape files, personal geo databases, Post GIS and other formats.

A simple website is created using HTML coding to obtain data and all the data will be extracted from Geo Server. The Hyper Text

Markup Language (HTML) is a standard programming language used to designed a web browser. It can be assisted by technologies such as Cascading Style Sheets (CSS) and scripting language such as Java Script. HTML describes the structure of a web page semantically and originally included cues for the appearance of the document. Finally a common user can go through the website and get the data of a particular region (city) easily when user wants to view different layers. This website is user friendly which helps to download the spatial data when there is a need. This will be further used for many applications.

One such application is Real – Time Web Mapping. Currently, with the ubiquity of sensors, large sets of observations about the world are being generated in a nearly real-time manner. Therefore, more and more Web GIS need to provide real-time visualization of spatial data. Before HTML5, several techniques, such as polling and Comet, have been adopted for showing real-time information. These techniques are often query-driven, where the update request is initiated by browsers. They are often complex to configure, and lead to high network traffic. HTML5 provides web socket to address these problems. Wed socket is event-driven, and can be used with JavaScript. With web socket, a bi-directional channel between the browser and server can be set up. An event happening on the server can be captured (such as new data are being stored in the database), and sent to the browser instantly.

Objective

The objective of this research is to develop a website for web based spatial planning and decision support system. Integration of information from many sources and establishing reliable and efficient access to geospatial data of Mysuru city

1.2 Scope of the study

The model will be developed for the Mysuru city selected from the Southern part of India. The research output anticipates a web developing model and simulating framework that can be applied to any other city. However the validations are limited to Mysuru city but the model developed can be used to add other cities.

Study Area

Mysuru, the rapidly urbanizing city of Karnataka was chosen for the analysis. Mysuru is one of the historic city of southern India and ex-capital of Mysuru state. Mysuru is one amongst few cities which had the privilege of serving as royal seats under the rulers, who devotedly contributed their own classic beauty to the architectural monuments of the city. Mysuru city is a district head- quarters which is located at the base of the Chamundi Hills about 150 km southwest of the state capital Bangalore. It is also called as cultural capital of Karnataka. Mysuru city is about 770 m height from the mean sea level. Longitude is 76°39' East and Latitude is 12° 39' North.

Mysuru is projected to have a population of 1.3 million in 2025, making it the second largest city in the state. Total area of Mysuru city limit is 128.42sq.km. This city is drained by Cauvery and Kabini rivers. Mysuru city is having most famous tourist places like palaces, zoo, temples heritage buildings etc., which attracts more tourists and also connecting city to Kerala and Tamil Nadu which causes high floating population.

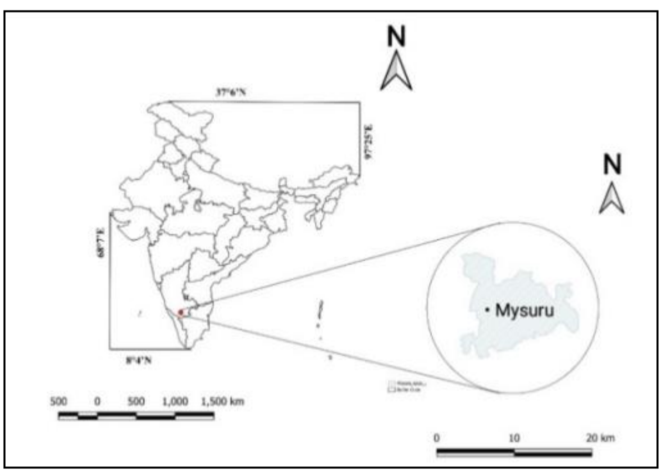

Figure 1: Study area Mysuru, Southern India (left). Mysuru region with administrative boundary enlarged.

Literature Review

Popular theories and Researchers across the globe have developed web-based SDSS's that were aimed to provide visualization of spatial data. Other existing models and new concepts will be discussed in the following section.

The Use of Geographic Information System (GIS) Based Spatial Decision Support System (SDSS) in Developing the Urban Planning Process

The use of computer-based information in the exploration of computer technology .As per the article, GIS was the most recognized tool of those Assisting Technological Tolls (ATT), And was well known to the planners, Decision makers as a decision support system tool (DSS), Every decision making process produces a final choice

Decision made by different authors in different phases all depend on the information available.(Hall 1996) and also ,planning , in its broadcast sense , is clearly an activity that requires the use of spatial information in under taking many core planning activities , including land –use plan formulation (Boddy,1995) .The classic tasks of GIS are the analysis and all graphical presentation of spatial data .

The decision –support system (DSS) provides a mean for decision makers make decision on the basis of information and analysis with aid of DSS combining with the GIS technology and software that makes the SDSS.

The Open Source Technologies in Web – based GIS and Mapping

The study provides a scientific and thorough analysis of alternative options to building spatial websites through the use of open source technologies. Open source technologies have proven to meet and in some cases surpass the abilities of proprietary software to produce effective and robust web-based spatial application.

This study proves that an open source web-based GIS configuration provides a viable alternative to proprietary software in terms of cost, ease of use, performance and conformance to open standards.

The growing trend of the adoption of open source technology for Web-GIS is largely due to the fact that many successful projects have proven under many circumstances to perform at acceptable and sometimes exceptional levels compared to proprietary products. Based on the results of both configurations, there are several advantages and disadvantages to both approaches in both financially and functionally. (Eric Harper, 2006)

The maximum extents of the data have to be manually set in the map files without the knowledge of where those maximum extents are set, the map file will not display the data correctly upon loading. This is the main reason why Open source technologies are considered as the best alternative in the recent times.

The limitations of this study include the inability to test and experiment with all other open source products that exist for producing Web GIS applications. It is also ideal if every product could be evaluated and tested for comparisons.

This study concludes that, rather than purchasing a proprietary database system and then purchase support from the proprietary database company, customers instead needs to choose an open source database system. The net effect is the same – customers have functioning and supported products but the balance of power is shifted in the favor of customers.

Methods and Materials

The Concept of web based spatial planning and decision support system includes server client architecture as shown in Fig. The Data input on web development is considered as client side operation, Generation and analysis of spatial data is carried out through spatial library and command on the server side.

4.1 Materials

4.1.1. QGIS

QGIS (Quantum GIS) is an open-source GIS software where processes like viewing, editing and analysis of geospatial data are done. In addition to composing and exporting graphical maps, QGIS supports both raster and vector layers and also the software geo-reference images.

4.1.2. Geoserver

Geoserver is open source web based software used to view, share, analyze and store spatial data on web. It is worked and supported by JAVA script that allows users to edit, process and share geospatial data. It can input spatial in a wide variety of format and deliver them in open standards based services.

Table 1: Software used to host the website.

No.	Software / Web platform	Application
1.	QGIS	Pre and post-processing of downloaded images to vector and raster data.
2.	Geoserver	Open source server to host and store the GIS layers.
3.	HTML, Java script & CSS	Used to build, design and development of the website.

4.1.3. Web portal

Web portal is designed using programming languages like HTML, Java script and CSS

4.2. Method

Initially topo-sheets images are downloaded from USGS, the downloaded images are in the form of basic .jpeg format. These images are geo referenced and geo registered for the digitization of the city. In other and Landsat images are downloaded from the USGS earth explorer. The downloaded images are pre-processed using QGIS3.6 Software. Pre-processing includes Clipping of images styling of images are done. The pre-processed images are extracted and cropped to our study area. QGIS supports both raster and vector layers the vector layer is extracted in the form of shape files i.e. .shp format and also raster layer is extracted in the .tiff format i.e. tagged image file format. Once vector and raster layers are ready in appropriate format .The false color composite (FCC) is essential for the visualization of multi-spectral images.

Once vector and raster layers are obtained from the QGIS after FCC process, these layers are referred to as spatial data .Spatial data is exported to Geoserver, Where viewing storing and sharing of spatial data takes place. Geoserver acts as an interface between the QGIS software and WEBGIS, However it imports spatial data from QGIS and exports to designing of web portal.

A simple website is developed using HTML as a markup language assisted by CSS JAVA SCRIPT.

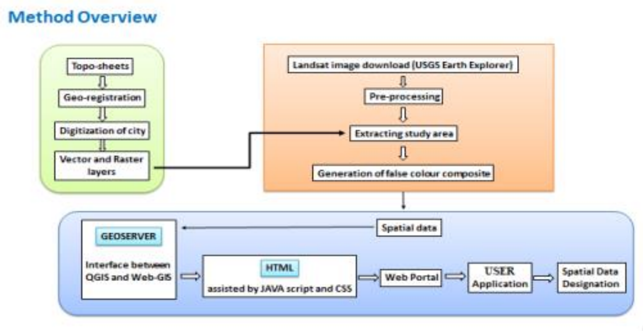

Figure 2: Flowchart of the procedure involved

4.3. Web based spatial analysis

Spatial analysis plays a key role in GIS. However, current Web GIS mostly provide data visualization only. This is probably due to the poor functionality support in HTML4. HTML5 introduces many APIs for complex applications, such as web SQL database. These APIs have high potentials for providing spatial analysis in Web GIS.APIs can be employed to provide load balancing spatial analysis in Web GIS. In contrast to implementing spatial analysis solely on the server or browser sides, load balancing spatial analysis executes spatial analysis on either the server or the browser side, depending on the estimated execution costs (i.e., network transmission and computational costs).

Based on HTML5, load balancing spatial analysis can be provided in Web GIS. HTML5 can also be used to implement server-based and browser-based spatial analysis, as both of them are two simple cases of load balancing spatial analysis. In summary, HTML5 is very promising in providing spatial analysis in Web GIS, which will enable users to access spatial analysis functions simply with a web browser.

The web GIS is an extension and application of client/server computing, where the geospatial data is accessible in a shareable environment. Client/server computing describes a model for computer networking that offers an efficient way to provide information and services to concurrent user(s) at the same time. Internet is a "connectionless" process, based on client/server architecture. In a client/server model, a client is defined as a requester of services and a server is defined as the provider.

Geospatial technology is an emerging multidisciplinary approach which involves computer science, geography, cartography, remote sensing, surveying, GPS technology, statistics and other disciplines concerned with handling and analyzing spatially referenced data. Traditional GIS can serve only dedicated users with sophisticated software and hardware with limited impact on the public. Furthermore, the widespread availability of geographical information systems (GIS) supports spatial data processing and analysis to increase the accessibility of spatial models.

Geospatial analysis such as spatial multi criteria decision analysis in the Internet GIS domain is the concern of the latest research and development in GIS and information technology known as Geo informatics.

4.4. Spatial Decision Support System

The developed web SDSS in present study is based on the server side and also a mix of client and server side technologies. The spatial data is available at a centralized server in a standard data format. The developed web enabled SDSS provides a GIS environment in a simple web browser at the client end; the decision maker's interaction with available data sets; and standard multi criteria analysis technique. The developed SDSS also provides all or almost all GIS functionality in simple web browser for spatial querying and analysis like query builder and selection of particular areas and calculation of statistical report.

The success of Spatial Decision Support (SDSS) system in Internet GIS domain is fully dependent on the performance of the application. A large number of multi criteria SDSS solutions are available commercially or freeware for desktop applications. Development of SDSS in web GIS environment with full spatial analysis capability is still evolving. The implementation of online analytical processing (OLAP) and related techniques at spatial data server level will certainly improve the performance and analytical capability of web based spatial decision support. In a web environment, performance is usually the most important factor, thus a developer should keep in mind the network performance when designing the database. The database normalization and indexing performs best for an Internet GIS application.

Results

In order to view the spatial data on web, Geoserver – an open source server for sharing geospatial data is used. It helps to publish data from any major spatial data source using open standards. In Geoserver, "workspace" is created as (Nie.mys). All the vector and raster layers are uploaded in the form of .shp and .tiff formats respectively by creating different "Stores" to each. After adding the layers, exact boundary of the location can be checked and evaluated by EPSG Code – 32643 for Mysuru. Latitude and longitude coordinates are evaluated and the layers are published in it.

5.1 Map server

The Map Server is used to store, render, and send maps to a browser-based client. The Map Server used in development of Smart Scape (TM) was Geo Server. Geo Server is open-source software that allows users to share and edit geospatial data over the web (http://geoserver.org). Geo Server implements a Web Map Service (WMS), which is a standard

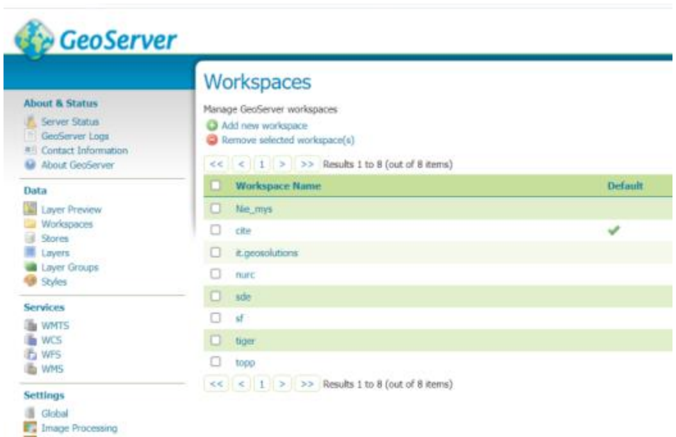

Figure 3: Creating workspace in Geoserver

for publishing maps in image format (e.g., Geo TIFF). Smart Scape (TM) uses WMS to allow two-way communication between the client and the Geo Server, since WMS is also able to accommodate requests for spatial data from several servers at the same time. The application server processes the input with available data sets in data server and sends it to map server; map server launches this output for the web browser by using the available map service in the service registry of the map server.

Web architecture

Geospatial data processing, visualization and analysis is based on the client-server architecture of web based SDSS. The client and server are connected through a communicating medium. Client side includes user interface through software such as QGIS or web mapping applications or browsers. Server side includes spatial data processing servers like Geoserver.

A simple website is created by using HTML. HTML is assisted by other programming codes such as Java script and Cascading Style Sheets (CSS). The layers are brought to the

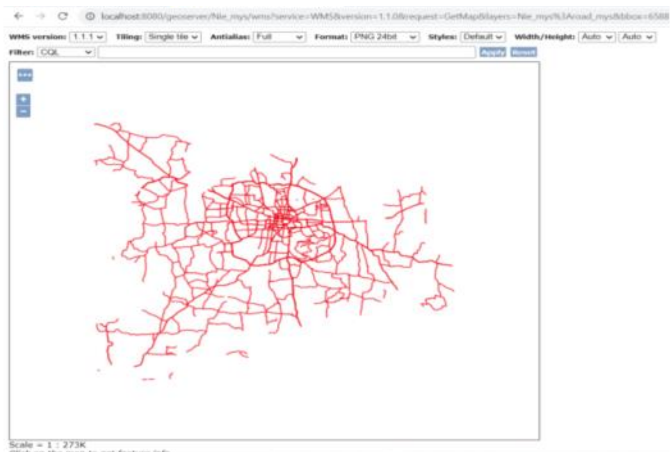

Figure 4: Published layer in Geoserver

website from Geoserver and Java script. Basic functions such a zoom in, zoom out, adding point, line, polygon and pinning the location are added in the website. These functions are the minimum requirement of any web based application. Finally, the users can get the information of different layer maps with respect to Mysuru through the website and it can be used for their further application.

Discussion & Conclusions

This study discusses the role of GIS in developing the web based spatial planning and decision support system for Mysuru city. The prototype of the proposed web based SDSS has been developed using Geoserver local host. The Open source tools are explored such as QGIS and Geoserver to analyze, visualize and to process spatial data. The user can go through the website and obtain the data of the city easily. The data includes raster and vector layers which are viewed, edited, analyzed, and geo referenced by QGIS. Hence, the user can obtain the data accurately for the specified location instantly.

Web GIS tools and information assists scientists and engineers for their investigation activities, operations, and scientific analysis. Therefore it provides efficiency in decision making and planning process.

In the study, it has been shown that HTML5 holds great promise in the future development of Web GIS. It can help to develop cross-browser and highly interactive Web GIS applications with true vector graphic capabilities and enhanced functionality (e.g., spatial analysis). In other

Table 2: Description of the layers available in website

No	Data/ layers	Type	Description
1	Aspect map	Raster	Represents the direction and degree of slope of a terrain.
2	DEM	Raster	Represents the relief between points of known elevation
3	Hillshade	Raster	Represents the realistic view of the terrain
4	Point	Vector	Includes point locations such as hospitals, Govt. offices etc
5	Polygon	Vector	Includes closed boundaries such as lakes and tourist places.
6	Road	Vector	Shows the road network of the city
7	Slope	Raster	Represents the steepness of terrain

words, in terms of interface and functionality, with the help of HTML5, the gap between Web GIS and their desktop counterparts can be narrowed.

However, there are some limitations and issues needing further studied, e.g., copyright issues, large dataset handling and aesthetics in web mapping. Beyond these, as more and more web maps are viewed from mobile devices, the aspects covered in the above studies also need to be investigated for mobile devices. The current frameworks of SDSS are: all maps are static - to introduce dynamic state, it is necessary to adapt advance mapping scripts; For real time spatial visualization – all spatial data is needed to be transferred from local host to cloud based system in future to access the

Figure 5: Screenshot of the website

datasets; data availability – due to time constraint, the preprocessed and analyzed data were done only for one city. Further development of the website can be made with

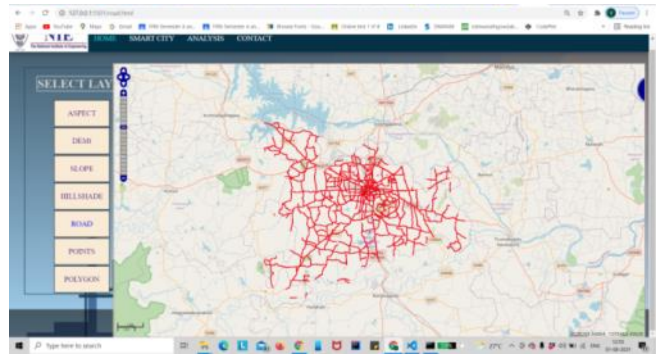

Figure 6: Road layer in Website

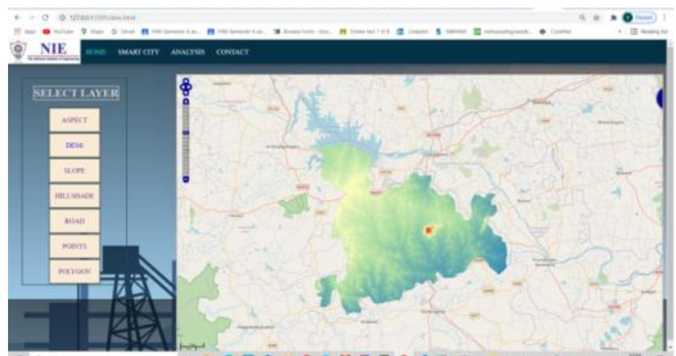

Figure 7: Screenshots of the analysis in website

addition of other nearby cities around Mysuru. Despite all the demerits the web application has potential usage in the future in terms of web based SDSS, E-governance and management of a city.

Acknowledgments

We are grateful to Department of Civil Engineering, The National Institute of Engineering, Mysore, for infrastructure support. We are thankful to OSGEO for GRASS and QGIS software and well maintained user forms for timely answers to solve bugs in the software. We are also thankful to Open Geospatial Consortium (OGC) for open source Geoserver platform.

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Open source web resources used

Quantum GIS:https://qgis.org/en/site/
GRASS GIS: https://grass.osgeo.org/
Google Earth pro: https://www.google.com/intl/en_in/earth/versions/

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Future Land Use Land Cover Scenario Simulation Using Open-Source GIS for the City of Banepa and Dhulikhel Municipality, Nepal

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Abstract

Free and Open-Source Software (FOSS) is making revolutionary in the present era of Information, communication and technology. Considering the availability of open source software, this study primarily aims to apply CA-ANN model available in MOLUSCE plugin of QGIS to predict the future scenario of LULC. Similarly, it also examines the responsible driving factors for the LULC changes throughout the study period (1992-2020) using desk study. In order to accomplish the objective of this study initially necessary datasets were extracted, then drives were selected for impact analysis, finally modelling and prediction was done. The future scenario of Banepa and Dhulikhel municipalities was generated using CA-ANN model via MOLUSCE plugin bbgavailable in QGIS. It reveals that agriculture and forest land are expected to decrease by 2.56 % and 2.62 % respectively by 2032 since 2020.Similarly, the barren land is predicted to decrease by 0.57 % whereas the builtup expected to increase by 5.73 % in 2032 since 2020.Moreover, results generated from this study reveals that agriculture and forest land are expected to decrease by 2.56 % and 2.62 % respectively in 2032 from 2020.Similarly, the barren land is predicted to decreas by 0.57 % whereas the builtup will be increased by 5.73 % in 2032 from 2020. Future prediction of LULC classes is crucial in Land Use Planning of every government/state. The prediction done by model is corrected up to 81.66%. In addition, this study reveals that during study period major drivers such as; internal migration, commercialization, real estate business are major drivers for LULC changes whereas establishment of Kathmandu university and dhulikhel hospital, climatic conditions, population growth, accessibility of Araniko and BP highways are the major drivers of LULC changes in Dhulikhel municipality. Thus, the methodology adopted and results generated from this study can be the basis or reference materials for the technical members of the council of the respective municipal offices; Banepa and Dhulikhel to develop their land use planning/land management related project.

Keywords: LULC, CA-ANN, MOLUSCE, QGIS

1. Introduction

1.1 Background

Free and Open-Source Software (FOSS) is making revolutionary in the present era of Information, communication and technology. FOSS primarily includes two fundamental concepts; (i) free freedom to use and open (ii) capability to read, redistribute, and modify the source code for a specific software (Wong & Sayo, 2004). In present scenario, FOSS movement has gained international recognition, and increasingly being used as a substitute for proprietary software (Espada, 2008). This moment has been realized in geoinformatics; thus, the development of FOSS - Geographic Information System (GIS) has been developed. The article published by application of FOSS-GIS such as; QGIS, GRASS, PostGIS, PgAdmin, Open Street Map etc. has been found in various domain like forestry, agriculture,

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urban development, land management etc. since, it is free and open to use and has comparable tools and functionality as available in GIS-related expensive proprietary software (Espada, 2008).

Land domain includes various aspects; social, economic, religious, environmental etc. (Ghimire, 2016). Land Use Land Cover (LULC) is one of the globally used term in the land domain (Mahmoud H. & Divigalpitiya P., 2017). The two terms “Land Use” and “Land Cover” are most often used interchangeably but each term has a very specific meaning. Land use is defined as “a series of operations on land, carried out by humans, to obtain products and/or benefits through using land resources” whereas the Land cover is defined as the “vegetation (natural or planted) or man-made constructions (buildings, etc.) which occur on the earth surface” (Coffey, 2013). At present scenario, LULC of the world are undergoing several changes. Global trend of the LULC changes can be categorized into two groups; intensification and extensification (Abbas , Yang, Zhong , & Zhao, 2021). Intensification refers to the deforestation and increase in agriculture and builtup areas whereas extensification refers to the afforestation and land protection (Paudel, , et al., 2016). Thus, it is now become the priority of every nation to achieve the sustainable land management and United Nations has also incorporated the sustainable land management in its 2030 goals (Christensen & Arsanjani, 2020).

In context of Nepal, trend of LULC changes is mainly on intensification manner since 1990 (Paudel, , et al., 2016). The major reason for this intensification is due to urbanization, increase in population growth and land value (Paudel, , et al., 2016). Besides, environment and climate conditions, internal migration, commercialization had also altered the LULC trend of Nepal (Paudel, , et al., 2016). Due to too intensification of built up areas with continuous degradation of agricultural and forest land has created so many impacts of land management of Nepal (Acharya, 2011). Therefore, to control this crucial issue federal parliament has endorsed ‘Land Use Act 2019’ in 2019 which articulate every local government should formulate their land use plan via ‘Local Land Use Council’ (MOLMCPA, 2019).

This study aims to predict the future scenario of LULC for year 2032 of two major growing cities; Banepa and Dhulikhel municipalities using CA-ANN model available in MOLUSCE plugin of QGIS. Modelling and prediction will depend upon given inputs; image datasets, driving factors and model parameters. Besides, the study also demonstrate the expected LULC changes between 2020 with predicted LULC 2032. In addition, the driving factors for LULC changes will be analyzed. Thus, the methodology adopted and results generated from this study can be the basis or reference materials for the technical members of the council of the respective municipal offices; Banepa and Dhulikhel to develop their land use planning.

2. Literature Review

2.1 Land management and MOLUSCE

LULC Planning, management and monitoring programmers at local, regional and national levels are important for achieving sustainable land management (Dahal , Shrestha, & Nepali, 2021). The major LULC classes/zone that has been classified by Land Use Act-2019 are; Agricultural, Forest, Commercial, Cultural and archeological, Residential, Mine and Minerals, River and Lakes, Public Space Zone, Industrial, Other zones as per prescribed by Nepal government (MOLMCPA, 2019). In order to effective planned these LULC classes of any geographical region components such as; present LULC maps, zoning maps, statistical charts and geospatial based future model plays a crucial role (Singh, n.d.). For generating these components, various sequential geospatial activities such as Classification, monitoring, analysis, modelling, and prediction are essential (Mishra, Rai, & Rai, 2020). Nowadays, various FOSS such as QGIS and freely available satellite images are widely used to perform these sequential activities for extracting the ground information for baseline thematic maps, and identifying the effects of humans on the environment (Mishra, Rai, & Rai, 2020). Classification, monitoring and analysis are comparatively easier task when comparing to modelling and prediction (Figueiredo, 2018). This study mainly focused on the modelling and prediction in an allocated study area despite the monitoring and analysis task. \

In context of Nepal, various research had been done at the national level and regional level for modeling the dynamics of LULC. The previous researches for modeling the LULC dynamics mostly focused on the method such as GEMOD and Logistic Regression using the proprietary software (Rimal, et al., 2020). But this study mainly based on the CA-ANN model via open source MOLUSCE plugin available in QGIS with main focus on the local level government which is not done widely in the Nepal after the federal system of government came into account in the country since 2015.

Module for Land Use Change Simulation (MOLUSCE) is a user-friendly plug-in for QGIS 2.0 and above which is designed to analyze, model, and simulate LULC changes (AAS, 2012). The interface of the MOLUSCE plugin consists of specific tabs for specific functionalities such as Inputs, Evaluating Correlation, Area Changes, Transition Potential Modeling, Cellular Automata Simulation, Validation (AAS, 2012). Various models are available in MOLUSCE plugin for modelling such as; Weight of Evidence (WOE), Logistic Regression (LR), Multi Criteria Evaluation, Artificial Neural Network (ANN) (GIS Lab, 2014).

2.1 CA-ANN Model

CA-ANN model is a nonlinear tool that has been applied successfully in LULC modelling and prediction (Mahajan, Yogesh & Venkatachalam, Parvatham, 2009). Cellular Automata (CA) consist of a simulation environment (grided cells) in which the new state is determined based on its previous state and that of its immediate neighbors according to specific transition rule (Khalid , Linda , & Alison , 2013). Similarly, Artificial Neural Network (ANN) is a system which consist the piece of a computing system used to simulate the way the human brain analyzes and processes information (Ujjwalkaran, 2016). The main reason to integrate the CA with ANN is; CA has open space model so can be easily integrated but dependent on spatial data and not appropriate to make a realistic simulation whereas ANN can detect potential interdependencies through the implied driving forces. Thus, to get effective modelling and simulation result the both models are combined; CA and ANN (Gharaibeh, Shaamala, Obeidat, & Al-Kofahi, 2020).

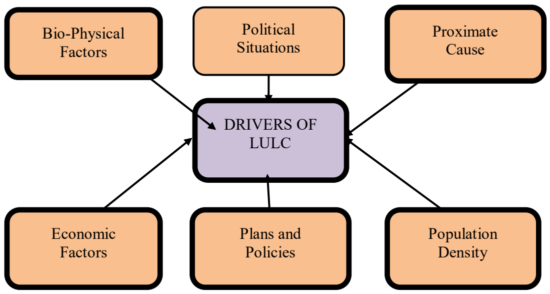
CA-ANN composed of various essential elements. In CA; cells, array dimension, transition rule are major parts whereas neurons, weights, input, hidden and output layer are major components of ANN (Gharaibeh, Shaamala, Obeidat, & Al-Kofahi, 2020). Similarly, the neurons are the basic unit in an ANN which receives input from some other nodes, or an external source and computes an output (Ujjwalkaran, 2016). Further, weight decides how much influence the input will have on the output (Banys & Kobran, 2019). The layer which accepts the independent variables or inputs in the model is called the input layer (Ujjwalkaran, 2016). The intermediate layer which is in between input and output layers is called hidden layers and these intermediate layers are called hidden because they are not visible to the external systems and are "private" to the neural network (Malik, 2019). The layer which is responsible for producing the final result from the inputs taken and processed in the hidden layer is called as output layer (Malik, 2019). Activation functions are mathematical equations that determine the output of a neural network. In the absence of activation function the ANN is just a linear regression model which cannot solve and perform more complex tasks (Akshay, 2020).

CA-ANN is very effective in handling incorrect and inferior data, and capturing non-linear, complex features in modeling processes (Li, Tianhong & Li, Wenkai, 2015). CA-ANN model incorporated in MOLUSCE plugin perform two different functionalities; ANN helps to determine the transition probability of LULC map with the help of multiple output neurons for simulating multiple LULC changes whereas CA is used to model the LULC changes by applying the transition probabilities from the ANN learning (Saputra & Lee, 2019).

2.2 Drivers for LULC Changes

In order to understand the process of the LULC changes and predicting its future scenario responsible the drivers should be properly studied and analyzed (Rimal, et al., 2020). In context of developing countries like Nepal, the major drives for LULC changes are depicted in figure 1. The impact of each driver on LULC change differ in their own way. In case of biophysical factors, the land classes having flat land has high possibility to change into built-up compare to the steep land. Similarly, the fertile land has high possibility to change into agriculture compare to the bare land. (Duwal, 2013). LULC pattern of any area also depends upon political factors. In case of Nepal, civil war (Maiost war) has influenced a lot in the LULC pattern of the Nepal since 2000 (Duwal, 2013). Similarly, proximate factors such as major services, roads, existing settlements etc. plays crucial role in the LULC change pattern significantly (Duwal, 2013). Besides, development of infrastructure is correlated with urban growth and also leads to LULC conversion, especially in Latin America, Asia, and Africa (Lambin & Geist, 2002).

It has been said that; "From an economic perspective, it is true that new economic activities always emerge around the existing economic center for the sake of economic agglomeration and market competition which increase the settlements" (Kivell, 1993). Further, the policy framework related to the land such as land use plan, transportation plan, investments plan etc. of any regions will influences how



LULC pattern will changes if plans will implement effectively (Mienmany, 2018). Similarly, in case of population growth, with increase in the population growth it increases the demand for food productivity and builtup areas which directly leads to the deforestation of forest areas (Mienmany, 2018).

3. Method and Materials

3.1 Data Used

The LULC raster datasets used for this study were basically acquired from previous study related to similar theme done in an allocated study area. Similarly, necessary driving factors datasets for modelling and prediction were initially extracted, then prepared on the basis of scope of study, data availability, and requirement of the model. The entire datasets and their raw acquired format in this study is depicted in the table 1.

Table 1: Data Used

Datasets	Format	Source
LULC (Agriculture, Forest, Builtup and Barren)	Raster (.TIF)	(Shrestha, Bhandari, & Twayana, 2021)
A. Proximity Factors	Vector (.shp)	Google Earth & Survey Department, Nepal
Distance to araniko highway, district roads, urban roads, existing settlements, major services		
B. Biophysical drivers	Raster (.TIF)	United States of Geological Survey (USGS)
i. DEM		
ii. Slope	Prepared via DEM	United States of Geological Survey (USGS)
C. Population density	Raster (.TIF)	World Population Organization (WPO)

3.1 Study Area

The Banepa and Dhulikhel municipality of Kavreplanchowk district in Bagmati Province were chosen as study regions for this study. These municipalities are located at 27°38′ N and 85°31′ E and 27°37′ N and 85°33′ E respectively. Figure 2 depicted the allocated area in order to carried out this study. These two municipalities are two major growing cities of Nepal due to high trade flow, tourist hub, commercialization etc. (Twayana, Bhandari, & Shrestha, 2021). Major ethnic groups found in this municipalities are Newari, brahmin, chhetri, Tamanag etc (MOFAGA). Moreover, similar climatic condition is found in these two municipalities i.e., moderate warm and temperate with much less rainfall (Shrestha & Buddha , 2021). Due to the high rate of the commercialization and trade flow the LULC in

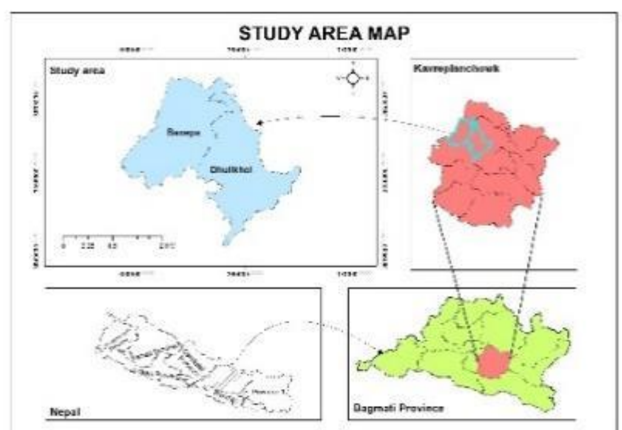


Figure 2: Study Area

these regions undergoes several changes. Thus, study related to the how this change will be in future using FOSS is essential to support in the land management projects/local land use planning with reasonable cost.

3.3 Methodological Framework

The methodological framework adopted to carried out this study is illustrated in the figure 4. Besides, other activities performed to accomplish the objectives of this study are described as below.

3.3.1 Acquisition of Image Datasets

After completing the literature review LULC image datasets of the respective years was acquired. The LULC for the year 1992, 2002,2012, 2020 were acquired. Figure 3

3.3.2 Selection and Preparation of the Drivers

Driver selection and preparation was one of the major tasks performed in this study. Initially, desk study using; journals articles, reports, and related documents was done to retrieve the responsible driving factors for LULC changes in study area. Then after all drivers were analyzed in order to examine their impact on LULC changes over study period which is comprehensively described in results and discussions sections. Further, to accomplished the main aim of this study driving factors for year 2002 was selected, categorized and prepared on the following same literatures. The main reason for only selecting the drivers of year 2002 was due to scope of study and model requirement which is explained detailly in further next step (Inputs). The procedure adopted for selection of drivers for year 2002 is illustrated in the figure 3.

3.3.3 Modelling and Predicting using MOLUSCE

Inputs

Inputs are the initial parameters to be inserted for modelling and predicting via MOLUSCE plugin. In this study model needs to predict for year 2032, thus it was first calibrated and validated by simulating the LULC of 2012. For this purpose, LULC raster datasets of 1992 and 2002 were inserted in plugin interface as initial and final year respectively. Then, n was inserted as 1 in the same plugin interface which will automatically simulate for the year 2012. The simulating year can be calculated as; (Simulating year = final year + difference of the initial and final year). Thus, model requires the drivers in final year (i.e., 2002) to precisely simulate LULC of 2012.

Evaluation of Correlation

The ‘Evaluating Correlation’ tab available in MOLUSCE plugin was used to assess the correlation between the input driving factors for year 2002. Assessment of correlation is vital before transition potential modelling because if highly correlated drivers will be there during modelling more computational power is required for the CA-ANN model. Slope was excluded in this study due to its high correlation with DEM, else other were carried as it is.

Transition Potential Modelling

This step mainly produced the transition potential maps which will act as the main basis for the further simulation of LULC 2012 by CA-ANN model. Various types of the operational parameters should be inserted in MOLUSCE plugin before initiating the transition potential modeling. It includes six parameters; Samples (Random), Neighborhood, Learning rate, Momentum, Maximum Iterations, Learning Procedure. These parameters were selected based on the literatures and necessity of study. During transition modelling, 5000 randomly selected pixels were divided into two sets; 80 % for training and 20% for validation. Similarly, 10 hidden layer was selected for precise prediction of the LULC classes for year 2012. Moreover, momentum (0.05), learning rate (0.1), and neighborhood size (3*3) are the other selected parameters that connects the all the layers (Input, Hidden, and Output layer) of the CA-ANN model.

CA-ANN Simulation for Year 2012

CA-ANN model simulates the LULC for year 2012 based on the four essential elements i.e. CA (C,n,K,R); where C are represented by pixels, n is represent by the number of classes, K represents the Moore neighborhood of size, and R represent the transition potential maps (TPMs). During this step CA-ANN model recognizes for each pixel of the year 1992 and 2002 with the highest TPMs values generated through transition potential modelling. This step and transition potential modelling are interconnected with each other and follows black box approach for simulating the LULC classes. After completing the simulation of the LULC for 2012 a raster map was generated which shows the spatial distribution of the LULC over the study area.

Validation

Validation was done to assess the potential of the CA-ANN model to predict LULC for year 2032 in an allocated study area. During this step actual LULC raster map for year 2012 (acquired) and simulated LULC raster map for year 2012 (generate) was inserted in the ‘Validation’ tab of the plugin. The two major outputs of this step were; % of correctness and kappa (overall). The outcomes generated from this step are detailly depicted in the results and findings section. This step was iteratively done until desirable accuracy was achieved.

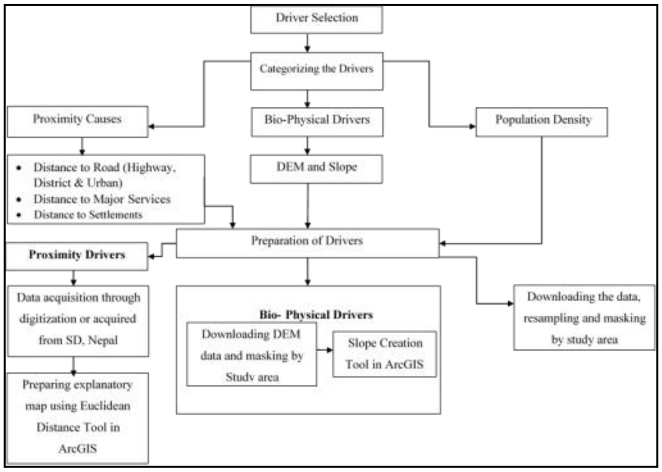


Figure 3: Procedure to prepare Driving Factors

Simulated LULC for Year 2032

After acquiring the desirable accuracy in the validation step the prediction of the LULC for year 2032 was initiated. At first, n value was changed into 3 in the Input tab of the plugin. Since, for n= 1,2,3…. will predict for 2012, 2022, 2032 when input was given as 1992 for initial and 2002 as final year respectively. Then after, assuming the same value of correctness of the CA-ANN model with same inputs, drivers, ANN operational value model was operated to predict for year 2032. The generated LULC for year 2032 is detailly depicted in the result and findings section.

Results and findings

4.1 Future LULC 2032 and Expected Change

The figure 5 represents the actual LULC for 2020 and predicted LULC for 2032.The CA-ANN model predicts that 45.701 % of the study area will be covered with agriculture land whereas 28.117% of land will covered with forest areas by 2032. Similarly, results generated from model shows builtup and barren areas are expected to cover the 21.82 % and 4.36 % of land out of total land available in the study area by 2032.

Table 2 shows two outputs of this study; expected LULC changes and conversion simultaneously. According to the expected LULC changes it reveals agricultural land was 48.349 % in 2020 whereas it will be decline by 2.64 % by 2032. Similarly, table 2 shows existing forest areas in 2020 will reduced by 2.67 % and will reached 28.11 % by 2032. Accordingly, the model predicts that builtup pattern seems

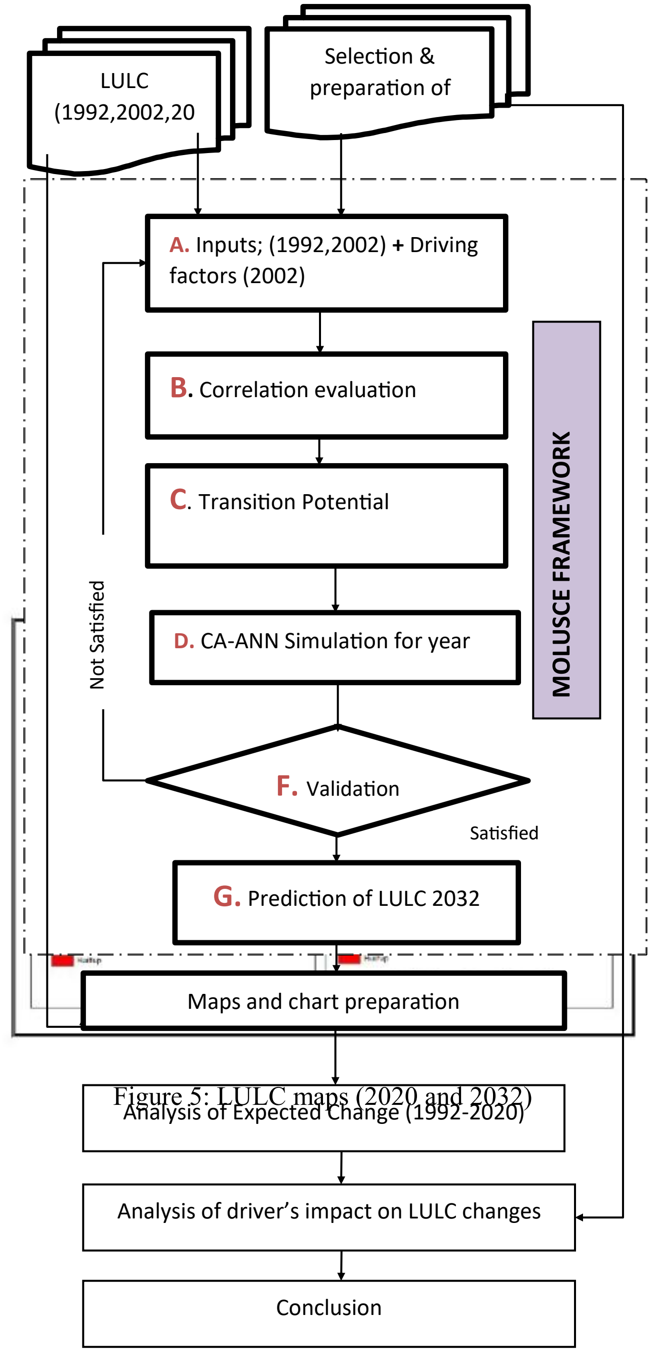


Figure 5: LULC maps (2020 and 2032)

Figure 4 : Methodological Framework

to rise by 5.69 % from 2020 and will reached 23.80 % in 2032 of the total land occupied by the study area. In case of barren land, it will decrease by 0.37 % from 2020 and will reached to 4.36 % in 2032.

Table 2 also represents the LULC conversion between each LULC classes. It illustrates that 78.66 % of agriculture land

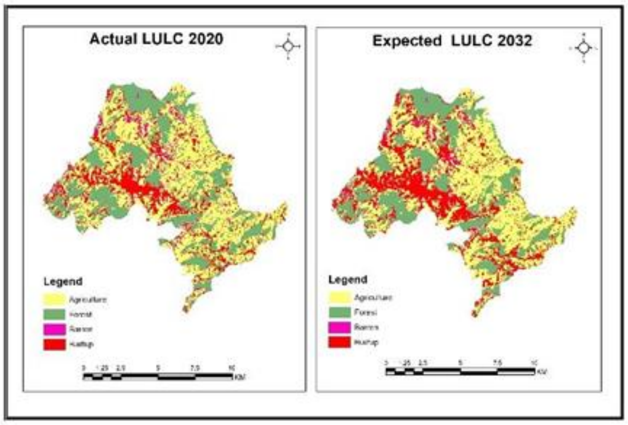


Figure 5: LULC maps (2020 and 2032)

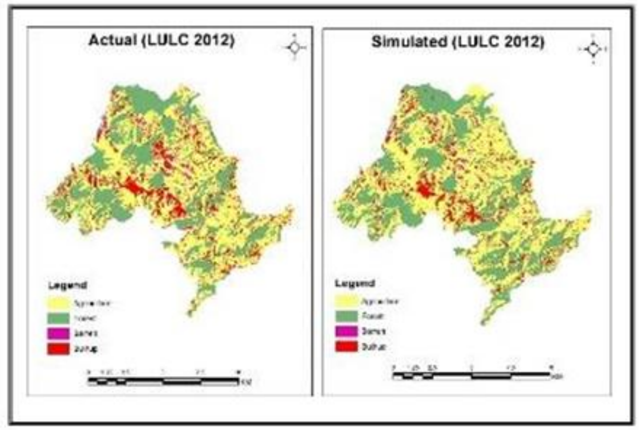


Figure 6 : Actual LULC and simulated LULC by model for year 2012.

will remain unchanged in 2032, and the remaining 3.64 % of agricultural land will be converted into the forest, 2.00 % into barren and 15.69 % into built-up areas. Similarly, using second part of table Expected LULC conversion for rest of LULC classes can be interpret accordingly.

4.2 Model Validation

The 81.66 % correctness and 0.69 as kappa (overall) were achieved after the validation of the CA-ANN model through MOLUSCE plugin. The figure 6 shows the actual LULC and simulated LULC by model for year 2012. The model performance can be evaluated using the error matrix illustrate in the table 3. It shows model accurately predict the 44.58 % of agriculture land out of 51.99 % whereas remaining 7.41 % of agriculture land were falsely predicted to forest (5.38 %), barren (0.77 %), builtup (1.26 %). Similarly, forest, barren, and builtup can be interpret accordingly using the table 3. Moreover, table 3 also compares the actual LULC 2012 with simulated LULC 2012 which shows the agricultural, forest, builtup, and barren in actual and simulated differs by -0.64 %, -2.326 %, +1.70 %, +1.53 % respectively. It can be also illustrated from the table 3 that high amount of agricultural land is falsely predicted to forest and vice-versa due to having the similar reflectance value. Despite the model predict with desirable accuracy but it fails to predict for builtup and barren accurately compare to agriculture and forest due to dominancy of agriculture and forest in an allocated study area.

Table 2: Expected LULC Changes

I. Expected LULC changes						
Year	2020		2032		Change (2020-2032)	
Categories	**%**	**km²**	**%**	**km²**	**%**	**km²**
Agriculture	48.349	52.77	45.70	49.88	-2.64	-2.89
Forest	30.791	33.61	28.11	30.69	-2.67	-2.919
Built-up	16.118	17.59	21.81	23.80	5.69	6.21
Barren	4.74	5.17	4.36	4.76	-0.37	-0.40
Total	100	109.15	100	109.15	-	-
II. Expected LULC Conversion						
2020						
2032	Agriculture	Forest	Builtup	Barren		
Agriculture	**78.66**	15.15	17.79	37.23		
Forest	3.64	**82.36**	6.08	2.87		
Built-up	15.69	2.18	**73.61**	25.52		
Barren	2.00	0.29	2.50	**34.35**		
Total	100	100	100	100		

Table 3: Simulated LULC 2012

	Actual LULC 2012					
	LULC	Agriculture	Forest	Built up	Barren	Total
Simulated LULC 2012	Agriculture	**44.58**	3.79	1.96	2.28	52.61
	Forest	5.38	**29.33**	1.61	0.04	36.36
	Builtup	1.26	0.85	**6.78**	0.11	9
	Barren	0.77	0.08	0.22	**0.97**	2.04
	Total	51.99	34.05	10.58	3.4	100

4.3 Prepared Drivers for 2002

The prepared drivers for year 2002 are depicted in the figure7. The first five maps shown in figure 7 are of the proximate drivers i.e., Distance to Araniko highway, district roads, urban roads, major services, existing settlements in 2002. It describes the Euclidean distance calculated for each cell to the closest source i.e proximate drivers. Similarly, to represent the biophysical drivers Digital Elevation Model (DEM) and Slope is represented in 6th and 7th maps depicted in figure 7. Finally, last map represents the population density (pixel/sqm) of the study area in 2020.

1.1 Impact of driving factors on LULC

Household surveys and focal group discussions are the foremost source to analyze the drivers impact on LULC changes. Due to limitation of this study, only literature-based information was used to analyze the drives for LULC changes in the study area during the study period.

The major drivers for LULC changes in the banepa municipality are illustrated in the figure 8.

The major builtup expansion since 1992-2020 in Banepa core city is due to the Internal migration of the people from rural areas such as; Dholalghat, Ramechap, Bethanchowk etc for the accessibility of the services and livelihood facilities (Twayana, Bhandari, & Shrestha, 2021). Moreover, newari communities had also pulled into the commercial

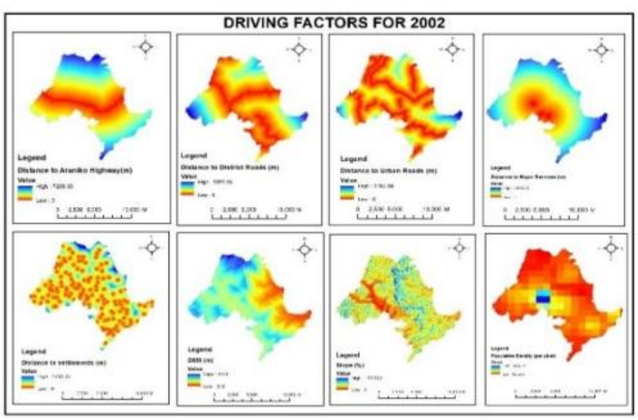


Figure 7: Driving Factors (2002)

trade since the 90's which ultimately rise urban growth of the city since 90s to 2020 (Twayana, Bhandari, & Shrestha, 2021). Similarly, real estate business had also altered the LULC of the banepa since 2000 because people were exploiting their arable land for housing development which has created the rapid urbanization in banepa until 2020 (Twayana, Bhandari, & Shrestha, 2021). Besides all these growing population had also altered the LULC of banepa by expanding the builtup areas simultaneously (Twayana, Bhandari, & Shrestha, 2021).

The major drivers for LULC changes in Dhulikhel municipalities are illustrated in figure 9. After the

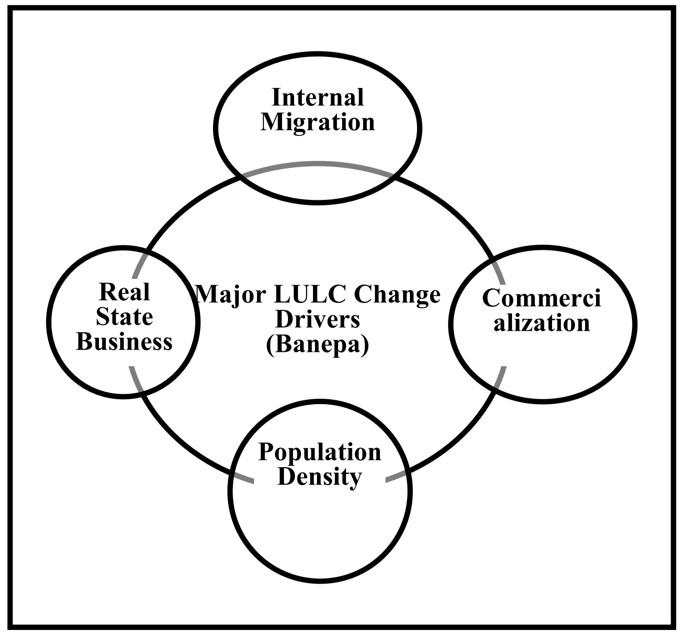


Figure 8: Drivers for LULC change in Banepa

Source (Twayana, Bhandari, & Shrestha, 2021).

establishment of Kathmandu university and Dhulikhel hospital in 1992 and 1996 respectively rapid expansion of the builup areas had been seen in proximate areas (Dhulikhel municipality, 2019). Similarly, LULC proximate to the araniko and BP highways also undergoes several changes i.e. conversion of arable agriculture land to urban builtup (Dhulikhel municipality, 2019). Since the climatic condition of the dhulikhel is suitable for livelihood thus people migrated in municipality from neighbour municipalities (Dhulikhel municipality, 2019). Besides all these major drivers, similar driver (population growth) is altering the LULC of the dhulikhel municipality.

Discussion & conclusion

Future prediction of LULC classes is crucial in Land Use Planning of every government/state. The future scenario of

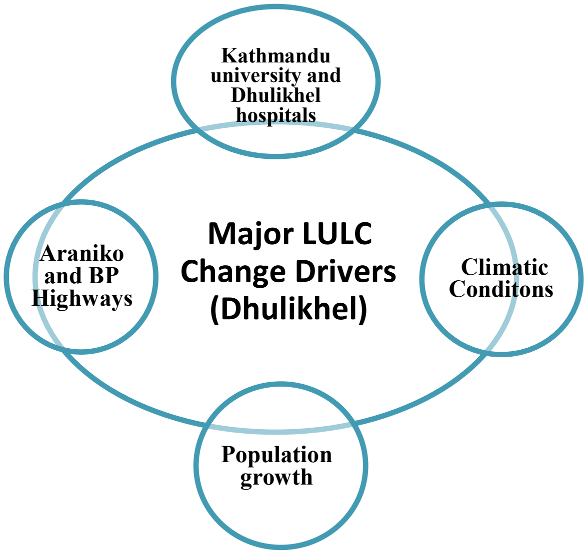


Figure 9: Drivers of LULC change in Dhulikhel
Source (Dhulikhel municipality, 2019)

banepa and dhulikhel municipalities was generated using CA-ANN model via MOLUSCE plugin available in QGIS. It reveals that agriculture and forest land are expected to decrease by 2.56 % and 2.62 % respectively in 2032 from 2020. Similarly, the barren land will be decreased by 0.57 % whereas the builtup will be increased by 5.73 % by 2032 since 2020. The prediction done by model is corrected up to 81.66%. It also reveals that about 78% of agriculture land will be preserved in 2032. Similarly, study also reveals that more than 20% of forest land undergoes deforestation in the study area. Thus, study also illustrates that LULC of study area will undergoes lots of intensification. Moreover, it investigates that CA-model fails to precisely predict in case of builtupareas since about 25% existing builtupareas undergoes conversion. This study reveals that about 75% of barren lands will utilized form of agriculture, forest and builtupareas by 2032. Besides, all the results obtained from this study indicate the capability of MOLUSCE plugin in open source QGIS to predict future land cover scenarios using the CA-ANN model. Mainly ten zones have been classified by Land Use Act-2019; Agricultural, Forest, Commercial, Cultural and archeological, Residential, Mine and Minerals, River and Lakes, Public Space Zone, Industrial Zone, Other zones as per Nepal government. Due to limitation of the spatial resolution of the image data this study classified the LULC classes into four; Agriculture, Forest, builtup areas (commercial, residential, public space zone, cultural and archeological, industrial) and barren (unused land). Remaining river and lakes, mine and minerals, and other zones as per Nepal government are not consider in this study. Thus, using the high-resolution image data other LULC classes can be identified and can be consider in further study.

This study also recommend impact of driver's analysis should be done via interview, focal group discussion with local communities and concerned authorities. Moreover, during prediction of 2002 only limited drivers are used. So, for precise prediction major responsible drivers for LULC changes such as plan and policy, climatic conditions, temperature, ecological degradation; hydrological variation, soil erosion, etc. are recommended to consider for future research. This study also predicts the future LULC scenario only based on the CA-ANN model. Thus, a separate comparative study could be done based on the result obtained from four available methods in the MOLUSCE Plugin of QGIS such as LR, WOE and MCE.

Nepal Government has endorsed "Land Use Act 2019" to achieve proper management of land by implementing land use plan. According to this act, to implement an effective land use plan at local governments,' Local Land Use Council' must be formed as a separate institution. Thus, methodology adopted and results generated from this study can be the basis or reference materials for the technical members of the council of the respective municipal offices; Banepa and Dhulikhel to develop their land use planning in reasonable cost.

Acknowledgements

Foremost, authors like to acknowledge Mr**. Shangharsha Thapa and Mr. Sanjeevan Shrestha** for providing support in the modelling and simulation. Authors also like to thank **Mr. Hari Krishna Dhonju** for sharing the knowledge regarding the previous research regarding the LULC modelling in the context of Nepal. Authors place the sincere thanks to all those, who directly or indirectly have assisted in the completion of this study.

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Spatio-Temporal Dynamics of Chamarajanagar Region, Karnataka, India

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Abstract

A Land use changes are irreversible, directly influence regional and global environmental quality. Mainly as a result of fast urbanization or industrialization, the major anthropological interference to the landscape is responsible for the conversion of many regions lush with flora into non-poor human populations. Developing Countries like India have problems in their present urban use regulation, Overcrowding of infrastructure, access to public services, housing growth, urban recovery, and harmful emissions, For example, pollution and community relocation owing to high home prices and site gardening. Productivity recovery is a fundamental necessity for progress in the region and encourages fast land conversion, Land cover, and usage (LU). LULC change is a significant driver of global climate change and ominously impacts ecosystem processes, biological cycle, and biodiversity. Temporal LU assessment, if not carried out, would become vulnerable to environmental threats. Analysis for LULC modifications is one of the most accurate ways of realizing the land use and what kinds of adjustments are needed to meet environmental sustainability goals for the future. In this regard, the proposed research aims to analyze the dynamics of LULC change using Landsat data over the temporal scale of 1990-2020for Chamarajanagar Region of Karnataka State, India.

The LU classification analysis was conducted using the supervised classification technique of the Gaussian maximum likelihood classifier (GMLC). The open-source SCP and MOLUSCE plugins were used for the simulation of LU changes for the year 2030 based on historical datasets. Results of LU analysis indicated a drastic change in the urban area, forest land, plantation, wetlands, and other classes. The urban area has been increased more than two folds over the past four decades. Subsequently, loss in classes was observed such as forest area, fallow land, and water bodies. A satisfactory overall accuracy of more than 78% and a kappa value of more than 0.7 were achieved for all the years of study. Further, demographic changes, economic activity, technological and institutional establishment, major policy changes at both state and central levels, and biophysical factors constitute another set of key drivers of LU change in the study area. Findings from the study will benefit society in natural resource management, wildlife habitat protection, routing, and logistics planning for resource extraction activities. Results also indirectly aids in assessing gross agricultural production, providing clues to decision-makers for developing crop management and increase land productivity, planning urban infrastructure in an efficient way.

Keywords: Land use management, open source, MOLUSCE, sustainable development, cellular automata, urban infrastructure.

1. Introduction

As the world's largest driver, the transition of natural ecosystems into agriculture to maintain human lifestyles was recognized. A common tendency is spatial dispersion of farm production for urban growth and diverse habitats. Truly global attention is changing in LULC and fast urban development has been acknowledged over the decades (BhagawatRimal et.al, 2017). Therefore, long-lasting monitoring of surface of the earth phenomena and their

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anthropogenic effect on the communities and ecosystems on a number of scales is vital to comprehending them. Spatial land utilization modification research may

assist to find regions with specific scales dynamics and land use patterns (Melo et.al, 2018; Putri et.al, 2018). This can also assist to build a land availability protection plan (Rafiuddin et.al, 2016).

Change in land use occurs with a mix of economical, governmental and physiological variables, which are called drivers of land use (Sitompul et.al, 2016). In addition, the major source of change in land use is postulated as population development and building activity. In sea shores near the center for development growth, changes in land usage are also present (Edwin et al, 2015).Therefore, it is extremely vital to useRS and GIS tools and modeling techniques to acquire evaluate and simulate historical, present, and potential LULC situations. Acquiring data on a Spatio-temporal scale serves as a basic condition for developing successful urban goals and procedures for socioeconomic, demographic, and environmental sustainability and environmental balance (Bhagawat Rimal et al, 2017).

LC research has accelerated, particularly since the weather and environmental consequences have been discovered. Researchers (Rawat et al., 2013; Misra and Balaji, 2015; Kaliraj and Chandrasekhar, 2012) have noted that the GIS and Remote Sensing unites several spatial information sets (in particular maps, aerial photographs, and satellite images for quantic preparations) and that the data is recognized in the scientific domain for decision- making purposes (Wickware and Howarth, 1981; Avery and Berlin, 1992; Jaiswal et al., 1999; Chandrasekhar et al., 2000; Alam et al., 2002; Jayappa et al., 2006; Santhiya et al., 2010; Mujabar and Chandrasekhar, 2012). Local scope and high resource demand are constrained in traditional field operations (personnel cost and time). Remote sensing and GIS can deliver very high resolution imaging (VHR) in recent advancements.

In this regard, researchers have performed virtual 'field trips' using Google Earth's images or comparable engines to confirm excellent findings or to train data. Categorization of land use is a systematic evaluation and approach to the best use of land to enhance socio-economic circumstances. This research communication covers, first, the idea of remote sensing and GIS, and then provides several implementations in earth surveillance and sustainable resource management for remote sensing and GIS. We conclude with a case study examining the terrestrial ecosystem's resilience to environmental disturbances in southern part India. We also highlight the future scope of remote sensing and GIS applications in terms of sustainability. Water, forest, and bare soil are some of the land use categories that were used in this research. Built-up and farmland are examples of land uses. Different classification techniques can be used to accomplish this. The application of spectral characteristics of Landsat image categorization can produce reliable results (L5, 1990; L5, 2000; L5, 2010; L8, 2020). The primary goal of this research is to classify and compare Landsat imageries of the Chamarajanagar area. The research also seeks to forecast Chamarajanagar future scene in 2030 by using the QGIS MOLUSCE Plugin for cellular automation. The LULC changes anticipated in 2030 revealed that the forest, grassland, damp and storm lands were declining further, as well as the agricultural and inner city lands were growing further. The results can enable decision-makers to draw up an appropriate action plan for the effective use of natural resources and reduce the adverse impacts of human activity on arid and semi-arid landscapes. These continuing developments in the future result in an increased energy and food demand for the rising population worldwide (Schaldach, 2006). Therefore LULC changes are essential to researchers, conservationists, farmers, policy experts, and landscape architects to analyze and monitor their impact (Babalola and Acinsanola, 2016). Moreover, RS technology enables access to LULC information from local to global levels across huge territories, at no cost (Mishra and Rai, 2016). The optimum technique to extract and evaluate is therefore a systematic process to RS and GIS.

The change of land is a natural phenomenon that cannot be halted, but it may be controlled. The findings aid in understanding the growth of a certain region in terms of population, economics, agriculture, and other factors during the last several years. Land cover changes are measured to assist monitor strain on ecosystems so that appropriate steps may be taken to preserve nature's richness. It also assists the relevant authorities in developing a comprehensive micro-level urban development plan that ensures planned infrastructure development and oversight.

2. Literature Review

Atiqur Rahman, et.al (2010) researched Delhi's North West District, utilizing remote sensing and GIS technology. In 1972, 1374, 24 (3, 09%) were all urban areas in the NW district, but it grew to 12631, 23 by 2003. (28.40 %). It shows that there has been a lot of change in the land use/ coverage in the northwest area of Delhi. Research has also shown that about 27.35 percent of productive farmlands have been converted into other land use groups from 1972 to 2003, included urban development.

Sheeja and Sabu Joseph (2010) In the Neyyar in basin Kerala, an attempt was undertaken to compare land use trends in 1914, 1967, and 2007. Between 1914 and 2007, the area saw a significant transformation. Amongst the most notable changes are declined in paddy fields, mixed crops, sparse vegetation and woods, and rises in built-up areas, rubber plantations, and thick mixed forests and water sources. The usage of land and land in particular in farming, built-up, and waste regions has changed dramatically. These changes took place mainly during 1914-1967.

Kavitha and Prakasam (2012) using RS and GIS technology, investigative research of LU and LC changes in Madurai district happened between 1973 and 2006. Land used for agriculture has experienced a decline from 57.37 % to 43.53 % in 1990. The percentage of land classified as fallow has risen from 13.93% to 18.90 %. A declined trend was observed in an area under water bodies from 8.21% in 1973 to 5.58% in 1990 and 2.78 % in 2006. The amount of land used for built-up areas increased thrice, from 5.48 % to 15.69 % between 1973 and 2006.

Amin,et.al (2012) the research on land use/land cover analysis was carried out in the region of Srinagar in Kashmir Valley. Between 1990 and 2007 the town of Srinagar witnessed significant shifts. The loss of forest land, open areas, and other natural resources have led to changes in land use patterns.

Usha and Anitha (2012) Image processing and remote sensing were used to evaluate land use changes in Palladam taluk, Tamil Nadu, India. Between 1972 and 2011, the agriculture area declined by 58.29 square kilometers, while the non-forested land expanded by 20.31 square kilometers. The agricultural land of 58.29 square kilometers was converted into settlements of37.39 square kilometers as a result of urban growth, increasing in land value. Similarly, Water bodies also increased due to stagnant quarry water pools.

Anirban et.al (2013) analyzed the land cover of Delhi from 1989 to 2011, and it revealed a significant shift in the landscape due to rapid increase in the built-up region within twenty-two years. Built-up regions have taken over sparsely vegetated lands, while fallow land has decreased marginally and water bodies have become nearly stagnant over time.

Ganasri (2013) projected the trend in LU/LC changes using LISS-III data for the years 2007, 2010, and 2013 in the Harangi catchment of Kodagu District, Karnataka. The analysis shows that a satisfactory LU/LC classification with a kappa coefficient of 0.81 was provided using the maximum probability technique. The loss in forest area and wasteland in the region has been highlighted as a result of deforestation. In addition, between 2007 and 2013, the area under the plantation category rose dramatically.

Rawat and Manish Kumar,(2014) made a research on land use/cover alteration of Hawalbagh block, Almora, Uttarakhand by carrying remote sensing and GIS techniques. The research shows that vegetation is the most important land use in the region studied. The land under vegetation rose by 3.51 percent (9.39 km^2) between 1990 and 2010 in afforestation activities. This is a 1.52 percent decline in agricultural areas (4.06 km^2) as a result of conversion to vegetation, rocky terrain, and constructed areas.

Reshma M, et.al (2015) study has provided a geospatial database on spatial patterns of forest cover and land use changes which is beneficial for conserving and strategically planning on the study site (District Idukki). The net rate of deforestation in 2012 was 0.6, using 1925 as a baseline. The annual net rate of deforestation from 1925 to 1975 was estimated as 1.09, 0.22 from 1975 to 1990, and 0.009 from 1990 to 2001. Between 1990 and 2011, the annual rate of deforestation was 0.01.

Harikrishna Karanam and Appala Raju Nadipena (2015) described land use/land cover dynamics of the Kolleru Lake in Andhra Pradesh categorized and studied using Remote Sensing and Geographical Information Systems. The results have shown that Lake Kolleru has a strong aquaculture potential (27, 91% of TGA aquaculture) and 60, 72% of the research area's overall geography (including planting, flowering, and horticulture) and farming land. At the cost of other businesses, aquaculture developed rapidly, decreasing farmland and lake regions.

Abdul Rahman,et.al (2016) conducted an experimental study in the Chamarajanagar district, on the assessment of land suitability and potential for agriculture. Land suitability for various crops such as banana, coconut, cashew, cotton, mango, and so on was depicted. The lands are divided into eight categories based on their capabilities and limitations. The research shows that landscape and soils are intimately related.

Swapan and Kutub (2020) machine learning approaches with landscape metrics and the class level matrix method were used to demonstrate the spatiotemporal dynamics of LULC changes and their modeling fragmentation likelihood in the Teesta River Basin. The analysis revealed that the TRB occupied by water bodies decreased by 6.21%, bare land by 14.59%, vegetation by 2.70%, and sand bar by 1.15% while built-up areas increased by 1.45% from 2010 to 2019.

Niladri and Prolay (2020) Land use/land cover fluctuation in Asansol (West Bengal) subdivision and its effect on land surface temperature were investigated. The coverage of land, industry, and greenery has grown, but land, watercourses, and wastelands have been decreasing. The settlements grew by 60% due to rapid urbanization, resulting in the loss of land resources. For the summer months, the highest and lowest temperatures increased by 0.15 C and by 0.011 C a year, correspondingly, while in the winter period by 0.19 C and by 0.05 C a year.

Sirishand Jyothi (2020) Chittor district in the Andhra Pradesh state which is located in the Rayalaseema region was a study region. Land area was classified into agricultural land, forest, empty land, buildings, and water each was represented by different colors. Cultivated soils, plantations, fallows, and present moving land are part of agricultural fields, whilst forest soils comprise semi-green, planting forests, grass and other forms of plants, and marshy and water bodies. Manjunatha and Basavarajappa (2020) attempted to investigate the spatiotemporal features of the Mysuru district through GIS techniques. They classified the area under 3 classes, used the classification data to address spatial changes, environmental & socioeconomic concerns, growing demand for economic natural resources, cropping patterns, vulnerability to specific management practices.

3. Methods and materials

Study area

The Chamarajanagar area is located in a semiarid climate zone. It has a geographical area of 1235.90 square kilometers and is located between 11º 40' and 12º 10' east latitude and 76º40' to 77º 15' longitude. Figures 1 and 2 shows a location map of the study area and an aspect map of the Chamarajanagar region, respectively. On a scale of 1:50,000, it includes 190 villages covered by survey of India toposheet Nos.57D/12, 57D/16, 57H/4, 58A/9, 58A/13, 58A/14, 58E/1, 58E/2, 58E/5. The climate of Chamarajanagar is pleasant, with a mean maximum temperature of 34°C and a mean minimum temperature of 16.4°C. There are no major rivers that flow through this area. Suvarnavathi and Chikkahole, tributaries of the Cauvery River that go through Kollegala taluk in Chamarajanagar District.

3.2 Data collection

Landsat imagery from the United States Geological Survey was utilized in this study for the years 1990, 2000, 2010, and 2020. For the years 1990, 2000, 2010, and 2020, the cloud cover on the whole Landsat imagery ranged from 1% to 5%, but it was below 1% in the research region shows in table 1. A pre-processing technique was used to eliminate atmospheric influences from Landsat images before actual

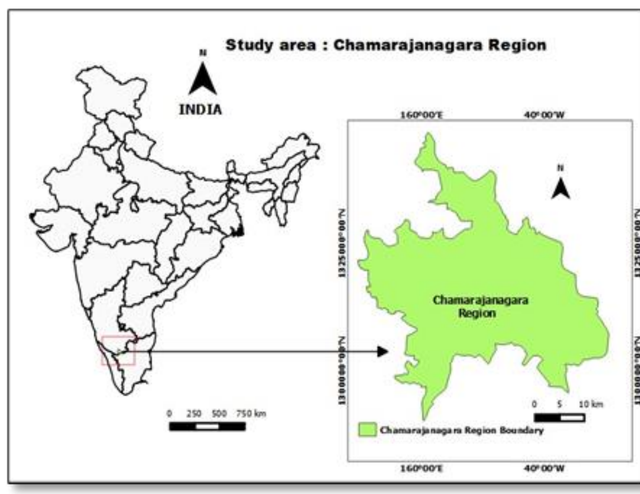

Figure 1: Location map of the study area.

categorization. For all four categorized images, the overall accuracy was greater than 78%. Thelocal government and the United States Geological Survey's internet data site provided the spatial variables data for computation, such as road shape files and DEMs.

4. Methodology

In this study, an examination of land use changes is conducted using open-source GIS software by correlating four distinct years of Chamarajanagar using GIS-based application. Geographic Information System is a computer

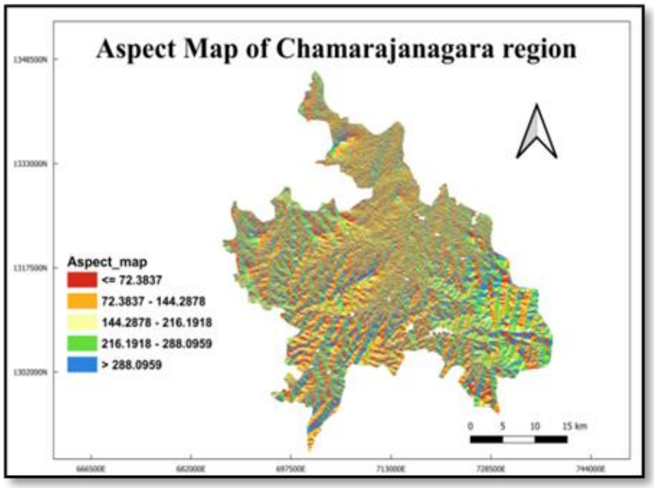

Figure 2: Aspect Map of Chamarajanagar region.

based technology, extensively used for the analysis of time changes generalized by statistical rule and expressed by symbolism (Mahanama et al., 2014).

In GIS, mainly QGIS & GRASS GIS (Geographic Resources Analysis Support System) were used. QGIS and GRASS GIS are software programs for geospace information management, processing images, visuals and maps production and spatial and temporal modeling, visualization, and the usage of geospatial workflows.

Table 1: Details of the Landsat data used in this study

Sensor type	Acquisition date	Spatial resolution	Cloud cover (%)
Landsat 5 TM	1990	30m	1
Landsat 5 TM	2000	30m	1
Landsat 5 TM	2010	30m	0
Landsat 8 OLI	2020	30m	0.28

Raster, topological vector, image analysis, and graphic data can be handled. Particularly in Quantum GIS, the Semi-Automatic Classification Plugin (SCP) is used for the measurement of the land use change&Molusce (Modules for Land Use Change Evaluation) plugin for future prediction.

The SCP enables remote sensing data semi-automatic supervised classification, provides tools for download, pre-processing, post-processing, and speeds up the categorization. Molusce is an extension feature that analyses and differentiates land use patterns over two years. In this research, the spatiotemporal data changes were evaluated in 1990, 2000, 2010, and 2020 on the maps for land usage.

For LULC classification, the Anderson classification method was employed, which is a widely used classification approach for Landsat data. An SVM classifier utilizing a maximum likelihood classifier method was used to classify different time-series images. Land usage and land cover were analyzed and predicted using the categorized findings.

The SVM (Support Vector Machine) technique was used to classify the collected Landsat images for the years 1990, 2000, 2010, and 2020, yielding the following land cover target classes:

a. Urban: Urban infrastructure includes industrial, residential, commercial, and transit networks.
b. Vegetation: Forests, parkland, trees, and meadows are examples of vegetation.
c. Water Bodies: Coastal water, lakes, canals, and streams are all examples of water bodies.
d. Others: Fallow land, sand, and empty land are all examples of barrel land.

The remote sensing and toposheet data were first rectified by projecting them onto a plane by using Universal Traverse Ground truth data from the land cover reference locations were acquired for validation and superimposed on high-resolution satellite tiles of Google Earth to assess categorization accuracy. All of these operations are illustrated in Figure 3 as a flow chart and as an image in Figure 4.

Land use/land cover was created using supervised classification and visual interpretation to improve classification accuracy, as well as ground truth points obtained from field visits. The kappa coefficient was used to measure classification accuracy, and total accuracy was determined using a confusion matrix, which is a frequently used approach for determining classification accuracy.

Here, the QGIS Software, with the MOLUSCE plug-in has been utilized for the forecast of the future i.e. 2030.Firstly, the SRTM layer and Hill shade map of Chamarajanagar are imported into the software with the initial and final datasets from the years 2010 to 2020. The next modifications are found in the area and the results are given in the table 2 and transition matrix shown in table 3.

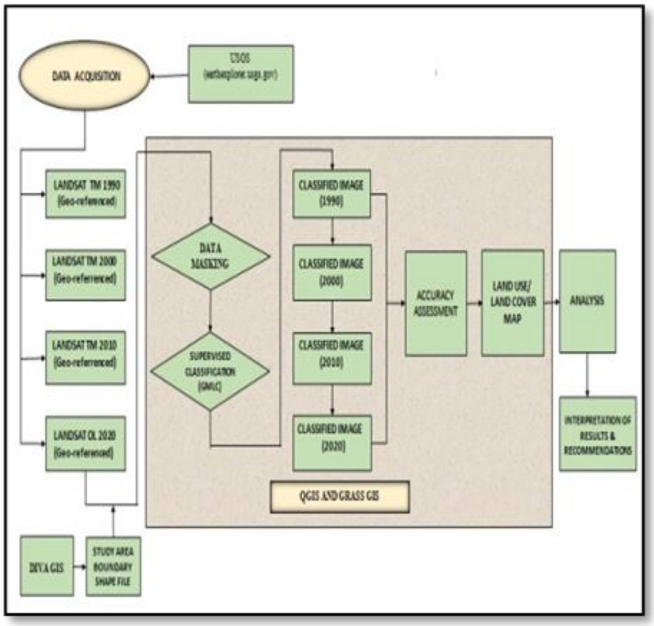

Figure 3 : The procedure involved in data analysis of supervised classification.

The transition matrix of probabilities of changes between any particular classes may be calculated by Molusce and a thematic map of any change in land use can be generated as an alternative. The resulting table is exported to the format converter and graph preparation tools of Microsoft Excel (Ibrahim and Ludin, 2015).

After completion of all these procedures, results were obtained in the form of a future predicted map 2030. The procedure is shown in Figure 5.

Artificial Neural Networking (ANN) was employed to achieve transition potential, as illustrated in Figure 6.

4. Results and findings

4.1 Land use analysis

The Spatio Temporal Land use changes between 1990 and 2020 are shown in figure 7. The details in Table 4 and graph in figure 8also showed how a percentage of land changes from year to year. The results show an increase in urban area from 3.89% in 1990 to 7.10% in 2020, the water bodies has been decreased from 1.64% in 2000 to 0.36% in

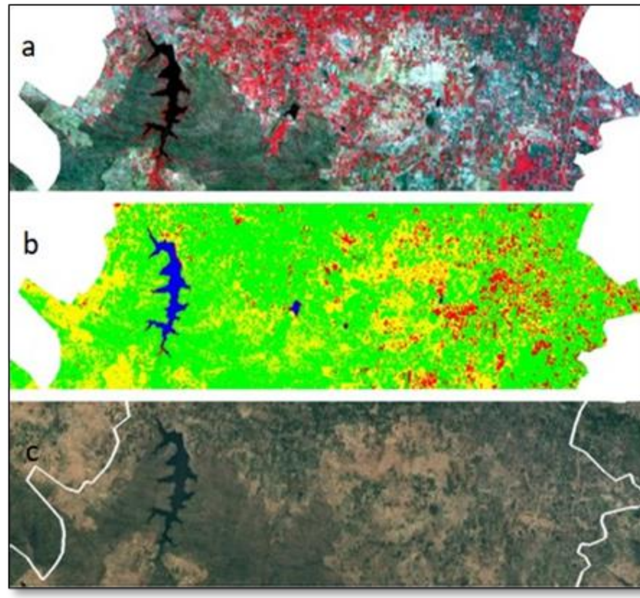

Figure 4: Supervised classification:
a. FCC image, b. classification image, c. satellite image of a study area

2020. Vegetation has reduced from 56.68% in 1990 to 46.90% in 2020, others (including the cultivation lands, barren lands, open lands, etc) have changed from 39.03% in 1990 to 45.64% in 2020. The Overall Classification Accuracy of more than 78 % was observed for the classified images table 5 gives the summary of the accuracy and kappa coefficients.

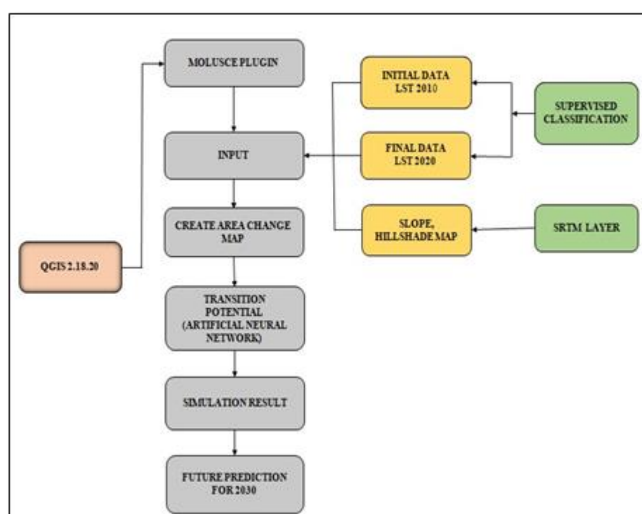

Figure 5: Steps in involved in future prediction.

Table 2: Land transformation details from the year 2010 to 2020.

	2010 (km^2)	2020 (km^2)	Δ (km^2)	2010 %	2020 %	Δ%
	76.69	86.94	10.25	6.26	7.10	0.83
	609.0	574.2	-34.80	49.74	46.90	-2.84
	8.9	4.38	-4.53	0.73	0.36	-0.36
	529.6	558.7	29.07	43.27	45.64	2.37

Transition matrix (2010 - 2020)

	1	2	3	4
1	0.163	0.369	0.001	0.466
2	0.055	0.729	0.0009	0.215
3	0.169	0.329	0.401	0.099
4	0.074	0.187	0.0002	0.738

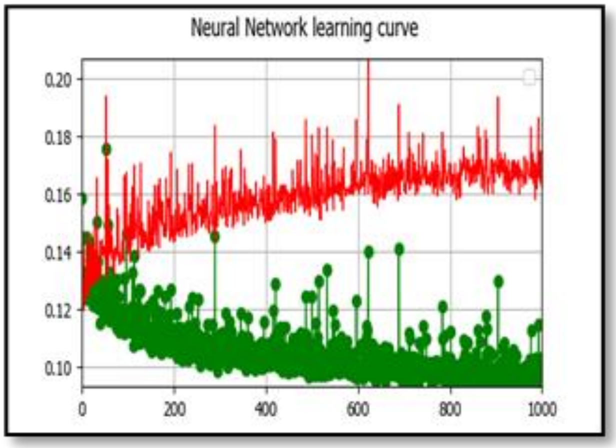

Figure 6: Neural network learning curve

4.2 Prediction using MOLUSCE plugin

Figure 9 shows the outcome of the 2030 future projection map, as well as information of area changes shown in a pie chart (Figure 10) and Table 6. It illustrates the steady expansion of built-up areas and communities. In 2020, it was 7.10 %, and by 2030, it would be 12.49%. Lakes, rivers, and ponds accounted for 0.36 % of land area in 2020, and are expected to drop by 0.35% in 2030. In the future, the vegetation, which was 46.9% in 2020, will be reduced to 41.97% in 2030, and barrel land or waste land, which occupied 45.64 % of the area in 2020, will be

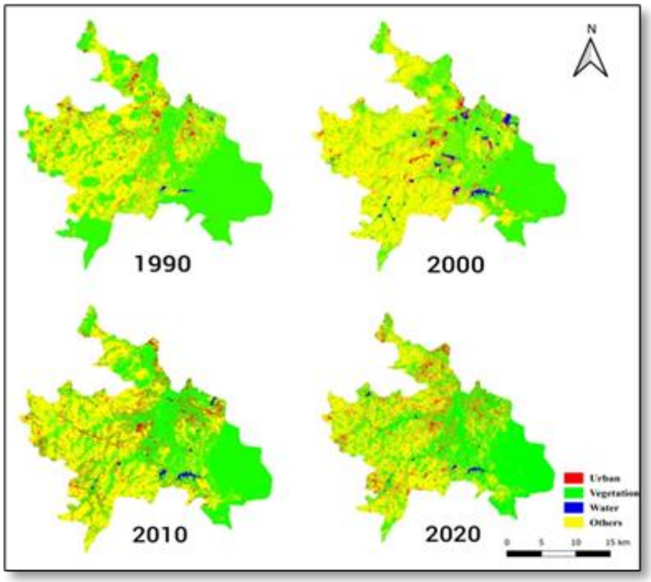

Figure 7: Land transformation of the study area from 1990 to 2020.

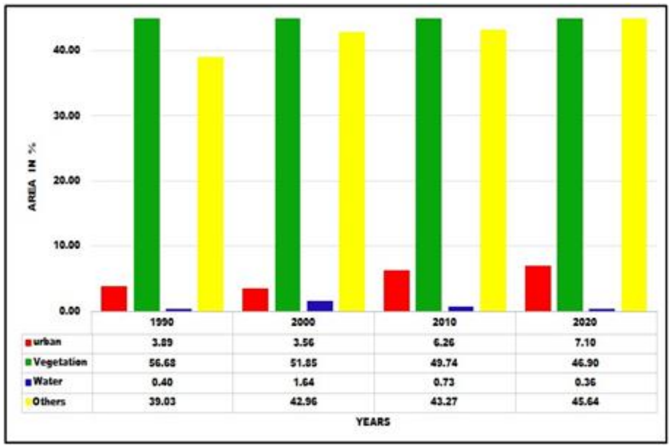

Figure 8: Graph showing percentage of land use area changes from 1990 to2020.

reduced to 45.19 in 2030. Molusce provided us with validation information as well as a multiple resolution budget curve (Figure11). The percentage of correctness is 94.14 %, and the total kappa is 0.9.

Table 4: Land use details

Year 1990		
Particulars	**Area (km^2)**	**Percentage**
Urban	47.58	3.89
Vegetation	693.97	56.68
Water Bodies	4.89	0.40
Others	477.85	39.03
Year 2000		
Particulars	**Area (km^2)**	**Percentage**
Urban	43.60	3.56
Vegetation	634.76	51.85
Water Bodies	20.02	1.64
Others	525.91	42.96
Year 2010		
Particulars	**Area (km^2)**	**Percentage**
Urban	76.69	6.26
Vegetation	609.01	49.74
Water Bodies	8.90	0.73
Others	529.69	43.27
Year 2020		
Particulars	**Area (km^2)**	**Percentage**
Urban	86.94	7.10
Vegetation	574.21	46.90
Water Bodies	4.38	0.36
Others	558.77	45.64

Table 5: Overall accuracy and kappa statistics

Year	Overall Accuracy (%)	Kappa
1990	95	0.9
2000	86	0.7
2010	78	0.7
2020	87	0.8

4.3 Future scope

a. Understanding the spatial land use dynamics.

b. Maps of different regions can be generated with each pixel assigned to a class based on its multispectral composition.

c. Land use /land cover analysis which is done for different years also provides a scope for future prediction of land use using machine learning based CA.

d. To provide land that is more enlightened and economically sound.

e. structure and delivery of local government services are being planned.

f. Advice on establishing good lending and borrowing strategies in the real \estate industry.

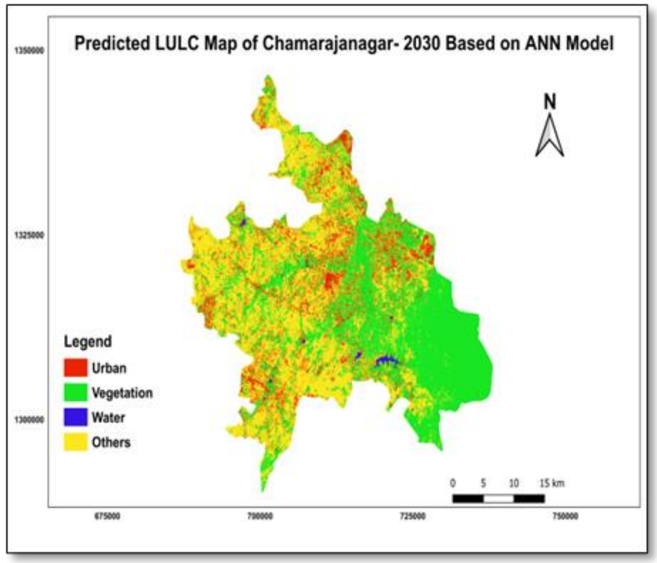

Figure 8: Predicted LULC map of Chamarajanagar-2030 based on ANN model.

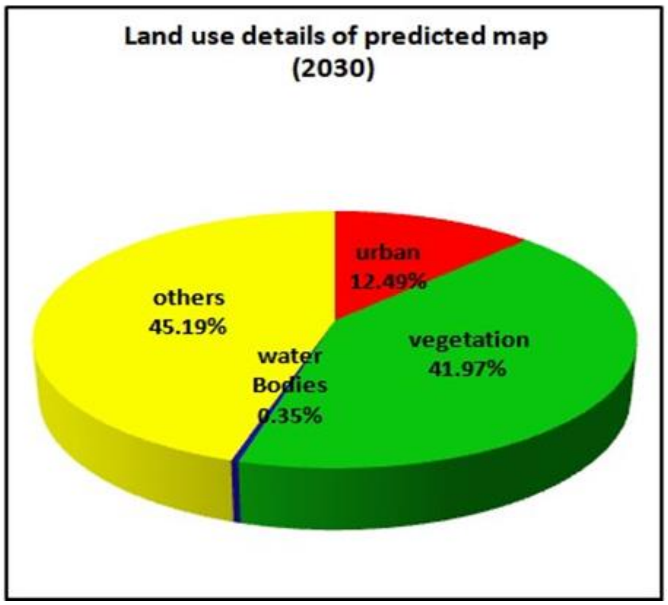

Figure 9: Pie chart shows the land use details of predicted map (2030)

Table 6: Land use details of predicted map (2030)

Year 2030		
Particulars	**Area(km^2)**	**Percentage**
Urban	152.94	12.49
Vegetation	513.81	41.97
Water Bodies	4.25	0.35
Others	553.28	45.19

2. Discussion & Conclusion

a. The current study shows the growth and transformation of the Chamarajanagar region over a period of 40 years. We calculated the land use/land cover area for the study region using supervised classification. Based on this, land cover from 1990 to 2020 shows a rapid change in the landscape as there is high growth in built-up areas.

b. As observed in the early 1990s, the major part of the study area was covered by agriculture and forest land, but as a result of urban expansion, a large number of built-up areas started to occupy the sparsely and densely vegetated areas, which led to the decrease in forest land. The development of the industrial sector as a call for employment opportunities also had an impact on the reduction of agricultural areas.

c. The total urban area was 3.56% in 1990year, which increased to 7.01% in the year 2020. The study further shows the fertile agricultural land has been transformed into other land use classes, including urban built-up areas. The results of the present study can serve as guidelines for future analysis of land cover areas and also give a rough idea of urban development plans.

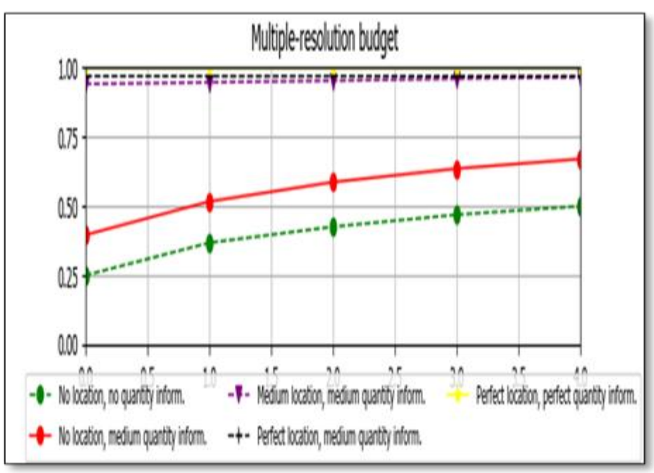

Figure 10: Multiple- resolution budget curve

5. Inference

a. KIADB - Badanaguppe - Kellamballi Industrial Area (Figure 12): This region had more vegetation in 1990, and it was an agricultural land at the time; however, owing to decreased rainfall, it became barrel land. As a result, KIADB intended to establish industries in this region. In the year 2020, 233 industrial units have been approved for establishment in the Badanaguppe-Kellamballi Industrial Area, with 10 of them being heavy industries that have received government permission. Because the population in this area is expected to grow, additional roads are being built in this area. The entire environment will be altered. Chamarajanagar industrial landscape will be given a new dimension.

b. Chamarajanagar town: Previously, it had less population, but by 2020, the population has increased, and development in this particular area is greater. Hospitals, educational institutions, and important structures have been constructed. In this area, some quarries (black granite) are being established (Figure 13). As a result, dimensions of roads got expanded and urban land has increased while vegetation has got reduced.

c. Yadapura, Kasaba Hobli: In 1990, Yadapura, a tiny village/hamlet in Chamarajanagar Taluk, included more waste land. District Hospital, Chamarajnagara, was established in 2014 as an affiliated teaching hospital of Chamarajnagara Institute of Medical Sciences (CIMS). As a result, urbanization has developed in this area.

Figure 11: Badanaguppe-Kellamballi Industrial Park (Source: https://starofmysore.com/)

d. Sathy Rd, Somwarapet: Due to the construction of roads, buildings, and small businesses in the previous decade, the majority of agricultural land has been converted to highways and industry. Weexpect additional urban growth in this area.
e. Punajur state forest (Figure 14) and Suvarnavathi dam near Attugulipura village (Figure 15): By eliminating or fragmenting forest cover, urbanization has a direct impact on forest ecosystems. By affecting hydrology, nutrient cycling, importing nonnative species, adjusting disturbance regimes, and changing meteorological conditions, urbanization indirectly affects forest ecosystems. It has an impact not just on forests, but also on water reservoirs. Urbanization has had a significant impact on river basins and the usage of river water in recent years. As a result, sewage and wastewater discharges into rivers can provide excess nitrogen and phosphorus, affecting water quality and aquatic creature diversity.

Figure 12: Quarry in Chamarajanagar taluk
(Source: https://igranites.com/)

Figure 13: Punajur State Forest
(Source: https://www.google.com/maps /https:// www.wallpaperflare.com/)

Figure 14: Suvarnavathi Dam near Attugulipura village
(Source: https://en.wikipedia.org/)

Acknowledgments

We are grateful to Department of Civil Engineering, The National Institute of Engineering, Mysore, for infrastructure support. We are thankful to OSGEO for GRASS and QGIS software and well maintained user forums for timely answers to solve bugs in the software.

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GRASS GIS: https://grass.osgeo.org/

Earth Explorer:https://earthexplorer.usgs.gov/

DIVA-GIS:https://www.diva-gis.org/

Google Earth pro: https://www.google.com/intl/en_in/earth/versions/

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Impact of land use and land cover changes on the land surface temperature: A case study of Bhokardan, Central Maharashtra

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Abstract

Global warming has been affecting human lives worldwide, but this is occurring more rapidly in recent years due to various human activities. The Earth's temperature has increased by 1.5 degrees, leading to change in weather conditions and subsequently affecting rainfall in a year. The increase and decrease in rainfall have directly impacted the land use and land cover of any geographical area and the land surface temperature (LST). The extent of extreme weather events such as droughts, heatwaves, high-intensity rainfall has increased significantly in the state of Maharashtra, India, during the last two decades. In the present study, we have attempted to analyze the impacts of land use land cover (LULC) changes on LST. The present study is carried out for the Bhokardan block, located in the Jalna district of Maharashtra, having a geographical area of ~1177 sq. km. The study area falls in a semi-arid region and faces drought and heatwave problems frequently. We have used freely available LANDSAT series satellite data (30 m.) to map the LULC features for 2001, 2011 & 2020. LST analysis is carried out using 8-day MODIS data (1 km.) for day and night separately for the same years. Since the temperature trend analysis shows the highest temperature during May in the Bhokardan block, we selected May for LST and LULC data analysis. The study suggests that the LST remains at the lower side in areas covered by vegetation/tree canopy during the summer season. It goes to highest in the open lands such as wasteland and barren rocky areas. Fallow land and wasteland areas are increased significantly in the study area during the last two decades. This study findings strongly indicate that the changing LULC pattern is one of the leading factors for the increasing trend in land surface temperature of the study area. Improper land management and alteration in land use and land cover lead to an increase in fallow land and wasteland, resulting in reduced agricultural production and affecting the livelihood of rural communities. The gradual increase in surface temperature of the land could be critical factors for drought-like conditions, increase in soil erosion, and heatwaves in the study region. Monitoring the areas with changing land use and land cover patterns and increasing LST, especially in the semi-arid regions, can help rural communities and policymakers take the early steps and prevent/minimize various arising problems such as heatwaves and increased soil erosion, reduction in agricultural production, and water availability

Keywords: Land Surface Temperature (LST), Land use and land cover (LULC), Climate Change, land management, Heat Stress.

Introduction

Global warming has been affecting human lives worldwide, but this is occurring more rapidly in recent years due to various human activities. The Earth's temperature has increased by 1.5 degrees, leading to change in weather conditions and subsequently affecting the amount of rainfall in a year (Gao, Y., Gao, X., & Zhang, X., 2017). The variations in the amount of precipitation directly impact the land use and land cover of any geographical area and the land surface temperature (LST) (Pielke et al., 2011). Alteration in the land use and land cover increases fallow land and wasteland, reducing agricultural production. On the

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other hand, the rise in surface temperature of the land is one of the critical factors which can lead to drought-like conditions, increase in soil erosion, heat waves, sea-level rise, etc. All these calamities lead to exacerbating many challenges faced by rural communities.

The impact of land use/land cover on LST is mainly studied using remote sensing and geospatial technologies recently. Nowadays, various open-source GIS tools and software are available to use freely, and these are effective in monitoring LULC changes and calculating land surface temperature. In the present paper, we have used open-source satellite data with open source tools, highlighting the role and importance of open-source tools and data in this era. LST represents the temperature of the Earth's surface, and it is calculated from radiance measurements. Remotely sensed thermal infrared data analyzes large-scale temporal and spatial LST from local and global scales (Hasnat, 2021). Furthermore, we can use geospatial technology to show the LULC changes atheists impact LST (Das et al., 2021).

LST is an important parameter that is used to measure the radiative surface temperature of the Earth derived from infrared radiation. It impacts ecosystem balance, sustainability, and, ultimately, human livelihood (Hasnat, 2021). The significance of examining LST variation relies on the fact that a change in LST may subdivide the net results of radiation into sensible and latent heat fluxes, which leads to cold or warm temperatures of Earth's atmosphere. In the last few decades, great efforts are made to bring the LST retrieval techniques, and it made a necessary and cautious consideration to the remote sensing experts (Firoozi et al., 2020). In the rural areas, higher LST was observed in the summer daytime than the urban area, resulting in a mean negative surface urban heat island. Low vegetation cover in the rural area results in negative SUHI as most agricultural land is converted into fallow-land during the pre-monsoon summer season. In summer pre-monsoon months, most cities act as arid or semi-arid zones and are identified as negative urban-rural LST differences in India (Mohammad et al., 2019; Yao et al., 2019).NDVI and LST have a strong correlation in the increasing trends of LST as the LANDSAT satellite images clearly indicate the LST fluctuation in 1999, having an average temperature of 25.02°C and rushed to the highest 31.41°C in 2018 (Athick et al., 2019). The LST directly varies with NDVI values as it shows high values with low NDVI and vice versa. It also differentiates the clusters with high LST from those with uncovered soil and the region with more vegetation cover with low temperature (Hussain & Karuppannan, 2021). By obtaining surface temperature information from LST, we can also monitor the drought of any region (Alshaikh, 2015). Through the results of LST, various information about the land surface features can be extracted on the basis of different LULC types (Sinha et al., 2015). According to Ding and Shi (2013), it is necessary to correlate the relationship between LST and LULC to study the impacts of LULC on LST of any area. Additionally, in many studies, it is reported that LST is entirely dependent on the land cover composition, including vegetation cover, forest, and soil. Various research has validated the environmental effects on LULC pattern changes (Cheema & Bastiaanssen, 2010; Das & Sarkar, 2019; Hussain & Karuppannan, 2021; Tan et al., 2020; B. Zoungrana et al., 2015). It is scientifically proven that there is an increase in temperature over the present century, and this rising temperature will continue in the future, too (Becker et al., 2012; Fearnside, 2015). Some study also indicates that due to climate change for the years ranging from 1990 to 2050, the temperature will rise to 2 to 2.9°C globally (Koc, 2019; van der Knaap et al., 2018). Some hypotheses also found that the Earth's surface temperature represents a unit change in climate from the "Land Surface Temperature" (LST) remote sensing platforms(Gallego-Elvira et al., 2016; Koc, 2019; Rosas et al., 2017). This study is aimed at analyzing the following objectives (1) LULC changes over the 20 years (decadal change). (2) Monitoring the NDVI changes from the year 2001 to 2020. (3) Impact of NDVI and the LULC changes on LST.

Materials and Methods

2.1 Description of the study area

Bhokardan is located in the Jalna district of Maharashtra. The area of Bhokardan extends from the latitude 20.02 N to 20.55 N and longitude 75.58 E to 75.97 E. The river Purna passes through some parts of Bhokardan, and the average rainfall of this area varies from 650 mm to 750 mm. Bhokardan starts experiencing the increasing heat from the last week of April and remains till the first week of June. In May, the temperature rises above 41 degrees Celsius, which sometimes results in heatwaves.

2.2 Data and Material Used

For LULC analysis, LANSAT TM, LANDSAT ETM and LANDSAT OLI satellite data were processed for May 2001, 2011 and 2020 to map various land use and land cover classes at 30m spatial resolution. The satellite data is downloaded from the free available open source website, i.e. USGS Earth Explorer.

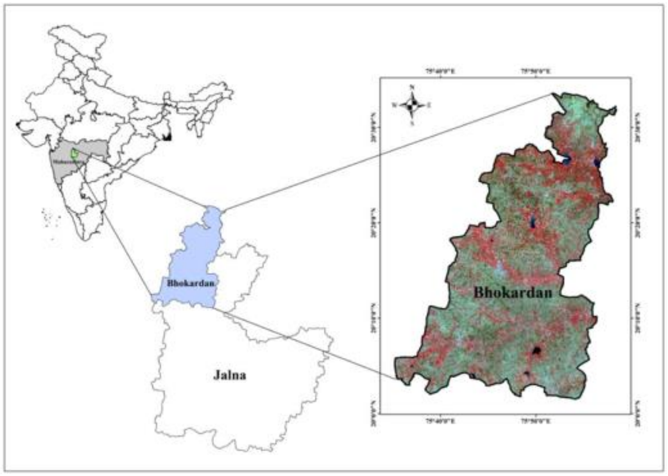


Fig.1: Location map of the study area

For LST analysis, 8-day MODIS LST data was processed in an open-source cloud-based geospatial platform, the google earth engine. This data comes in 1 km spatial resolution. The data is downloaded in Sinusoidal map projection, which is re -projected to Geographic Coordinate System (GCS-WGS 84) for LST analysis. For LST analysis, the MODIS LST data product gives an accuracy of approximately 1K and is widely used worldwide (Wang et al., 2021).

2.3 Data processing and analysis

2.3.1 Land Use/Land Cover analysis

Satellite data of the year 2001, 2011, and 2021 were downloaded from USGS Earth Explorer. Then all the band images are stacked in an open-source QGIS software for the LULC analysis. The images of the same /nearest available date are downloaded for all the years to achieve accurate results. The satellite data was collected and processed for May, covering all the years. Supervised classification of all the images is carried out for 2001, 2011, and 2020. The LULC classes used in this study are irrigated land, fallow land, scrubland, plantation, forest, wasteland, and settlement, dry river bed, and waterbody. In order to avoid mistakes during the classification, the derived pixels are also thoroughly verified by taking the reference of the exact location from the high-resolution Google Earth data. This step improves the classification accuracy and, subsequently, the LULC analysis. After that, the area has been calculated for each LULC class to observe the percentage change in the study area's land use and land cover.

Table 1: Details of the satellite images used in study

Satellite	Sensor	Path/ Row	Year	Resolution
LANDSAT	TM (Thematic Mapper)	146/46	2001	30 meters
LANDSAT	ETM (Enhanced Thematic Mapper)	146/46	2011	30 meters
LANDSAT	OLI/TIRS (Operation al Land Imager)/ (Thermal Infrared Sensor)	146/46	2020	30 meters

2.3.2 Land Surface Temperature analysis

MODIS or Moderate Resolution Imaging Spectro-radiometer is a sensor onboard Terra and Aqua platform that provides information about the Earth's surface in wavebands covering the visible, near-infrared, short wave infrared, and thermal ranges. MODIS satellite data is widely used for global mapping of mean surface SUHI for daytime and nighttime (Chakraborty and Lee,2019). First, all the MODIS LST data was downloaded and processed through Google Earth Engine for the LST analysis using Javascript code. Then the data has been sub-set to the study area and have also been re-projected from Sinusoidal projection to UTM Zone 43 N projection system with WGS datum. After that, calculation of day and night land surface temperature data was also done for the May month of the above decade years. Then the LST images of each year have been overlapped on the LULC data in which spatiotemporal profiles are prepared. These profiles represent the variation of LST according to the LULC changes of that study area. After the analysis and findings, decadal LULC maps and decadal LST variations are shown on the map.

Results & Findings

Fig. 2 and table 2 represent the decadal LULC changes, indicating that the irrigated land is more in 2011 than in 2001 and 2020. In 2001, a significant amount of the wasteland was converted into irrigated and fallow land due to increased rainfall. There is an increase in fallow land every decade as the farmers only took the Kharif and Rabi season for crop cultivation.

Fig. 3 shows the decadal changes in the Normalized Difference Vegetation Index (NDVI) of 2001, 2011 and 2021. LST has been linked to NDVI as NDVI is the difference between the near-infrared and red band reflectance that is often a divisible sum of two and indicates the vegetation cover of that area (Dissanayake et al., 2019). Mathematically, NDVI is written as (Townshend and Justice, 1986)

$$NDVI = (NIRr - Redr) / (NIRr + Redr)$$

Where NIRr refers to the reflectance of the Near-Infrared band and Redr refers to the reflectance of the Red band. LANDSAT images are used to extract the NDVI value for all the years. NDVI values often vary from -1(Negative) to +1(Positive), where Negative values show water and

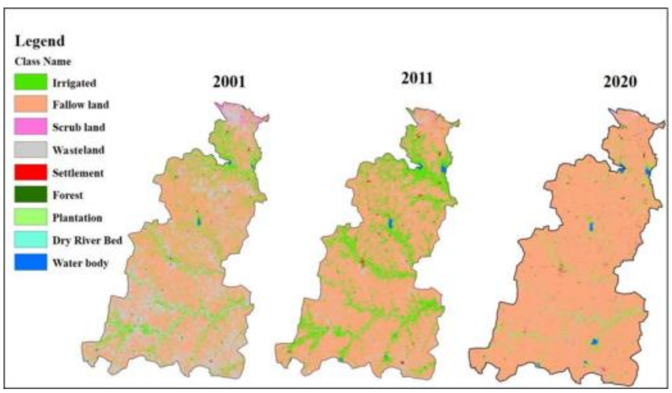


Fig. 2: Land Use and Land Cover maps of study area

Table 2: LULC area statistics for 2001, 2011 and 2020

	Area (Hectares)			Area (%)		
Class Name	**2001**	**2011**	**2020**	**2001**	**2011**	**2020**
Irrigated	14095	25055	2270	11.59	20.60	1.87
Fallow land	68343	84522	110969	56.20	71.15	91.25
Wasteland	28543	4104	775	23.47	3.37	0.64
Scrubland	3431	1275	758	2.82	1.05	0.62
Settlement	423	705	991	0.35	0.58	0.81
Plantation	6266	4442	3637	5.15	2.01	2.99
Forest	40	283	512	0.03	0.23	0.42
Dry River	308	799	1159	0.25	0.66	0.95
Waterbody	162	425	539	0.13	0.35	0.44

positive values indicate vegetation of that area (Das et al., 2021).

From Fig. 3, it is clearly shown that in 2011 the NDVI values goes up to 0.55, and in the other 2 years i.e., 2001 and 2020, the NDVI is raging between 0.54 and 0.48.

Fig. 4 shows the decadal variations in land surface temperature for daytime, ranging from 40°C to above 50°C. Compared to all the decadal years, 2011 has the lowest temperature because of higher irrigated land and vegetation cover. On the other hand, the land surface temperature of

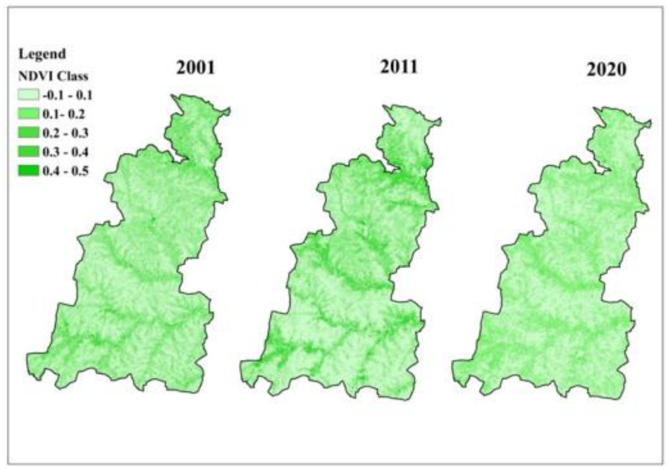


Fig. 3: Decadal NDVI of study area

2001 and 2020 is higher than that of 2011 and above 50 °C.

Fig. 5 shows decadal variations in land surface temperature for night-time, some patches of 2001 and 2020 having the temperature above 28°C, whereas, in 2011, the maximum temperature went up to 27°C. This variation in LST indicates that 2001 and 2020 were hotter than 2011, even during night times.

3.1 Land Surface Temperature of Bhokardan

Fig. 6, 7, and 8 show a profile of LULC classes as a line

Class	Classification Criterion
Bare soil and/or water	NDVI $\leq$ 0
Very Low	0< NDVI$\leq$ 0.2
Low	0.2 < NDVI $\leq$ 0.4
Moderately Low	0.4 NDVI $\leq$ 0.6
Moderately High	0.6 NDVI$\leq$ 0.8
High	0.8 NDVI $\leq$ 1

Table 3: Description of NDVI classed for vegetation cover (Das et al., 2021).

graph of varying land surface temperatures. In all the profile graphs, the areas with higher land surface temperature fall under wasteland, fallow land, dry river bed, scrubland, and settlement categories, whereas those with lower land surface temperature fall under irrigated land waterbody, plantation, and forest categories.

This analysis suggests that the land surface temperature remains at the lower side in vegetation/tree canopy-covered areas even in the summertime. At the same time, it goes to highest in the open lands such as wasteland, barren rocky

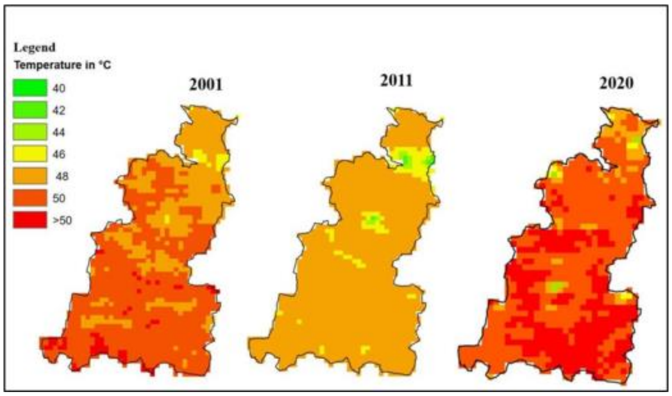


Fig. 4: Decadal variation in May Month Land Surface Temperature-Day (°C) of the study area

areas, etc. Thus, in the climate change scenario, the future pattern of land use and land cover will affect human communities and ecosystems. This may influence how and where human lives and use the land for various purpose.

Discussions & Conclusion

Change in the LULC pattern of Bhokardan was the main

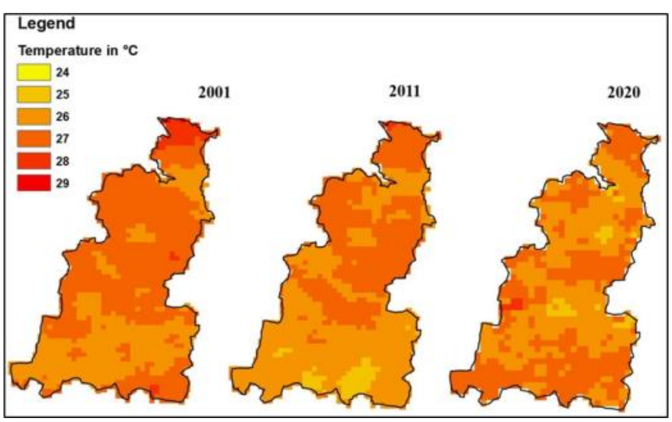
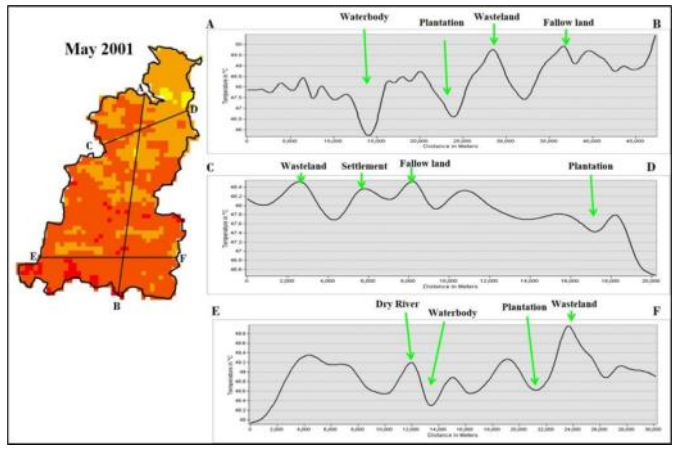


Fig. 5: Decadal variation in May Month Land Surface Temperature-Night (°C) of the study area

leading factor observed in the whole study. Since 2008, Mahatma Gandhi National Rural Employment Guarantee (MGNREG) started watershed development in the entire area of Bhokardan, and also some of the interventions were done by Watershed Organisation Trust (WOTR). The water availability in Bhokardan is sufficient to grow crops during the summer season. Secondly, the rainfall in 2011 was very high; this increased water availability for irrigating land during summer in 2011. Therefore, the irrigated land in 2011 suddenly increases after a decade. But after one decade, the water availability in the study area is not



Fig, 6: Land Surface Temperature of the study area-2001

sufficient to take crops in summer due to the high demand. Due to reduced water availability, a lot of the irrigation land converted into seasonal fallow-land in 2020. The farmers of this region were only growing crops in Kharif and Rabi season, and most of the areas remain uncropped during summer. This increases fallow-land during the summer season, resulting in a higher LST of the study area in 2020. Hussain & Karuppannan (2021) found that the region

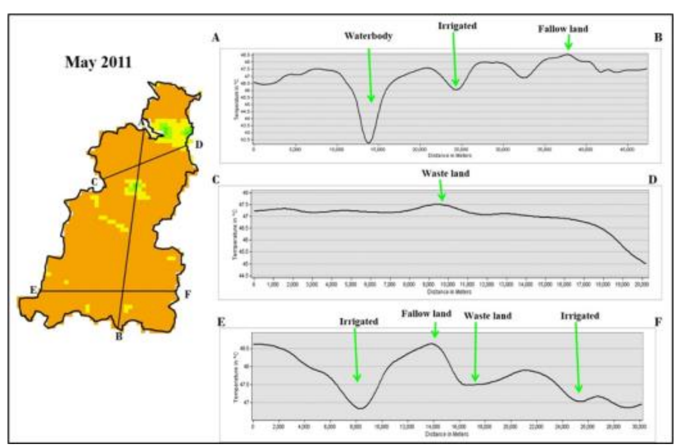


Fig. 7: Land Surface Temperature of the study area- 2011

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having more bare soil and vegetation with low temperature is more prone to having higher LST. This has also been analyzed that expansion of excess agricultural land, settlement, harvesting of forest products, and mining

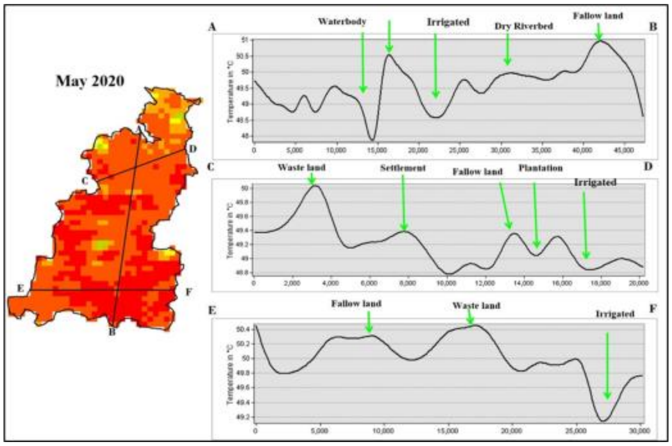

Fig. 8: Land Surface Temperature of the study area -2020

activities are the main key factors that contribute to land-use changes (How et al., 2021). Some research studies have already shown a rise in temperature of approximately 2 - 3.5 °C in ten years. This increasing temperature day by day was evolved due to the land cover and excessive land-use conversion of forest to urban areas and agricultural land to urban areas (How et al., 2021). The relation between land use land cover change and land surface temperature change is complex and multi-directional as the land-use change affects the local, regional, and global climate (Hasnat, 2021).

The present study concluded that low vegetation (NDVI) cover is one of the critical factors responsible for the unusual pre-monsoon summer day heat islands in rural areas like Bhokardan. In the study region, the fallow and barren/ waste lands are seasonally converted from croplands, resulting in higher LST during the summer months in the study area. Higher LST also resulted in intensified heat waves in the plain barren region of the rural area during summer days. Secondly, the changing LULC patterns in rural areas are also associated with higher heatwaves and health impacts related to heat stress in the local area. Therefore, monitoring the changing LULC patterns could help better plan the mitigation steps and policies in such regions to avoid the impacts of high LST, such as heat stress.

Acknowledgments

The author acknowledges the USGS Earth Explorer (https://earthexplorer.usgs.gov/) for free access to Landsat series satellite data. The author is grateful to the Google Earth Engine team (https://earthengine.google.com/) for making available the system free and open source. Also, acknowledge the QGIS community (https://www.qgis.org/en/site/) to make available this open-source software. Special thanks to Dr. Marcella D'Souza and Mr. Crispino Lobo for their support and encouragement during this study.

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Envisioning Rural Development in India through Spatial Planning and Decision Support System

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Abstract

India is on the road map to development in leaps and bounds due to the technological advancement that has taken place in the last two decades. With a massive population with diverse socio-cultural background, it is quite a challenge for the country to match with the benchmarks set by the advance nations. However, spatial planning and Decision Support System have acted as change agents. The country where 69% of the population is agriculture based, trickling of technological advancement comes out as a necessary step. In this article, the authors explore the use of spatial planning and Decision Support System to help a cluster of villages in proper allocation of resources, prioritising their needs and using the budget in a more justified manner in the future. The authors use survey method and Open Data Kit to collect data and GIS application to map the assets and create thematic maps for visualisation of data. The authors have used advanced open-source technologies to create a web GIS application with the help of Geoserver, Leaflet and PostgreSQL. The data published in Geoserver the in the form of Web Service (WMS) and Web Feature Services (WFS). Leaflet API was used for creating cost effective web-GIS applications, and it is an open-source JavaScript for displaying map services data in web the interface. PostGIS is an extension of PostgreSQL used to store spatial data in database. The developed application has basic web GIS functionalities like measure area, distance, toggle layer selection, pan, zoom, home, legend button etc. For the same, an interactive Performance Monitoring Dashboard had been created to help all the stakeholders be it the government officials, the Panchayat members or the community people to see and envisage the allocation of resources for better and efficient planning. An attempt has been made by the authors to map already existing development entities and to identify the gap areas and suggest for future village development plans.

Keywords: GIS, GPS, Sustainable, Mapping, Rural, Spatial Planning

Introduction

Even after seventy four years of attaining Independence, India struggles to provide the fruits of development to the masses whose live are riddled with poverty. There is ever widening gap between the haves and have not's. The various government interventions focus on bridging this gap through multiple schemes and programs. Yet due to diversity and plurality in our socio-economic structure, there is a section of people who are marginalised from benefitting from these interventions. Hence, creation of rural employment and access to livelihoods for sustainable development to mitigate economic delinquency has been on the cards of all the governments that have risen to power. When one talks about rural development, it is inferred that development in relation to all indicators be it education, health, basic infrastructure including roads, buildings, water and sanitation, drainage, common grounds, etc.

Moreover, the spatial plans are prepared for cities and towns popularly known as Master Plans and Development Plans. These are notified under the respective State Town and Country Planning Acts and Urban Development Acts. These Acts in their title include Country Planning, but in actual

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terms, there is neither provision of preparing Master/ Development Plans for countryside village nor much attention has been given by the State Governments to prepare the same. However, over the period of years it is evident that stress has never been laid on preparing Spatial Plans for rural areas and taking into account the vast rural population of the country who have been deprived of the access to basic facilities. Herein lays the importance of preparing a template for a spatially integrated version of the GPDP, namely the GPSDP (Gram Panchayat Spatial Development Plan).

Gram Panchayat Development Plan aka GPDP is to be prepared by the Gram Panchayat (Local Body) for the basic services within the functions devolved to them as per State laws. Participation of people is the key factor in the success of GPDP. This is mandated under the 73rd Amendment Act that has paved way for democracy and laid stress on decentralised governance. The XIV Finance Commission award has created an opportunity for responsive local governance at institutional level of the Gram Panchayat and the guidelines issued by Ministry of Finance instruct that proper plans i.e. Gram Panchayat Development Plan be developed. Main role is played by the community, especially the Gram Sabha in the formulation of priorities and projects and will also have to ensure the mandates of social justice and economic development mentioned in Article 243G. GPDP has a clear component addressing vulnerabilities of poor and marginalized people and their livelihood opportunities through an integrated poverty reduction plan. It allows for different local models and innovations that are locally appropriate and cost effective. It helps to transform GPs into institutions of local self-governance and to cement the GP's identity as development institution. From a vantage point, the process of participatory planning for a Gram Panchayat Development Plan envisages to improve service delivery, enhance citizenship, motivate volunteerism, create space for an alliance of people's institutions and groups, and improve governance at the local level. The above contents mentioned only refer to the sectoral development of the villages/Gram Panchayats but no spatial reference is made.

Literature Review

Due to vast diversity in the country, given the various topographical, geographical, physical, economic or social and agro-climatic zones, planning is a big challenge per se. spatial planning in rural areas is found to be completely absent. Spatial planning in rural areas means, arranging the land use that is critical to the economic development of aspirations of the rural people. It refers to the methods used to influence the distribution of people and activities in spaces of various scales and topology, for habitat environment, having basic infrastructure of communication and transport, and access to basic provisions of life and sustenance.

Spatial planning can be done with the help of latest geospatial technology tools like GIS, remote Sensing and GPS. The absence of planned spatial development in rural areas has major impact on regional development. The Rural Area Development Plan Formulation and Implementation Guidelines (RADPFI, 2017) emphasize the need for the preparation of rural spatial plans, integrated with the overall development. The RADPFI guidelines aim to provide direction for the preparation of spatial plans for Gram Panchayat (GP) and also mentions the required alterations and additions in the existing statutory provisions of planning.

The need for the RADPFI guidelines arises from the fact, that there are 6.49 lakh villages in the country and 68.84 percent of the total population lives in the rural areas (Gram Panchayat Spatial Development Plan, SPA, Bhopal 2018).

Spatial data analysis is a multidisciplinary activity concerning land and water resources, geography, urban planning, hydrology and earth sciences. These data sets may be derived from text, maps, charts, organizations, aerial photographs, satellite images and ground information. The management and analysis of such large volumes of spatial data require a computer-based system called Geographic Information System (GIS) which can be used for solving complex geographical, hydrological and planning problems (Garg P.K, 2008).

GIS is defined as system of computer hardware and software, designed to allow users to collect, manage, analyse and retrieve large volumes of spatial referenced data and associated attributes collected from a variety of sources (Burrough, P. A. and R. A. McDonnell, 1997). In planning process at regional level, integration of various spatial data and their attributes is required to arrive at different alternatives. GIS is a useful tool for the integration and analysis the multi-thematic information for a particular application, thereby, providing managers and planners with necessary tools for generating new information from existing thematic layers of information required for a particular need.

Using spatial planning in local self-governance can ensure openness and accountability in the functioning of GPs. With the aid of GIS and satellite imagery, a detailed visual record of the project scan be maintained, which can be accessed any time. Physical verification of the projects can be done by anybody, from anywhere and at any time. GIS can increase legitimacy and acceptability of the PRIs among its stakeholders (Guidelines for preparation of GPDP by MoPR, 2018).

A spatial decision support system (SDSS) is an interactive, computer-based system designed to assist in decision making while solving a semi-structured spatial problem. It is designed to assist the spatial planner with guidance in making land use decisions.

To effective management of development process on a sustainable basis, local government planners increasingly depends (Densham, P.J. and G. Rushton, 1988) on the use of information technologies, spatial modelling techniques and Spatial Decision Support Systems (SDSS) (Sugumaran et al. 2007).

“Interactive computer systems designed to support a user or a group of users in achieving a higher effectiveness of decision making while solving a semi structured spatial decision problem structured spatial decision problem ” (Sugumaran et al. 2007).

A SDSS has five key modules (Armstrong and Densham, 1990):

1. A Database management system (DBMS)
2. Analysis procedures in a model base management system (MBMS) - defined later
3. A display generator
4. A report generator
5. A user interface

Sprague (1980) presents a development framework for SDSS as three levels of technological development and five functional roles.

Precision farming may be the catalyst that will awaken the Indian agricultural sector to the power of remote sensing and GIS technologies for spatial data manipulation and integration. Precision crop management has been defined as “information and technology based agricultural management system to identify, analyse and manage site specific spatial and temporal variability within field for optimum profitability, sustainability and protection of the environment” (Robert et al., 1995).

Roy et al. (2002) have developed Biodiversity Information System (BIS) with an objective of collection and organization of the available but distributed spatial and non-spatial database, into an interactive system, which is capable of presenting a user friendly interface to its clients.

Method and Materials

The research team envisaged to create an interactive dashboard for visualisation, monitoring and evaluation of various government interventions at panchayat level. Both qualitative and quantitative approaches were used in this study. Burgula Village in Farooq Nagar Mandal, Rangareddy District in Telangana was selected for Gram Panchayat Spatial Development Plan. When the study was conceptualized, it was one Burgula Panchayat. But as the time progressed, the Panchayat was divided into six Panchayats which shared one Panchayat Secretary. On 2nd August, 2018, Burgula was divided into six Gram Panchayats namely: Burgula, Chintaguda, Kadiyala Kunta Tanda, Kasireddyguda, Kundel Kunta Tanda and Nerella Cheruvu.

The Spatial data is created using open Source Quantum GIS (QGIS). The data sets were used for creating Spatial thematic layers are Survey of India Topographical sheets of 1:50,000 and high resolution of Indian Satellite data. Contour data derived from toposheet is used to generate the slope map of the study area. The spatial layers corresponding to attributes like physical features, land holding and land ownership of revenue lands, land use in Abadi area, overall physical and social infrastructure, built environment parameters like housing typology etc. It also integrates the non-spatial attributes like socio-economic condition, governance dimensions, etc. The data collection included intensive primary survey, data from Census 2011 and Mission Antyodaya data. The data was collected through crowd-sourcing approach in collaboration with local youth through an NGO and PRI members. Open Data Kit (ODK) forms were used to collect data including pictures, videos, etc. and geo-tagging the same. Other data collection tools such as interview and schedules, questionnaires were used to collect data from government officials working at village level. Household surveys were conducted to gather data for mapping the whole village along with ODK. The ODK forms helped in generating excel sheets and maps, and subsequently converting raw data into insights. Visualization dashboards were finally created.

In this article, study team used advanced open-source technologies to create a web GIS application using Geoserver, Leaflet and PostgreSQL software. The data published in Geoserver is in the form of Web Service (WMS) and Web Feature Services (WFS). Leaflet API is used for creating cost effective web-GIS applications, and is an open-source JavaScript for displaying map services data in web interface. PostGIS is an extension of PostgreSQL which is used to store spatial data in database. For the preparation of geodatabase, QGIS software has been used. The developed application has basic web GIS functionalities like measuring of area, distance, toggle layer selection, pan, zoom, home, legend button etc. In addition, the study team has developed spatial dashboard for visualization of socio-economic data of households collected through Open Data Kit (ODK) forms and geo-tagged the same.

For the same, an interactive Performance Monitoring Dashboard had been created to help all the stakeholders be it the government officials, the Panchayat members or the community people to see and envisage the allocation of resources for better and efficient planning. An attempt has been made by the authors to map already existing development entities and to identify the gap areas and suggest for future village development plans.

The eleventh scheduled of the constitution created by the 73rd Amendment contains 29 subjects on which the Panchayats shall have administrative control. The study team took all the 141 indicators in these 29 sectors and created a real-time interactive dashboard for easy monitoring, evaluation and dissemination of data. The authors have attempted to map the same through GIS and remote-sensing and corroborating data with first hand ethnographic approach.

To achieve the above objectives, the following procedure is adopted in the present study.

- Mapping of Gram Panchayats under Mission Antyodaya.
- Collection of satellite data, topographical maps, and other collateral data for the study area.
- Preparation of land use and transport network map.
- Preparation of Relief map, drainage and watershed maps.
- Generation of derived maps like slope and contour map using DEM.
- Generation of water resource development plan using Hydrological Analysis.
- Generation of various socio-economic development plans.
- Preparation of Web portal for Accessing the Spatial plans at GP level
- Preparation Dashboard for in-depth analysis.

Results and Findings

As mentioned above, this study aimed at mapping and finding gap areas in the study area i.e. Burgula Cluster. This study proposed Web based interface an efficient visualization method to graphically display the collected data. Users can visualize charts in combination with maps which are spatially distributed. The dashboard platform includes more functionalities like word cloud, toggle-based map, layer control panel, marker cluster, dropdown selection, disable and enable charts, map as seen in Figure 1 below.Apart from the Interactive Performance Monitoring Dashboard, the study team created a web GIS application to visualise various development indicators covering 29 sectors in mentioned under Mission Antyodaya. A select few are shown here for a better comprehension. These depict the pace of development at Burgula Cluster.

i. Agriculture Sector

India is an agriculture-based country, which agriculture employing more than half of the population. Hence analyzing status of Agricultural Parameters is very much necessary for development. This sector includes various parameters such as;

- Government seed shops
- Watershed Development Project
- Community Rain Water Harvesting System/Pond/Dam/ Check Dam
- FPOs/PACS

Figure 1: The screenshot of the Interactive dashboard created for Burgula Panchayat

- Warehouse for Food Grain Storage
- Primary Processing facilities
- Custom Hiring Centre
- No of households engaged majorly in Non-Farm activities

Farmers Collective Facility such as Farmer Producer Organizations (FPOs) or Primary Agriculture Cooperative Society (PACS) are agricultural cooperatives that are emerging as a practical approach towards empowering a great number of smallholder farmers and ensuring their prosperity. In the figure above, all the villages have been marked by a boundary. Burgula, Kadiyala Kunta Tanda and Nerella Cheruvu are shown in green depicting they have availability of Farmer's Collectives. However, Kasireddyguda, Chintaguda and Kundel Kunta Tanda are marked in red depicting they do not have such facility. This representation makes the Sarpanchs and the concerned authority realise that there is a gap and they need to furnish it in the coming times.

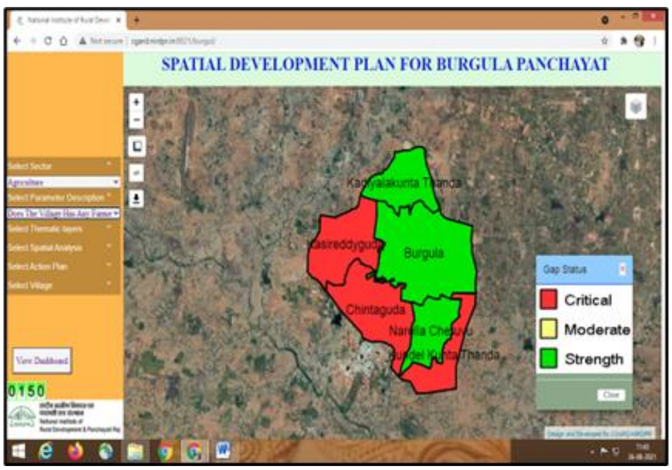

Figure 2: Availability of Farmer's Collective

ii. Financial & Communication Infrastructure Sector

Financial & Communication Infrastructure Play an important role in the economy of an area. A Financial Institution (FI) is a company dealing with financial and monetary transactions, such as deposits, loans, investments and currency exchange. Financial inclusion is highly stressed for the rural people as it given them a boost to come out of the clutches of poverty. It is necessary to have proper baking services to one and all.

This sector includes various parameters such as

- Availability of Banks
- Availability of Business Correspondent with internet connectivity
- Availability of Post office/Sub Post office
- Availability of telephone services (Landline/Mobile)
- Availability of Internet/Broad Band Facility

From the figure 3 it can be inferred that there is only one bank facility at Burgula village and all adjacent villages have to access it.

iii. Drinking Water Sector

Water is an essential thing in day to day life. Supply of good quality water in sufficient and safe sanitation practices in rural area are interconnected with the health and economic well-being of the people. Water is not only required for drinking and cooking but also to maintain hygiene. Every rural household has drinking water supply in adequate quantity of prescribed quality on regular and long-term basis at affordable service delivery charges leading to improvement in living standards of rural communities.

As per the figure, it is seen that al the villages under Burgula Cluster have connection to piped drinking water. This is one of the basic necessities required by all people.

iv. Health and Sanitation Sector

Environmental sanitation envisages promotion of health of the community by providing clean environment and breaking the cycle of disease. Environmental sanitation is a major public health issue in India. India is still lagging far behind many countries in the field of environmental sanitation. The unsanitary conditions are appalling in India and need a great sanitary.

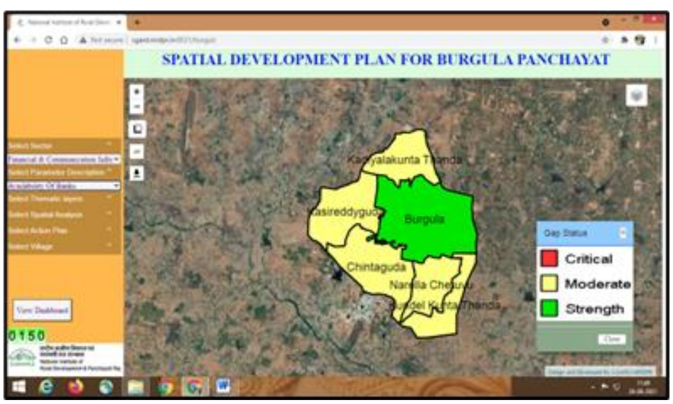

Figure 3: Availability of banks

This sector includes various parameters such as ;

- Availability of sub centre/PHC/CHC
- Availability of Jan Aushadhi Kendra
- Community waste disposal system
- Total no of households using clean energy (LPG/Bio gas)
- Community Bio gas or Recycle of waste

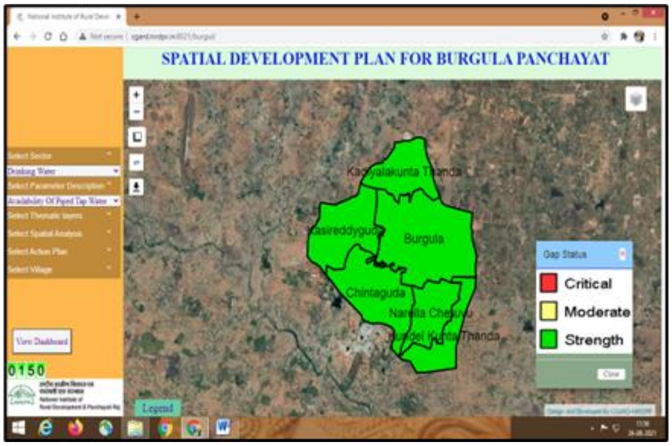

Figure 4: Availability of Drinking water

Public health depends on the condition of health and sanitation of that place. It is essential that people have access to a Primary Health Centre, have proper drainage facilities and waste disposal system in place.

It is seen from Figure 5 that a Primary Health Centre is located at Burgula only and other villages are devoid of having a centre. The people of these villages have to commute and access services at Burgula.

v. Roads Sector

Roads play an important role in connecting people all over the world. It also gives its important contribution to the economic growth of a country. roads link rural villages and towns among each other and, in many cases, connect to secondary roads, which allow their residents, product and factor markets to access.

This sector includes various parameters such as

- Whether the village is connected to all weather road
- Whether village has internal pucca roads (cc/ brick road)
- Availability of Public Transport

All weather roads form the spine of the economy of the country. It is of utmost importance that infrastructure; especially roads are developed all across the country to make transportation easy and commutable.

Figure 5: Availability of Primary Health Centre (PHC)

As can be seen from Figure 6, three villages namely Burgula, Kasireddyguda and Narella Cheruvu are connected with All Weather roads while the tribal villages on the outskirts of the Gram Panchayat are yet to be connected and are left in silos.

vi. Thematic layers

As per Demarmels (2017), thematic maps mainly consist of phenomena and occurrences of non-topographic type, which however, are related to the earth's surface. These are things which have a geospatial location, extent or motion. These can either be real things as well as relationships, functions, hypotheses, mental imaginations, possibilities and projects. Thematic maps give explanations on type and attribute, location, extent and distribution of a phenomenon. They can depict completely qualitative as well as quantitative information in the shape of diagrams or mosaic depictions. In addition, it is possible to visualise frequencies, durations, motions, directions or relations on the map.

In this research, the study team made thematic layers in reference to assets, cadastral map, drainage, groundwater perspectives, land use and land cover, MGNREGA assets, roads, railway lines, settlements and built-up growth and watershed. The attempt was to map the existing assets, settlements, watershed areas, etc. and see the access and usage given the geographical area in the background. Mapping these have helped in understanding the needs and gaps areas of the village. For example, Mahatma Gandhi

National Rural Employment Guarantee Act (MGNREGA) is a flagship program by the government to provide 100 days of wage employment to the needy. It is a programme which focuses on generation of wage employment and creation of sustainable and productive assets assuring a sustained source of income for the rural poor. Efforts have been made over a period of time to create quality assets. The major works implemented under this programme are drought proofing, individual land works, land development and rural sanitation works. The information on existing assets will give an idea for future planning at Gram Panchayat level. It will reduce the redundancy in proposed works and help in proper allocation of resources.

Similarly, roads form a critical part when rural infrastructure is studied. Rural roads facilitate better accessibility of services, promote the development of market centres, and provide an incentive to farmers to generate more marketable surplus. The rural road delivers fertilizers, pesticides, seeds and other agricultural inputs to farmers to improve both production and productivity. A good rural road network would be able to move marketable surplus efficiently and effectively to consumption centres and promote agro-businesses. The researcher mapped the major roads in the study area and they included village roads and other districts roads. Moreover, the research team also mapped the watershed areas. A watershed is an area of land where all of the water that is under it, or drains off of it, collects into the same place. This watershed maps along with slope, soil and ground water prospects will give idea of prioritizing the water and soil conservation measures in the study area. There are seven micro watersheds present in the study. The micro watershed codes are also shown in the map below.

Discussion and Conclusion

Through this study, it is envisaged that the panchayats can utilize this application to plan and monitor developmental activities on real time basis. Gram Panchayats can achieve transparency and accountability by adopting spatial planning for governance at grassroots level. With the aid of GIS and satellite imagery, a detailed visual record of the projects can be maintained, which can be accessed any time. Physical verification of the projects can be done by anybody, from anywhere and at any time. This dashboard would therefore help in visualizing and planning at grassroots level in a more suitable manner.

Acknowledgments

The research team is grateful to NIRDPR for funding this research project. Gratitude is also expressed towards the people of Burgula Cluster for rendering support during data collection.

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An Open-source Approach to map land-use in Urban areas based on Deep Learning Technology

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Abstract

Land use (LU) of developing countries and their spatial structures are changing more frequently, due to the impacts of rapid urbanization. Thus, urban planners and decision-makers taking decisions based on the available LU data. Thus, accurate and updated LU data is essential. There are various approaches to map land uses in the world. Hence, the application of those approaches is depending on the technology, resources, and financial capabilities of different countries. However, developing countries like Sri Lanka (SL) LU mapping methods have many limitations such as difficult update regularly, time-consuming, labor-intensive, inefficient, costly, etc. Further, in SL most of the LU data has a smaller number of attributes, for instance, building type, numbers of floors, and property value are not available under the buildup data. Generally, once in a ten-year, fifteen-year LU maps are preparing by relevant authorities. In such a background, the study develops a novel approach to map land use (LU) in urban areas: based on deep learning technology and open data and software while overcoming the constraints noted in the existing practices. Accordingly, the study proposed a new LU mapping framework to map LU in 2D and 3D utilizing deep learning technologies. The study comprised three main stages. In the first stage, the study conducted literature reviews on existing LU mapping practices worldwide and SL. After, expert discussions were conducted to identify the applicability of the modern LU mapping practices in the SL context. In the second stage, the study develops the mapping framework. The framework was developed on 5 main sources which are Open Street Map (OSM) data, Google Street View images (GSV), Digital Elevation Model (DEM), and google earth images. The main software used in QGIS. The OSM data was acquired by the Qgis Open layers plugin, line features used to derive transportation layers and stream layers, multi polygon used to derive building footprints, land cover data, and point features used to derive specific locations such as industry, education, and administrative. Although OSM data is widely available, there can be some gaps area that does not fill the building footprints and other natural elements. Hence, it was needed to obtain absent data from other sources. To full fill, the gap, a feature extraction method was proposed. For that, georeferenced Google Earth (GE) images were needed to download via Terra Incognito's application for the study area. Terra Incognito's application is a freely available source. After, GE images were imported to the Qgis. then the "OTB" plugin is used to extract the features from the google earth image. Once all features are extracted as an SHP file, building footprints and other relevant polygons are needed to select. However, the output polygon is not precisely matched with the real ground buildings therefore polygons were reshaped using Qgis editing tools. This process can reduce the digitizing time when creating shapefiles. At the end of this process transport layers, complete building footprints, and other polygon layers are prepared. GSV is the main data source of the framework. They were downloaded by GSV API via the python program. First, coordinates were generated for each building using QGIS. Then the attribute table was exported as an excel file. Once the coordination file was prepared, it was imported to the python script. After georeferenced GSV, images were downloaded automatically. In that process 13, 000 images were downloaded. Among them 3251 had distortion by vehicles, humans, vegetation, etc, therefore they were released from the dataset. After, 80% of the data used to train the model, and 20% used to model testing. The training data set was categorized into 5 classes (residential one-story, residential two or more stories, commercial one-story, commercial two or more stories, and others). The image processing model was

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developed using “TensorFlow” and” Keras” open libraries and python. The model was developed to identify building uses and their heights by given GSV images with respective building coordination. Once the model was trained, it showed 95% accuracy from the testing dataset. Finally, a 2D land use map was prepared by extracted information from the OSM and the GSV image processing model results via QGIS. Further, 3D urban simulation was performed by QGIS “threeJS” plugin by integrating DEM, building layers which were updated by building use and building height. Finally, the study validated the proposed framework (PF) using three case studies. They are Boralasgamuwa-Colombo, Ranna-Hambanthota, and Hikkaduwa-Galle. Further, the study assesses the applicability and effectiveness of the proposed method based on an expert survey. The framework recorded an accepted level of kappa accuracy. i.e., 95%, 94%, and 92% for three case studies. Moreover, the results indicated the accuracy level of the proposed 2D, and 3D mapping framework is significantly high compared to the exciting conventional LU mapping techniques. Furthermore, the expert survey results indicated that the PF is applicable and effective for developing countries like SL. The main contribution of the study is developing a free and open-source method for accurate, financially affordable, less time-consuming, less data consuming, technically simpler, labor effective, and efficient framework to map LU 2D and 3D, which is especially beneficial for developing countries. Urban and Regional Planner, Geographers, GIS experts can employ the PF to map 2D & 3D maps. Identification of LU is a critical initial step in the planning process. Therefore, it is essential to map LU utilizing a fast, accurate, and cost-effective method.

Keywords : Land Use Mapping, Image Processing, Deep Learning, Open Data, Urban Planning

AI based Land use Planning for Nepal

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Abstract

The use of Artificial Intelligence (AI) in the sector of land use planning has been a very growing concept in Nepal. Despite the fact that Artificial Intelligence (AI) hasn't been completely integrated in the conventional land planning models of Nepal, it promises an exponential growth in the efficiency and precision of the outcomes of the land use planning projects. Nepalese economy is highly dependent on agriculture where it is the primary income source of more than half of the Nepalese population. However, despite having such significance, there have not been many effective advancements in the sector of agriculture of Nepal. Similarly, as a developing nation, Nepal is currently witnessing a rapid urbanization in its territories. While urbanization promises the much-awaited pace of socio-economic prosperity, it also threatens the existence of forests, grasslands and greenery creating a direct impact on the environment and sustainable development. For such issues which are directly affecting such important fields like agriculture and sustainability, it becomes important to explore new faculties that can alleviate contemporary challenges.

In such situations, Artificial Intelligence (AI) has proven itself to be propitious in various nations. Where it does require a huge amount of data to process favorable outcomes with precision in the input process, its accuracy remains unquestionable. Hence, it becomes crucial to analyze the prospects of Artificial Intelligence (AI) based working models in the sector of land use planning in Nepal to address and mitigate the negative repercussions of modernization and urbanization whilst providing long-term advancements in the land use planning mechanisms. Analyzing the severity of the current situation of land use planning mechanisms in Nepal, this paper argues that the integration of Artificial Intelligence (AI) in certain land use planning models in Nepal can bring revolutionary advancements to the efficiency of the traditional land use planning models.

Furthermore, based on the data from the results of the use of Artificial Intelligence (AI) in other countries, the paper highlights the circumstances under which the use of Artificial Intelligence (AI) can bring better precision than traditional working models. The paper tries to encapsulate theneed for an update in the traditional working models and proposes a further Artificial Intelligence (AI) based mechanism to overcome the contemporary challenges.

Keywords: Artificial Intelligence (AI), Land use planning mechanisms, Urbanization, Agriculture

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THEME 4

Artificial Intelligence for Geospatial Applications (Geo AI)

Experimentation with Generative Adversarial Networks for Building Extraction from a Very High-Resolution Remote Sensing Imageries

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Abstract

Spatial feature extraction from high-resolution remote sensing images has received significant attention over the decade. The increasing availability of satellite images and high-performance computing facilities is the primary factor influencing the focused application domain. The trend of notable improvement in automated techniques is witnessed ever since using convolutional neural network-based deep learning models towards spatial feature extraction from remote sensing images. However, supervised deep learning methods require labeled datasets to train the model, which involves huge manpower and is expensive to prepare. The spatial feature extraction capabilities of deep learning models are highly influenced by the quantum and quality of labels. The diversity in the scenes, especially in the urban context, creates the building feature extraction complicated. To tackle such issues, unsupervised methods such as Generative Adversarial Networks (GAN) are developed. In this research, experimentation using a generator made up of inception segmentation architecture and a patch GAN discriminator is utilized to for building footprint extraction. Additionally, a comparison is made with the results of standard architecture and modified experiments. The outputs indicate that a generator model and discriminator of depth nine layers outperformed the reference model. In this combination, an overall accuracy of 90.85% and a Jaccard score of 49.55 are achieved. The accuracy of the modified model is improved compared to the original GAN architecture. The experiments carried out show that with high-performance computing, unsupervised scene segmentation methods can help extract buildings from high-resolution remote sensing data in the urban context.

Keywords: GAN, segmentation, remote sensing, building extraction

1. Introduction

The state-of-the-art remote sensing technologies generate a tremendous amount of imagery datasets that can greatly value earth observation applications. In recent times, numerous earth observation satellites are made available for civilian applications that provide high-resolution imageries. These imageries contain a large amount of information that needs to be extracted for developing intelligent applications. The use of remotely sensed image datasets spans over several application domains such as urban studies (Brovelli et al., 2017, Bharath et al., 2018), environmental studies (Nakayama & Mori, 2012, Nimish et al., 2020), energy estimations, disaster, and risk assessment (Ramachandra et al., 2019), 3D city models (Bharath et al., 2020) and several others. However, these application domains require the datasets in a readily usable format for statistical analysis.

The machine learning methods proved to be efficient in generating meaningful information from imagery datasets. However, at higher resolution, the utilization of machine learning techniques is primarily limited due to the generalization capabilities of the models and limited availability of labelled datasets.

Automated feature extraction techniques are mainly

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replacing the process of converting images into meaningful information. In recent times, the automatic information extraction from images is majorly conducted through deep learning-based models. The deep learning-based models built using concepts of Convolutions Neural Networks (CNN) can be categorized into two types, namely semantic segmentation (Gonzales et al., 2019, Subrahmanya et al., 2021) and object detection (Li et al., 2020). The semantic segmentation classifies all pixels of the imagery to the specified number of classes, thereby helping to extract targeted features. In object detection, the central aim is to get the imagery's location, count, and bounds of the objects of interest. The deep learning-based semantic segmentation applied to remote sensing imageries achieved significant improvement in performance recently (Zhu et al., 2017, Xu et al., 2018). Nevertheless, the methods require substantial labeled datasets to train the model to achieve acceptable results. The past studies indicate that various efficient CNN-based deep learning methods are trained using supervised learning techniques.

Numerous research works use CNN architectures for building extraction as image segmentation tasks such as U-Net (Chhor et al., 2017), VGG-Net (Alhassan et al., 2019), Res-Net (Ghassemi et al., 2019), Seg-Net, and many other variants of them with modifications in network parameters, However, these models are essentially used supervised learning concepts to train network. Liu et al. (2019) proposed a fully convolutional network for remote sensing image segmentation targeted to extract building features. This paper points out that the complicity of spatial features on remote sensing imagery in an urban context is complex, and therefore further attention is needed in improving the models. After introducing a deep CNN-based unsupervised technique called Generative Adversarial Networks (GAN) (Goodfellow et al., 2014), several works attempted to use them in remote sensing image segmentation.

Zhang et al. (2019) modified the standard GAN model for road extraction using the Massachusetts roads dataset. Pan et al. (2019) used U-Net architecture as a generator network in the GAN model along with spatial and channel attention mechanisms. The discriminator is used as a ground truth image that says the generated image is true or false. Feng et al. (2019) evacuated three networks U-Net, residual U-Net, and GAN model, to generalize building footprints. The study also evaluates the results by considering various map scales such as 1:10,000, 1:15,000, and 1:25,000. The research by Li et al. (2020) tried using GAN-based models for new image generation to improve the generalization performance of the deep learning models. Abdollahi et al. (2020) adopted the Seg-Net model as a generator network within the GAN network to segment aerial images into buildings and non-buildings. The study used the Massachusetts building dataset that consists of high-resolution remotely sensed images and corresponding building masks. Sun et al. (2021) experimented with GAN-based networks for segmentation tasks using two models separately for buildings and background to improve the performance of building extraction. In this work, the standard conditional GAN model (Isola et al., 2017) is modified for testing its version for remote sensing image segmentation. We use the inception-based model as a generator network (Liu et al., 2019) and change the depth of the network in this experimentation. A detailed explanation of the architecture is given in the method section.

Recent developments in semi-supervised and unsupervised techniques have shown significant advancement that can minimize the efforts of labelled data preparation. This paper presents experiments conducted using Generative Adversarial Networks (GAN) for semantic segmentation of aerial images. The article is organized as follows. The following section discusses the relevant state-of-the-art approaches of GAN-based segmentation. In the method section, the overall process formulated for segmentation is explained. Later, the properties of datasets used for the experiment are presented. The results and the discussion section is followed by the conclusions of the work. The deep learning-based studies related to remote sensing images are supported by benchmark datasets such as ISPRS (Rottensteiner et al., 2012), Inria (Maggiori et al., 2017), SpaceNet (Van Etten et al., 2018), and several others (Ji et al., 2018). The benchmark datasets provide the head start for researchers in doing the experiments with the models for a specific purpose. The datasets provided by Inria Aerial Image Labeling (Maggiori et al., 2017) were captured using an aerial survey that contains ortho rectified images, and buildings are labeled using an official cadaster.

1. Model architecture

The GAN model comprises generator and discriminator parts, as shown in figure 1. They both follow up a sequence that helps in image generation. The generator model stimulates the providing data possibility while the discriminator helps determine if the image specimen belongs to the actual map or generative model. Using GAN models, traditionally, two maps are trained side by side in both generator and discriminator. Both generator and discriminator try to adjust the network parameters as discriminator tells the differences and generator thereby produce the image as accurately as possible utilizing adversarial training.

Inception network is constituted of repeating patterns of convolutional configurations which are called inception modules. It consists of an Input layer, 1×1 convolutional layer, 3×3 convolutional layer, 5×5 convolutional layer, max -pooling layer, and concatenation layer. The inception module is quite beneficial as it gives good gain while

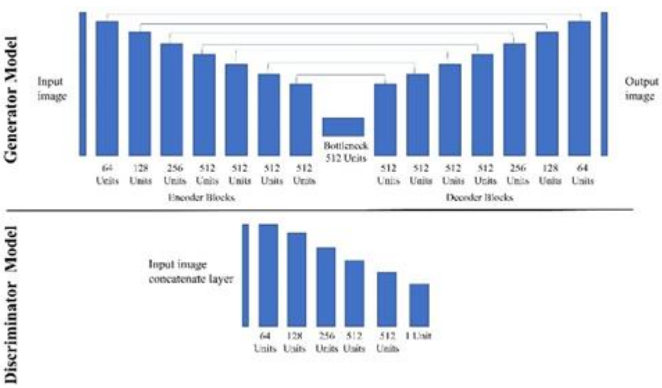

Fig 1. Generative Adversarial Networks architecture

working on convolutional neural networks. It utilizes various sizes of convolutional filters and thus helps in the extraction of information. Moreover, 1×1 convolutional filter learns cross-channel patterns and aiding to feature extraction capabilities. After a thorough study of the inception V3 architecture (Szegedy et al., 2016), five unique modules could be identified, renaming them A to E, as shown in figure 2. Modules A, C, and E are typically used for the feature extractions, and Modules B and D are used for dimensionality reduction.

Inception module A

The original Inception V3 architecture comprised three similar Inception modules at the beginning that the researchers termed as Inception module A. This module is a combination of 1×1, 3×3, and 5×5 kernel size convolutional filters. All of them had a standard structure, as shown in figure 3, with the only change being in the box highlighted in purple with x convolutional filters in them. This module had a stride equal to one, due to which the size of the input and output images from this module remains the same.

Inception module C

The middle portion of the Inception V3 architecture

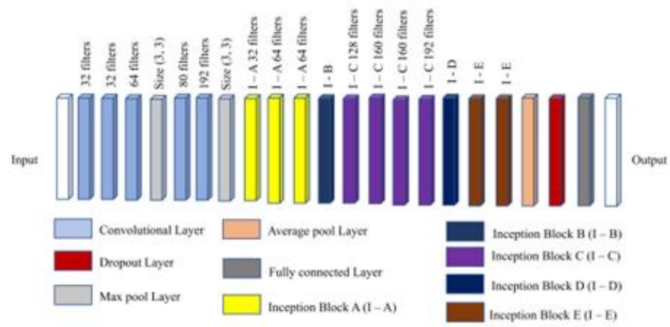

Fig 2. The Inception V3 model explained using Inception blocks

comprised four similar Inception modules that the researchers broadly classified as Inception module C. This module is a combination of 1×1, 3×3, and 7×7 kernel size convolutional filters with a relatively higher number of filters than the Inception module A. All of them had a typical structure, as shown in figure 4, with the only change in the box highlighted in purple with x convolutional filters. This module had a stride equal to one, due to which the size

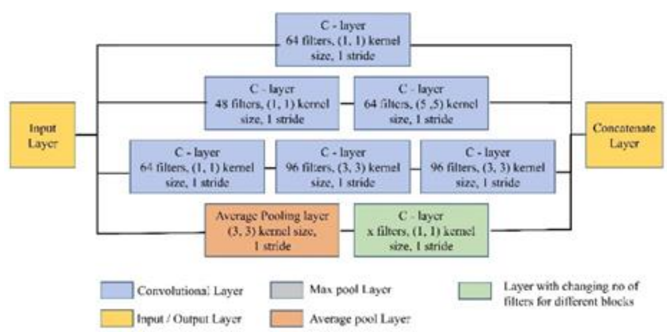

Fig 3. The Inception module A

of the input and output images from this module remains the same.

Inception module E

The end portion of the Inception V3 architecture comprises two similar Inception modules that the researchers broadly classified as Inception module E. This is somewhat more complex and has a higher number of filters compared to modules A and C, resulting in robust feature extraction. This module is a combination of 1×1 and 3×3 filters only, as shown in figure 5.

2. Method

The overall method adopted is indicated in figure 6, which includes preparation of image & labels, training a model,

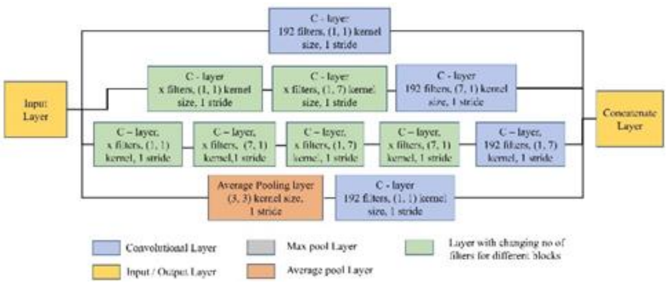

Fig 4. The Inception module C

and predicting building footprints. In the experiment, the images along with their respective building footprint masks were divided into train, validation, and test datasets. Thereafter image patches were made and then fed to the GAN model which was trained for 'n' epochs, as shown in figure 6. After the end of every epoch, the performance of the model over the validation dataset was evaluated, and if the current model breached the highest Jaccard score achieved in the earlier epochs on the validation dataset, then the model was considered as validated. After the end of 'n' epochs, the validated model with the best Jaccard score was

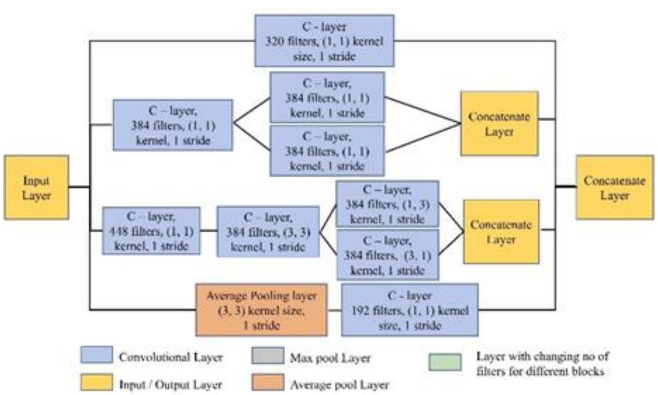

Fig 5. The Inception module E

used for the evaluation of the test dataset and the results were compiled together for all the models for final comparison.

2.1 Plagiarism

The original GAN model is used as a benchmark for the performance of building extraction for satellite images. To increase the performance of the GAN model, various experimentation was done by increasing the number of filters in a layer and by increasing the number of layers itself in both encoder and decoder models. But no significant improvement over the performance was observed. This is due to a saturation of model learning parameters and overfitting over the training dataset. Simply increasing the number of filters or layers barely affect the model performance, if not worse. The architecture shown in figure 1 above is the original GAN architecture.

2 2. InceptionV3+GAN

The Inception-based segmentation model is build using the Inception model as the backbone in a U-net architecture

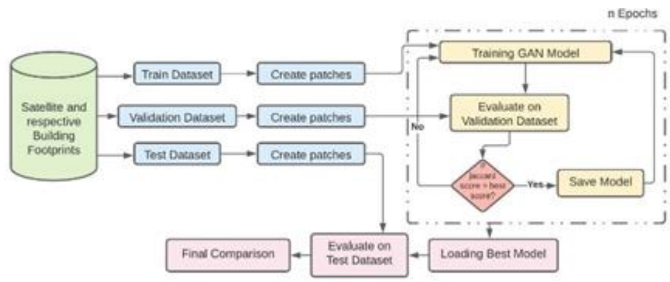

Fig 6. The overall method adopted in the study

where the Inception model is responsible for the feature extraction part, and four deconvolutional blocks use those features to rebuild the building mask image. Since the Inception model is a robust architecture, highly tuned for best feature extractions, an attempt was made to use this Inception-based segmentation model as a generator within the GAN architecture, as shown in figure 7.

2.2 Modified GAN

Due to no effect of increasing the number of filters or layers in the generator of the GAN model, Inception modules were inserted between the convolutional blocks to enhance the learning capability of the model. To maintain the symmetry, the same number of modules were inserted in the encoder and decoder blocks of the generator model. Since the existing encoder blocks made dimensionality reduction, only Inception modules A, C, and E were inserted. The Inception modules' variable component was kept equal to the number of convolutional filters the subsequent block has embedded in them. The architecture of the modified GAN is shown in figure 8 below.

2.3 Evaluation metrics

The standard method of a confusion matrix is used for evaluating the performance of the image segmentation.

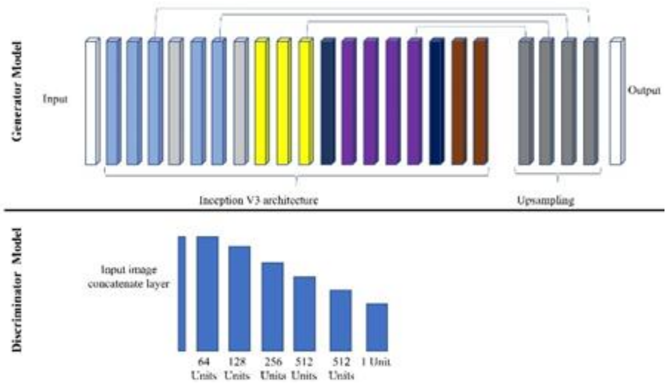

Fig 7. The modified Inception based generator in GAN architecture

Parameters such as overall accuracy, precision, recall, F1-rate, and Jaccard score are used as evaluation metrics. The IoU is an evaluation metric that helps in finding the difference between ground truth images and bounding boxes. It is also known as the Jaccard index or Jaccard score and is the most popular metric for segmentation and object detection techniques. In mathematical terms, IoU is an intersection (overlap) divided by the union. The formulae used to calculate the metric evaluation parameters are given in equations 1 to 5.

Overall accuracy = TP+TN/(TP+FP+FN+TN) Eq.1

Precision = TP/(TP+FP) Eq.2

Recall = TP/(TP+FN) Eq.3

F1-Rate=2*Recall*Precision/(Recall + Precision) Eq.4

Jaccard score (IOU) = TP/(TP+FN+FP) Eq.5

3. Datasets

The remote sensing images captured using aerial surveys are used in the current work. The full dataset contains 180 tiles of 5000×5000 pixels training images and 180 test images

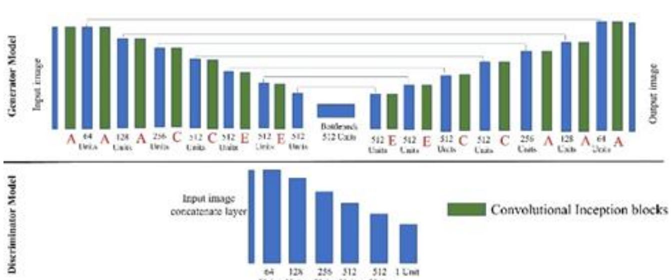

Fig 8. The modified GAN architecture

over 10 cities spread across continents (Maggiori et al., 2017). However, in this work, we utilized 36 image tiles from the city of Vienna. The spatial resolution of images is 30 centimeters, and images are of 8-bit data over red, green, and blue bands. The orthorectified image follows the projected coordinate reference system, and each image covers a geographical area of 2.25 km2. The images considered for this study are accompanied by ground truth or building masks, as shown in figure 9.

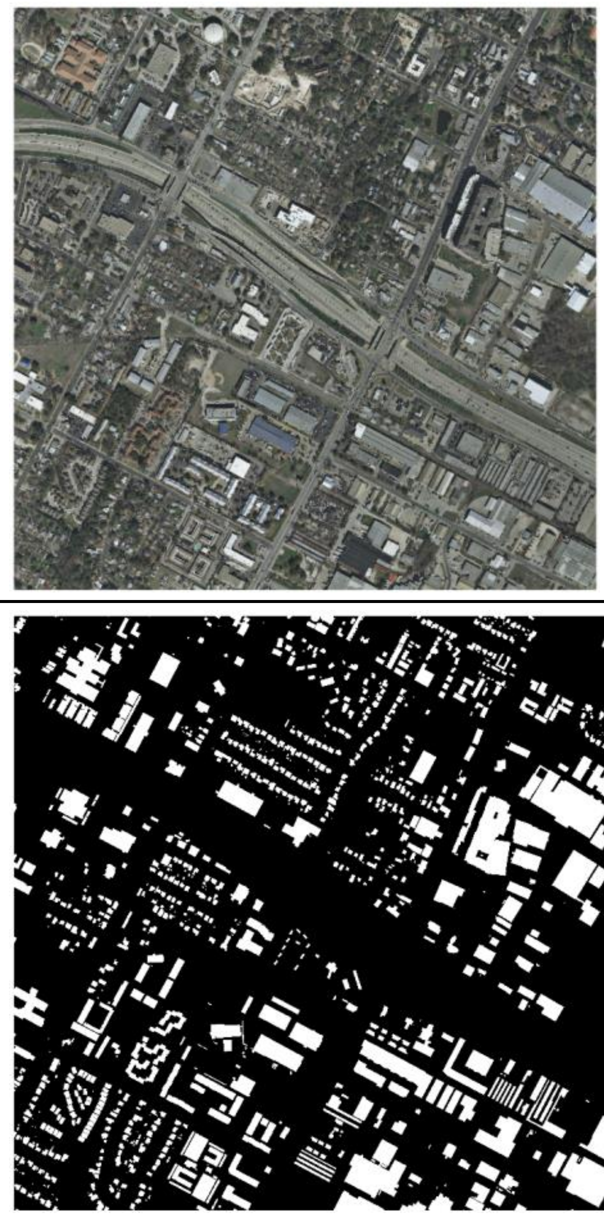

Fig 9. A subset of images and building mask used to train the model

4. Results and discussion

The models were trained with image patches of size 256×256×3 in RGB format. The models were trained for 150 epochs, with checkpoints being created for the best score over the validation dataset. This checkpoint was then used for the final comparison with other models. After training the models using the training dataset, the model with the highest IoU score is used over the validation dataset was stored to compare the performance of the models. For the overall comparison, the Inception-based segmentation model was also trained. The comparison was made over the test dataset, and the results of evaluation metrics are shown in table 1.

From the results, it is observed that the Inception-based segmentation model outperformed the original GAN model by a significant margin. The overall accuracy of InceptionV3 is 95.24%, but the original GAN model only could achieve 81.75%, thereby showing a difference of 13.5%. To reduce this margin, two experiments are conducted. Firstly, the Inception-based segmentation model as a generator model within GAN architecture; however, this experiment was not successful. The modified GAN, with added Inception modules between encoder and decoder blocks of the traditional generator model of GAN, performed better than the original GAN model by achieving an accuracy of 90.58%.

The IoU values suggest the closeness of similarity between two outputs. In this case, a comparison is made with mask and model outputs. The InceptionV3 produced 0.72, while the second-best modified GAN could achieve 0.5. However, the modified GAN improved IoU values by a value of 0.13. The map outputs of the models are shown in figure 10. A careful observation of the prediction indicates that InceptionV3 closely resembles the mask followed by modified GAN. Maximum false positives are seen in InceptionV3+GAN output, which is the cause of the lowest precision values. The significant improvement of prediction from the original GAN model to the modified GAN model can be seen in the image. The majority of misclassification of modified GAN occurred at places where roof materials appear in a distinct color. Also, at the bottom left corner, false positives are appeared due to the wrong prediction of roads as buildings.

5. Conclusion

The original GAN model consists of a generator with a series of encoders and decoders blocks, responsible for learning the important features of an image, and a discriminator model responsible for helping distinguish the generator model between the real and fake images. Such a generator model is relatively inferior in extracting the crucial curves required to re-build the original image compared to state-of-the-art architectures like InceptionV3. Their capabilities, however, can be increased by either introducing inception blocks between their encoder-decoder framework or by using the Inception-based segmentation model itself as the generator model in replacement of the older version of the generator model. The current research compared these models for building extraction tasks over the city of Vienna, where the insertion of Inception modules between encoder and decoder blocks in the GAN produced better results. The outputs suggest that higher attention needs to be given to enhancing the IoU values to ensure accurate building footprint retrieval. The behavior of the GAN model with various other segmentation models as generator network can be tested in furthering the work. Also, the trials do not include significant modifications in the discriminator network. Further, the modified GAN model or improved models can be tested over multiple cities to evaluate the generalization capabilities.

Table 1. The accuracy metric of the segmentation models

Models	Accur-acy	Precisi on	Recall	F1	IoU
Original GAN	81.75	41.68	79.49	53.59	0.37
InceptionV3	95.24	79.29	90.04	84.26	0.72
InceptionV3 + GAN	77.78	36.53	84.14	50.12	0.34
Modified GAN	90.58	65.87	67.64	66.04	0.50

6. Acknowledgement

We are grateful to NRDMS, Department of Science and Technology, Government of India, Indian Institute of Technology Kharagpur for the financial and infrastructure support. Also, we are thankful to Emmanuel et al. (2017) for making labeled datasets available open to research.

7. References

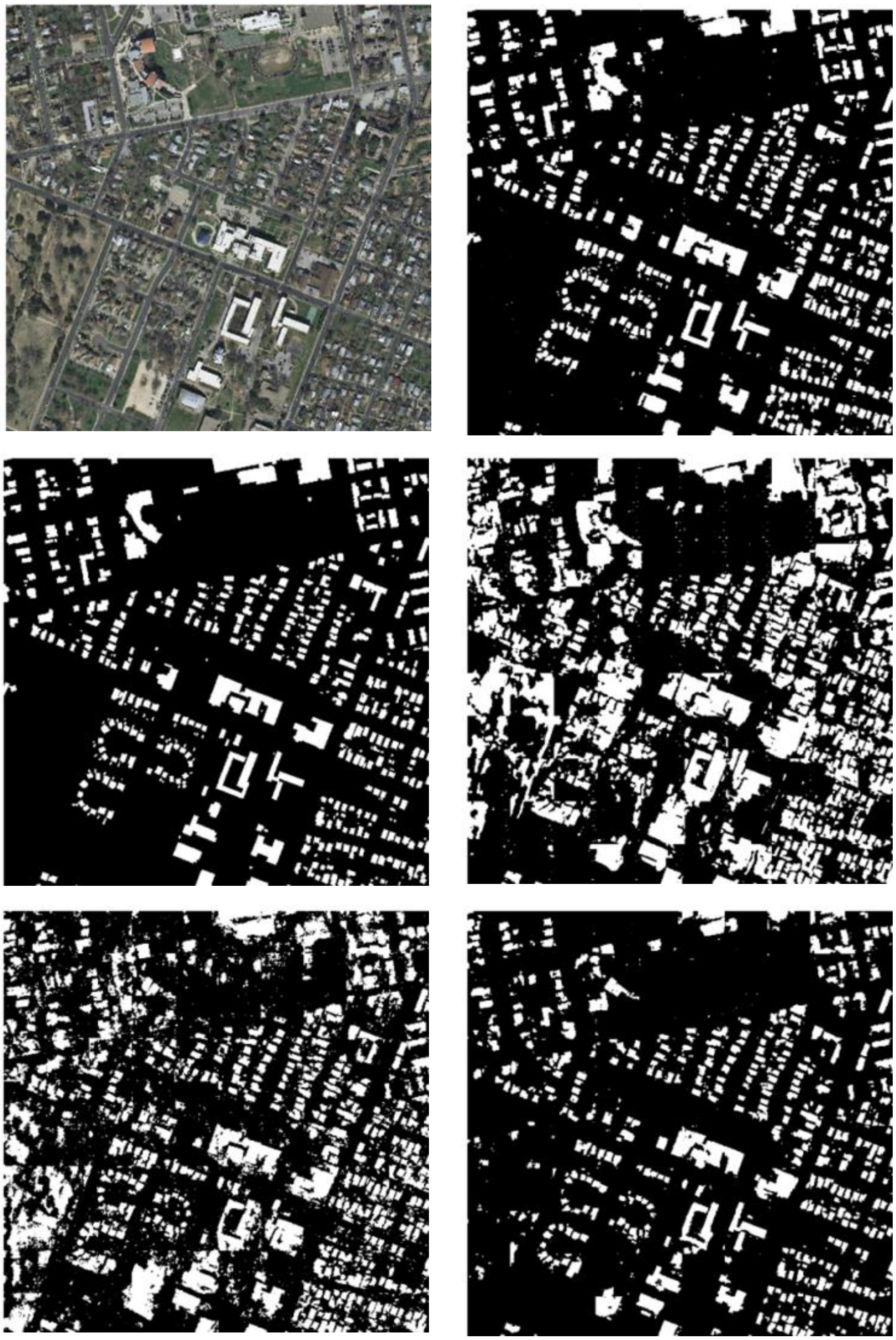

Fig 10. The prediction obtained from various models

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Need of Open Spatial Data Infrastructure: Application of Machine Learning Tools in Disaster Management and Mitigation.

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Abstract

In recent decades, the distribution of the global population and concentration of physical infrastructures also known as exposure is significantly increasing in an urban and rural environment. This increasing exposure simultaneously increases the likelihood of potential consequences (fatalities and economic losses) during natural catastrophes. Thus, managing and mitigating the potential consequence due to natural catastrophes is a key challenge for the decision-makers.

Decision-makers need information on potential losses following natural disaster events to develop and execute effective disaster risk reduction strategies and to systematically react during post-disaster situations. Various classical methods are available to estimate the potential consequences after a natural disaster. However, the application of such classical methods is a resource and time-consuming because they require a lot of information related to exposure and the intensity of the natural disaster.

Over the last decade, the progress in machine learning tools and their application in various domains has increased significantly. Yet, there is only a very limited number of applications of machine learning tools for disaster risk mitigation and management. Existing studies have shown that the use of the rapidly growing machine learning tools in the field of disaster risk management and mitigation provides a reliable estimate of potential consequences.

Meanwhile, globally, significant effort has been made to collect the spatial distribution of the portfolios defining the exposure, and the consequences of previous natural disasters. Moreover, such information is starting to become openly accessible. For example, the Nepal government collected and published the 2015 Nepal earthquake building damaged portfolios, thanks to the concerned authorities. It is interesting to note that such open database contains very crucial information to develop our understanding in the framework of disaster risk management and mitigation.

Keywords : Open spatial data portal, machine learning, disaster mitigation and management, earthquake building damage prediction, open street map

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Novel approach to delineate cities and their population based on Open source GIS applications, Machine learning and Open-data

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Abstract

Cities are the ubiquities of modern urban development as it comprised with divers of socio-economic potentials. Hence, migrating population towards the cities is inevitable task and caused significantly to the increasing of urban population and scales of cities. This allometric nature of cities and their underneath population become subject to the variety of urban population and urban allometry studies in last two decades and has been proposed multiple approaches to distinguish their characteristics. However, it identified that there are extremely limited studies have been carried out to delineate cities and their population based on free and opensource software and open data. Therefore, in order to fill this limitation this study trying to elaborate a novel modeling framework to delineate cities and their population based on open source GIS applications, machine learning and open-data. The case study selected as Sri Lanka, which is island country which is situated in South-ASIA. The proposed modeling framework mainly divided into two major modeling sections, I. Development of novel modeling framework to delineate individual cities with their existing urban scale, (i.e., in here urban scale defines the functional urban territory of a city). II. Development of population estimation model to calculate the underneath population of each derived individual cities which are obtained in the model I. The study utilized percolation theory and fractal geometry as the fundamental theories to delineate the cities by utilizing the proxy of transportation network configurations. In this study we utilized bond percolation and street intersections as proxy to uncover the city clusters because, street intersections are considered as the primary points of interactions and urban agglomeration. Hence, the study utilized QGIS Software to prepare the transportation network into the road intersections. In order to acquire the transportation data, it utilized the Open Street Map Database, (i.e., OSM). It utilized the DBSCAN Plugin, which is freely available in QGIS Plugin Repository to calculate percolation clusters. Afterwards, to calibrate the derived percolation clusters to the existing urban scale, the study utilized fractal geometry. It is identified that, urbanized space contains specific urban morphological characteristics which cannot distinguish in the rural area, and these features can well exhibit in the fractal nature of the transportation network. Thus, the study calculates the fractal dimension at each distance threshold and identify the maximum self-similarity distribution of percolation clusters as the existing scale of the cities. The study utilized Minkowski–Bouligand Dimension Calculator Plugin (MBD) in QGIS Plugin Repository to calculate the fractal dimension. In order to estimate each cities population, the study utilized the state of the art of the machine learning technics by incorporating urban morphological and allometric properties of each derived city cluster as the model covariates. These parameters fitted with each derived city occupied urban population by using several linear and nonlinear regression models to identify the most prominent modeling framework to model the urban population. The linear model includes the Linear Regression (LR)model. The nonlinear models are included, Random Forest (RF) model and Multilayer Perceptron Neural Network (MLP) model. The study utilized Python programming language (v.3.6) and scikit-learn machine learning library to develop the proposed population estimation model. It utilized Jupyter Notebook IDE, which is open-source application, to run the Python programming language and develop the proposed modeling framework. Findings of the study depicts that, proposed opensource modelling framework is excellent proxy to delineate cities of Sri Lanka. It identified, QGIS and other model equipped third-party Plugins, (i.e., DBSCAN Plugin, MBD Plugin etc.) provide

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outstanding contribution to implement each modelling steps and identify the cities with their existing urban scale. Thus, the study derived the existing city scale of Sri Lanka at the percolation threshold 500m, where it reach to the maximum fractal dimension distribution. Other way, the study distinguished that, urban morphological and allometric properties of cities are excellent proxy to distinguish their underneath population. It identified; Transportation Accessibility Level (0.68), Cluster Area (0.60), Cluster Intensity (0.57) and Land Availability (0.47) as the highly correlated variables with each city's population. The model received more than 9% of MAPE and 81% of R2 values for the Random Forest Model and 10% MAPE and 78% of R2 value for the Multilayer Perceptron Neural Network. Hence, it classified that, the Random Forest model is excellent proxy to model the urban population along with the model utilized urban morphological and allometric properties. The contribution of this study stimulate the international research community to utilized FOSS and Open-Data approaches for their studies, which are provide more accurate and cutting-edge solutions to overcome the limitations of exiting commercialized solutions. This also encourages various governments bodies and practitioners to equip these techniques for the future development measures which are freely available and customizable for their specific research needs. Other way, since all modelling measures are opensource, it can easily improve and develop the proposed models without any specific copyright issue. This significantly help to improve the quality and validity of opensource research.

Keywords: Cities, Population, Open Data, Free and Open Source Software (FOSS), Machine Learning, Urban Allometry, Percolation Theory, Fractal Geometry, Transportation Network

Model Land Fragmentation by Using Feed Forward Neural Network and Decision Tree: Case of Western Province, Sri Lanka

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Abstract

Land fragmentation refers to the division of the lands into smaller parcels that are too small for their rational utilization. Land fragmentation connects with the morphological changes like irregularity and complexity in the urban area and their consequent scattering on land uses. Land fragmentation affects sustainable development through its multiple impacts on environmental, economic, and social costs. The influence of anthropogenic activities on land fragmentation has been studied based on the investigation of the linear relationships between demographic and economic factors. Few empirical studies have modeled land fragmentation. However, the investigation of nonlinear relationships on land fragmentation is more realistic than linear relationships. Because land fragmentation is a phenomenon that occurs in the complex urban environment. Therefore, the study was accomplished to address the following four theoretical and practical issues noted in the field of land fragmentation related to spatial planning. First, limited studies attempted to investigate nonlinear complex relationships between multiple factors' influences on land fragmentation. Second, most of the contemporary studies have identified the factors but limited attention has been given to explain the relationship quantitatively. Third, the identification of the magnitude of factors' influences on land fragmentation needs to develop effective land-use policies and rules. Fourth, the unavailability of a modeling framework to model the complex process of land fragmentation spatially. Accordingly, the main objective of this research is to develop an artificial intelligence-based simulation framework to simulate land fragmentation in urban areas. The study comprised three key stages as identification of the factors of land fragmentation based on literature reviews; development of simulation modeling framework; and simulation of future land fragmentation. The case study is carried only in the Western Province, Sri Lanka. Landscape Ecological theory and Patch-Corridor-Matrix model used as the basic theoretical concept of study to determine the factors of land fragmentation. The study computed the level of vegetation land fragmentation (Landscape Division Index) by using raster files of 2505 Grama Niladhari Divisions (GND) of Western Province that were used as the input files of FRAGSTATS. FRAGSTATS is freely available software that can be used to quantify landscape metrics. Qgis is used as the main platform for manipulating spatial data during the data processing (including the level of built-up land fragmentation (LBLF). Qgis tools like Image Classification(SCP), Geo Processing tools (Batch Processing) and Lecos (Landscape Ecology Statistics Plugin) were utilized in the data processing stage. The study executed the identification of factors of land fragmentation based on non-linear relationships. Therefore, supervised feedforward neural network (Deep Learning) was used to determine the factors of land fragmentation with their behavior and simulate the future land fragmentation. 2505 GNDs' statistical data are used as the inputs of the neural network(ANN). Output was set as the land fragmentation value which was derived from division calculations. Two different models were framed by using the R language in Rstudio for the level of vegetation land fragmentation (LVLF) and level of built-up land fragmentation (LBLF). Keras, Neuralnet, and Tensorflow are the main packages that are used to frame the ANN in Rstudio. The decision tree (supervised classification) model is used to distinguish the possible scenarios in land fragmentation. Two different decision trees were framed by using the WEKA software that is an Open source software. Olden and Lekprofile algorithms of artificial neural network (ANN) and J48 algorithm of the decision tree (DT) specified the results to achieve the research objectives. The research

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successfully develops an artificial intelligence-based simulation framework to model land fragmentation in urban areas. Accessibility growth has the highest importance level (45) in the level of vegetation land fragmentation (LVLF) model according to the ANN olden algorithm between the ranges of -50 to 50 that can be considered as a novel finding compared to the contemporary studies reviewed by this study. It is 75 in the level of built-up land fragmentation (LBLF) model in the range of -100 to 100. The Decision Tree of LVLF demonstrates that small irregular and dispersed vegetation patches are highly vulnerable to fragmentation. On the other hand, large, smooth, and assembled built-up patches are also highly vulnerable to fragmentation. Findings further show the opposite direction between building density and land fragmentation. Mean Square Error (MSE) and Root Mean Square Error (RMSE) are respectively 0.025% and 1.574% in the LVLF neural network. MSE and RMSE are respectively 0.008% and 0.092% in the LBLF neural network. The LVLF decision tree model shows 12% of Relative Absolute Error (RAE) and 29% of Root Relative Squared Error (RRSE). Model validation of the LBLF decision tree also shows 19% of RAE and 29% of RRSE. Future simulation of land fragmentation from 2010 to 2030 indicates that the Gampaha District has more than 80% level of fragmentation in more than 20% of the areas compared to Colombo and Kaluthara Districts. It further demonstrates the significant increment in land fragmentation along the expressway interchanges and it shows the declining trend of land fragmentation in the Colombo core area according to 2010 to 2030 future simulation. The key methodological contribution of the research is that it has employed AI-based applications such as ANN and DT to unravel non-linear and complex relationships to analyze and model land fragmentation. More importantly, the study is based on open-source software that anyone can access to utilize the method in the future and also it helps to achieve research objectives without any technical cost. Therefore, it can be concluded that the method and findings of the study provide the framework to quantify, analyze and model land fragmentation that enables the planner to analyze the existing situation, forecast future trends, and develop effective spatial planning strategies and land monitoring mechanisms to achieve sustainable development.

Keywords : Land Fragmentation, Artificial Neural Network, Decision Tree, Spatial Planning Method

Object-based Image Classification Using Mask R-CNN and CNN

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Abstract

With the development of modern technology, the spatial resolution, spectral resolution, radiometer resolution, and temporal resolution of remote sensing imagery increasing rapidly. As the resolution of remote sensing imagery increases, it becomes more difficult to classify urban land use-land cover and recognize complex patterns in urban areas using traditional pixel-based methods. Since pixel-based methods are often used to extract low-level features, based on per-pixel spectral information, and do not take into account the contextual information, it is not suitable for the classification from very high-resolution imagery of urban areas. For example, man-made objects share similar spectral properties, such as roofs and parking lots with similar construction material, which makes it even harder to accurately classify very high-resolution imagery. And rich spatial information presented in very high-resolution images hinders accurate interpretation and classification. As the resolution of remote sensing imagery gets finer, small objects are conjointly distributed around target objects which results in a strong confusion. Especially in Ulaanbaatar, Mongolia, it is extremely difficult to classify very high-resolution imagery of urban areas using pixel-based methods due to poorly planned residential and industrial areas, high-density buildings, "ger district" (it consists of a group of Mongolian traditional nomadic tents that coexists with urban areas) sprawl, and diversity of land use-land cover types. Therefore, we proposed a combination of the most advanced methods in the field of remote sensing, Object-based Image Analysis (OBIA) and Deep Learning, to accurately classify very high-resolution imagery in this study. Object-based methods offer an efficient strategy to classify objects with precise boundary information, such as shape, size, and edge from very high-resolution imagery, although it is difficult to recognize or detect complex patterns and objects in urban areas. To reduce this problem, we combined it with deep learning methods, Mask R-CNN and CNN (Convolutional Neural Network). Mask R-CNN is a deep learning algorithm for instance segmentation and object detection from an image. In other words, it can separate different objects in an image. And CNN is a deep learning algorithm, which is adopted a wide range of aspects in image processing, including image classification, object detection, super-resolution restoration, etc. In this study, deep learning models of building footprint extraction and car detection from very high-resolution imagery were developed using Mask R-CNN, in order to accurately classify dense areas. And the deep learning model of land cover recognition from very high-resolution imagery was developed using CNN. Then results of these deep learning models were used for Object-based Image Analysis, such as object-based classification and rule-based improvement. In object-based classification, segments were created using a Multi-resolution segmentation algorithm and a Vector-based segmentation algorithm. Rule-based improvement, so-called Knowledge-based improvement is one of the key advantages of Object-based Image Analysis, which allows the classification results to be improved based on the spatial characteristics and spectral characteristics of the segments. The main purpose of this study is to combine the most advanced and rapidly developing methods in the field of remote sensing to perform a high accuracy classification from very high-resolution imagery of urban areas, and to introduce the advantages and possibilities of this method, as well as to develop deep learning models that can be used for classification or object detection in similar urban areas. In this study, very high-resolution images were used to classify three urban scenes in Ulaanbaatar, Mongolia. The first scene was used as the training site, while the second

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and third scenes were used as test sites. The training site was selected in a location that included all the urban and geographical elements of Ulaanbaatar. And test sites were selected in locations that similar to the training site and includes all urban and geographical elements. The area of each scene is about 120 ha, and it has three spectral bands with a spatial resolution of 0.12 m. It contains typical residential and commercial buildings (with different heights and sizes), ger districts, and other urban and geographical elements, such as water, grassland, tree, road, parking lot, cars, concrete, and bare soil. As a result, the final classification with ten classes of selected scenes in Ulaanbaatar was created. The overall accuracy of classification results was above 90% in each scene, including 92.69% in the training site, 91.76% on the first test site, and 93.04% on the second test site. The results indicate that the combination of Object-based Image Analysis and Deep Learning method is highly effective and suitable for classification from very high-resolution imagery of complex urban areas. In addition, these deep learning models can be used in similar urban areas and scenes, as the classification results of test sites were as high as the training site classification result. Furthermore, these deep learning models can be used separately depending on the purpose of study or activity.

Keywords: Object-based Image Analysis, Deep Learning, Convolutional Neural Network, CNN, Mask R-CNN. Object-based classification, very high-resolution imagery

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Multi-layer perceptron-Markov chain-based artificial neural network for modelling Urban Expansion in Ulaanbaatar, Mongolia

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Abstract

Urban growth in various cities across the world, especially in developing countries, leads to change in land use. Thus, predicting future urban growth in the rapidly growing region of Mongolia becomes a significant endeavor. The vast majority of Mongolia's population lives in Ulaanbaatar. Since 2000, natural disasters such as droughts and dzuds in agriculture have hit herders hard, and migration to large cities and towns, especially Ulaanbaatar, has increased. The availability of reliable jobs in urban areas is attracting more people and expanding the urbanization process. In the near future, migration is expected to continue having a significant impact on Ulaanbaatar's population growth. This is due to the over-concentration of social forces in Ulaanbaatar, such as education, health, economy, infrastructure, public administration, and culture. In the "ger district" (circular nomad's tent-yurts detached to a land lot is a type of slum settlement district in Mongolia) sprawl area, which covers about 32% of all territory of the city, urban expansion has accelerated so far so it adversely impacts green belt areas, wetlands, riparian zones, open space, and public land. According to the 2019 survey, 67.2 percent of the total population of Mongolia lives in urban areas, of which 45.3 percent or one in two people live in the capital city. Ulaanbaatar, which accounts for only 0.3 percent of the country's territory, is densely populated, with a large population. In particular, 95.1 percent of the total population of the capital city lives in the six central districts. Mongolians are starting to use GIS with remotely sensed data and artificial neural network modelling techniques for urban expansion studies. The aim of this study is to simulate urban growth using multiple Landsat data of 2018, 2019 and 2020 by integration of multi-layer perceptron neural network and Markov model. This study primarily considered Ulaanbaatar, the capital of Mongolia, which experienced rapid Land use land cover (LULC) change due to anthropogenic factors. Multi-layer perceptron neural network approach has been used to calculate conversion probabilities for urban growth. These conversion probabilities have been used in Markov model for urban growth simulation. This method has been implemented to Ulaanbaatar to find out urban growth. The satellite data were classified in the most similar way by creating a total of 5 class segments: buildings, forests, plants, soil, water, and sand. Landsat-8 was classified using the most similar method using satellite data. In the calculation of the change, each classified class had different spatial increases and decreases, which resulted in significant changes in the size of the constructed area depending on the redevelopment. The greatest change occurred in the soil, and in terms of location, a significant amount of soil cover was reduced in the southern part of the study area. Clark Lab's (Clark University) Geospatial Monitoring and Model software had been used for the urban expansion prediction. A new 22.4 sq.km built-up area or residential area has been created within the study area, of which 20 sq.km, or the largest change, has been converted from soil to built-up area. Between 2018 and 2019, the location of the newly constructed area has increased significantly to the southwest, west, and suburbs of the study area. The new settlements indicate that Ulaanbaatar is expanding in an unorganized and chaotic manner. The results of the 2018 and 2019 classifications were used to calculate the surface change using the "Land Survey Calculation Model" (LCM). To calculate the probability of the transition, the multi-layer perceptron model, one of the artificial intelligence network structures, was used as the baseline, using the results of ground cover changes and sub-data

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such as roads, city centers, surface water, and buildings. When using multi-layer perceptrons, 7 hidden layers were created to make the calculations more accurate, with an accuracy of 70.63 percent. In 2018-2019, the vegetation cover in the study area increased by 26.9 percent, while the soil cover decreased by 13.1 percent. The results of the study show that the urbanization trend in Ulaanbaatar is to the west and southwest, with vegetation and built-up areas increasing, while soil cover tends to decrease. For the data validations, and accuracy assessment error matrix was calculated to compare with archived field reference data mapped in two years 2018 and 2019. The simulated urban growth for 2020 is cross tabulated and validate with actual urban growth of 2020. Based on the LULC analysis the classification results showed that the overall accuracy of LULC maps achieved from 59.2 to 94.4 percent. We found that the land use/land cover map resembles previous field survey data assessments of areas with the same classes of land use. Our Markov chain model map corresponded with the field reference map. The Kappa coefficient of urbanized area in 2020 had a positive 0.88 value, which indicates that the classified map has a strong agreement with ground truth data. This result showed that the CA-Markov chain model has good potential to accurately predict future land-use changes.

Keywords: simulation validity, land use/land cover, growth prediction, Ulaanbaatar

THEME 5

Geospatial Technologies in Agriculture, Forest and Environment (GeoAFE)

FOSS4G-ASIA 2021

KATHMANDU UNIVERSITY, DHULIKHEL, NEPAL

Growth Monitoring and Yield Estimation of Maize field using UAV

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Abstract

The world is changing at a greater pace with the advancement in science and technology. This new advancement can prove as a blessing to the agriculture industry to meet the increasing demands of food and fodder. More than 66% of the country's population is actively involved in agriculture but Nepal is still a food deficit country as almost all the people are practicing a traditional approach to agriculture. For sustainable agricultural production, continuous monitoring of crops can be done, which ultimately helps understand environmental factors that affect the crop growth and yield it gives. Constant monitoring demands detailed and multi-temporal crop datasets. As UAVs provide the best means to collect multi-temporal and high-resolution spatial datasets, they provide a powerful means in crop monitoring. With the help of UAV images at different stages and using different open-source software, Orthomosaic and Crop Surface Model were produced and Vegetation Indices were calculated using RGB spectral bands. CSM monitors growth by providing the plant height of the crop plots and helps visualize how they are growing throughout the plot. The orthomosaic obtained from image processing was used to calculate the crops' Green-Red Vegetation Index (GRVI). Plant height, leaf area, wet biomass and wet mass of yield were measured from sample plots. Relation of biomass with plant height and relation of crop yield with plant height, vegetation index, and biomass was developed. The accuracy of DSM was compared against the GCPs established from the DGPS survey. The plant height at the first, second and third study stage was up to 1.5 meters, 3 meters, and 3.6 meters respectively as obtained from CSM which was validated using the data collected from the direct field survey. Some errors occurred in plant height estimation and also in the estimated yield. The main possible reasons for the errors in the plant height are CSMs becoming more complex as the height of plants goes on increasing and tie points matching become more complex due to the similar patterns of the leaves. The plant height and vegetation index of sample plots were used to develop and validate the regression model. The yield was estimated using a developed regression model for each of the plots and was validated by comparing it with the final yield obtained in the field. The total estimated yield was 2671 kg. Mean Absolute Percentage Error is calculated for the estimated and real crop yield data and the error was less than 3%. UAV can be used to capture temporal and high-resolution imagery of the crops, different open-source software can be used to process these images, from which plant height can be estimated and vegetation index can be calculated. The estimated plant height and vegetation index can be used to continuously monitor the growth of the plants and to estimate the biomass and yield of crops. So, the advanced technology helps to monitor the crop growth in every development stage of the crop which results in better production of the yield of the crops.

Keywords : Agriculture; Crop Monitoring; Crop Surface Model (CSM); Green Red Vegetation Index; Yield Estimation, UAV

Introduction

Agriculture is a basic survival activity that has been practiced long before. In Nepal more than 66% of total population (Statistics, 2013) are involved in agriculture as their major occupation. Land is the most common natural resource which fulfils the basic needs giving platform for food production, shelter and other basic needs. As land is limited in a sense that its area cannot be increased. Thus, for

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the increasing population, the only thing to maintain food resources is by increasing its productivity. Due to the advancement of technology, use of fertilizers and other means productivity can be increased thus maintaining balance between population and food resources. For sustainable agricultural production, its study is necessary. Monitoring of crops can be done by studying its phenology and biomass estimation that ultimately helps in understanding environmental factors that affect the crop growth and yield it gives.

During the growing season of the plant, the plant height gives the important information in the plant health and growth. So, it is essential in crop monitoring. Manual height measurement is time consuming and somewhat difficult. So, images taken before crop plantation helps to create DSM and compare it with DSM of other phenological stages of the plant's life cycle for plant height. Plant height also gives information about biomass of the plant assuming and estimating certain parameters as biomass is directly dependent on plant height.

UAV can cover big areas in comparatively less time than other means of surveying. Due to low cost, high coverage and high-resolution images and easy maintenance UAV is becoming a powerful tool to carry out survey works and research activities. For our project we are going to use UAV to capture images of the Maize crop plot in various phenological stages of the plant. Images taken at different stages give the average plant height at the corresponding phenological stages by image processing and creating Crop Surface Model. Furthermore, UAV images are used to calculate Vegetation Indices using RGB spectral bands. Orthophoto generated from captured UAV images can be used to calculate Vegetation Indices like Green Vegetation Index and Green- Red Vegetation Index. Also Leaf Area Index can be calculated by measuring leaf area directly on the field. These vegetation indices can be used to monitor crop and estimate biomass, provided they can be used to estimate the yield of the crop.

The main objective of this study is to monitor the crop growth and estimate the yield of the Maize plant using low altitude remote sensing i.e., UAV platform. The sub-objectives of this study are listed as follows:

- To use Crop Surface Model (CSM) for monitoring crop growth.
- To utilize Green Red Vegetation Index (GRVI) for monitoring crop growth.
- To use Leaf Area Index (LAI) for monitoring crop growth.

This study focuses on estimating biomass and yield of the crop along with monitoring the crop through analyzing VI and height of the crops. GRVI is used to analyze temporal change in vegetation. However, the camera used for image acquisition will be based on RGB spectrum so NDVI and SAVI will not be used for crop monitoring though they are considered as effective VI.

Literature Review

Agriculture in Nepal

Nepal is an agricultural country and it provides employment opportunities to more than 66% of the total population and accounts to 34.7% of the country's GDP (Ministry of Agriculture (MoA), 2074/75). The share of the agriculture sector in GDP has been in a declining trend in the last 15 years. Despite having the country's more than half of the population in the sector of agriculture it only accounts to the country's less than one third of the GDP. So, agriculture is one of the most expensive human resources in our country. The use of modern technology and communication in farming can increase the yield of crops. "In the current milieu, use of sustainable information and communication technology in agriculture is not an option. It is a necessity." (Sylvester, Food and Agicultural organization, 2018) Using modern technology is not enough, utilization of improved seeds, sowing crops, fertilizing them, protecting them from diseases etc. are also the important aspects. In the modern agriculture trend the land is considered as a heterogeneous field in terms of nutrients. By treating a plot like this, necessary nutrients could be given to all the plants thus all the plants get the proper nutrients giving the maximum yield. One of the recent developments in agriculture is the use of UAV in crop monitoring. UAV provides the best means to provide high resolution and temporal dataset of the crop plot which is necessary for the crop monitoring. One of the major advantages of UAV over satellite-based imagery is they provide one of the best means of collecting very high-resolution imagery below the cloud level with much more detail than the satellite does. They are easy to use and flight is done autonomously i.e., UAV essentially files by itself after giving the necessary flight plans. Moreover, the data processing applications are becoming less expensive and easier to use (Sylvester, E-AGRICULTURE IN ACTION:, 2018). Ground-based methods for crop monitoring are more time consuming and tedious. In a field like crop monitoring where temporal datasets are needed, carrying out ground-based survey works could not fulfil the requirements of the project.

Crop Monitoring

The process of monitoring different phenological stages of the crop's life cycle is called crop monitoring. The monitoring of crop and performance during development stages is an important aspect of agricultural management (Stars-Project, 2018)). Crops do not grow evenly all over the plot due to differences in light, nutrition. UAV can be used for monitoring crop growth. During different development stages of crops, crop height gives important information of crop growth and health. By using UAV imagery variation of plant height within the field can be easily visualized; thus, it helps in effective measures to increase productivity. CSM simply represents the plant height within the field. CSM can give important information about crop growth (Sylvester, E-AGRICULTURE IN ACTION:, 2018). CSM can be obtained by subtracting the DSM of crop plot from the DSM of barren land.

A Vegetation Index is a spectral transformation of two or more bands designed to enhance the contribution of vegetation properties and allow reliable spatial and temporal inter-comparison of terrestrial photosynthetic activity and canopy structural variations (Huete, A.; Didan K., Miura T., Rodriquez E. P., Gao X. & Ferreria L. G, 2000). Vegetation Index can also be defined as some mathematical combination or transformation of spectral bands that accentuates the spectral properties of green plants so that they appear distinct from other image features (Enhancing green vegetation, 2010). Several vegetation indices have been developed for monitoring the crop. Vegetation Indices can be used to identify stressed plants, identify green parts within the field, nutrient deficiencies, damaged plants and plant species in crop fields, detecting soil properties like gravimetric soil water content, pH, organic matter etc.

Some of the commonly used Vegetation Indices are:

Normalized Difference Vegetation Index (NDVI)

NDVI =(NIR-R)/(NIR+R)

Normalized ratio of reflectance of NIR and R bands that ranges from -1 to 1.

ExG Vegetation Index (ExGVI)

ExG VI = 2G-R-B

Where G, R and B are the reflectance values of green, red and blue light respectively. ExGVI indicates the greenness present in the field which ultimately gives the amount of vegetation present in the field.

Green Red Vegetation Index (GRVI)

GRVI = (G-R)/ (G+R)

Where G and R are the reflectance values of green and red light respectively. GRVI is the normalized vegetation index used for calculating greenness of the plant and its value ranges from -1 to 1. Places having more green features have the GRVI value near to 1 and places having more red features have the GRVI value near to -1.

Life Cycle of Maize Plant

Zea Mays is commonly called as Maize and is one of the most grown cereal crops grown worldwide. Without the proper understanding of the plant's life cycle and its phenological stages crop monitoring could not be possible. By understanding the plant's life cycle, we could easily understand the growth stages and nutrition requirements of the plant. Various phenological stages of the Maize plant is are as follows:

Week 0: Germination and emergence
Week 0-2: Beginning of Tillering
Week 2-4: Formation of Tillering
Week 4-6: Leaf development stage
Week 7-9: Stem extension
Week 9-10: Flowering
Week 11-18: Ripening

Growth of Maize plant can be differentiated into two parts i.e., vegetative growth stage and reproductive growth stage. Vegetative growth stages are denoted by the label 'V' and reproductive stage with 'R'. Vegetative parts of the plant grow like the root system, leaves and stem. It takes 7-8 weeks to complete vegetative stage where the size and height of the plant is determined. Reproductive stage of the plant starts, once the plant starts to develop the silk from the top of the corn plant. Rest of the R stages depend on the development of the kernels, or seeds in the ear of the corn. R stages begin when the tassel pollinates the ear. To be able to identify the next stages of corn development, husk should be removed. As soon as seeds are fertilized, they begin developing. Seeds that are fertilized first are on the base of the ear, and as seeds get fertilized, they fill the ear to its tip. Kernel or the seed of the corn plant consists of three main parts: the pericarp (also known as seed coat), the starchy endosperm, and the germ (embryo). Pericarp part of the seed protects it before it is planted and after it has been planted against bacteria and fungi. Endosperm part of the seed provides enough energy for the plant to start growing and producing leaves. And lastly, the embryo part of the seed contains firstly developed parts in new seedling, consists of the point when the corn plant starts growing, which includes the first five to six leaves, and it also contains the initial root. (Austrilian Government Office of the Gene Technology Regulator, 2008).

Leaf Area Index

Leaf Area Index (LAI) is another method of monitoring crop growth. LAI is defined as the one-sided green leaf area per unit ground area in broadleaf canopies, or as the projected needleleaf area per unit ground area in needle canopies (WatsonDJ, 1947). LAI is a dimensionless quantity characterizing the canopy of an ecosystem. LAI index varies from 0 to 10, 0 is for bare land and 10 for dense forests. A canopy with a LAI of 3 means leaf area to ground area ratio is 3:1 and LAI of 1 means ratio of leaf area to ground area is 1:1.

Biomass

Crop biomass serves as one of the critical inputs in growth monitoring and yield estimation models, and plays an important role in agricultural, ecological, and meteorological applications (Eitel, J.U.H.; Magney, T.S.; Vierling, L.A.; Brown, T.T.; Huggins, 2014). It is, therefore, essential to accurately estimate crop biomass. However, accurate estimation of crop biomass remains a challenging task. Field measurement techniques, such as destructive sampling, can accurately obtain crop biomass. However, they are labor-intensive and time-consuming, and not suitable for large-scale spatial and temporal measurements (Li, W.; Niu, Z.; Huang, N.; Wang, C.; Gao, S.; Wu, C, 2015). Estimation of biomass from remote sensing imagery is also an option but they do not seem to give accurate results (Gong, P.; Pu, R.; Biging, G.S.; Larrieu, M.R, 2003). Various models developed from statistical and modelling techniques were developed in the past decade but they seem to vary due to climatic conditions, soil type, and soil reflectance. Passive optical sensors record electromagnetic energy which is mostly reflected or absorbed in the uppermost canopy layers. In this case, optical remote sensing sensors provide limited information of vegetation vertical structure, the estimation accuracy of crop biomass may, therefore, be affected (Chen, J.M.; Cihlar, J., 1996). Thus, for the accurate estimation of biomass, combination of remote sensing data and field-based data were used.

Methods and materials

The methods used for accomplishing the project are discussed in this section. The workflow of the method used is demonstrated in the flowchart below.

Planning, Reconnaissance and Establishment of GCPs.

The Maize field of RaviOP, Kavre, Nepal was chosen as our project site. Horizontal and vertical control points were established using static DGPS surveys. Stonex S8+ DGPS was used. Three DGPS sets were used out of which one was used for base station and two were used for rover stations. For a static DGPS survey the base station was selected and kept in one control point. Two rovers were used for establishing the control points. Rovers were kept for twenty minutes in each station and the time overlap between two rovers was ten minutes. Then, data was downloaded in RINEX format and further processed using freely available open-source software to get coordinate values.

Flight planning and Image Processing

Images were captured in different phenological stages using DJI Phantom 3 Advanced UAV. Control DJI and Pix4Dcapture applications were used for the flight planning. End and side overlap were entered. End overlap was 80% and side overlap was 60%. The flying altitude of the UAV was kept at twenty-five meters.

Then images were processed in webODM to generate Digital Surface Model (DSM) and Orthomosaic. With the help of QGIS, we processed the DSMs of different growth stages of the maize plant and the Crop Surface Model was developed. The orthomosaic is used to calculate the GRVI for each flight. The method used to complete this project is shown in the flowchart below.

Growth monitoring

Growth of maize crop can be monitored by two approaches. Growth can be seen by the help of CSM and vegetation indices. CSM of crop simply represents the height of the crop. Images captured at different phenological stages were used in order to monitor the growth of maize crop. We have subtracted the DSM value of crop plot with the initial DSM of the crop plot, which helps to obtain the CSM of crop. Subtraction of DSM was done in QGIS. Thus, the obtained raster was a representation of CSM. Also, growth was monitored by the help of vegetation index. With increasing in the height of crop the value of GRVI also increases. LAI of the crop plot increases with increasing the height of the crop which eventually helps in monitoring the crop growth. GRVI was calculated in QGIS by using the image analysis tool where we defined the formula of GRVI. Input field for

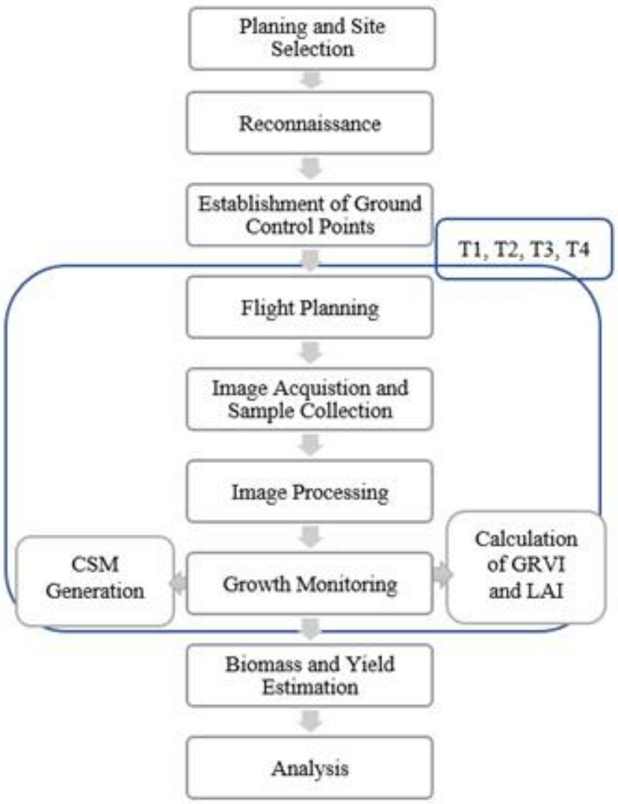

Figure 1:Methodological Workflow

calculation of GRVI was orthomosaic having three bands Red, Green and Blue.

$$GRVI = (G-R) / (G+R) \quad (1)$$

where,

GRVI= Green Red Vegetation Index
R=Recorded value of red band
G=Recorded value of green band
B= Recorded value of blue band

LAI of the maize plant was calculated by a field-based method. For the calculation of LAI, we designed a sample quadrat of size 1m x 1m. Four such quadrats were placed in the trial plots whereas five in demo plots. The plant height and LAI of the plants that fall in the region of such quadrats were measured. Pathic D (Pathic D, 2001) has developed a way for calculating LAI through non-destructive way. For each sample quadrant we measure the plant height, number of leaves present, maximum width of each leaf and length of each leaf.

Where l is the length of the leaf, w is the maximum width of the leaf, is the area of the leaf, is the number of leaves present in the plant, is the average area of leaf in a plant, is the average number of plants in the sample area, A is the total area of the sample plot and LAI is the Leaf Area Index.

Crop yield and biomass estimation

For the estimation of biomass and crop yield, wet biomass and wet mass of yield was measured from sample plots. The relation between the biomass and plant height and biomass and vegetation index and relation between yield and biomass and yield and vegetation index and yield and plant height are generated and analyzed. Low coefficient of determination is obtained in some cases where the data are not highly correlated, this occurs due to some sample plant having the average plant height but no yield. The relation between the biomass and plant height and yield and biomass are more correlated than the relation between the others. So, we had estimated biomass with the relation with plant height and yield with the relation of biomass.

Relation of biomass with plant height and relation of crop yield biomass was developed. For the trial plots, three sample areas of each site were taken for developing the regression line and the rest one of each site is used for the model validation. Similarly, for the demo plots three sample areas of each site were used for the model development and the rest two of each site were used for the model validation. The developed model was used to estimate the biomass and crop yield of the plots. Plant height from CSM was used for estimating biomass and the biomass was used to estimate the yield.

Results and findings

Crop surface model

One of the major techniques for growth monitoring is the analysis of CSM obtained from different temporal datasets at different growth stages of the plant's life cycle. CSM allows to monitor growth by providing the plant height of the crop plots and helps to visualize how they are growing throughout the plot. For the validation of CSM, the data collected from the direct field survey was used. CSMs at different growth stages and the graph of the plant height at different growth stages is shown below.

Green-red vegetation index

Another approach to monitor the crop growth is the use of remote sensing products i.e., vegetation index of the plot.

Table 5: Developed regression models

Plot	Regression Model between Biomass(y) and Plant Height(x)	Coefficient of Determination (R^2)	Regression Model between Yield (y) and Biomass (x)	Coefficient of Determination (R^2)
T1	y = 0.0142x - 0.446	0.3046	y = 0.4499x + 1.554	0.5768
T2	y = 0.0214x - 2.863	0.5555	y = 0.1328x + 2.854	0.8209
T3	y = 0.015x - 0.814	0.4208	y = 0.3851x + 1.947	0.5778
T4	y = 0.012x - 0.067	0.5189	y = 0.2528x + 2.366	0.5662
T5	y = 0.0234x - 2.995	0.8624	y = 0.2835x + 2.458	0.7242
T6	y = 0.0052x + 1.860	0.5309	y = 0.6715x + 0.845	0.6464
T7	y = 0.0167x - 1.518	0.4907	y = 0.3518x + 1.763	0.6325
T8	y = 0.0165x - 1.901	0.8008	y = 0.2234x + 2.214	0.4282
T9	y = 0.0102x + 0.608	0.343	y = 0.3512x + 2.152	0.7783
A1	y = 0.0066x + 1.169	0.5806	y = 0.5068x + 1.641	0.6309
A2	y = 0.0056x + 1.265	0.5756	y = 0.4876x + 0.706	0.4703
B1	y = 0.0186x - 1.885	0.6314	y = 0.6856x + 0.666	0.4185
B2	y = 0.0109x + 0.259	0.6711	y = 0.8545x + 0.095	0.7974
C	y = 0.0108x + 0.6898	0.4343	y = 0.1918x + 2.618	0.5033

Among various types of sensors that could be used for crop monitoring according to the need, requirement and availability we have used the RGB band and with the help of that we calculated the GRVI. GRVI gives the greenness of the crop. Thus, the greener the plant, the higher the value of GRVI. From the emergence stage of the plant to the flowering stage, the number of leaves continuously increases and also the greenness thus increasing the value of GRVI. As the plant reaches the maturity stage, the leaves start to turn yellow, decreasing the value of GRVI. From the figure below, we can deduce that the GRVI value of the plant increases with time in the earlier stages and has decreased at the final stage.

Estimation of yield and biomass

Relations between various factors that help in monitoring plant growth and estimating yield of the plant were developed. From the data collected in various stages of the project, relations between various factors are generated and

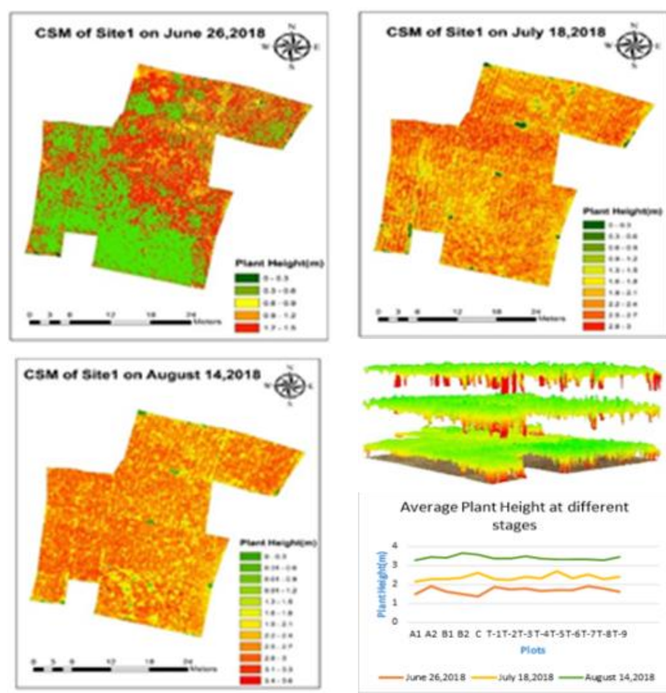

Figure 14: CSM on June 26, July 18 and August 14

then validated. The relation of plant height and biomass is used to estimate the biomass which was then used for estimating the yield of the maize plant.

Discussion and Conclusion

This study has introduced a simple method for monitoring growth and estimating yield of maize plants through the use of a low altitude remote sensing platform. The plant height can be modeled with a very high accuracy for different growth stages of maize using UAV based high resolution images. Size, design, texture and number of GCPs were suitable for the study since they could be clearly identified in the images. With increasing height of maize plants, the visibility of the GCPs at the chosen place was obstructed by plants in some cases. Flight planning including flight route generation enabled capturing images of the study area. Generally weather conditions limit the applicability of a UAV-system for data collection.

Besides inaccuracies caused by moving plants during data acquisition or inaccuracy of the DGPS data, the resulting

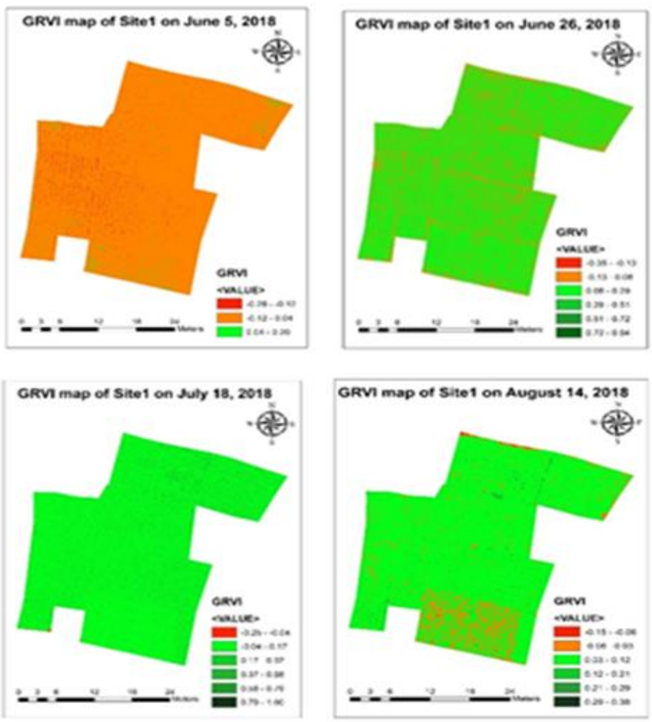

Figure 15: GRVI Map at Different Growth Stages

CSMs enable plant growth monitoring with very high accuracy. Vegetation indices and plant height also contribute to the estimation of yield. The mean height difference between CSM and field survey showed some error in plant height estimation also same errors occurred in the estimated yield. The main possible reasons for the errors in the plant height are CSMs becoming more complex as the height of plants goes on increasing and due to the similar patterns of the leaves, tie points matching become more complex. Also, another reason is the difficulty in measuring

Table 6: Estimated biomass and Yield

Plot	Total Estimated Biomass (kg)	Estimated Biomass kg per Sq. meter	Estimated Yield kg per Sq. Meter	Total Estimated Yield (kg)	Error in Validation
T1	101.761	4.0704	3.3853	84	2.45%
T2	94.5015	3.7800	3.3566	83	4.30%
T3	95.2856	3.8114	3.4155	85	1.00%
T4	92.0575	3.6823	3.2975	82	1.15%
T5	107.93	4.3172	3.6819	92	1.23%
T6	83.285	3.3314	3.0829	77	3.13%
T7	90.9431	3.6377	3.0433	76	1.01%
T8	78.3706	3.1348	2.9146	72	2.15%
T9	97.0045	3.8801	3.5149	87	1.67%
A1	458.931	3.0595	3.1915	478	4.17%
A2	433.662	2.8910	2.1159	317	3.76%
B1	536.349	3.5756	3.1183	467	1.38%
B2	500.842	3.3389	2.9484	442	4.85%
C	530.988	3.5399	3.2969	494	2.25%

the height of the plants in the field as the plants are too high in height.

Crop growth can be monitored well with the help of low altitude remote sensing and also with the vegetation index and yield can be estimated. Open-source software such as webODM and QGIS can be used in the field of agriculture for growth monitoring and estimating the yield of the crops. With the help of webODM, images captured from UAV can be processed to generate DSM and orthomosaic. The generated DSM and orthomosaic can be used for monitoring the growth of the crop by calculating crop surface model and vegetation index such as GRVI. Crop surface models provide important information about the height of the crops and help in monitoring the growth in different stages of crop lifecycle. So, the open-source system could be a milestone to bring revolution in the field of agriculture. These technologies can be used to monitor the crop growth in each and every development stage of the crop.

Acknowledgement

The authors would like to express gratitude to the CIMMYT -Nepal for providing their continuous support for the study. We would like to acknowledge Shangharsha Thapa for his support. Also, we would like to thank Shashish Maharjan, Srijana Paudel, Kushal K.C. and Naba Raj Koirala for their support and coordination. We acknowledge University Grant Commission (UGC) Nepal for financial support under the Faculty Research Grant (Award No. FRG-73/74-Engg-01).

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Multi-temporal Unmanned Aerial Vehicle (UAV) data for Quantitative Measurement of Soil Deposition and River Track Change due to Flooding in an Agricultural Watershed

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Abstract

River floods in Nepal have damaged more than 400,000 hectares of productive agricultural lands. Basic needs, for instance, food are listed as the major sustainable development goals by the UN indicating a major issue and need of enduring solutions . One of the crucial reasons for damaging those productive lands is erosion. Erosion is the process by which natural forces move weathered rock and soil from one place to another. Gravity, running water, glaciers, waves, and wind all cause erosion. The material moved by erosion is sediment. And deposition occurs when the agents (wind or water) of erosion lay down sediment. With a high rate of population growth, subsistence-based rustic economy, and progressively strong rainfall events within the monsoon season, Nepal is inclined to several forms of debasement, such as floods, landslides, and soil erosion. Due to this annual flooding and erosion, the river tends to change its path creating parcel border issues demanding readjustment of land parcels close to the river banks. Moreover, agricultural crops damage and physical infrastructure destruction seems to be another momentous effect of soil erosion and deposition despite several infrastructural, awareness-raising and policy measures.

The efficient implementation of conservation management practices in agricultural and urban areas still remains a major challenge of soil conservation. Several traditional approaches have been made to quantify the amount of soil deposition caused due to erosion. Such studies are made much more facile with the use of the remote sensing techniques. However, these earth observing satellite techniques are limited to low spatio-temporal resolution, compromising the quality of overall result. These days, the Unmanned Aircraft Vehicle (UAV), a low altitude remote sensing technique, has become a powerful tool in geospatial technology for quantifying natural disasters. UAVs have been proven to be a well known tool within the geoscience domain for demonstrating the use of high-resolution datasets to monitor topographic change-detection studies at reasonable cost. This research aims to focus on the application of UAV to fill the data gap between field scale and satellite scale to investigate the dynamics of deposition in a certain section of Punyamata River, Dhulikhel, Nepal. The terrain within the study area has overall flat topography with an elevation of approximately 1447-1451 metres above mean sea level. With the analysis of Digital Terrain Model (DTM) and the orthomosaics of different time periods, this research focuses not just to quantify the volume change but also to analyze the change in river track.

The overall data was collected using a hybrid method of surveying technique which normally incorporates using UAV for aerial survey and Differential Global Positioning Service (DGPS) for high precision ground control points to be used later for georeferencing UAV images. UAV images were acquired on three different time frames (February 2016, January 2018 and June 2021) at an altitude of 50m. The frontal and side overlap was set to 80-60%. An adequate number of GCP's were established in order to obtain optimal accuracy. In addition to UAV surveys, total station (TS) based ground surveys were conducted in the area so that the collected point data could be later used in the validation of UAV derived DTMs. River cross section data were also measured at several chainages in order to compare it with cross sections derived from DTM.

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The acquired images were post-processed using an open source software application called OpenDroneMap i.e. WebODM, a convenient and extendable application for aerial image processing. The chosen software application provides a web interface to ODM with proper visualization to produce georeferenced orthomosaics and DTMs of respective time periods. As the GCP distribution pattern affects the overall accuracy of the UAV derived products, an attempt to find out the optimal GCP distribution pattern was made and eventually applied to create the photogrammetric products i.e. the orthomosaics, DTMs etc. The accuracy of derived DTMs were validated against the data collected from TS. The cross-section data collected using TS at 3 different chainages of the river was compared with cross-section derived from DTM at the same location to analyze the change in elevation due to deposition. Finally, these accuracy assessed DTMs were used to quantify the overall soil deposition in the study area. Orthomosaics were used to visualize the change in river flow path using QGIS.

The case study shows that UAVs seem to be capable of generating a time and cost effective method of monitoring, estimating and mapping the spatial and temporal variability of soil deposition/depletion along the river shores. Furthermore, such results could serve as an asset for visual inspection of the damage caused to the physical infrastructures. Routine observation of the river and its bank may be considered as an alternative method for surveying, recording and processing river centerline and cross section data for flood modelling and flood hazard analysis. The generation of high resolution orthophoto allows policy makers to visualize the river course change over an interval of time and implement preventive measures. These datasets can be used to analyze the adverse effect of flooding on agricultural ecosystems and fight against hunger which is listed second on Sustainable Development Goals by the United Nations. Local government bodies can benefit from the high resolution UAV datasets to visualize the land parcel change due to change in the river track, update the geo-database and even reckon the compensation for the loss obtained.

Keywords : Flooding, soil deposition, UAV photogrammetry, river track change, spatio-temporal volume change.

Banana Acreage estimation using Sentinel-2 data and Google Earth Engine over Chamarajanagar district, Karnataka, India

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Abstract:

Acreage estimation under a particular crop is an important aspect of farming. Obtaining the acreage information using traditional survey methods is labor intensive and time consuming, which makes it difficult to collect the data frequently and accurately over large region. Whereas with the help of remote sensing techniques we can estimate the crop acreage with much ease and over large regions with less manpower. Crop acreage information is useful for crop insurance agencies and government firms especially in case of crop loss. Providing accurate and timely data will reduce the burden for farmers. Current study aims at estimating the crop acreage of Banana over Chamarajanagar district of Karnataka, India using Sentinel-2 data from Jan- 2020 to Jan-2021. The acreage estimation is performed using the Google Earth Engine. Unsupervised classification has been performed on NDVI raster and Supervised classification (Random Forest) using training datasets on the same platform, the acreage obtained by both the techniques, then compared with the field acreage. The obtained Banana acreage through Supervised classification showed deviation of 6.68% from it's field value recorded by district agriculture department. Detailed accuracy assessment for Supervised classification resulted in overall classification accuracy of 86.3% for Banana class using confusion matrix and Kappa coefficient as 0.957. Thus, Classification results showed that the Supervised classification method is more efficient and accurate for finding acreage compared to Unsupervised classification techniques.

Keywords : Acreage, Google Earth Engine (GEE), Banana, Sentinel-2;

Introduction

Agriculture is one of the most important parts of our country and Indian economy too. Due to many natural disasters like heavy rains, severe droughts, floods etc., may cause harm to crops present in the agricultural fields. In such situations, the Government's role is to pay the penalty to the farmers and the penalty depends on the type of harm caused to the crops, type of crop present in the field and the acreage under that particular crop. So, it isn't always possible to go to the field and get frequent updates regarding the area under each crop.

Policies made for farmers by different insurance agencies also depend on the acreage and type of crop present in the field, so to avoid the different types of investments in going to the field and measuring the areas manually, remote sensing technology can be used.

In case of different fruit crops grown in India, Banana stands second as per its importance. According to the export criteria, it has good exports. In all over the world almost in 120 countries, Banana is grown. The origin of Banana is mainly from humid areas in tropical regions having warm atmospheric conditions. As if we consider the production of Banana in India, it has the highest production and when we deal with areas under the Banana crops, it stands third in all fruit crops. Banana mainly grows in the atmosphere where the temperature range is 15ºc to 35ºc and has relative humidity ranging from 75 to 85%. Planting of Banana can be done

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throughout the year except in too hot or too cold climate. The harvesting time of Banana is approximately 12 to 15 months from the time at which planting has been done ((*BANANA*, n.d.).

Optical remote sensing data can be helpful to analyze the connection between photosynthesis and optical properties of the leaves, various Vegetation Indices which can be used for discrimination of crop present in the field, one of the such index is NDVI (Normalized Difference Vegetation Index) which uses the RED band and Infrared part of Electromagnetic Spectrum (EMS) which can be used for the crop identification (Nageswara Rao et al. 2004; Rahman et al. 1991; Shao et al. 2010). Different satellites provide the optical data which are Landsat, MODIS, Sentinel-2 etc. this data have different spatial, temporal resolutions. MODIS NDVI time series can be used for crop identification directly instead of downloading the data and calculating NDVI values, but it fails to obtain higher accuracy because of lower spatial resolution (Gumma K. M., et al. 2014; Shao Y., et al. 2010). Depending upon the type of area chosen for study and quality of results wanted from the study, the use of satellite data may vary. However, Sentinel-2 has the highest spatial resolution among all optical data sources, which can be key for identification of small crop areas. While using Sentinel-2 data, studies have included only use of single day data (Mohite J.et al. (2016)) along with the comparison of the accuracies obtained using different classification techniques.

Shelestov A. et al. (2017), Amani M. et al. (2020), Luo et al. (2021) have introduced the GEE platform for classification and identification of crops. Luo et al (2021) have followed the use of GEE in recent years, for composite images of 10 day, 15 day and 30 day, the prepared composite were just for a specific number of days for Sentinel-1 data. Most of the referenced researchers have implemented use of NDVI time series for crop identification along with analysis performed on softwares, instead of cloud platform. Use of GEE for Sentinel-2 over a period of year along with machine learning algorithm haven't been focused much for crop discrimation and acreage estimation and it quite difficult to process Sentinel-2 data for a year Hence, present study involves use of GEE platform for visualization, processing and analysis of Sentinel-2 data, together with time-series NDVI variation for crop discrimination.

This study will be dealing with Banana acreage estimation over Chamarajanagar district using Sentinel-2 data. Visualization and analysis on the Sentinel-2 data will be done simultaneously on Google Earth Engine platform using JavaScript language. Overall scripts used during the study can be directly applied for the evaluation of acreages using Sentinel-2 satellite data having suitable shapefile of study area, training datasets and required time period. The results obtained using Supervised and Unsupervised classification are then validated using field data.

2. Literature Review

Remote Sensing plays an important role in spotting the crop present over the area and finding the acreage under a particular crop. Acreage using Remote Sensing depends mainly upon the type of the data and classification method. Vegetation Indices and their temporal variation plays a crucial role in recognizing the crop. Previous studies mainly involve the use of NDVI index along with its temporal variation. Below section contains the reviews of Literatures pertaining to the current study:

Use of IRS LISS II digital data and the NDVI data for acreage estimation under sugarcane visualized by Rejaur R., et al. (1991). Main objectives of study were identification of the extent of sugarcane area and mapping it with the help of remotely sensed and NDVI data. For differentiation of the features present in the study area, NDVI values have been used.

Crop classification using Landsat TM images along with ERDAS IMAGINE software were included in Noordman E., et al. (2003) research. For classifying the crops, study consists particularly use of 3 bands i.e., NIR, MIR, Red. ERDAS IMAGINE software was used for the supervised classification of the area after NDVI calculation along with 85% accuracy.

Nageshwara R., et al. (2004) have gone through the use of IRS 1D with LISS-III sensor for finding crop production and acreage under the crops in Kolar district. Maximum Likelihood Classification(MLC) algorithms were mainly used for the classification in growing periods. Accuracy has been calculated through the error matrix. Time-series NDVI variation found to be key criteria for acreage estimation.

Mapping of the banana plantations using SPOT-5 with the help of object-orientated classification were mapped by Johansen K., et al. (2009). The SPOT-5 result then compared with the results obtained from airborne images. Firstly, for knowing the agricultural area, the mask is prepared with the help of Definiens Professional Software.

For separability of banana plantations study involves the use of definiens tools. Accuracy obtained by using Definies and SPOT-5 is almost 92.64%.

Use of MODIS NDVI product, for mapping of different crops over Great Lakes Basin and NDVI temporal profiles (time-series variations) for crop discrimination were done by Shao Y., et al. (2010) different crops from 2002 to 2007. Creation of training data has been done by observing the time series NDVI. Through the generated training dataset different crops were classified from the cropland area. Pixel-wise accuracy has been found out for four major crops. Pixel -wise accuracy has been found out for four major crops, the obtained accuracy for overall classification is 84%.

Mapping of the rice crop in Odisha using MODIS NDVI time series data named under MOD09Q1, having 8 days of temporal resolution was studied by Gumma K. M., et al. (2014). In the processing part stacking of year wise satellite data from 2000 to 2011 is involved, followed by Unsupervised classification and matching of similar classes by visual matching/ interpretation with the help of correlation coefficients. The mean accuracy obtained for area identification was about 80%.

Use of LISS III, LISS IV data and their comparison for 3 districts in Gujarat state for acreage were estimated by Nishant N, et al. (2016) in their study. NDVI values for each pixel particularly for truth points have been obtained and classified into 6 clusters using Maximum Likelihood Classification on both the data. Acreage estimation followed by accuracy assessment has been done.

Acreage estimation under Grape crop and it's mapping using Sentinel-2 data visualized by Mohite J., et al. (2017). For classification, the evaluation of many classification techniques such as Random Forest, Artificial Neural Network and Support Vector Machine has been done for areas under Nashik district in Maharashtra. According to the result obtained in the study, Random Forest is one of the best algorithms in case of crop classification compared to the other classification methods. Accuracy achieved by this method is 90%.

Feasibility and accuracy for mapping of multiple crop types, using MODIS EVI & NDVI time series data for 3 years of data from 2015-17 were examined by Yanfei W., et al. (2019). Study involves the derivation of phenological matrices. For classification Random Forest classification has been used, the software used for Random Forest was EnMAP-Box environment which is open source. The accuracy obtained through this was about 70%.

Areas under banana crop growing in the districts using SAR images of Sentinel 1A with VV and VH polarization have been focused by Karthikkumar A., et al. (2019). In case of preprocessing, study involves use of MAPscape-RICE software and classification purpose MTF algorithm has been used. For training and validation consist of use error matrix and kappa statistics. The accuracy obtained in the study using Sentinel-1A SAR data was about 87%.

Sehgal V. K., et al. (2020) studied the method of disaggregation at district level using the Enhanced Vegetation Index(EVI) for sorghum and wheat in Parbhani district, Maharashtra. The satellite dataset used for the study was MODIS product MOD13A1 having temporal resolution of 15 days. To map the crops, the decision tree method has been used for cross verification purposes the statistics given by the agricultural department of state has been used and error through Remote Sensing method has been obtained.

Application of Object-Oriented classification on Google Earth Engine platform using Sentinel-1 data focused on work carried out by Luo C., et al. (2021). Data used for the study is from May to September, it is observed that for seasonal crops growing in this duration shows that 10- day composite give improved accuracy compared to 15-day and 30-day composites, Random Forest classification has performed after Object-Oriented classification followed by accuracy assessment. Study introduced the completely new cloud computing platform named as Google Earth Engine (GEE) for processing and analysis, which helps enhance the speed of analysis and processing.

3.1. Methods and Materials

This section consists of the methods followed forc ollection, visualization and analysis of the data.

3.1. Study crop and study area:

Planting of Banana can be done throughout the year except in too hot or too cold climate. The harvesting time of Banana is approximately 12 to 15 months from the time at which planting has been done.

The study area shown in fig.1 is Chamarajanagar district (11º55'17.40" N, 76º56'21.52" E) located in Karnataka state, India (Figure 1). Chamarajanagar comprises the taluks which are Gundlupet, Chamarajanagar, Yelandur and Kollegal. Chamarajanagar district has 5700 sq.km geographical area. In case of soil types mainly it has Medium black soil followed by Red loamy soil and Red sandy soil.

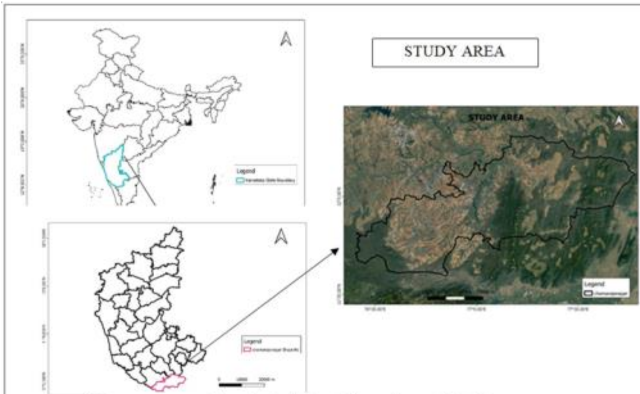

Figure 1: Study Area (Chamarajanagar District)

The main cultivated crops in Chamarajanagar are Maize, Paddy, Pulses, Sugarcane, Sunflower, Banana, Coconut, Turmeric, Jowar. The temperature in the district varies from 10°C in winters to 32°Cin summer.

3.2 Methodology Framework:

The flowchart shows the steps followed during the acreage estimation under Banana crop over whole Chamarajanagar district.

1.3 Data Processing

Sentinel-2 data were directly loaded on Google Earth Engine (GEE) for period of Jan-2020 to Jan-2021. Google Earth Engine (GEE) is the platform where we can visualize the geospatial data all over the globe.

This link (https:// explorer.earthengine.google.com/) will take us to the Google Earth Engine. The API of Google Earth Engine is available in JavaScript and Python. For interaction purposes Google Earth Engine's Code Editor is helpful, link for the Code Editor is (code.earthengine.google.com). The code editor is a web-based IDE for API. Cloud masking of the data has been done using QA60 band present in Sentinel-2 data followed

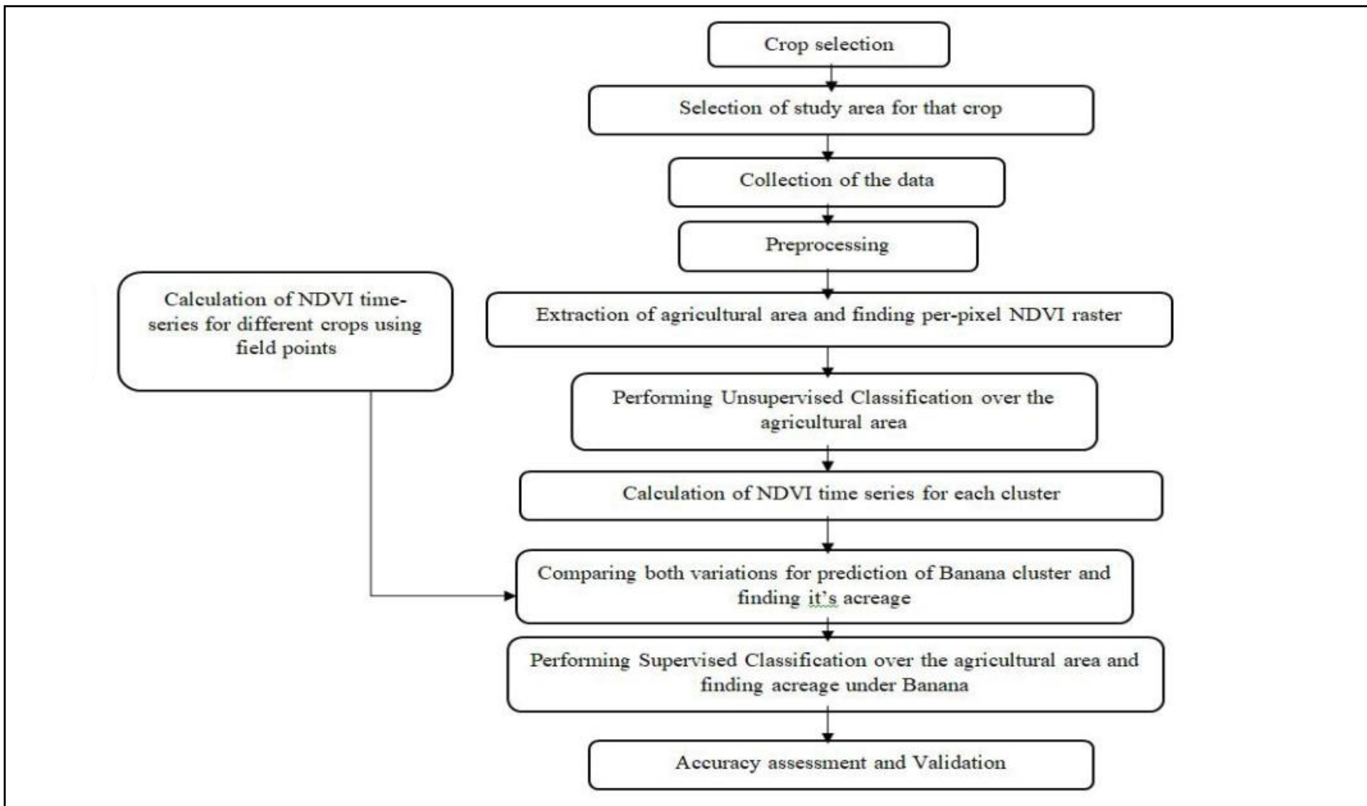

Figure 2: Flowchart of the Methodology

by clipping the data for the agricultural area of Chamarajanagar. Agricultural area of Chamarajanagar district was evaluated using MODIS (MCD12Q1) Land Use Land Cover product. Preprocessed data then processed for calculation of per-pixel NDVI raster followed by Unsupervised and Supervised classification.

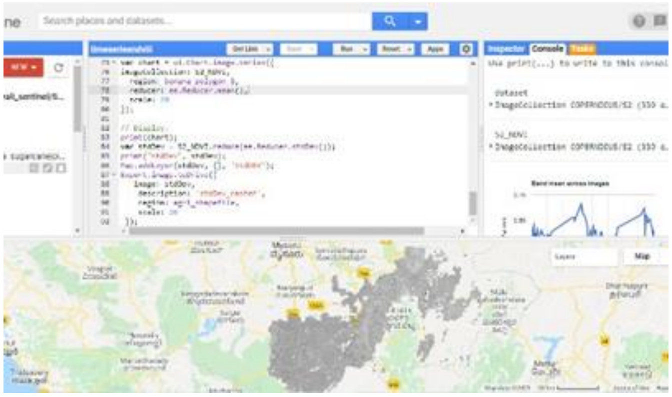

Figure 3: Sample view of Google Earth Engine Code Editor.

1.4 Unsupervised classification:

Unsupervised classification is also referred to as clustering. In this method, we don't need to have training datasets; the general input given in case of unsupervised classification is number of clusters or number of classes that we want to divide the data into. Unsupervised classification works better when training data isn't available. Banana cluster identification has been done through NDVI time series variation along with it's mean values. (Shao Y., et al. (2010); Gumma K. M., et al. (2014); Yanfei W., et al. (2019); Sehgal V. K., et al. (2020)).

3.5 Supervised classification:

Supervised classification uses the information called training data which consists of the number and the information of classes in which we have to classify our whole study area. Study includes the use of Random Forest algorithm for classification. Random Forest is a Supervised Machine learning algorithm which uses the number of trees as input for classification of the data. After giving inputs as training dataset in the decision tree, automatically it formulates the rules for making predictions of the features in which it will lie. Random Forest machine learning algorithm works better for crop classification compared to other Supervised classification (Ok A. O. et al. (2012); Hao P. et al. (2015); Mohite J. et al. (2017)).

4. Result and findings

Study employs cloud masking over the clipped agricultural area and finding the mosaic of NDVI raster followed by classification. Unsupervised classification (clustering) was performed by taking input as a mosaic of mean NDVI value. Unsupervised classification consists of formation of 4 clusters, determinationof Banana class among all four clusters has been done by observing NDVI variation of the clusters throughout the year along with the box-plots. The cluster numbered as one were showing the similar NDVI behavior as Banana (Figure 4). The mean NDVI values for cluster numbered as one were having values equal to and greater than 0.4 as shown in the box-plots (Figure 5, 6).

Obtained Banana cluster from Unsupervised classification has acreage of 12746 hector (Figure 7) and field Banana acreage is 10040 hector.

Coming to Supervised classification, polygon shapefiles of farm boundaries were used as training datasets for performing Random Forest machine learning algorithm. The resulting class obtained after performing Supervised classification has an area of 10735 hectares (Figure 8).

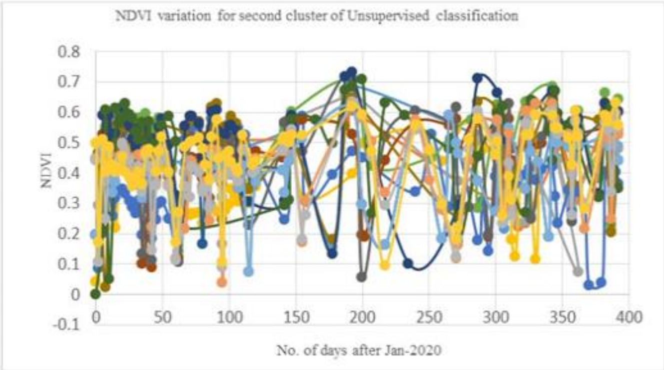

Figure 4: NDVI variation for second cluster (numbered as 1) of Unsupervised classification

Accuracy estimation of supervised classification consists of the confusion matrix analysis, kappa coefficient, user accuracy and producer accuracy. All the above analysis and processing were performed on Google Earth Engine(GEE) using JavaScript language. The confusion matrix obtained is as follows

Accuracy for Banana class = 0.8748

Figure 5: Box-plot for second cluster of Unsupervised Classification

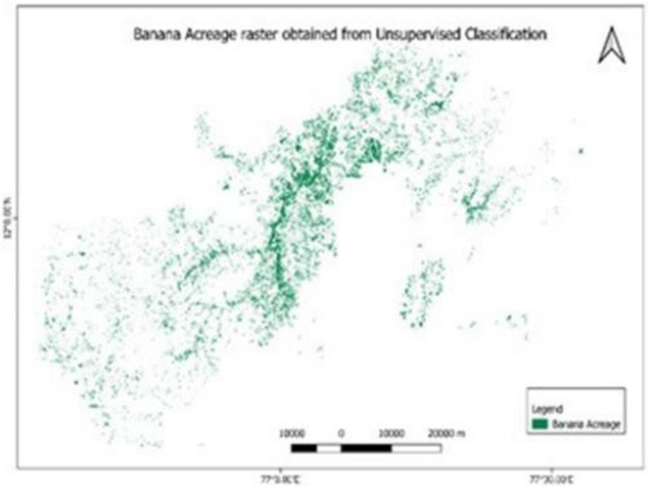

Figure 7: Result obtained for Banana Acreage raster obtained from Unsupervised Classification

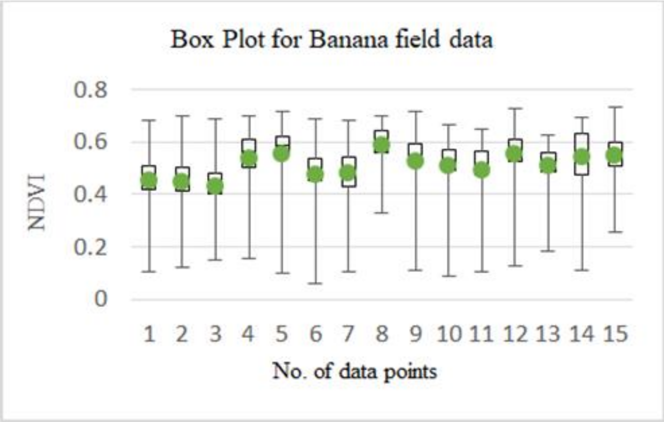

Figure 6: Box-plot for Banana field data

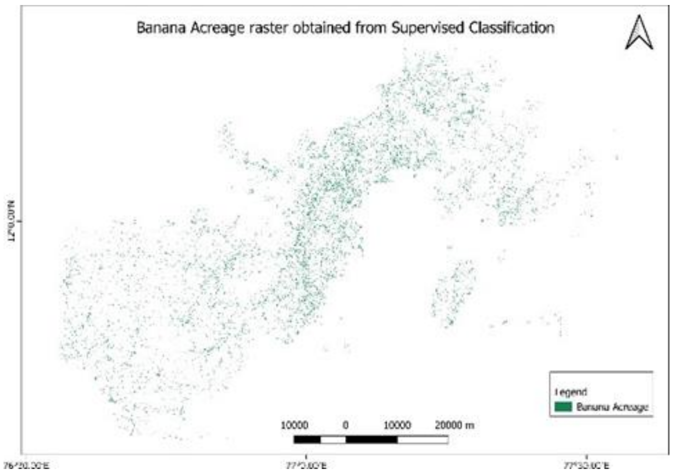

Figure 8: Result obtained for Banana Acreage raster obtained from Supervised Classification

Obtained user and Producer accuracy for Banana class is 0.979 and 0.875 respectively, along with Kappa coefficient of 0.9535. For validation of obtained results, 35 Banana location were used out of 35,27 locations were falling in Banana class as per Unsupervised classification is concern and 30 were falling in Banana class for Supervised classification. The validation accuracies obtained for Unsupervised and Supervised classification are 77.14% and 85.714% respectively.

5. Discussion and Conclusion

This study aims at acreage estimation under Banana crop over Chamarajanagar district using Unsupervised and Supervised classification methods along with comparison of accuracies obtained by both the techniques. Compar- ing the obtained classification results with other studies reveals no surprise. Ok A. O. et al. (2012), Hao P. et al. (2015), Mohite J. et al. (2017), in their research concludes that Random Forest machine learning algorithm works better for crop classification compared to other Supervised classification. In this study also the accuracy obtained from Supervised classification is more compared to Unsu- pervised. Also, the current study shows time series NDVI works better for crop identification and mapping, same conclusion has been obtained by Shao Y., et al. (2010), Gumma K. M., et al. (2014), Yanfei W., et al. (2019), Sehgal V. K., et al. (2020)

in their study. Downloading the Sentinel-2 data offline all over the district and performing analysis is difficult and time consuming. Shelestov A. et al. (2017), Amani M. et al. (2020), Luo et al. (2021) have explained capability of Google Earth Engine (GEE) while dealing with machine learning algorithms for crop classification along with the enhancement of analysis process by using JavaScript coding language instead of download- ing the satellite data and processing it. Results depict that classification accuracy obtained for Banana class is 87.4% with 0.957 Kappa coefficient. From the validation results and obtained acreage values, it is observed that Supervised classification yields more accurate results compared to Unsupervised classification. The obtained NDVI variation over time-series can be useful to study phenological stages of Banana crop over the year. Addition to all above, deviation of only 6.68 % has been obtained through Random Forest algorithm compared to the field acreage value of Banana. This study is helpful to assess the alternative plat- form for finding the acreage under a particular crop using high spatial resolution optical data. Since the study has been done using optical data, the classification may not be possible during cloudy conditions. In such cases improving the model with microwave satellite data will be a step forward.

6. Acknowledgement

I take extreme pleasure in expressing my deep sense of gratitude to all faculties of Remote Sensing and GIS department from National Institute of Technology, Warangal for their constant support throughout my work and guiding me in fulfilling the objectives of my thesis. I would like to extend my gratitude towards Satyukt Analytics Pvt. Ltd. for constantly guiding and helping me in every phase of this project.

Lastly, I would like to thank my parents, friends and classmates for being my pillar of support through highs and lows and to have kept me ever enthusiastic for the completion of my research work.

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Multi Criteria evaluation for potential forest ecosystem resilience

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Abstract

Climate change is evident and posing many challenges to the existing ecosystem across the globe. The rapid rate of urbanization, bursting out of the population, exhaustion of natural resources are few reasons for climate change. Effects of climate change are occurrences of various natural disasters, extinction of flora and fauna, heat waves, melting of glaciers, forest fires, exploited watersheds, floods, drought, etc. Ecosystems are deteriorated and becoming vulnerable as it is getting disturbed by various causes. One of the most important terrestrial ecosystems is forest, which is shrinking day by day as forest areas are getting converted to agrarian lands, then into plantations or settlements. Forests are the oxygen tanks and need to be preserved at any cause. Ecosystem resilience is a measure of the ability of a system to recover from a damaged state. The study is carried out in Valmiki national park, West Champaran, Bihar, India which is bordering Nepal and is connected with Chitwan national park. The study aims to evaluate the ecological resilience of the area in order to understand, maintain and restore the ecological conditions. With the help of remote sensing datasets and ecology datasets, the resilience index is calculated for the area by considering factors that influence the forest ecosystem such as soil, terrain, climate, and ecology. For determining the resilience index, the indicators are uniformly reclassified and weights are assigned to the parameters based on the priority. Discriminate factor analysis is a robust technique that has been developed to find out the resilience index in a simpler way. Based on the results, the area is classified into five classes namely, very low, low, moderate, high, and very high. With the geospatial analysis, it is evident that the area is low to moderately resilient in the national park with an average of 2.56. Thus, better management of the national park is required to increase the resilience of the forest ecosystem by reducing anthropogenic activities and promoting green innovation. This conceptual study is also applicable to global-level studies in the path of mitigating climate change.

Keywords: Ecosystem resilience, resilience index, discriminate factor analysis, geospatial

1. Introduction

Earth is getting warmer day by day and one important reason for it is human-induced emissions of greenhouse gases. According to Intergovernmental Panel on Climate Change (IPCC), “Climate change is a huge threat to global health in the 21st century”. There are various researches that are going on climate change to understand the factors, effects and mitigation measures across the globe. Impacts of climate change are intense heat waves, sea level rise, melting of glaciers, etc. Climate change also has a huge impact on ecosystems:

> *“Ecosystem is a geographic area where plants, animals, and other organisms, as well as weather and landscape, work together to form a bubble of life” (Morgan Stanley, National geographic).*

Impact on the ecosystem due to climate change includes, extinction of species, migration and relocation of species, forest fires, dried watersheds, floods, etc. Forest is an important ecosystem, besides providing habitat for animals and livelihood for humans, forests also enhance groundwater potential, improve soil quality and mitigate climate change. Forest cover is the total geographical area declared as forest by the government.

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The total forest area across the globe is around 4.06 billion hectares, as of 2019:

> *"The total forest cover in India is 712,249 SqKm (71.22 million hectares), which is 21.67 percent of the total geographical area. Whereas, the total forest and tree cover in India is 807,276 SqKm (80.73 million hectors), which is 24.56 percent of the total geographical area of the country" (Forest Survey of India report, 2019).*

India is one among the ten countries which are responsible for Earth's green colour. There are so many initiatives in India which are focusing on improving the green (forest) and blue (water) cover of the country. Water bodies play a major role in forests as it is an essential component of the forest ecosystem. Restoration and repairing the water bodies across the country is improving the quality and quantity of water bodies. Afforestation is adapted in various regions, but there is a lack of indigenous plantation which results in the extinction of indigenous species in an area.

In order to provide land and food for the growing population, forests are getting converted to real estates and agrarian lands. As there is a positive trend in expansion of urbanization, there is also a positive trend in the decline of forest areas. Many aspects related to climate change are likely to affect forest growth and productivity. Ecosystem resilience is the measure of forest ability to recover to its original state after a state of damage. Forest resilience can be calculated by considering factors like terrain conditions, climate and ecology. There have been so many qualitative and quantitative researches related to forest ecosystem resilience which shows there is a declined trend of the resilience index across the globe. In a forest, younger flora are the ones which dies at an enormous rate during a disaster even though it has a higher resilience than the older ones (D'Amato et al. 2018; Ibanez et al. 2016):

> *"The resilience and stability viewpoints of the behaviour of ecological systems can yield very different approaches to the management of resources. The stability view emphasizes the equilibrium, the maintenance of a predictable world, and the harvesting of nature's excess production with as little fluctuation as possible" (C S. Holling, 1973).*

Floods are the most common natural disaster in India which results in various losses to the country. According to), "Forests are the lifelines for flood vulnerable households and India needs to shift its focus from flood relief to resilience and adaptation" (Kasturi et al, 2018).

2. Literature Review

Climate change increases the vulnerability of forests (Sharma J, 2017). Climate change results in biome shifts, frequent extreme events, changes in the rate of forest growth and mortality (Grimm N.B, 2013). To tackle the upcoming challenges, understanding resilience would be a huge step to model and simulate the scenarios. Resilience under ecology has been defined in numerous ways such as, to withstand an external pressure, time duration taken to bounce back, recover or transforming after stress (Holling CS,1973; Fisichelli NA et al, 2016). In forests, generally it is attributed with recovery, i.e., engineering resilience. It is the ability of an ecosystem to absorb the disturbances created by external factors and return to its original (undisturbed) state (C. Folke, 2006). Resilience is the ability to sustain external pressures and return to its original state after a period of time. At present, ecosystems are vulnerable thus, maintaining and restoring the ecosystem is an important attribute of climate change (FS Chapin, 2005). As the world is unpredictable and exposed to many threats, it is better to be prepared to face the challenges. "Enhanced resilience allows better anticipation of disasters and better planning to reduce disaster losses" (Committee on Science, Engineering, and Public Policy). Cutter et al (2008), generated a DROP (Disaster Resilience of Place) model which improves the assessment of disaster resilience at a local scale. Ives et al (1995), developed a mathematical tool for calculating resilience of a stochastic system (a system which doesn't have a constant behaviour, e.g., population). The study found that the resilience is high in places where the population density of a species is less. Most of the theories about resilience considers species populations at a large scale than the interactions that take place amongst individual organisms (C. Hawes et al, 2006). Currently, the theory of dissipative structures has proven to be effective and few researches has also been carried out based on the it (Haiming Yan et al, 2014).

Ecosystem resilience is value of the maximum amount of external stress (MS) it can withstand or reciprocal of the time taken by an ecosystem to re-bounce to its normal state (1/Tr) (E. M. Bennett, 2005). Changes in the ecosystem may lead to alterations in Net Primary Productivity (NPP) (Grimm N.B, 2013), which is attributed with climatic factors (Shufen Pan, 2015; Jha, 2019). Researchers are working on models which can represent the complete ecosystem resilience which in terms need a huge data requirement. Forest resilience can be measured by considering the factors influencing resilience like ecological memory, human disturbances, etc. (Haiming Yan et al, 2011). Also, Correlation analysis between Normalized Difference Vegetation Index (NDVI) /Enhanced Vegetation Index (EVI) and climatic factors identifies the resilience of forests (Maneesh Kumar, 2021). Forest ecosystem resilience across the globe shows a negative trend therefore, quantitative assessment of ecosystem resilience can be a step towards better understanding of the ecosystem processes (J. K. Strickland-Munro et al, 2010). Rosset et al (2011), assessed the resilience of species to warming in Switzerland, by considering five ecological and biogeographical factors and allotted equal weights to each of the factor which made the study biased whereas, Haiming Yan et al (2014), quantitatively assessed the forest ecosystem resilience in Yongxin County with stand conditions and ecological memory of the forest. By integrating the two and allotting weights to each and every indicator according to Analytical Hierarchy Process and Coefficient of variance method, the resilience was determined and divided into five classes namely, very low, low, medium, high and very high respectively in order to identify the vulnerability. There are also various ecological models which explains the mechanisms of resilience (G. C. Gallopín, 2006). Albrich. K et al (2020) analysed different types of simulation models that yields unique insights on the resilience, depending on the type of drivers and responses thar are relevant for a given study (Figure 2.1). Hirota et al (2011) and MD Behra (2018), modelled the forest resilience using logistic regression and polynomial equation. Both the studies were based on tree canopy cover and precipitation rates whereas, Staal et al (2018) analysed the interdependency of tree cover, forest fire and herbivory.

Anjos LJS et al (2018) measured the resilience by combining the ecological stability and niche theories. Based on the ensemble strategy the distribution of ecosystem was modelled in ten different methods, Bioclim (SRE), Classification Tree Analysis (CTA), Maxent, Random Forest (RF), Generalized Linear Models (GLM), Generalized Additive Models (GAM), Generalized Boosted Regression Models (GBM), Function Discriminant Analysis (FDA), Artificial Neural Networks (ANN), and Multiple Additive Regression Splines (MARS) then the quality of each models has been checked using True Skill Statistics (TSS) and Receiver Operating Characteristic (ROC) metrics.

It shows that grasslands present in high altitudes with arid environment, forests near the equator and savannas along continental diagonal polygon has high resilience in South America. P. Das et al (2018), used binary logistic regression technique to estimate the dependency of precipitation on forest cover resilience for India and found that the resilience shows a positive trend with precipitation. Later, with the help of MAPSS-CENTURY dynamic vegetation model version 2 (MC2 DVM) the study found that 83% of the forest in wet regime areas had high resilience whereas the remaining areas were low in resilience denoting perturbations (P. Das et al, 2019).

Van Nes et al (2014), generated a model for understanding the interaction between tree dynamics and environment by including two non-linear losses, low tree cover and fire mortality. By integrating vegetation and climate, tipping points and stable states can be predicted. Verbesselt et al (2016) carried out a study of tropical forests in three continents namely, Australia, Africa and South America to analyse the spatial pattern of inferred slowness in the

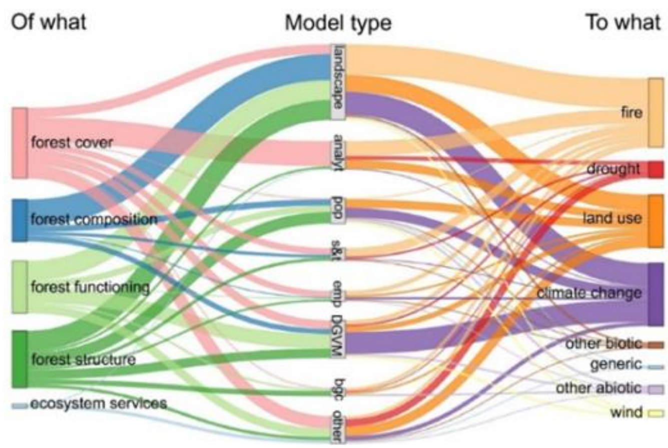

Figure 2.1: Models used for simulation

resilience. By considering Normalized Difference Vegetation Index (NDVI) and Vegetation Optical Depth (VOD) in additive regression model, it was found that the rise in temporal autocorrelation reflected the slowness. Also, resilience was low even at places with high precipitation denoting tipping points (Marina Hirota et al, 2011). These tipping points might gradually lead to critical slowing down, which is a phenomenon where the recovery takes more time than the usual. Critical slowing down is considered to be the early warning signals for loss of resilience in an ecosystem (Dai L, 2012).

3. Methods and Materials

3.1 Study Area

The study has been carried out in Valmiki national park, West Champaran, Bihar, India (Figure 3.1) covering an area of 335 SqKm. It lies between 83°50'– 84°10'E and 27°10'–27°30' N along the international border of Nepal connecting Chitwan national park. The region was prior called as Valmiki nagar and has a wildlife sanctuary from 1978. Later, in 1990 the national park was established which is a home to many species and it is the only tiger reserve in Bihar. Total forest area comprises of about 900 SqKm, out of which Valmiki Wildlife Sanctuary is 880 SqKm. The area has a humid subtropical climate with an average temperature of 26°C and an annual precipitation of 1472.6 mm. The Valmiki national park is situated in the gangetic plains and has bhabar, terai tracts. According to Champion and Seth classification, the park has seven types of forest namely, Sal, Sissoo, Cane brakes, Swamp, Mixed deciduous, Grasslands and dry Sal Forest. Gandak and Masan are the two rivers flowing through the national park.

3.2 Data and processing

The study has utilised Landsat – 8 OLI data from USGS, to prepare vegetation canopy map and Land Use Land Cover (LULC) map which is generated with the help of Semi-automatic Classification Plugin (SCP) in QGIS according to NRSC level-2 classification. SRTM data acquired from USGS has been used to understand the terrain conditions of the area by preparing slope and aspect maps for the area. Climate data from Worldclim.org has been considered for obtaining annual average temperature, annual precipitation and annual sunshine hours which is later recreated using Inverse Distance Weighted (IDW) interpolation technique. Soil fertility information is taken from farmer.gov.in website and demographic data was acquired from the official website of West Champaran which is also interpolated using the IDW technique. With the help of LecoS Plugin, various ecological parameters are determined for better understanding of the study area.

3.3 Methodology

The forest ecosystem resilience was quantitatively calculated with the help of following factors, climate, terrain, soil fertility, soil structure, population and biological legacy. These factors combinedly affect the resilience of the forest ecosystem (D. Zirlewagen et al, 2007). Terrain plays a huge role in determining the soil fertility, seed germination rate and plant growth. Usually, low slope areas are enriched with nutrients than high slope and plain areas (TJ Martin et al, 2002). The terrain indicators in this study include slope and aspect. Soil fertility and soil structure were considered for the study where organic content, nitrogen content and soil depth as indicators respectively as these indicators are important when it comes to structural loss and nutrient cycles (Carpenter et al, 2001). Climate has a huge impact in the growth of plants and thus indicators like annual average temperature, annual average precipitation and annual sunshine hours were considered for the study. Humans have a huge part in determining the resilience as anthropogenic activities leads to destruction of various resources. In the view of forest ecosystem, humans exploit all kind of resources available in the forest which leads to instability and negative trend in ecosystem resilience. Thus, for the study, population density was considered as an indicator. Vegetation canopy was considered as an indicator for biological factor, as tree cover in an area matters a lot in determining the resilience of the area. It is calculated with the help of Landsat-8 OLI data by deriving NDVI and then Leaf Area Index (LAI). At last, with the help of LecoS plugin in Qgis, ecological parameters were derived like patch area, patch density, splitting index, etc. to understand the distribution of different features.

After the needed indicators are generated, each and all indicators were reclassified from 1-5 to find out the resilience index for the study area. Then weights are allotted (Table 3.1) on the basis of priority. There are so many methodologies to find out the resilience index such as AHP (AHP), weighted overlay analysis, regression, coefficient of variance, etc, but this study has adapted Discriminate factor analysis, a new robust technique which solves the spatial

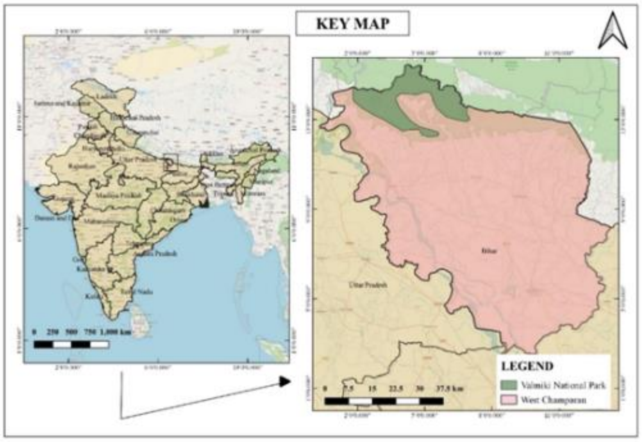

Figure 3.1: Key Map

problem by integrating geographical data and value judgments. It is similar to multicriteria analysis or multivariate decision support system. The formula used for generating the result is given in equation (1).

The equation to calculate the Resilience Index is,

$$((W1*I1)+(W2*I2)\dots+(Wn*In))/n \quad (1)$$

Where,

I – indicators
W – weights
n – total number of indicators

The analysis is carried out based on the pixel values of the raster files in raster calculator which is a tool available in the raster menu in QGIS

4. Results and Findings

The weights are assigned for each of the indicators and resilience index is calculated. Based on natural breaks method, the resilience index is divided (Table 4.1) into five classes namely, very low, low, moderate, high and very high

Table 3.1: Factors and its weights allotted for the study

Factors	Indicators	Weightage
Climate	Annual average temperature	0.075
	Annual average precipitation	0.09
	Annual sunshine hours	0.03
Soil fertility	Soil organic quantity	0.055
	Soil nitrogen quantity	0.065
Population	Population density	0.07
Terrain	Slope	0.25
	Aspect	0.08
Biological	Vegetation canopy	0.2
Soil structure	Soil depth	0.085

resilience levels. The resilience map (Figure 4.1) for the entire district. The result indicates that the resilience index of West Champaran district ranges between 0.19 – 9.73 with an average around 2.752. In the Valmiki national park, the resilience level is low to moderate with an average of 2.56.

The resilience map clearly depicts the resilience pattern which is mostly moderate and low resilience levels. Besides, a small region in the south eastern part of the district has high resilience which might be due to the presence of wetlands (inland). Areas with very low resilience is witnessed in the north eastern part of the district but in a very small areal coverage. The total area covered at each resilience has been calculated (Table 4.1). Almost 70.51% of the district is moderately resilient, 28.22% is low resilient, 1.08% is h ighly resilient, 0.18% is very low resilient and 0.01% is very highly resilient. This indicates that the resilience is not good and measures must be taken before the ecosystem completely falls under very low resilient category.

If the ecosystem resilience becomes low, then the species population within the national park will collapse. The Valmiki national park is covered with deciduous broadleaf forest which in general possess fertile soil. In the areas of high resilience, the soil quality is very high, tree cover is moderate and annual average precipitation is very low. On the other hand, moderate resilient areas are covered with croplands, high population density, less tree cover than the

Resilience Level	Resilienc e Index	Area (SqKm)	Area (%)
0.19 - 0.26	1	93.07	0.18
0.26 - 0.30	2	14698.21	28.22
0.30 - 0.37	3	36723.07	70.51
0.37 - 3.18	4	561.61	1.08
3.18 - 9.73	5	6.42	0.01

Table 4.1: Classification of Resilience index and their area at each resilience level

high resilient areas. Low resilient areas are along the district's boundary where the human population density and annual precipitation is very high attributed with low soil quality. Verbesselt et al (2016) has also stated that areas with high precipitation had low resilience in tropical forests, which is similar to the results obtained in this study.

Generally, in plain and low hilly areas, the indicators are favourable for human settlements and forests. Bihar being one of the Indian states situated in the gangetic plains (flat terrain) with high quality of soil makes it favourable for forests and humans. Inside the national park, there are almost 22,000 people residing in 26 revenue villages. Mostly the people are belonging to the Tharu community (scheduled tribes) whose livelihood depends on agriculture and forestry products. Also, the area has been exposed to mining activities, construction of resorts and hotels, over

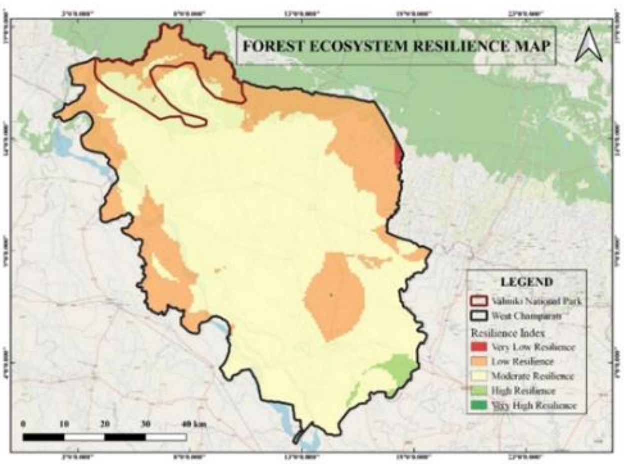

Figure 4.1: Resilience Map

grazing of cattle's leading to soil degradation, extensive usage of wood for commercial purposes, expansion of agrarian lands and many anthropogenic disturbances which has affected the ecosystem at a large scale. The northern part of the state is prone to water logging (floods) on an annual basis, which leads to damage of ecosystem functions. Recently, the state has started green initiative which encourages afforestation, green energy, green solutions, but resilience-based management is lacking which must be focused in order to sustain the climate change. Overall, the result yields a geospatial approach to estimate the forest ecosystem resilience index based on the influential factors.

5. Discussion and Conclusions

5.1 Discussion

This study has quantitatively measured the ecosystem resilience by considering factors that influence the ecosystem functions. However, to assess the ecosystem resilience more accurately many factors must be taken into consideration like ecological parameters, soil structure profiles, biological legacies and so on. In this study, ecological parameters like patch area, patch density, number of patches were determined with the help of Land Use Land Cover (LULC) map using LecoS plugin in Qgis software to get an overall idea about the distribution of various features in the region. It is found that the cropland has the highest number of patches. This is also evident with the help of sunburst map (Figure 5.1) which denotes 70% areal coverage of Cropland in the region followed by deciduous forest, rural areas. For the upcoming studies, ecological parameters can also be taken under consideration while evaluating the resilience of the area. Also, methods like multivariate analysis like the copula theories (Jha, 2019) can yield great results. There are so many researches and theories on ecosystem resilience but, still there is no clear theoretical foundations (Haiming Yan et al, 2014). Geospatial assessment of ecosystem is challenging as the data availability is limited to few ecological indicators which urges the need for the development of new assessment models to integrate all the possible indicators to estimate the ecosystem resilience.

This study has estimated the resilience by weighted sum indices of the selected ecosystem drivers which might not be very accurate but, is a robust technique to spatially assess the ecosystem resilience. In 2015, Bihar announced it would achieve 15 percent forest/tree cover through agro forestry and social forestry as schemes under MNREGA (Mahatma Gandhi National Rural Employment Guarantee Act 2005). Also, encouragement of farm nurseries in the private sectors are needed as the Environment and Forest department alone cannot fulfil the needs of the State.

Some of the measures that can be taken to improve the resilience are, prohibiting all kind of anthropogenic disturbances in the core area, encouraging agroforestry, rain water harvesting and better management of forest fires:

> *"Valmiki Tiger Reserve is an important landscape connecting tiger reserves in the Himalayan terai region and spread over India and Nepal. This area is constantly plagued by forest fires which are initiated by human activities" (Murthy et al, 2019).*

Adapting resilience-based management would be complex in the dynamic world but trying to take a step towards the approach is not a harm as climate change is creating many catastrophic events across the globe.

5.2 Conclusions

Ongoing climate change can hasten the loss of ecosystem resilience which would initiate the alle effect (increased mortality of trees). By considering the literature and availability of datasets, the study chose selective indicators of the influencing factors to estimate the ecosystem resilience and quantitatively assess the forest ecosystem resilience of the Valmiki national park. The result depicts that this conceptual model would be able to assess the ecosystem resilience at a global scale and identify the areas which are vulnerable in nature to provide mitigation measures and resilience-based management strategies. There

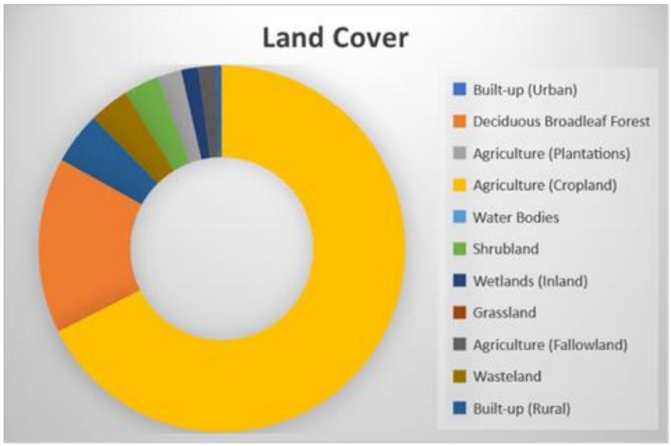

Figure 5.1: Areal distribution of LULC features

is still argument about integrating the necessary factors that are attributed with the ecosystem resilience and availability of high-resolution data is lacking. This geospatial assessment might not be accurate but the overall analysis could be an approach towards conservation of forests, which is a significant step towards mitigating climate change:

> *"Reducing vulnerability of forests and plantations in anticipation of climate change is a 'win-win' option whether or not climate change occurs" (Sharma J, 2017).*

Acknowledgement

First and foremost, we would like to thank God, the Almighty for blessing us with the strength and intellect during this COVID-19 pandemic and to cross all the obstacles that were placed in our way to complete this project. A hearty thanks to our family members for their constant motivation and support throughout the research work. We are thankful to the USGS, famer.gov.in, World clim, for providing the necessary datasets that was required for the study. We are also extremely thankful to the anonymous reviewers for their valuable suggestions.

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Continuous Assessment of Land Degradation and Its Impacts on Land Resources of Sivagangai Block, Tamil Nadu, India

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Abstract

Tamil Nadu is an agrarian state with more than 60% of its people still depending on agriculture for their livelihood. Out of the total geographical area of 13 million hectares, only about 50% is available for cultivation. This limited cultivable area is under severe strain due to increasing population pressure and competing demands of various land use. Because of this, there is a significant diversion of farmlands and water resources for non-agricultural purposes. Further, degradation due to soil erosion, salinity/alkalinity, water logging, and depletion of nutrients has already affected about 6 million hectares of land in the state. The degradation and diversion are continuing every year without any checks and need to be corrected urgently to maintain the sustainability of the ecosystem. The land resources of the Sivagangai block, like in other parts of the state, are facing serious problems of degradation like severe soil erosion and nutrient loss in the uplands, salinity, and waterlogging in the low lying and tank irrigated areas. A detailed cadastral level survey of land resources occurring inSivagangai block of Tamil Nadu state, India, covering an area of about 44,600 ha,was carried out during the period 2010âˆ'2020. The study revealed severe sheet erosion on the uplands, heavy siltation of tanks, and development of salinity at the lowlands as major causes for the drastic decline in productivity. The study warrants systematic and timely efforts to arrest soil erosion on the uplands, proper maintenance of tanks to increase the storage capacity and recharge of the aquifers, and providing drainage facilities to reclaim the lowlands and prevent the development of salinity in the study area. The degradation has drastically affected the productivity of the resources and because of this, the cultivable area has come down to less than 20% of the total area in the block. Since the problems of the area are linked with each other, only an integrated management strategy will help in restoring the degraded resource base to its original glorious past. Keywords: Geospatial, land degradation, erosion, resources

Keywords : Geospatial, land degradation, erosion, resources

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A Research on EIA (Environment Impact Assessment) Data Visualization using Open Source

Sanghee Shin | Hakjoon Kim | Sungdo Son

Gaia3D, Inc.

Abstract

This research is about the development of an EIA decision support system that effectively integrates and visualizes the results of the EIA review process and related information such as BIM/GIS, modeling data, and sensor data. The final goal is to improve the EIA process so that not only experts but also non-experts can participate in the EIA process and easily understand the EIA statements using innovative technologies such as 3D GIS and Easy Finger real-time simulation. The final system will be developed and opened as an open source. This research is 5 years long project funded by Ministry of Environment, South Korea. This talk will focus on the 1st year's research outcome and future plans.

Keywords: EIA, FOSS4G, Environment Impact Assessment, mago3D

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THEME 6

Innovative Technologies, Research and Experience Sharing in Geospatial Capacity Development (IRGCD)

FOSS4G-ASIA 2021

KATHMANDU UNIVERSITY, DHULIKHEL, NEPAL

Potential of Free and Open-Source Software for Education in Developing Countries

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Abstract

Free and open-source software (FOSS) has produced collaborative software to assist the education system during the last two decades. It is less expensive to run and maintain than proprietary software programs, making it a unique way for developing nations to enter the digital education system. The need for software in the education sector of emerging countries has recently exploded despite the lack of educational resources and facilities such as schools and teachers. This article investigates the academic potential of free and open-source (FOSS) software in Nepal. Its goal is to develop the platform and present a case study for its adoption to expand educational opportunities. It will also offer an alternate method free of economic constraints and requires no licensing from an educational provider.

Keywords: Free and Open Source Software, Education, Developing Countries, Potential

1. Introduction

Free and open-source software (FOSS) can use, copied, studied, improved, and redistributed without restriction (Fortunato & Galassi, 2021; Steiniger & Bocher, 2009; Steiniger & Hunter, 2013). Every country recognizes the need for free and open-source software for effectively and efficiently sharing and educatingâ€"concerns concerning an upgrade, renewal license, incompatibility, and monopoly. On the other hand, free and open-source software is an open and free platform to participate as a user or a developer. Furthermore, it is base on the idea of generating peer production, such as source code, blueprints, and documentation, which are all available to the public for free and open use (SÃ¶derberg, 2015). End-users have complete access to the software's source code under this concept, which encourages new features and problem patches. As a result, the software's user base proliferates while defects diminish and resolve. Furthermore, it introduces the Open Source License (OSL), which encourages user and developer communities to share and innovate.

The educational sectors of developed countries support and deploy free and open-source software for teaching and learning (Rajani et al., n.d.; Tong, 2004). Few developing countries handle education in the same way. First, this is a trend toward open standards, which allow the software to communicate with one another. Furthermore, the program may customize to meet regional and local requirements. Second, open-source licenses are nearly unrestricted and unrestricted. Finally, instructors and students may utilize legal software in their projects and share them with the world. Nepal has made significant progress in higher education growth since the country's democratic transition in the 1950s (Easterly, 2006). It comprises nine institutions and one open university, all of which need free and open access course materials, academic software, and research resources, including reports, software, papers, and books. This research demonstrates the potential of free and open-source software in higher education, its current state, prospects, and suitable recommendations.

2. Free and Open Source Software: Pros and Cons

This section discusses the benefits and drawbacks of the free and open-source platform, focusing on education. Quality, performance, and resolution are all questioned by software

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professionals, programmers, and researchers. Others lack user-friendly interfaces or functionality, as well as installation problems. Furthermore, free and open-source software has a limited warranty and incompatible drivers, which leads to malfunction and higher maintenance expenses (Golden, 2005). Nonetheless, there is a limited amount of free and open software for education, learning, and teaching. Furthermore, educators and learners acquire experience from this increasing community for sharing codes, materials, and resources for many applications, which is a promising possibility. It also saves time and money for developers because they have a starting point and can use existing open-source libraries (Janert, 2010). Finally, it promotes software interoperability b removing copyright restrictions and focusing on accessibility, cooperation, and combination. As a result, clever use combined with care will maximize free and open-source software benefits, which exceed the downsides. It's also a safe and dependable community of independent programmers for software testing and problem fixes.

3. Free and Open Source Software in Education

Free and open-source software is prominent in the education field. For example, the popular open-source operating system (Linux) releases on September 17, 1991, and was and flexible and continuous sharing process they require published under Creative Commons licenses (creativecommons.org). Low cost, dependability, performance, and security are the primary factors. Furthermore, the FOSS development process helps to ensure that the software is of good quality (Scacchi, 2007). The removal of bugs by a large number of developers improves dependability. For example, MySQL, a free and open-source database, has six times fewer bugs than commercial databases. One of the reasons for improved security is the availability of source software and the ability to fix issues swiftly. It also conforms to academic freedom and the open transmission of knowledge and information prevalent in academia (Terbuc, 2006). The widespread sharing of ideas, theories, studies, and research has resulted in advancements in the arts and sciences.

Despite this, many schools utilize pirated or cracked versions of the patented software. Its implementation will deter piracy by students who cannot afford to buy licensed versions of proprietary software. Furthermore, because we have access to and can alter the source code, the open nature of FOSS allows it to translate. As a result, students can benefit from studying high-quality, real-world programs. FOSS Nepal, Open Knowledge Foundation Nepal, Wikimedia Nepal, GPF Nepal, Looma, and many more groups, for example, operate primarily in the education and open tech domains in Nepal (Aryal, 2015; FOSS Nepal, n.d.). E-Pustakayla is a free and open platform that delivers knowledge and education to anybody in school or community settings. Sambad, a Nepalese study on how technology may assist non-literate or semi-literate people, is similar.

Integration steps of FOSS in Nepal's Education

The first stage is to identify problem areas by collecting primary and secondary data on materials and software. Furthermore, a training and seminar have been held for new users to familiarize them with the benefits of FOSS.

Figure 1: Seven steps for integrating FOSS in Nepal Education System

Advanced training and meeting are held for existing users to improve their capacity building a prototype through rigorous thinking and localizing the technology tested for feedback. Such suggestions will incorporate into the implementation. Finally, this process will be monitor and regularly evaluate to ensure that it performs as expected. As a result of the pandemic, there is a high need for digital education, which developing nations may meet with FOSS. Few Open Communities, such as FOSS Nepal, Mozilla Nepal, Wikimedia Nepal, VTS, and GPF Nepal, have used this technology to teach teachers, librarians, and students about free, open, and sharing skills, knowledge, and resources.

5. A Case Study of Nepal

With virtual help from instructors, staff, and students, education portals and warehouses are supported by free and open-source software. It comprises online courses, massive open online courses (MOOCs), tutorials, blogs, wikis, and podcasts for student-centered learning that emphasizes education via prototyping, testing, and implementation. Such technologies are practical for underdeveloped nations since they need minimal investment, no licensing cost, and a

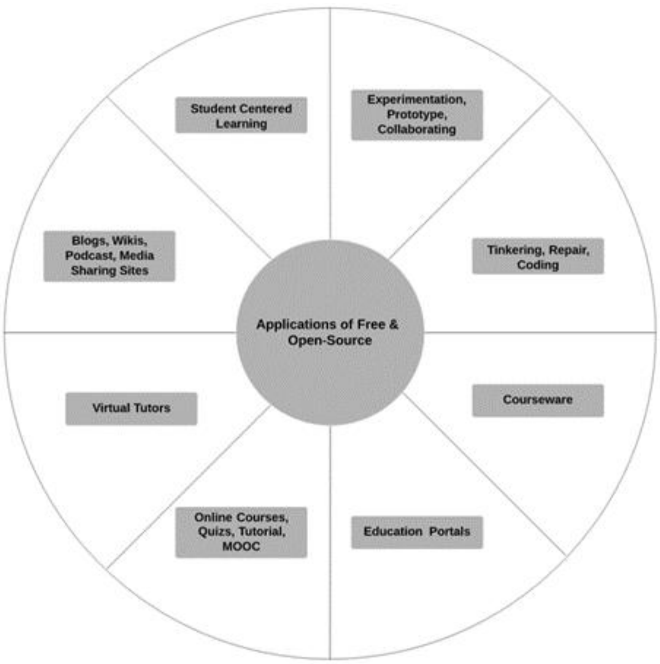

Figure 2: Application of FOSS in Nepal Education System

flexible and continuous sharing process. Furthermore, a FOSS connects all platforms in a single method â€“ to exchange offline and online information to enable data access through communication, cooperation, and coordination. According to previous research findings, the FOSS application might be appropriate in the following sectors in developing nations.

The most popular program is Linux, which was first published in Nepal in 2005 as NepaLinux. Its main goal is to promote free and open-source software, such as Linux, on the desktop in Nepali. India, China, Japan, and South Korea are working together to create a standard Linux distribution to compete with the international Windows market (276800Open0Sou1re0nov0200301public1.Pdf, n.d.; Li et al., 2004). Furthermore, making an effort to make this software's UI user-friendly improves its use. The challenges are a meager budget, restricted usability laboratories, user surveys, comprehensive tests, and other specialists like technical authors and visual designers. Despite this, technology usage is rising due to the adoption of nature, which is less expensive, more accessible, and more open. As a result, there will always be a demand for digital classrooms and libraries that address educational access. However, a few efforts such as OLE Nepal, E-Paath, and E-Pustakalaya have been launched.

Similarly, this pandemic realizes that an integrated approach to teaching and learning is fundamental for students to learn on virtual platforms. They apply classified education media, such as narrative for attending and understanding (e.g., printed material), interactive for investigative and exploring (e.g., digital library resources, web portals). Moreover, communicative for discussing and debating (e.g., online discussion forum, video conferencing), adaptive for experimenting and practicing (e.g., quiz providing feedback, virtual laboratory), and productive for articulating and expressing (e.g., blogs, wikis)(Laurillard, 2002; Yang & Shadiev, 2019). Implementing free and open-source Geographic Information Systems such as GRASS GIS and Quantum GIS at universities, public and commercial offices, for example, is cost-free, cheap, and unrestricted licenses. The FOSS Nepal Community introduced NepaLinux to twenty-five schools in Nepal. Similarly, the Kathmandu University Open Source Community established E-Libraries in 35+ Nepalese E-Libraries to provide Information and Communication Technology (ICT) in Education to government schools. Furthermore, the 2008 e-governance master plan incorporates e-education. However, there is currently no national policy in place regarding free and open-source software or content. It must address promptly for the improvement and development of this community.

6. Discussion

Free and Open Source Software (FOSS) commences with the introduction of Nepal Linux in 2005. Since then, it has partnered with companies, organizations, colleges, universities, volunteers and organized programs and campaigns in Nepal. It conducts workshops, research, and training about FOSS. A research and training center such as Help Nepal Network, e-libraries, Linux FOSS help, and service center. Similarly, FOSS help and service provides free classes related to Linux, Wiki-school. Besides the School Sector Reform Plan, Open Learning Exchange, One Laptop Per Child are substantial efforts to bridge the gap between ordinary, rural, poor, and girls. It provides an opportunity for rural area people to understand the importance of digital learning via the FOSS platform. It supports lessening digital illiteracy, especially in remote and isolated areas.

There is exceedingly potential for transforming digital literacy and education by applying FOSS in Nepal. However, there is a lack of skills, knowledge, and experience. Moreover, personal resistance could be another significant obstacle to FOSS use (Gallego et al., 2007). Similarly, the unwillingness of the education sector to transform on this particular platform. Also, difficult to migrate from standard proprietary software. Therefore, it will create a challenge for students, educators, and the education sector. In contrast, it provides an opportunity that can be used to reduce fear, uncertainty, and doubt in the context of the education sector in Nepal. This research suggests a prerequisite to examining the development model of FOSS and essential features required for Nepal's education sector. Future researchers have an immense opportunity to develop a framework to understand FOSSâ€™s impact on the education sector's performance in Nepal, which will support national policy formulation.

7. Conclusions

The study depicts there is a potential of FOSS in the education sector of Nepal. Using this platform may be challenging for beginners; however, research, workshops, and training are conduct to make familiar. Also, these are not compatible with existing software, uncertainty on desired results. Still, its free and open concept will be an obligatory aspect for implementing this in the education sector, supporting financially and increasing knowledge, skills, and code. The government and communities have launched the Linux Nepal Initiative that focuses on developing resource centers, special interest groups, pilot projects, assisting in the localization of Open Source software, and supporting research studies. The study shows that Free and Open Source Software (FOSS) is not essential nevertheless crucial for the growth of the Nepal education sector.

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Lock down turned 'farm to fork' - Dream or Reality! Agricultural situation in Thanjavur, India before, during & after COVID 19

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Abstract

Thanjavur being the foremost district of the Cauvery delta occupies an important position in the agricultural map of Tamil Nadu as 70 percent of the population is engaged in Agriculture and allied activities for their livelihood. As always, the "Rice bowl of Tamil Nadu" cultivated the paddy crops in the year 2019-2020, but the farmers couldn't afford COVID lockdowns. This caused a worser condition more than a drought scenario. In this context, we aim to synthesize the early evidence of the COVID-19 impact on the Indian agricultural system viz., production, marketing and consumption followed by a set of potential strategies to recover and prosper post-pandemic. Normalized Difference Vegetation Index (NDVI) derived from Sentinel-2 images for February, May, and July 2020 was used to assess the crop situation, representing three crop seasons, i.e., Kuruvai, Samba and Thaladi. NDVI images of 2020 were compared with corresponding images of 2019. Change images were generated, and state-level NDVI values were computed. The district-level cropped area proportion was also mapped using the NDVI thresholding approach. The crop sown area, crop situation, adequate quantity of crops couldn't sell due to pandemic conditions were also compared for both the years. The pandemic wreaked a substantial physical, social, economic and emotional havoc on all the stakeholders of Indian agricultural system. Seizing the crisis as an opportunity, the study recommends a raft of measures and long-pending reforms.

Keywords : Remote sensing, Normalized Difference Vegetation Index (NDVI), COVID-19, Lockdown, Multi Criteria Analysis.

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Passport in my shoe: The History of FOSS4G

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Abstract

FOSS4G has now been around so long, that the true history of what brought FOSS4G together has long been forgotten. This talk tries to tell a few funny stories of the beginnings, and the friendships and laughs shared all over the world. What to expect in this short presentation: a few funny pictures, laughs, and some friends getting together to tell some FOSS4G stories, from 2 of the founders of FOSS4G, Venka and Jeff. #foss4g4ever

Keywords : FOSS4G, history, fun, passion, beer, passport, shoe

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MapServer Project Status Report

Jeff McKenna

Gateway Geo

Abstract

MapServer is known as the fastest online Web mapping engine, and has been serving spatial data and standards for over 20 years. This talk describes the features of the upcoming MapServer 8.0 release, as well as how MS4W handles the demands of Windows deployments (thousands each month). The presenter is a longtime member of the MapServer Project Steering Committee, and the developer behind the popular MS4W installer.

Keywords : MapServer, web mapping, Open Source

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Automated Coastal Monitoring Using UAV Images and Deep Learning Techniques

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Abstract

Maritime surveillance and monitoring are of great importance for the coastal life to act on the activities like illegal border encroachment, fishing, marine transportation, safer navigation, search and rescue operations. Ships are the most used means of sea surface related activities like fishing, surfing and transportation, and are categorised into different classes based on their structure of construction or purpose of use. Recognizing the presence of ships and their classes can assist in extracting useful information about their activities. UAVs for their easy-to-operate and automatic handling on demand basis with the facility of integrating camera and sensors of interests have been used widely for monitoring ships these days. However, images generated from their cameras suffer challenges like camera motion, scale variability, variability in the sea surface and sun glares. So, manual ship recognition has become a challenging tasks. However, advancements in computer vision technology and development of deep learning techniques in the recent years have shown remarkable performances in the field of image recognition with strong feature learning ability, fewer model learning parameters and higher recognition accuracy. This paper presents the potential of deep learning techniques with deep convolutional neural networks by integrating the concept of transfer learning to recognize ships on the sea surface with their respective classes using the images generated from UAV captured videos over different areas of Atlantic Ocean. The study modifies architecture of four of the state-of-art performing pretrained network models of ILVSRC Challenge, namely Xception, VGG16, ResNet50 and InterceptionResNetV2 trained on ImageNet dataset, and the modified models, either as feature extractor or fine tuning techniques are used for classifying ships present in images. The model modification involving freezing, addition or removal of different layers are optimised and regularised with different hyperparemeters. Final results of all the modified models performed with higher accuracy ranging from 99.6-99.9 on the evaluation dataset. Resnet50 has been recommended as the suitable model by comparing the model´s training -validation accuracy and network performances on the test dataset. The output of this work is the final model trained on the research dataset with suitable hyperparameters and can be used for recognizing ships with corresponding classes.

Keywords : Coastal Monitoring, Deep Learning, UAVs

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Teaching Geographic Information Science concepts with QGIS – lessons from 4 years of distance education

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Abstract

As part of the first quartile of its Master in Geo-Information Science and Earth Observation, Faculty ITC (University of Twente, The Netherlands), offered a fully online first quartile program of 14 ECs (roughly 392H of study load) that could be taken as a standalone course as the first step into the full MSc degree. The course Principles and Applications of Geographic Information Systems and Earth Observation, also known as 'The Core' ran as pilot experiment from 2017 to 2019 before becoming an important part of the response given the students that could not travel in 2020 due to travel restrictions imposed by the COVID pandemic.

The course was developed around four fundamental principles:

- It primarily teaches GI Science concepts;
- Every concept taught should be demonstrated and operationalized;
- Use as few software tools as possible to help the students to focus on the Science and not on the tools;
- The software tools should be inclusive and encourage technological independence.

To comply with these requirements, two essential tools were used: The Living Textbook - an open access tool developed in-house that allows the students to explore concepts both as a traditional wiki and as an interactive concept map, and QGIS for operationalization of the concepts described in the Living Textbook. Another innovation was that the course was exercise led, that is, students were introduced to concepts from the exercise descriptions as opposed to doing the all the readings prior to the practical exercises. Overall, the experience was extremely successful, with high levels of satisfaction from the students reflected in final marks typically higher when compared with the equivalent, in-house, course based on proprietary software and on a more traditional approach. The courseware developed for the course is now offered to the community as open courseware and is the basis of having the Faculty recognized as a QGIS Certified Organization thus strengthening the relation between academia and FOSS4GIS, particularly QGIS. The development of these exercises also led to a number of bug reports that contributed to improve QGIS. Internally, this experience brought important insights on how to successfully design online courses.

These include but are not limited to

(A) consistency – the tools and support materials of the course should remain the same along the course;
(B) communication – both Synchronous and asynchronous is of paramount importance. An online course has to have interactivity and it cannot be just a repository of teaching materials;
(C) accessibility – the tools used should not have any kind of accessibility barrier, especially when it comes to licenses, but also when it comes to imposing operating system platforms or assuming file format preferences. Finally, it is worthy to note that this course made the teaching staff aware and confident on the use of QGIS. This resulted in having a paradigm shift faculty wide where FOSS4GIS is now the primary choice when it

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Solutions for monitoring air quality: A proposal of air quality monitoring sensor network based on Internet of Things (IoT)

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Abstract

The poor air quality in the urbanized cities has become one of the most alarming issues to human life. The degrading quality of air has adverse effects on health causing various diseases like lung cancer, asthma, heart disease, etc. There is a need to have a system that could measure and monitor the real-time air quality data for a particular geographical location. Satellite-based observations of surface air quality data have advanced dramatically for environment monitoring in recent years. There is a wide range of both regional and global earth observation satellite systems already in orbit that is available for observing many air pollutants. However, these satellite systems are not capable of delivering air quality data in near real-time because of low temporal resolution. In addition, the satellite observed air quality data are of coarse spatial resolution, hence cannot capture the local variations of air quality. Thus, this research 'IoT based Air Quality Monitoring' can be a significant as well as cost-effective way to continuously measure, monitor, and eventually disseminate air quality data in near real-time of a particular location. The designed sensor system uses MQ135 gas sensor to measure the quality of air as MQ135 sensor detects the level of a wide range of harmful gases like ammonia, nitrous oxide, alcohol, benzene, carbon dioxide, and smoke. This sensor is connected to the local server (computer) with an Arduino UNO microcontroller. The Arduino UNO microcontroller is an open-source controller which is used to write and upload computer code to the physical board. In addition, the Wi-Fi module ESP8266, a low-cost Wi-Fi microchip has been used to access multiple users to the system by connecting to the local server that has been set up for demonstration purposes. After the connection is established between the device of the user and the IP address of the router, the user can view the tabulated real-time air quality data displayed on the webpage. This sensor system was exposed to two different air conditions for about 30 minutes to measure the air quality. The sensor system is capable of measuring air quality data every sec and can be adjusted as needed. The air quality data from these two conditions were stored in the MySQL database. It was observed that the sensor was highly capable to sense the change in the air quality of the surrounding environment.

To this end, an approach is presented in this research article to evaluate the performance of this system in a wider geographical range to measure, monitor the variations of air quality. For this, a network of similar sensors can be created and stationed at residences of local inhabitants belonging to different spatial locations by following the concept of the Citizen science approach. The installation of a sensor network in this way helps to regularly inspect the sensor performance which eventually minimizes the cost and secures the sensor. Thus, all these substantiate that the Citizen science-based approach can be the sustainable and cost-effective method for air quality data collection to a larger extent. The recorded air quality data from these sensor arrays are forwarded to a central server in near real-time. The air quality data processing package programmed to operate at a central server then do the quality assessment by flagging outliers and finally publish the processed data into the dedicated webpage, ready to be disseminated to the general public. Each sensor system stationed at one geographical location measures the variations of air quality data throughout the day for that particular location only. The air quality data obtained from

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these geographical locations could be utilized to generate continuous air quality surface raster data that offers the user air quality information for the whole geographical region where all sensors are located. There are many open-source tools such as spatial interpolation techniques (e.g. Kriging, Inverse Distance Weighting) within different open-source GIS platforms such as QGIS. By utilizing these openly available platforms, one can generate continuous air quality surfaces which will allow estimating the data of uncovered locations.

This IoT-based air quality monitoring system measures, monitors and disseminates near real-time air quality data to the general public which informs about the quality of the air. Furthermore, it helps to study the air quality variations in local geographical regions. A network of similar sensors as described above could help the local government to forecast valuable information about the pollution levels in the air. Not only this, by studying and identifying the time and area of peak concentrations, governments can implement preventive measures and ways to reduce the air pollution levels. In addition, the research community can benefit from high Spatio-temporal resolution air quality data on a local level. The data from this sensor system together with satellite-derived air quality surfaces can help the scientific community to study the relationship between air quality variation at local as well as global levels. The local level air quality data from a sensor system like this could serve as a good foundation for satellite data validation and upscaling. For the holistic understanding of dynamic variations of air quality on a local and global level, a network of spatially representative numbers of low-cost sensor networks together with a global satellite network could help us provide reliable and locally representative datasets on air quality. Such reliable datasets could be a valuable asset in assessing the human health impact of air pollution.

Keywords: Air quality monitoring; Internet of things; Sensor Network; Satellite observation; Spatial Interpolation

THEME 7

FOSS4G for Disaster and Epidemiology (FOSSDE)

Multivariate building damage model for scenario-based flood risk assessment

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Abstract

Tidal water inundation of low-lying coastal areas a detrimental effect on buildings, agricultural lands, and fish ponds. The developing countries shall bear the disproportionate effect of coastal flooding due to relatively high MSL and large density of impoverished populations residing along the coasts. A global framework such as Hyogo and Sendai priorities preparedness against differential risks using a proactive planning mechanism for disaster risk reduction (DRR). EMDat concludes floods to be the costliest natural disaster adding recursive burden to the global economy every year. Therefore, damage reduction from recurring and inevitable future flooding events requires a proactive adaptation strategy to plan sustainable alternatives for combating climate extremes. Flood damage assessment is the primary procedure for developing a planned adaptation strategy and becomes a difficult task for a data scare region. The paper puts forward a multivariate building damage model for losses assessment within the data-scarce region. The intuitive hazard scenario for Sagar Island, West Bengal, is developed using a long-term tidal analysis and coastal surges data in an enhanced bathtub model. The enhanced bathtub model produces a connected depth map that takes into account topographic factors such as elevation, slope, and surface roughness. The inundation above the High-Water Line (HWL) is conjoined with the multivariate building damage model to identify the building Damage Stage (DS) across the flooded region. Damage stages (DS) that have been developed from a comprehensive review of flood effect on buildings. The damage model derives a component-wise building damage estimation using a flood hazard matrix. The flood hazard matrix is a logical set of rules developed for a realistic interpretation of aggregate flood risk on buildings. The aggregated flood risk/damage associated with each DS is expressed in terms of building replacement cost. The research work estimates the replacement cost ratios i.e., the percentage of the total building cost for each of the flooding scenarios such as DS0 – 0; DS1 – (0.28-0.39); DS2 – (0.53-0.63); DS3 – (0.66-0.90); DS4 –(0.93-0.94). The approach is pragmatic and essential in allocating assets for flood relief or redevelopment. Also, the use of open data resources and the minimum requirement of primary datasets make the method widely acceptable. The novelty lies in its application for vernacular buildings that appear as the most prominent and least explored building typology in terms of flood resistance.

Keywords: Coastal flood, Damage matrix, enhanced bathtub model, High Water Line, Multivariate damage model

1. Introduction

Coastal water ingress due to high tide anomalies, storm surge, and rising sea levels are frequently observed as one of the life-threatening consequences of climate change (Oppenheimer et al., 2019). The incidents cause distress among coastal communities, who face irreplaceable loss of life, livelihood, and infrastructure (IPCC, 2018).

Anomalous high tide events, also referred to as 'future high tides,' are scenarios with water levels exceeding 0.45m above the long-term average high-water records (NOAA,). The long-term average is the mean of the highest high tide occurring over an observed period, also called Mean Higher High Water (MHHW) (NOAA; Jeon et al., 2018). The MHHW threshold is geographically represented using an

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imaginary HWL line demarcated based on tidal water revisits along the coast. A seawater rises above MHHW due to several physicals, hydro-meteorological and climatic reasons will inundate the low-lying coastal regions. Therefore, it is critical to ascertain the effect of storm surges and tidal anomalies on disaster risk reduction/ development of risk reduction strategy.

From the discussion above, it is relevant to note that developing countries with relatively high mean sea level (MSL) shall bear the disproportionate burden of floods on the large impoverished population density residing along the coasts (Laczko & Aghazarm, 2009; Pravin et al, 2016; Edmonds et al., 2020). EMDat confirms floods as the costliest natural disaster, and thus their reoccurrence will add recursive damage to the already stressed developing economy. This makes proactive risk management meaningless if not integrated with the seriousness of damage cost reduction within local level adaptation strategy.

The contemporary research on coastal floods more often focuses on the hazard exposure and identification of elements at risk (Dhiman et al., 2019; Sahana & Sajjad, 2019; Duo et al., 2020). The impact assessment of a coastal risk scenario is rarely prioritized considering its resource-intensive nature, lack of socio-political interest, absence of existing damage catalogues/ damage records, and specificity of the issue that prevents generalized replication of the method (Davar et al., 2001).

Dhiman et al., (2019) point out the need and success of local -level adaptations that intend to minimize the impact of flooding on the build infrastructure (building in this case). Hence, the article proposes a multi-variate building damage model for assessing the impact of flooding in various risk scenarios. The flood scenario in the region is depicted using an enhanced bathtub model developed from open-source software. The direct impact of flooding on a residential building is evaluated as replacement cost using a probabilistic technique. The entire method is highly suitable for replication in a data-scarce and resource-constrained environment.

2. Literature review

Floods can result in direct and indirect damage depending upon the nature of contact with floodwater (Messner, 2007; Romali et al., 2015). Direct damage occurs when the building comes in direct contact with the floodwater, leading to indirect damage or losses. The direct or indirect damage that can be quantified in monetary terms is known as tangible damages. The direct impact of floods water can detrimentally affect both buildings envelop and the household elements within (Merz et al., 2010; Pristica et al., 2014). However, the losses corresponding to flood characteristics such as depth, damage velocity and contamination can be subdued with the help flood-resistant building design (BMTPC, 2010; Mtapuri et al., 2018) that requires explicit details about either.

High-resolution remote-sensing data is vital for providing precise information about the spatial character of flood exposure and elements at risk (Sensing et al., 2015; Narendr et al., 2020). GIS-based simple bathtub model has been extensively used for mapping coastal flood risk zones considering its intelligibility to deliver results in a data-scare and resource-constrained environment (Hadipour et al., 2020; Narendr et al., 2021). The simple bathtub models use DEM as primary input with an inundation threshold decided based on historical observations. The simple bathtub model puts all elevation chosen below this threshold as inundated for that event. Though favored, the model is likely to overestimate results due to its sole dependence on surface elevation (Yunus et al., 2016; Williams & Lück-Vogel, 2020).

In the recent past, Williams & Luck-Vogel (2020) came up with an enhanced model for coastal flood mapping, later presented as ESRI ArcGIS toolbox. Apart from elevation, the model also considered other terrain characters such as slope and surface roughness coefficient realizing their influence on surface water movement. A gentle slope with a smooth surface allows unrestricted movement of water and vice-versa otherwise. The model also tests the pertinence of DSM over DTM, derived from 2m Lidar data, in creating more realistic inundation scenarios.

The preceding research on micro-level mapping of floods has listed the potential for improvement. One among them is the insufficient representation of building typology (vernacular building in this case) in assessing flood impact (Duo et al., 2020). Resource limitations, such as absence damage data from previous flood incidents or unavailability of stage damage curves for the vernacular buildings, are some reasons for their under-representation.

Vernacular buildings have been popular habitat choices. They are indigenous, functional, made of locally available material and techniques. For instance, mud buildings have accommodated 50% of the global population, specifically within the developing countries, due to cost-effectiveness and climate benefits. Despite benefits offered (Fernandes et al., 2014), the traditional mud housing has high flood susceptibility that is likely to increase with aggravating hazard risk (Moles et al., 2013; Cramer, 2017); thus, making flood damage assessment procedure exceedingly significant for guarantying risk reduction in the developing regions.

2.1 Damage assessment of mud buildings

Shah et al., (2013) identified the most common cause of structural failure in mud buildings from an array of causes enlisted based on the primary survey done across Pakistan. Likewise, Mohd et al. (2016) classified building damage into four damage grades: inaccessible, minor, major, and destroyed based on an exhaustive review of damage models across the globe. The failure attributes corresponding to the damage grades were later validated from field survey data. Thereafter, Englhardt et al. (2019) used a cumulative stage damage curve to represent material sensitivity of traditional buildings with respect to rising flood depth. Similarly, BMTPC prescribes a five-point "inundation intensity scale for damage to houses" using both depth and duration variables in India. It documents damage attributes for each stage along with the resultant loss of value G1, less than 10%; G2, 10-25%; G3, 25-50%, G4, 50-75% and G5, more than 75% up to 100%. (BMTPC, 2010)

3. Methods and materials

3.1 Study area

Sagar island, located between 21.6276oN to 21.8842oN and 88.0408oE to 88.1278oE in South 24 Paragana district of West Bengal, witnesses recurring floods events since its transformation into a habitable region. The population recorded by census in 2011 was 212,037, among which about 75% of people live in kutcha housings, extremely sensitive to climate extremes.

These extreme incidents of high-water floods or surges in the coastal region often get unreported unless paired with cyclones causing extensive loss to human life (Danda, 2010; Ghosh, 2018). In the last three years, the island has experienced consecutive flooding from severe to very severe cyclones Yass (2021), Aamphan (2020), and Bulbul (2019), causing extensive damage to the built infrastructure.

The resultant damage from reported disasters is often compensated. The government remuneration varies based on the housing typology (pukka or kutcha) and the building's damage state (partially or fully damaged). However, these remunerations do not put forward the idea of 'building back better' (BBB) that is undoubtedly a pressing priority for proactive adaptation to climate change.

A careful assessment of damage leads to informed decision-making and policy proposal. The article thus presents a method based on the concept of Source – Pathway – Receptor – Consequence (Narayan et, 2014; Duo et al., 2020) to evaluate flood sensitivity of buildings in the data scare region.

The intuitive hazard scenario for cyclone Yass is created using an enhanced bathtub model. Here, the sensitivity of the receptor, building specimen, is determined using component wise analysis for a possible depth-duration combination. The fragility is expressed as damage cost values for each predefined damage state of the building

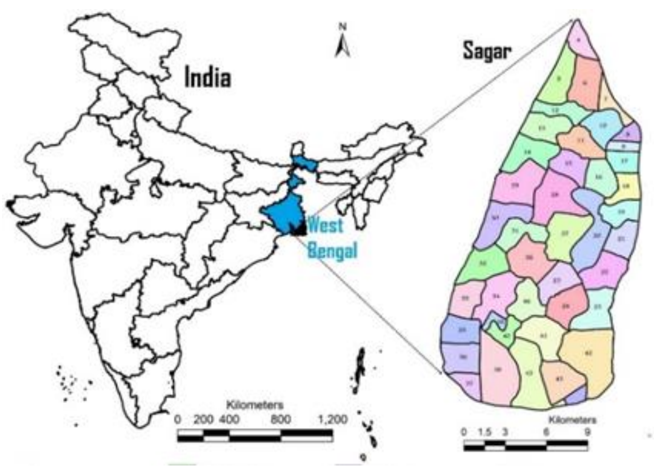

Figure 1: Sagar Island

specimen. DS corresponds to the degree of damage that a building may endure when in direct contact with floodwater. Thus, the damage costs and deterministic outcomes from the exposure model are obligated with duration values from past flood observations to exhibit damage variability spatially.

3.2 Data collection

Data collection was done at both building and terrain levels for analysing sensitivity and flood exposure, respectively. The building specimen data was collected in form of photographs from primary survey. Optical remote sensing data from Cartosat and LISS IV were used for extracting

DSM and generating land use map respectively. Apart from these daily tide data and extreme events were collected from NOAA, IMD and INCOIS. The spatial analysis was carried out using free and open-source software Q-GIS and GRASS GIS.

3.3 Remote sensing data analysis:

Optical remote sensing data LISS IV was used to produce land use 2020 map for Sagar Island using a standard protocol on QGIS and Grass GIS software (Jensen and Lulla, 1987; Lillesand et al., 2004; Narendr et., 2020). Gaussian Likelihood Maximum Classifier (GMLC) was used to classify the multispectral data into six prominent land use categories in the region: built-up, water, agriculture, inland vegetation, forest vegetation, and others. The accuracy of the classified land use map was validated using field observation and the google earth database. Each of these landuse classes was assigned standard runoff values prescribed by Chow (1962) to develop a surface-runoff map. Cartosat I stereo pair data was used for deriving Digital Surface Model (DSM) using standard processes (Ahmed et al., 2007; Giribabu et al., 2013). DSM was then used for the generation of a slope map for the study area

3.4 Development of flood exposure map

Yaas occurrence was on 26 May 2021, a limited amount of information was available on its effect through the government sources except hydro-meteorological condition that IMD and INCOIS shared. Its convergence with the perigeean spring tide led to widespread and prolonged inundation from seawater ingress. The inundation or flooding level is marked when the water exceeds HWL or Mean Higher High Water (MHHW) threshold (NOAA,). Thus, long term daily data of the last 50 years were analysed to estimate Mean Higher High Water (MHHW) value and high-resolution remote sensing data were used to trace HWL using predefined terrain characteristics (ISRO, 2014). The MHHW value was subtracted from the sum of astronomical tide and surge value reported during Yaas to estimate flooding over the HWL denoted as 'flood threshold'. The flood threshold value is used for making binary classification of DSM as flooded and non-flooded zones using Grass GIS. This process is also referred as the simple bath tub model discussed in the previous section.

3.4 Development of Enhanced bathtub model

The development of an enhanced bathtub model involves terrain attributes such as surface runoff coefficient and slope and elevation values. A 'flow feasibility map' is generated by dividing the slope map by the surface runoff map. A flow feasibility map consists of raster cell values directly related to water movement in a terrain. A higher cell value indicates a smooth flow due to gentle slope and minimum resistance. However, a lower cell value represents vice-versa. The flood threshold layer is used as 'mask 1' to extract inundation pockets from the 'flow feasibility map'. Detection of the flooded area based on terrain convenience requires establishing an actual flow pattern between the inundation pockets and the water source, in this case, HWL. Therefore, each pixel of HWL is converted into vector points to establish the channel flow from them. The inundation pockets are also converted into vector points (taking centroid of each polygon) and a 'cost surface' is developed using the 'r.cost' in Grass GIS. The 'cost surface' uses the flow feasibility map acting as a base layer and ranks the pixels in order of adequate water flow. This map act as an input 'r.drain' that helps us to create the final water mask highlighting the region where water might stagnate due to its flow within the region. The flood mask is multiplied with an elevation raster to identify the water depth at each pixel. Finally, the map becomes an input for the damage model and duration values to assess the micro-level impact of flooding in Sagar.

Table 3: Details of MHHW, astronomical tide, and surge on 26th May 2021

MHHW	Astronomical tide	Surge
5.02 m	5.6 m	3.3 m

Figure 2: Inundation during cyclone Yaas

3.5 Flood risk assessment

3.5.1 Building damage assessment

Flood risk assessment identifies the consequence of hazard based on the sensitivity of system here, vernacular buildings. The assessment is crucial for approximating disaster-related losses and serves as a critical argument for policy modification. The steps building damage assessment are described as follows:

1. Identification of building typology
The primary step in the damage assessment process is identifying prominent building type along with its materials, layout, and basic detail of its building envelop. A primary data survey was organized to identify the primary specimen representing the region.

2. Component wise-damage analysis
Depth and duration values are used as representative of flood character. The building specimen was divided into individual components, and based on the resistance value, damage tables were developed for each of these building components. The damage table comprised minimum and maximum failure threshold values and average and two standard deviation values obtained using eq(i) & (ii) respectively. It also consisted of repair cost values (Govt. of West Bengal, 2017) excluding labour charge for each building component. The minimum and maximum resistance of building component against flood depth and duration was obtained from a thorough review articles published on experiment research.

$$\mu=(Xmin+Xmax)/2 \qquad \text{- (i)}$$

$$\sigma= (Xmax-Xmin)/4 \qquad \text{- (ii)}$$

3. Development of damage matrix
A damage matrix is an array of loss percent for various depth–duration combinations. Based on logical insights from the damage table, the matrix was developed using the following hypothesis:

a. No significant damage when both depth and duration values are zero.
b. When the depth is zero, the building has no contact with flood water, hence no significant damage
c. When the duration is zero, the building came in contact with the floodwater for the negligible time period. Hence no significant damage. The damage percent is suggestive of the repair cost of the component. The total damage cost of a building is the summation of the individual repair cost of its component subjected to damage by flood.

$$DC = \sum_{i=1}^{n} a \cdot CC_i$$

Where DC = damage cost of the entire building, CC = cost of an individual component, n= number of components in the building, a = loss percent of the component.

4. Spatial representation of building damage stage
Damage stages are defined about various publications on damage assessment of mud buildings. They are validated using the actual images illustrating damages from post scenarios. Each successive stage represents a rising damage intensity has been adapted based on a comprehensive review of several literatures.

The spatial representation of the damage stage requires mapping of the residential building in Sagar Island. The building clusters are then randomly divided in a 75:25 ratio, the former class being kutcha/ vernacular housing type, and the latter is categorised as pukka housing. The analysis is carried out on vernacular housing, assuming the negligible effect of flooding on pukka housing.

4.0 Results and Discussion

The paper proposes a multivariate damage model for assessing flood risk impact on Sagar Island. The previous studies on impact assessment have prioritised the needs of urban centres over the rural areas; this is because of the data constraint in the region that leads to pronounced uncertainties both aleatory and epistemic in nature (Hammond et al., 2015; Parodi et al., 2020). Aleatory uncertainties occur when an entity is used to symbolically represent an entire group, excluding internal variations. Epistemic are caused in the absence of complete understanding of the system. The absence of past damage data or damage stage function are the major bottlenecks in damage estimation. Likewise, under or over estimation of flooding and its characteristics can result into erroneous outcomes. Although it is impossible to eliminate the system biases entirely, the robustness of the damage assessment method could be enhanced by limiting those (Duo et al., 2020).

In line with the discussion above, the present article puts forward an innovative approach for assessing flood damage of vernacular building transferable to data scarce regions in developing countries. The exposure assessment includes a high resolution Cartosat Dem data that has proven efficiency over free global dem sources and comparable efficiency to LIDAR (Mohanty et al., 2020). The DSM data hence, extracted was used as an input in a state-of-art enhanced bathtub model developed in open-source environment.

3.3 Flood exposure assessment

The flood exposure map in Figure 4 illustrates the areas that are likely to get flooded from cyclone Yaas. The total area under submergence is about 70 sq. km. The inverse relationship between the terrain height and flood level was used to understand the actual height of inundation as described in table 3. Since the highest recorded flood level during cyclone Yaas was about 4m, the terrain height was subtracted from flood level in order to obtain inundation at each pixel. The flood exposure map was used as an input to damage assessment model for evaluating losses subjected to element at risk.

3.4 Damage assessment model

Flood damage assessment model is a tool for assigning damage stages to buildings depending on their exposure and resistance to floods. Flood depth, duration and building material were identified as the most significant factors for residential building damage (Mohd et al., 2016; Zin et al., 2020 ;). Apart from literature, it was also evident from the images (figure 3) captured during the event. Prolonged inundation has detrimentally affected the stability of vernacular housings. The first step of damage assessment comprises of data collection from field observation. Figure 5 represents the primary housing typology in the region. The census (2011) also ascertains the use of mud, urburnt bricks, polythene sheets, wood, thatch etc as typical housing-material. Therefore, the building specimen adopted for the study resembles the most commonly occurring single-storey housing of 30 sq. m area with 2.1 m height upto lintel. The building specimen was then divided into six components namely plinth, floor, wall plaster, wall, door and window for a component-based damage analysis.

The minimum and maximum damage threshold for each component obtained from the damage table and mean and standard deviation values is used to design a damaged matrix shown in figure 6. The damage matrix exhibits the

Table 3: Flood level and area under inundation

Terrain height (m)	Flood level (m)	Area (%)
0 to 1	4- 3	17
1 to 2	3-2	25.63
2 to 3	2-1	35.43
3 to 4	1-0	21

combined effect of depth and duration on each building component in terms of damage ratio, between 0 to 1. The flood depth associated to the building varies as per its spatial location from figure 3. The flood duration was taken constantly as 36 hours. The flood duration was decided based on newspaper reports and behaviour during previous events. Therefore, the flood damage ratio of each component in the building is assigned considering all these things.

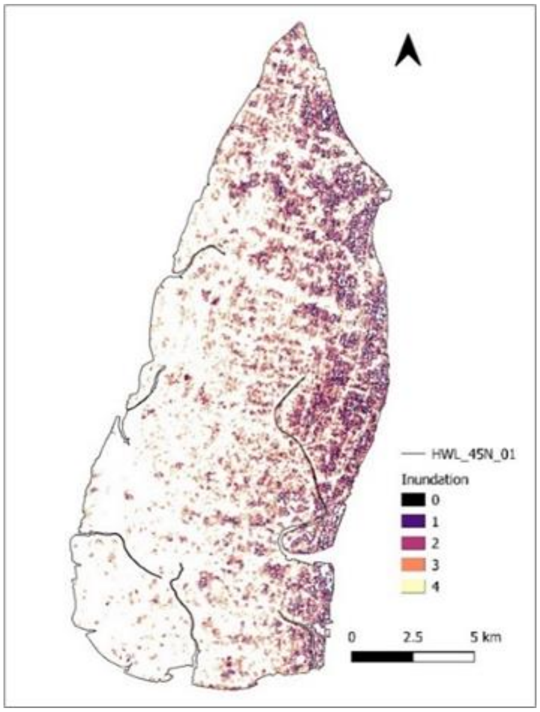

Figure 4: Flood exposure map for cyclone Yaas

Figure 6 represents the DS for each building assimilated as per the summary drawn from literature. 80% of buildings suffered negligible damage are in DS0. The rest 20 % has been classified as follows: DS1-5.22%; DS2-4%; DS3-

5.28% and DS4- 4.66%. The repair cost corresponding to each damage category has been expressed as the ratio of total building cost i.e. DS1-(0.28 -0.39); DS2 – (0.53 – 0.63); DS3 – (0.66-0.90) and DS4 – (0.93-0.94).

Figure 7 reveals that the spatial location of the receptor is a critical aspect governing its vulnerability. In addition to this, the damage cost also varies under similar condition. On this account, the compensation slab that is rather flat and developed based on visual inspection needs to be modified to better disaster coverage. Integration of spatial information in the damage assessment process will prevent generalized results and pave the way for informed decision making.

Figure 5: Building typology data collected at Sagar Island

The reason behind a large portion of the building being in DS0 is local adaptation strategy. Recurring floods have compelled the people to construct on raised mounds or platforms. Hence, they might not come in direct contact with floodwater. Thus, the area around the buildings may be entirely submerged making them inaccessible during floods. Since, the inconvenience is a result of indirect flood effect, it is beyond the scope of the paper.

5. Conclusion

The present research proposes a multi-variate damage model based on the Source – Pathway – Receptor – Consequence concept. The floods impact assessment is carried out by using the spatial hazard mapping technique as an input for evaluating the flood damage during cyclone Yaas. The flood exposure of the region is identified using an enhanced bathtub model that integrates surface runoff coefficient and slope angles and surface elevation to give precise delineation. The model was developed using free and open-source software and high-resolution data obtained from NRSC. The building specimen for a component-wise damage analysis is identified through a field survey. The specimen is divided into six damageable components. The

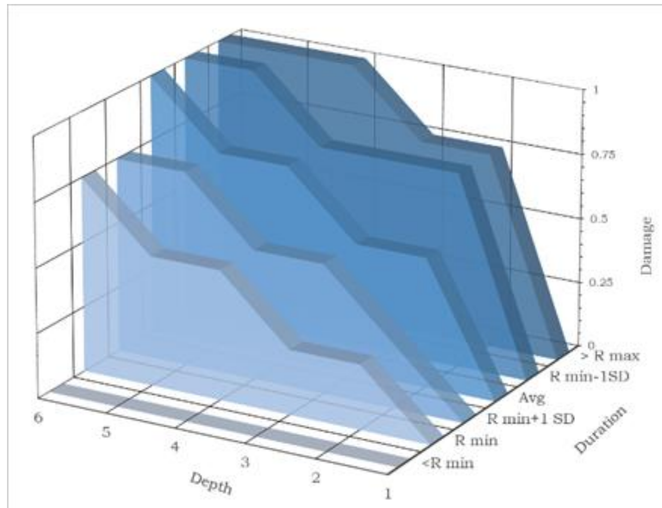

Figure 6: Building damage matrix

flood resistance of components and inundation scenario from the hazard map are used to assign DS and respective damage cost to each building.

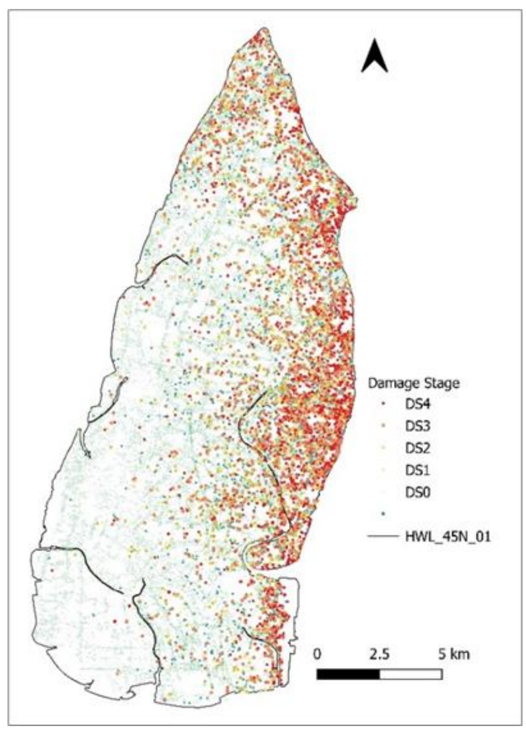

Figure 7: Building damage state map

The flood impact assessment techniques emphasise the importance of spatial analysis in damage assessment procedure. DS of a building is influenced by the terrain character and thus built back better approach shall not be efficient unless it integrates these variations. Therefore, the proposed process can be a catalyst for informed decision making in accomplishing the goal of DRR. The research framework promotes inclusivity by integrating the concern socially backward and disintegrated areas. Also, this method will find applicability in resource constrained location wherein data intensive techniques are not found feasible.

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Detection of shoreline change due to impact of breakwaters at Ariyankuppam river mouth in Puducherry, India by using Remote sensing and GIS

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Abstract

The shorelines are unique geographical feature and a major element used in Remote Sensing and coastal GIS. The Shoreline provides the key details on coastal landform dynamics. Shoreline change occurs every decade and creates its impact on coastal landforms. To observe these decadal changes proper acquisition of long sets of data, decadal monitoring of shorelines and reasonable accuracy detection is essential. Construction of breakwaters and other natural factors negatively impact the shoreline by causing alterations and upsetting the natural setup resulting in Coastal erosion and accretion which indicates very serious problem in the forth coming years and should consider as a serious threat to coastline environment. A comparative study is conducted for the following 5 decades – (1980-1989, 1990-1999, 2000-2009, 2010-2019 & 2020-2029) to observe the decadal shoreline changes for Puducherry coastline length of approximately 24 km which is located along the Coromandel Coast, bordering the Bay of Bengal. The Landsat 4-5 TM, 8 OLI /TIRS and Sentinel 2A satellite images were used to extract shorelines for the decadal comparative study . The (Digital Shoreline Analysis System) DSAS tool version 5.0, an opensource software in ArcGIS is used for the shoreline analysis by casting transects perpendicular to the entire shoreline for every 50 meters and smoothing distance of 1000 meters is stored in a table for proper understanding and analyzation of Erosion and Accretion rates. These rates are then calculated by statistical analysis such as (Linear Regression Rate) LRR and (Net Shore Movement) NSM. The result of this comparative study is shown in detailed graphs. The overall change of the coast shows that 58.94% of the area is affected by erosion and 41.06% of the area is affected by accretion. The decadal comparative study indicates that the Puducherry coast is an overall eroding coast, showing significant changes for every decade.

Keywords: Shoreline Change, Remote Sensing, Digital Shoreline Analysis System, breakwaters, Accretion, Erosion, GIS.

1. Introduction

A board range of natural and human induced activities is an on going pressure and a crucial situation, experiencing by the coastal zone of India. Shorelines are complex and it varies according to its environmental and other external factors. The coastal zone of India is at high risk and proper coastal management is essential for coastal protection and the habitants surrounding it. The coastal zone undergoes multiple developments for the expansion of existing ports and construction of new ports along with other coastal structures especially breakwaters playing an very important role in deciding the areas of coastal erosion and accretion, in shaping and orienting coastal landforms and finally in the evolution of the coast. After the introduction of breakwaters for the port, shoreline erosion and accretion trends are considered as critical problems, resulting in damages to the natural set up of the coastal region. Breakwaters are coastal structures that are made up of hard rubble mound rock blocks, granites, concrete as well as other coastal structures like jetties, groins and sea walls create their impact on shorelines which does not show major changes at the beginning stage but through decades these breakwaters tremendously create significant changes along long duration of period greatly affecting the local wave

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conditions, currents and sediment transport processes and causing consequential changes in the configuration of the adjacent shoreline. Thus, disturbing the equilibrium state of the shoreline by upsetting their natural mechanism. Nature's activities like wind, storm, seasonal weather patterns along with natural disasters like tsunami also contribute their impact on the shoreline and upset the natural mechanism. Therefore it is essential to analyze and determine the coastline trend rates for every interval of time period to understand the coastline and its environmental mechanism which will help us to evaluate the risk and pressure on the coastal morpho-dynamics and to prognosis for decisions as the shorelines are complex and dynamic of the natural phenomenon resulting in future changes in the shoreline environment.

A shoreline is basically classified into three trends consisting of erosion trend in which the shoreline is retreated landward, the equilibrium trend stating the shoreline is stable and finally the accretion trend which indicates that the shoreline is extending seaward. The aim of this research is to analyze and understand the decadal shoreline change trends due to the impact of breakwaters for the shoreline stretch of approximately 24 km of Puducherry, union territory, India which is located along the Coromandel Coast, bordering the Bay of Bengal . The research mainly focuses on Puducherry coastline and their breakwaters which created its significant impact on the shorelines of these areas and the following data are extracted from different satellites since 1988. The construction of these breakwaters respectively has made notable changes in the shoreline through decades by upsetting the natural mechanism of the shorelines and implementation of threat and pressure on the coastal morphodynamics. This study is made in order to understand the threat to the shoreline and its surroundings and can be used for coastal management. Future studies regarding shoreline change detection and the impacts on their surroundings can be done. The figure 1.1 represents the satellite imagery of Ariyankuppum breakwaters.

2. Literature review

A major threat facing coastlines globally is shoreline change due to the processes of erosion and accretion. These are largely due to the human activities of constructing protective structures commonly impacting coastal characteristics such as distribution of headland, cliffs and

Fig 1.1 Satellite Imagery of Ariyankuppam Breakwaters

beaches. A major challenge worldwide is to arrest the threat due to erosion/accretion, a problem that can intensify with sea level rise due to climate change. Increase in understanding of shoreline changes along the coast helps in identifying underlying causes and may allow us to have a better understanding of the shoreline structures.

E Tamassoki , H Amiri And Z Soleymani (2014) the study indicated that during each period in which the shoreline made more progress changes in the Length of shoreline is very low in the coastal city of Bandar Abbas. S.Thangaperumal (2020) the study of marina coastline is done by using Multi temporal landsat (7 ETM+) satellite images from 2009 to 2019 were used to extract shorelines. The data is processed and analyzed by (Digital Shoreline Analysis System) DSAS an extension tool of ArcGIS and results shows that both erosion and accretion were observed but majority shows accretion. R.A.Rejin Nishkalank, B.Gurugnanam,Gandhigram (2016) the study proves that majority of the villages in the study area has been subjected to erosion and certain parts had undergone accretion. EPR spatial distribution maps proves that the erosion rate is higher when compared with deposition in the study area in the recent years. Glitson Francis Pereira, Gurugnanam .B,Bairavi S, Dharanirajan .K (2018) the study shows that the region was been in accretional during past decades, but gradually changes occurs as erosion from the beginning of the year 2000 in parts of Cuddalore district, Tamilnadu, India. R. Mani Murali, R. Dhiman, Richa Choudhary, Jaya Kumar Seelam, D. Ilangovan, P. Vethamony (2015) the study concludes that shoreline of

Odisha coast is under high pressure of erosion and also indicates that shoreline behavior is highly dynamic in the area, which could be due to reduced deltaic characteristics of rivers and intense cyclonic activities in the area over the decadal years. Deepa Naik and Pravin D. Kunte (2016) the study shows that around 60 Km of the beach is confronted with erosion and more severe in Dakshina Kannada and Udapi coasts, where about 28 % of the total stretch is critical. In Uttar Kannada region, 8% of this is subjected to severe erosion. R.Mani Murali, R. Dhiman, S. Jayakumar, D. Ilangovan and P.Vethamony it is found out that Dhamara coast showed a net increase in length of 1.89 km in 22 years, (accretion). Maipura coast confirmed the net loss of 470 meters in length of coastline,(erosion) . Richa Choudhary , R.Gowthaman, and V.Sanil Kumar (2013) by this study, it is understood that rocky beaches have not undergone any major changes, since sediment discharge takes place near river mouth as it is very dynamic and only changes seasonally. R.Kannan and Dr. Abhrankash Kanungo (2016) by this study, it is understandable that erosion activities are moderately high compare to accretion in the study area of Nellore Coast at east coast Andhra Pradesh district using remote sensing and GIS. N.N.Salghunaa, S.Aravind Bharathvaj (2015) it is known from the study that the analysis part for the study area is done by direct as well as visually interpreted from the satellite data. The data was processed for getting a basic information and idea of various parameters about the study area. The data used in this study is a wide range of data varying in spatial and spectral resolution. The data used for the study are LANDSAT MSS (August 1980), LANDSAT TM (September 2006; July 2009, July 2013), LANDSAT ETM (November 1999; October 2000; September 2001; January 2002, September 2011) and the results for the current coast is clearly an eroding coast and accretion is seen in minor scale in some parts of the northern part of the Coromandel coast.

All the study was well analysed and understood before proceeding . The papers were clear and findings were up to the expectation. But the results in few were not well represented. More papers were based on temporal analysis of shoreline change detection. The concept was well clear and understandable. The Methodology was well explained and precise . The collection data and their usasge could be much elaborated in detail. The discussions gave clear view of the study and the main focus of the research. It represents the importance of coastal management and the risks an threat to the shoreline and its surroundings. The importance of coastal management and such studies should be done for better understanding of the threats and future risks about to occur and remedial steps and measures can be implemented. All these papers provides with key details on coastal landform dynamics and the importance of coastal management. Coastal Management is very essential for future prediction of coastal and shoreline changes and such studies encourage coastal preservation and better understanding of detailed shoreline morphology. Risk vulnerability assessment is also one of the key factors essential for coastal management. One of the major threat all around the world is the rise of mean sea level. The Coastal zone management is very important to predict, analyse and induce prevention methods from the extreme events like cyclones, storms and tsunami and also the frequent monitoring of coastal hazards is also an important parameter to follow. Coastal managment and sustainability is a very important parameter to determine and analysis the coastal risk factors , coastal trends and coastal hazards induced by human activites and other natural phenomenon as coastal landforms are dynamic in nature and frequent and constant monitoring of shorelines are essential as it a complex geographical feature and observation of coastal and shoreline morphological changes can be recorded and stored in a geo database for future prediction and also to conduct temporal and decadal shoreline change studies for better understanding of shorelines and coastal landforms and its morphology.

3. Method and Materials

The satellite data images of years 1988, 1991, 2004, 2017 and 2021 is acquired from USGS earth explorer sites. The satellite data products used in this study is collected from Landsat 4-5 TM, 8 OLI /TIRS and Sentinel 2A and the selection is done based on the criteria of Cloud cover less than 10% . The details of data description and method adopted for this study is shown in table.3.1.

3.2 Study area

The study covers the following area for the shoreline stretch of approximately 24 km starting from Kanachettikullam till Pudukuppam in Puducherry which lies in the latitude 11° 57’27’’N to latitude 11°46’14’’N and longitude 79°50’19’’E to longitude 79°84’44’’E. The Ariyankuppam river mouth has a port that lies at 11°54’18’’N and 79°49’44’’E which is constructed with two breakwaters located on the northern and southern side of the river mouth in Puducherry. The Puducherry coast started undergoing tremendous amount of erosion and accretion in various regions along the shoreline

Table3.1 Satellite data description

S.No	Satellite and Sensor	Date of Satellite data	Land cloud cover	Scene cloud cover
1	Landsat 4-5 TM	04/26/1988	0.00	1.00
2	Landsat 4-5 TM	01/29/1991	0.00	0.00
3	Landsat 4-5 TM	03/05/2004	1.00	0.00
4	Landsat 8 OLI /TIRS	01/04/2017	0.02	0.03
5	Sentinel -2A	02/04/2021	1.30	1.02

after 1989 since when the construction of two breakwaters took place. In order to control the coastal erosion in Puducherry, a sea wall was constructed for about 2 km long above the sea level. But still the zone is observed to undergo severe sea bed erosion which eventually results in coastal erosion and extreme loss of bio diversity within this zone.

3.3 Methodology

3.3.1 Preprocessing

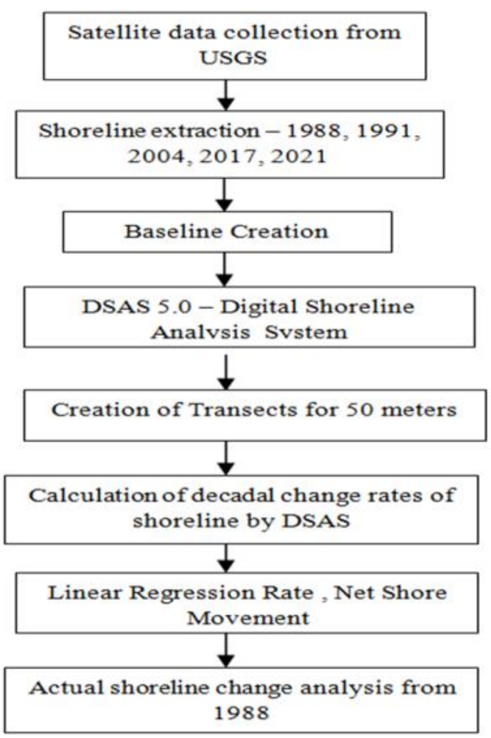

Fig.3.1 - Schematic Representation of Detailed Methodology

The image of each satellite data product is carefully examined before proceeding the process. The acquired satellite data undergoes visual interpretation by creating false colour composite for better understanding of various features in the data. Mosaicking of bands is adopted in this study as the data sets consists of Landsat and Sentinel data which has different spatial resolutions of 30m and 10m respectively. The digitization process of shoreline is carried out in ArcGIS for the 1988, 1991, 2004, 2017 and 2021 georeferenced satellite data in UTM projection. The shorelines were digitized for each of the five satellite data with possible high accuracy. The shorelines of the five decadal years were digitized as polyline shape file and saved in a personal geo database. The multiple shorelines datasets of years 1988, 1991, 2004, 2017 and 2021 were combined by using the merge geoprocessing tool in ArcGIS and a new single output shape file is created. The process of buffering, a geoprocessing tool in ArcGIS is done in order to create the baseline for the shoreline change analysis and saved in another shape file in the same Database. The actual baseline taken is 1988.

3.3.2 Analysis by using DSAS

To create the baseline orientation and shoreline change rate calculation, the Digital Shoreline Analysis System (DSAS) version 5.0, which is a plug in tool available in ArcGIS is installed to carry out the shoreline change rates.

The basic purpose of baseline orientation is to use as a reference to orient where land is relative to water and important for assigning the proper sign (positive and negative) to the rate calculations. The baseline was established on-shore. The following Shorelines obtained were assembled in a single file in ArcGIS and the shoreline dates were labeled in order to identify the year and added in the attribute table. The baseline was constructed parallel to the orientation of shoreline. Transect lines were auto-generated by the software after casting them. The transects were constructed perpendicular to the entire shoreline by casting spacing of 50 meters, smoothing distance of 1000 meters and maximum search distance of 1000 meters from the baseline by using DSAS.

The LINEAR REGRESSION RATE method and END POINT RATE method is used in this study as it has the capability to use more than two shorelines and analyze future shoreline prediction respectively. A linear regression rate-of-change statistic can be determined by fitting a least-squares regression line to all shoreline points for a particular transect. The regression line is placed so that the sum of the squared residuals (determined by squaring the offset distance of each data point from the regression line and adding the squared residuals together) is minimized. The linear regression rate is the slope of the line. The method of linear regression includes these features: 1) All the data are used, regardless of changes in trend or accuracy, 2) The method is purely computational, 3) The calculation is based on accepted statistical concepts.

However, the linear regression method is susceptible to outlier effects and also tends to underestimate the rate of change relative to other statistics, such as EPR (Dolan and others, 1991; Genz and others, 2007). In conjunction with the linear regression rate, the standard error of the estimate (LSE), the standard error of the slope with user-selected confidence interval (LCI), and the R-squared value (LR2) are reported. EPR was calculated by dividing the distance of horizontal shoreline movement by the time elapsed between the earliest and latest measurement. The statistics run for the following shorelines of 1988, 1991, 2004, 2017 & 2021 and an output is created in the form of a table.

The output is generated as points and polygons and this generated output from the table is analyzed and the shorelines of each year is derived in a separate individual table for analysis of erosion and accretion rates of shoreline change through decades. The positive values in the output table indicate accretion rates and negative values indicate the erosion rates.

4. Results and findings

By the analysis from the following coastline stretch of 24 km in Puducherry, it is understood that the coast is going through erosion for decades due to the high impact of breakwater structures and few other natural factors which clearly defines that the coast is an eroding coast. Accretion is also noticed in few regions around the coastline stretch of 24 km but erosion has created a huge impact on the coastline with almost 81.5% eroding the coast compared to accretion. The details of erosion and accretion rates are provided in the tables 4.1, 4.2 and 4.3.

From the analysis , It shows that the coastal area eroded is 448900 m2 on the northern side of the port and the area accreted on the southern side is 358100 m2. On the southern side of the Ariyankuppam River accretions is reported over a distance of nearly 3.5 km. From the various data sets, used to estimate the shoreline change, the change rate of the coast

Table 4.1 Erosion Summary Report

Study Area Distance affected by Erosion in meters	**228 m**
Overall Study Area affected by Erosion in %	**58.94%**
Study Area with Max. significant Erosion in %	**25.5 %**
Maximum Value Erosion	**-8.63**

Table 4.2 Accretion Summary Report

Area Distance affected by Accretion in meters	**1591m**
Overall Study Area affected by Accretion in %	**41.06%**
Study Area with Max. significant Accretion in %	**6.1%**
Maximum Value Accretion	**20.11**

Table 4.3 Status Of Transect Rates

LRR	STATUS OF TRANSECT RATES	
3.0 < LRR <= 20.2	Very High	Accretion Rates indicates positive values
2.0 < LRR <= 3.0	High	
1.0 < LRR <= 2.0	Low	
0.5 < LRR <= 1.0	Very Low	
-0.5 < LRR <= 0.5	Stable Coast	
-1.0 < LRR <= -0.5	Very Low	Erosion Rates indicates negative values
-2.0 < LRR <= -1.0	Low	
-3.0 < LRR <= -2.0	High	
-8.7 < LRR <= -3.0	Very High	

varies randomly for every alternating erosion and accretion. But the overall change of the coast shows that 58.94% of the area is affected by erosion and 41.06% of the area is affected by accretion. The overall erosion rates and net shore movement are represented as graphs in figure 4.1 and 4.2.

4. 1 Comparative study of shorelines

Comparative study is made for the five decadal years by using the shorelines 1988, 1991, 2004, 2017 and 2021. The study proves that the erosion and accretion rates are constantly increasing very decade. The construction of breakwaters has severely impacted the Puducherry coast. More changes were observed around 10 km near the breakwaters and erosion rates were observed in northern regions and accretion rates were observed in southern region. Figures 4.3, 4.4 and 4.5 represents the shoreline

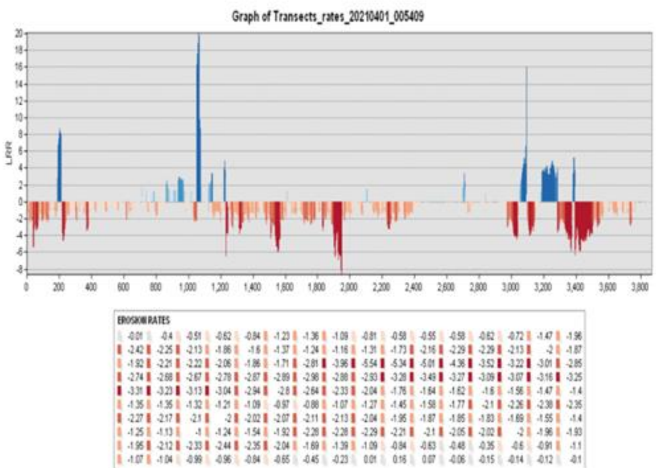

Fig 4.1 Overall Erosion Rates in Meters

erosion and accretion rates throughout the five decadal years from 1988 till 2021.

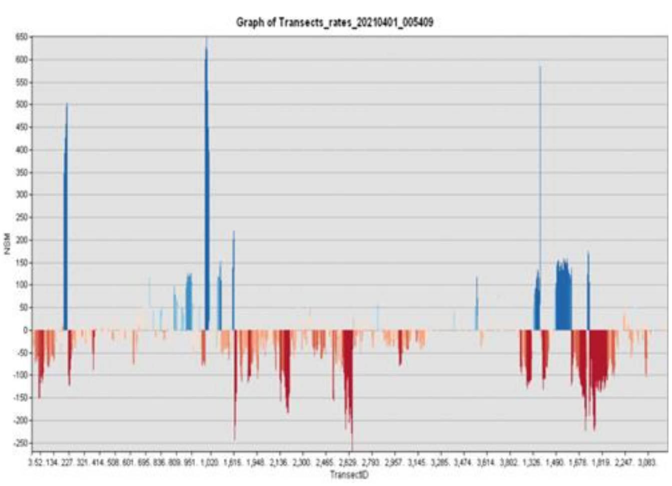

Fig 4.2 Overall Erosion and Accretion rates in meters

The graphs from the research and their findings show that the erosion rates is constantly increasing comparing the accretion rates. But both show significant changes throughout the decades. Major changes have occurred during the decade 1990 to 2009. Natural factors and natural disasters also shows sudden major changes and their impact could be detected my using remote sensing and GIS.

4.2 Rate of change near breakwaters

The shoreline rate of change (erosion & accretion) rates for the Puducherry shoreline from 1989 till 2021 near the Ariyankuppam river port breakwaters is represented in the figure 4.6. This image represents the erosion and accretion trends impacting the shoreline and the entire morphology of Puducherry. It is observed more erosion near the breakwaters and more of stable and low erosion around the breakwaters.

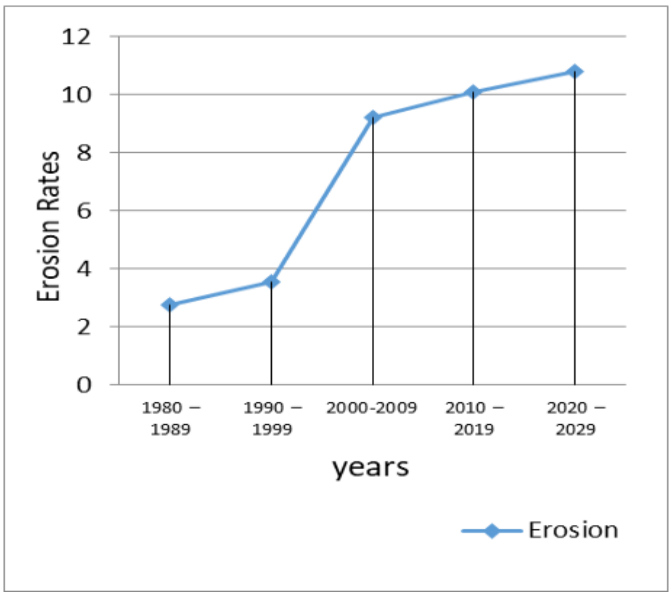

Fig 4.3 Graphical Representation of Erosion rates/Year

4.2.1 Detection of shoreline change of rates

The changes in the shoreline due to impact of breakwaters is shown by classifying the output in seven zones for detail understanding of the results. From the Analysis and findings it shows that the high erosion region is in the northern part of the Puducherry coast and high accretion region in the southern part of the Puducherry coast respectively. Figure 4.7, 4.8 and 4.9 represents the three different zones of erosion and accretion rates. The findings represent that the

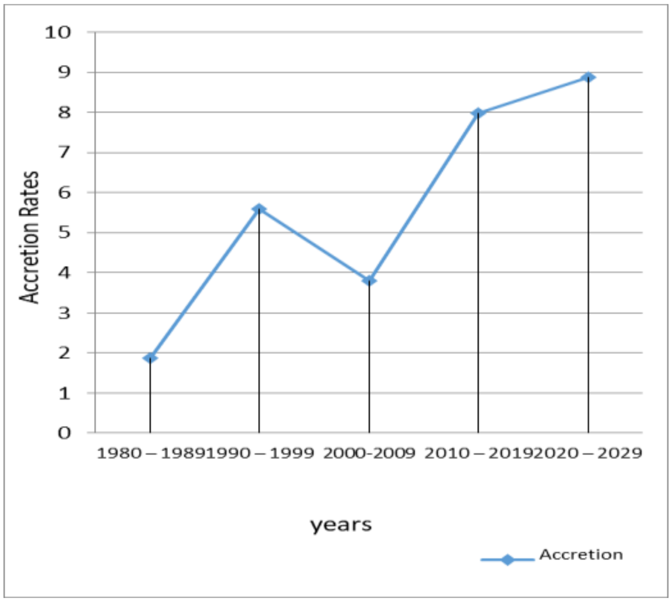

Fig 4.4 Graphical Representation of Accretion rates/Year

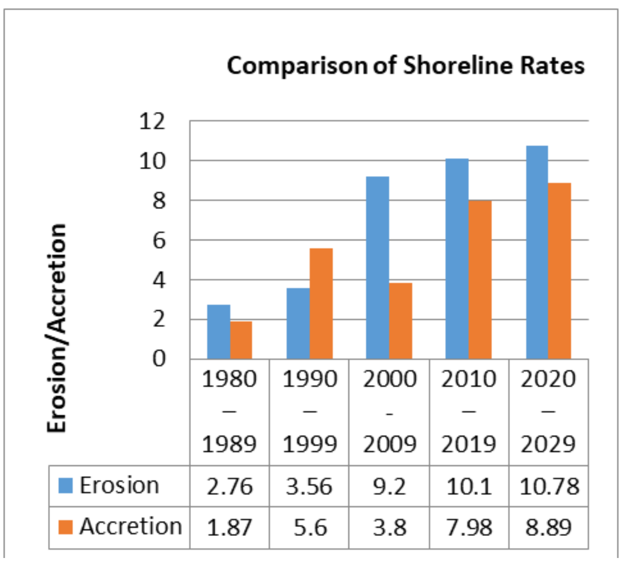

Fig 4.5 Comparison of Erosion and Accretion rates/ Year

Puducherry coast is at major risk and the breakwaters have significantly impacted the shoreline for a long period of time. The coast is being showing threats to the surrounding villages and the habitants living near the shoreline.

4.2.2 Shoreline movement detection

The following shorelines and their movement towards the

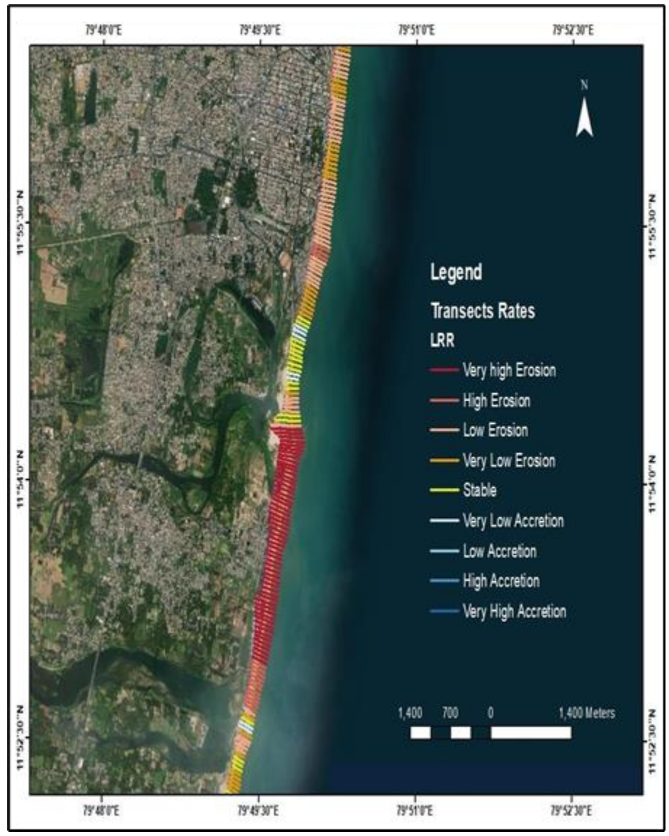

Fig 4.6 Representation of Erosion and Accretion rates near Ariyankuppam Breakwaters

sea and far from sea and difference between the shorelines through out the following five decadal years of Puducherry coastline is represented in the figure 4.10 . The shoreline movement differs for various data sets and it depends on the wind, man made structures and natural disasters occuring during the particular year. The shorelines of years 1988, 1991, 2004, 2017 and 2021 are represented in the following figures throughout the five decades.

5. Discussion & conclusions

5.1 Shoreline Forecasting

The Puducherry shoreline change near the Ariyankuppam river port breakwaters for 15 km has been forecasted using the beta-forecasting in DSAS tool for the upcoming year of 2032. The beta forecasting tool is used to predict upcoming 10 and 20 years. The figure 5.1 and 5.2 represents the 2032 year shoreline forecast.

The present study is carried out to detect the decadal shoreline changes due to the impact of Ariyankuppam river port breakwaters in Puducherry coast, India which covers 14

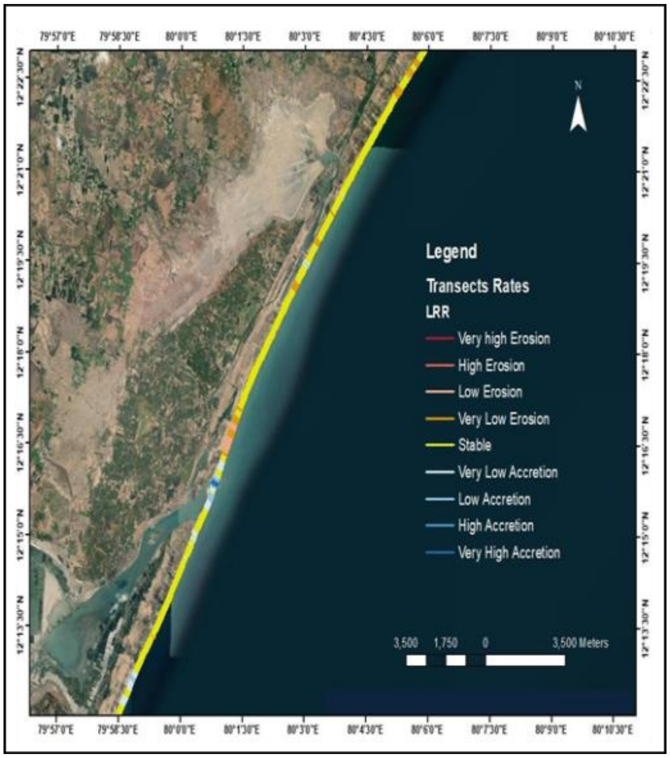

Fig. 4.7 ZONE I

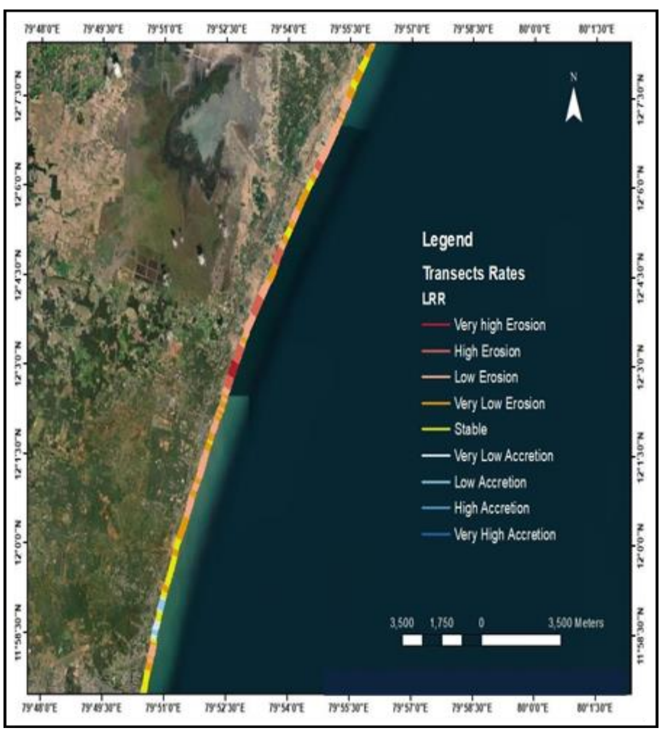

Fig 4.8 ZONE II

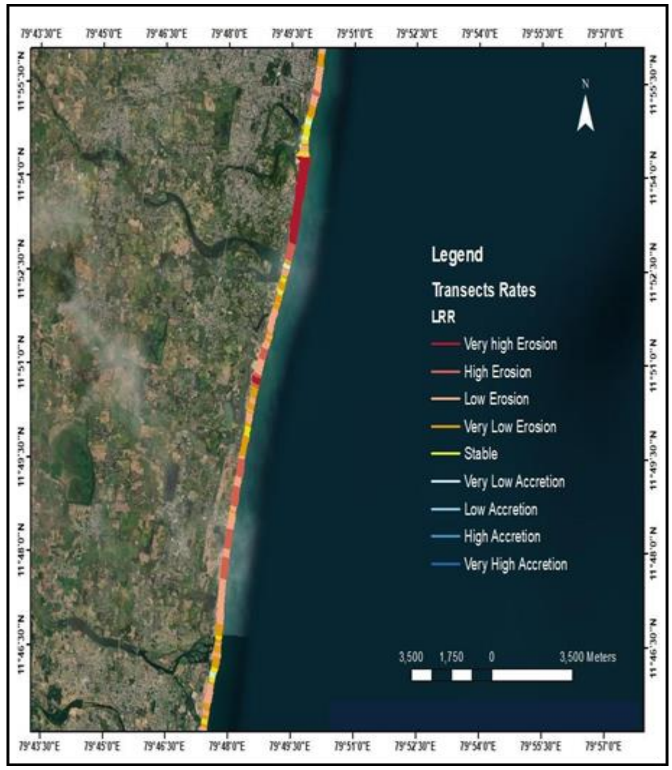

Fig 4.9 ZONE III

km on the southern side and 10 km on the northern side overall covering 24 km through DSAS and remote sensing technique. The shows that the northern part is mainly affected by erosion and the southern part is mainly affected by accretion. During the decade 1980 – 1989, the analysis and results shows that there wasn't much accretion and there was general trend of erosion in the coast. During the decade 1990 – 1999, the analysis and results shows that there is change in trend where the coast is been subjected more to accretion and subjected less to erosion. During the decade 2000-2009, the coast has undergone more erosion and comparatively less accretion. During the decade 2010 – 2019, the coast has undergone both erosion and accretion but erosion has undergone more during this decade compared to accretion. During the decade 2020 – 2029, the coast has undergone more erosion and Accretion while comparing with the previous decade. Overall from the comparative study it is noticed to be an eroding coast till 2021. The bird's eye view also implies that the Puducherry coast is a eroding coast. Remote sensing and GIS together benefit with various advantages. Combining both remote sensing and GIS helped to create an output with possible reasonable accuracy and implement better visual representation of findings and results. The Digital Shoreline

Fig 4.10 Representation of shoreline

Analysis System tool in ArcGIS provided with better understanding of the shoreline . The coastal management is very essential and crucial and should be regularly monitored n analysed for avoiding threats and precautions could be implemented from futher threats. This present study shows that the overall shoreline of Puducherry coast is an eroding coast and such situation is crucial to the species habitant to the shoreline and also threat to the coastal management.

Acknowledgements

First of all, I thank the great Almighty God for his showers of blessings and for providing me the good environment and self-confidence to do this Project Work successfully. I express my sincere thanks to our beloved Regional Director and Dean Prof. Dr. M. Krishnaveni, M.E, Ph.D., Department of Civil Engineering, Anna University Regional Campus, Tirunelveli Region for their kind support for the project.I express my immense gratitude for thanking especially to Head of the Department Dr. J. Thirumal, M.E, Ph.D., Assistant Professor, Department of Civil Engineering

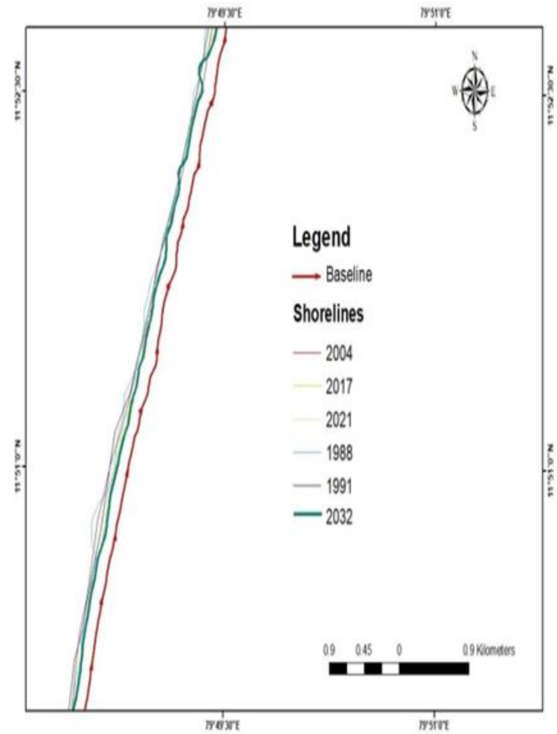

Fig 5.1 Year 2032 Shoreline Forecast

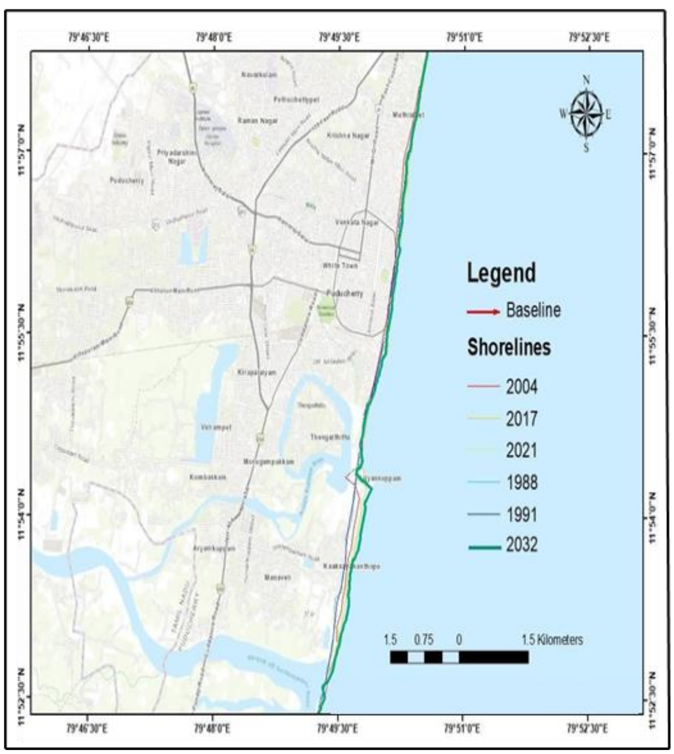

Fig. 5.2 Topographic view of Year 2032 Shoreline Forecast

for providing the foundation and support to carry out the project successfully in all aspects. I have a immense pleasure in expressing my sincere and heartful thanks to Dr. O. Ganesh Babu, M.S, Ph.D., Assistant Professor, Department of Civil Engineering, Ph.D., for his valuable suggestion, advice, encouragement which has resulted in the successful completion of the project.

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Spatial Modelling of Tamil Nadu Economic Crisis During Covid 19

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Abstract

As the World know, the COVID-19 pandemic has become a greatest nightmare to humans and the world's economy. It is imperative, to conduct a Risk based analysis of Covid 19 impacted districts in Tamil Nadu to arrive at a suitable and the need of the hour solutions, while the decisionmakers are exploring viable actions. This study aims to identify the economic imbalances caused across the districts in Tamilnadu, due the Covid 19 Lockdowns and the level of impact realized in people from various financial statuses. The outcome of this research shall provide the statistical data especially on the Middle, Lower-Middle and the Low-Class people; that supports in performing a root cause analysis to identify the rudimental reasons for the crisis. Thus, the researcher shall be in a better position to come up with the required measures, recommendations and new strategies; that may be considered by the government of Tamil Nadu to minimize the socio-economic impact in such future situations. The Researchers established a Spatio Pandemic - Economic Risk Assessment (SP-ERA), to identify risks in the Economy of the Districts of Tamil Nadu by illustrating the threats evolved due to the pandemic and vulnerabilities existing in policies and measures deployed by the state government during the fight against covid 19. The Risk identification and evaluation methodology includes the analysis of probabilities and potential consequences through the following steps, i) Data gathering of District wise Population density, ii) Data Gathering of total covid cases, iii) Different types of Lockdown Strategies and durations deployed across the states, iv) Identification of Covid "Hotspot" areas in each state based on the number of positive cases reported till date, v) Generating GIS layers, pointing high risk settlements based on occupational and socio-cultural gatherings proportionate to the virus infection ratio, vi) Evaluating and Mapping socio-economic issues in different states/regions & vii) Derivation of new strategies and mitigation controls for respective states categorized as Severe, High, Medium, Low and Very Low risk zones. The final results of this analysis, shall help the State Government to prioritize their focus on areas for implementation of the recommended mitigation controls.

Keywords: Covid 19, Risk Zones, Lockdown, ERA-CC/SERAM-CC, Socio-economic crisis, Maps, Economic Growth strategies

1. Introduction

The World has been gripped by a pandemic over the years 2019 - 2021. It was identified as COVID-19 which is the disease caused by a new coronavirus called SARS-CoV-2. While COVID-19 originated in the city of Wuhan in the Hubei province of China, it has spread rapidly across the world, resulting in a human tragedy and tremendous economic damage. As of 30th August 2021, there are 217,415,551 (still counting) cases of COVID-19 globally, with over 4,518,600 deaths.

Given the rapid spread of COVID-19, countries across the World have adopted several public health measures intended to prevent its spread, including social distancing (Fong et al. (2020). As part of social distancing, businesses, schools, community centers, and non-governmental organization

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(NGOs) have been required to close down, mass gatherings have been prohibited, and lockdown measures have been imposed in many countries, allowing travel only for essential needs. The goal is that through social distancing, countries will be able to “flatten the curve”, i.e., reduce the number of new cases related to COVID-19 from one day to the next in order to halt exponential growth and hence reduce pressure on medical services (John Hopkins University, 2020a).

The spread of COVID-19 has resulted in an Economic devastation across the world especially on small and medium scale businesses. The spikes of the pandemic are being measured in waves such as wave 1 (March 2020), Wave 2 (April 2021) and the wave 3 (has been predicted to raise up during the quarter 4 of 2021).

Before reviewing the potential economic impact, socioeconomic consequences, and governmental response, it is important to contextualize the data related to COVID-19. Without such data, it will not be possible to comprehend the scope of the pandemic. Timely and reliable data inform the World of how the disease is spreading, what impact the pandemic has on the lives of people around the world, and whether the counter measures taken are successful or not (Roser et al., 2020).

2. Literature review

Pandemics are not new and have occurred at different stages in human history (Ferguson et al., 2020). While there have been many outbreaks and human catastrophes, there has been a notable rise in the frequency of pandemics from the year 2000 and thereafter. This is particularly due 5 to increased emergence of viral disease amongst animals (Madhav et al., 2017). Given the rise in the frequency of pandemics, many researchers including Garrett (2007) Keogh-Brown et al. (2008) and most recently Madhav et al. (2017) and Fan et al. (2018) argue that a largescale global pandemic was inevitable. Ferguson et al. (2020) from the Imperial College London COVID-19 Response Team claim that COVID-19 is the most serious episode since the 1918 Spanish Influenza pandemic. Despite the comparisons, Barro (2020) concludes that the non-pharmaceutical interventions implemented during 1918 Spanish Influenza pandemic were not successful in reducing overall deaths. This was because the interventions were not maintained for a sufficiently long period of enough time. He estimates that the mean duration of school closings and prohibitions of public gatherings was only 36 days, whereas the mean duration of quarantine/isolation was 18 days (0.05 years). These numbers were quite small compared to the number of days that the 1918 Spanish influenza pandemic was active.

Pandemics are expected to have a severe negative impact on economic activities, at least in the short run. According to Jonas (2013), the impact ranges from: i) avoidance reaction due to social distancing measures (e.g., individuals might forgo consumption and purchases of certain goods and services), ii) small direct costs (e.g., hospitalization and medical costs), iii) larger indirect costs (loss of labor, production), and iv) offsetting and cascading effects (disruption of services, travel and others). A number of studies tried to anticipate the economic loss from a pandemic.6 For example, Jonung and Roeger (2006) forecasted that a hypothetical global pandemic would lead to 1.6 percent drop in GDP for the European Union (EU) due to both demand and supply side factors. Other studies analyze the impact with a historical comparison. For example, ‘how would the casualty numbers during the 1918 Spanish Influenza pandemic transpire today?’ Barro et al. (2020) estimate that, holding everything else constant, the 2.1 percent death rate during the Spanish Influenza pandemic in 1918-1920 would translate to roughly 150 million deaths worldwide (compared to the World’s population of 7.5 billion in 2020) during COVID-19 pandemic. The authors also find that, on average, the 2.1 percent death rate corresponds to 6 percent decline in GDP and 8 percent fall in private consumption.

Compared to previous pandemics, COVID-19 has a disproportionate impact on the elderly from a health perspective. The lockdown measures, however, are more global in scope and scale than their predecessors, and they have disrupted international supply chains as well as aggregate demand and consumption patterns. This in turn has led to heightened financial market turbulence and amplified the economic shock. Moreover, greater borrowing and higher debt levels among firms and households during this time make the short-term shocks more potent compared to previous pandemics (Boissay and Rungcharoenkitkul, 2020).

There are only a few studies of economic costs of large-scale outbreaks of infectious diseases to date: Schoenbaum (1987) is an example of an early analysis of the economic impact of influenza. Meltzer et al. (1999) examine the likely economic effects of the influenza pandemic in the US and evaluate several vaccine-based interventions. At a gross attack rate (i.e., the number of people contracting the virus out of the total population) of 15-35%, the number of influenza deaths is 89 – 207 thousand, and an estimated mean total economic impact for the US economy is \$73.1-\$166.5 billion.

Bloom et al. (2005) use the Oxford economic forecasting model to estimate the potential economic impact of a pandemic resulting from the mutation of avian influenza strain. They assume a mild pandemic with a 20% attack rate and a 0.5 percent case-fatality rate, and a consumption shock of 3%. Scenarios include two-quarters of demand contraction only in Asia (combined effect 2.6% Asian GDP or US\$113.2 billion); a longer-term shock with a longer outbreak and larger shock to consumption and export yields a loss of 6.5% of GDP (US\$282.7 billion). Global GDP is reduced by 0.6%, global trade of goods and services contracts by \$2.5 trillion (14%). Open economies are more vulnerable to international shocks.

3. Methods and materials

3.1 Study Area

The study area lies between 11.1271° N, 78.6569° E extending an area of 130,058 km². There are 38 districts in Tamil Nadu namely Ariyalur (1949.31 sq.km), Chengalpattu (2,944.96 sq.km), Chennai (426sq.km), Coimbatore (4,723sq.km), Cuddalore (3,703sq.km), Dharmapuri (4,497.77sq.km), Dindigul (6,266.64sq.km), Erode (5,722sq.km), Kallakurichi (3,520.37sq.km), Kanchipuram (1,655.94sq.km), Kanyakumari (1,672sq.km), Karur (2,895.57sq.km), Krishnagiri (5,143 sq.km), Madurai (3,741.73sq.km), Mayiladuthurai (1,172sq.km), Nagapattinam (1,397sq.km), Namakkal (3,368.21sq.km), Nilgiris (2,545sq.km), Perambalur (1,757sq.km), Pudukkottai (4,663sq.km), Ramanathapuram (4,068.31sq.km), Ranipet (2,234.32sq.km), Salem (5,245sq.km), Sivagangai (4,189sq.km), Tenkasi (2916.13sq.km), Thanjavur (3,396.57sq.km), Theni (3,242.3sq.km), Thoothukudi (4,707 sq.km), Tiruchirappalli (4,403.83sq.km), Tirunelveli (3842.37sq.km), Tirupattur (1,797.92sq.km), Tiruppur (5,186.34sq.km), Tiruvallur (3,422.43sq.km), Tiruvannamalai (6,188sq.km), Tiruvarur (2,161sq.km), Vellore (2030.11sq.km), Viluppuram (3725.54sq.km) and Virudhunagar (4,241.0 sq.km).

3.2 Methodology

The Methodology Spatio Pandemic - Economic Risk Assessment (SP-ERA) has been developed to identify Socio -Economic risks across the state of Tamil Nadu by illustrating the threats evolved due to the pandemic and vulnerabilities existing in policies and measures followed to implement and release lockdowns in different districts of Tamilnadu during the fight against covid 19. The Risk identification and evaluation methodology includes the analysis of probabilities and potential consequences through the following steps;

The data has been predominantly gathered from The Government of Tamilnadu website for each district to analyze socioeconomic parameters, such as population, population density, percentage of main workers, percentages of literates, Percentage of workers and their dependence relying on the Primary occupation of the respective districts and Children Population between the age group 0-6 in each district.

Further, Covid Intense Locations as classified in Ministry of Health and Family Welfare are used as input to generate various hazard zones, using GIS-based proximity analysis. Along with that Pre-processed satellite imagery of May 2021 is used for land-use/landcover (LULC) mapping to validate the identified Hazard parameters.

As per our understanding of the COVID19, several parameters have been identified to affect its deadliness and contagion (Campos et al., 2020; Imdad et al., 2021; Mishra, Gayen, & Haque, 2020; Rahman, Islam, & Islam, 2020, 2021). These include various hazard, biophysical, and socioeconomic parameters, determining an area’s actual risk to COVID-19 disease (WHO, 2019). The Researchers tried to calculated the risk by integrating hazard and vulnerability to this pandemic with respect to each district as per CRAM model (Shruti Kanga et al.,2021) and validated with the real time data. The results obtained were incongruous for the objective of this study. Hence, researchers developed a New Risk Assessment Methodology shown in Figure 1: SP-ERA Model with the weighted Sum as the key approach in QGIS.

$$SP - ERA = H + V, \qquad (1)$$

According to Equation (1), H are overlay of all the identified Hazards which are assessed using a GIS-based proximity analysis of the covid cases registered with respect to lockdown and release patterns. V are overlay of all the existing Vulnerability parameters of COVID-19 which in turn refers to the socioeconomic and biophysical set up of the communities, making them prone to this infection. Therefore, the hazards when exploiting the vulnerabilities shall increase the COVID-19 risks in the impacted districts of Tamil Nādu.

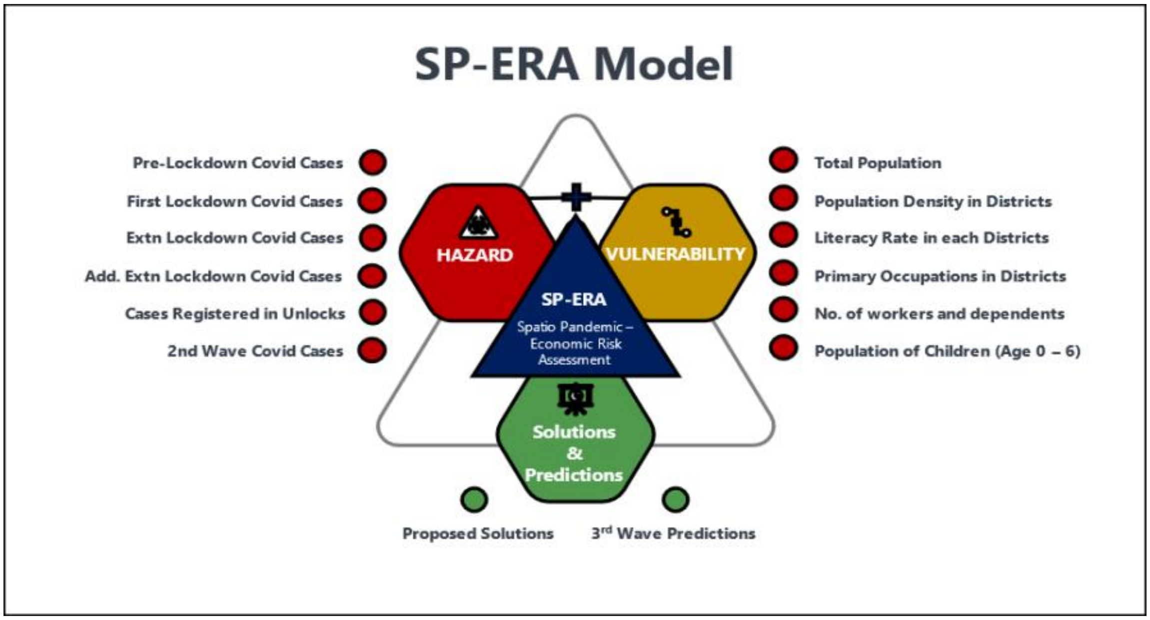

Figure 1: Spatio Pandemic – Economic Risk Assessment Model

The Researchers theorized, hazard in our study as the potential of COVID-19 posing a danger of exposure to Tamil Nādu population. The Researchers used the locations with high density of confirmed positive COVID-19 cases with respect to the lockdown patterns (Pre-lockdown, First Lockdown, Extension Lockdown, additional extension Lockdown and Second wave) as hazards and hazard zones based on governments pre-defined Very High, High, Moderate, Low and Very Low zones. In addition to that, LULC of the districts were also taken into hazard parameter; as settlements of LULC are associated with the high probability of COVID-19 infections, where there are high number of cases registered and the Researchers have digitized Built Up areas from Google Earth and is shown in the Figure 2 : Land Use Land Cover Map.

As far as hazards are concerned, each class is classified on a scale of 1–5 (1= very low and 5 = very high) based on total number of cases. The weightage to additional lockdown is slightly higher than the first lockdown; considering the fact that the number of registered cases is comparatively higher. Whereas, the weightage for third phase (additional extension lockdown) and the second wave has been considered to be same, since the number of registered cases vs actual infections were not accurate, as people started isolating themselves at home instead of hospitalization.

The maps prepared for the identified Hazard Parameters are shown in the Figures 3 (a – f): Which demonstrates the

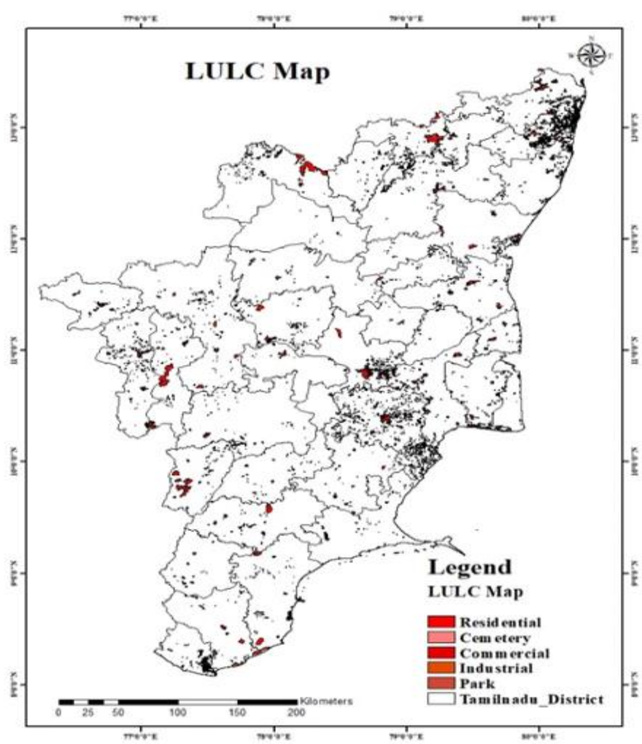

Figure 2 : Land Use Land Cover Map

spatial distribution of the hotspots in the districts of Tamil Nādu during the period :

- 30th Jan - 24th March 2020 (Pre-Lockdown),
- 25th March - 14th April 2020 (First Lockdown),
- 15th April - 3rd May 2020 (Extension Lockdown),
- 4th May - 17th May 2020 (Additional Extension Lockdown)
- 18th May 2020 (Unlocks) and
- 10th May 2021 (Lockdown 2021) respectively.

In our study, vulnerability refers to the area's exposure to COVID-19 infection based on the demographic (Total Population, Population Density and total number of children under the age 6) and Socio-Economic conditions (Total Literacy Rate, Primary Occupation and Total Number of Workers under primary occupation). The total number of (middle and lower middle class) workers relying on the primary occupation within the district and their economic impact due to lockdown and the release patterns, were the key criteria used in identification of these vulnerabilities. Further, The Researchers took literacy rate as an additional parameter, with an assumption that the number infections among the literate population (with higher level awareness of this disease) is expected to be significantly lesser than among the illiterate population.

Vulnerabilities are classified on a scale of 1–5 (1= very low and 5 = very high) based on the identified socio-economic parameters. The weightage to the Literacy Rate & the Worker Population are rated higher in comparison to the other parameters.

The maps prepared for identified Vulnerability parameters are shown in the below mentioned Figures 3 (g – k) for Total Population , Population density , Main workers, Literacy rate and Third wave expectations respectively.

3. Results and Findings

As described in the methodology section, the outcomes of all hazards and vulnerabilities parameters were overlayed using the GIS platform to arrive at a consolidated Hazard Map and Socio-Vulnerability Map respectively. Refer the Figure 4(a) and 4(b)below for a detailed understanding and observations of the most hazardous and the highly prone zones / districts

Upon following the CRAM Methodology (Shruti Kanga.et al., 2021) to integrate the hazard and vulnerability components for risk assessment, it is understood that the outcome is incongruous (refer Figure 4 (c). Hence, The Researchers developed the new risk assessment methodology SP-ERA to arrive at a more appropriate and accurate result (refer Figure 4 (d) as shown below.

Table 1 illustrates the level of impact and the number Covid 19 cases registered during the various phases of lockdown and the relevant releases of the lockdowns.

It is evident that Chennai was the only area affected before the first lockdown (Refer figure 3(a)). However, post the first lockdown demonstrates the western part of Tamil Nādu such as Coimbatore, Erode, Tiruppur, Dindigul and southern part Tirunelveli districts were also observed to have very high infection rate and the districts Karur, Namakkal,

Table 1 : Number of Positive Cases with respect to the Lockdown/Releases dates

Districts of Tamilnadu	Initial Phase	First Phase	Second Phase	Third Phase	Unlocks	Second Wave
	30th Jan - 24th Mar	25th Mar - 14th Apr	15th Apr - 3rd May	4th May - 17th May	18th May 2020	10th May 2021
	Pre Lockdown	First Lockdown	Extn Lockdown	Add. Extn. Lockdown	Unlocks	Lockdown 2021
Ariyalur	Not Affected	Very Low	Very Low	Unregistered	High	Low
Chengalpattu	Low	High	Moderate	Unregistered	Very High	Very High
Chennai	Very High	Very High	Very High	Very High	Very High	Very High
Coimbatore	Low	Very High	Very High	Very High	High	High
Cuddalore	Not Affected	Moderate	Very Low	Low	High	High
Dharmapuri	Not Affected	Unregistered	Unregistered	Unregistered	High	Very High
Dindigul	Not Affected	Very High	High	High	High	High
Erode	Moderate	Very High	High	High	High	Very Low
Kallakurichi	Not Affected	Very Low	Very Low	Very Low	High	Low
Kancheepuram	Low	Low	Very Low	Very Low	Very High	Very High
Kanniyakumari	Not Affected	Moderate	Very Low	Low	High	Moderate
Karur	Not Affected	High	Low	Low	High	Moderate
Krishnagiri	Not Affected	Unregistered	Unregistered	Unregistered	Low	Low
Madurai	Low	High	High	Moderate	Very High	Very High
Nagapattinam	Not Affected	High	Low	High	High	Unregistered
Namakkal	Not Affected	High	Low	Low	Very High	Very High
Nilgiris	Not Affected	Low	Unregistered	Unregistered	High	Moderate
Perambalur	Not Affected	Unregistered	Very Low	Very Low	High	Low
Pudukkottai	Not Affected	Unregistered	Unregistered	Unregistered	High	Very Low
Ramanathapura	Not Affected	Low	Very Low	Very Low	High	Moderate
Ranipet	Not Affected	Moderate	Very Low	Low	Very High	Very High
Salem	Not Affected	Moderate	Low	Low	High	Moderate
Sivaganga	Not Affected	Low	Very Low	Very Low	High	Low
Tenkasi	Not Affected	Very Low	High	Very Low	High	High
Thanjavur	Not Affected	Moderate	High	Low	Very High	Very High
Theni	Not Affected	Moderate	Moderate	Very Low	High	High
Thiruvallur	Not Affected	Moderate	Very Low	Unregistered	Very High	Very High
Tiruvannamalai	Not Affected	Low	Very Low	Very Low	High	Moderate
Thiruvarur	Not Affected	Moderate	Moderate	Moderate	Very High	Very High
Thoothukudi	Not Affected	High	Very Low	Moderate	High	Moderate
Tiruchchirappall	Not Affected	Moderate	Very Low	Very Low	High	Moderate
Tirunelvelli Katta	Low	Very High	High	Moderate	High	Moderate
Tirupattur	Not Affected	Moderate	Very Low	Very High	High	Moderate
Tiruppur	Low	Very High	Very Low	Very Low	Very High	Very High
Vellore	Not Affected	Low	Very Low	Low	Very High	Very High
Villupuram	Not Affected	Unregistered	Moderate	Low	High	Unregistered
Virudhunagar	Not Affected	Moderate	Moderate	Very Low	Very High	Very High

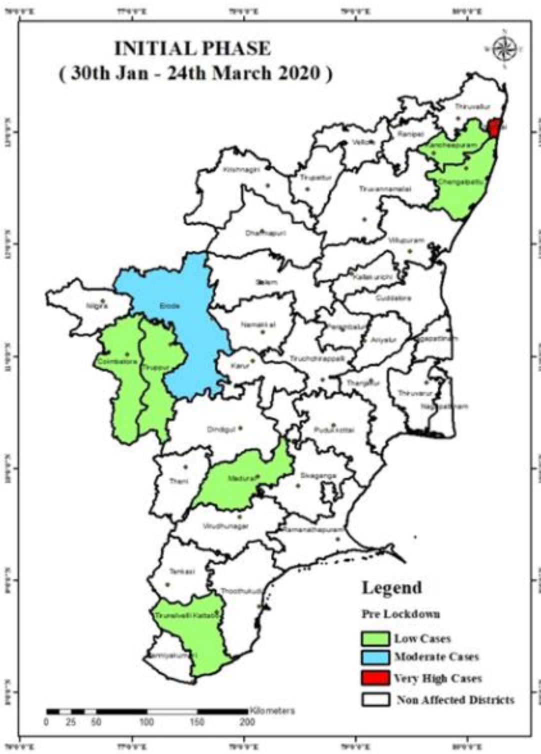

Figure 3(a): Pre-Lockdown Map

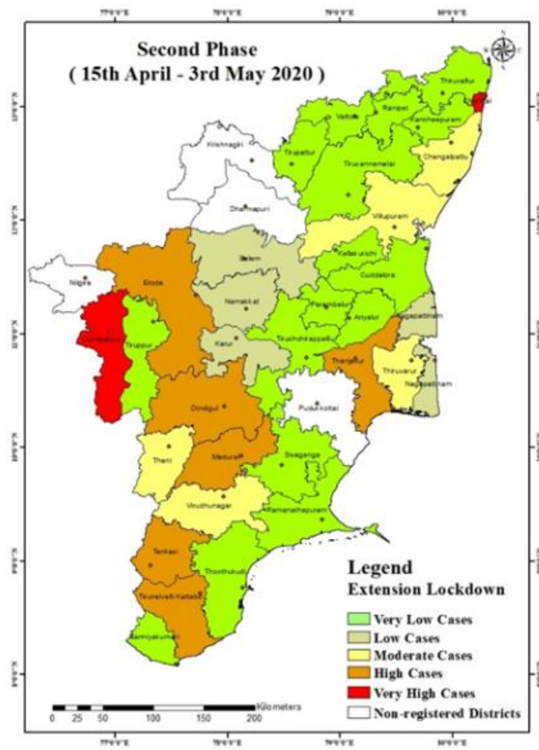

Figure 3(b): First-Lockdown Map

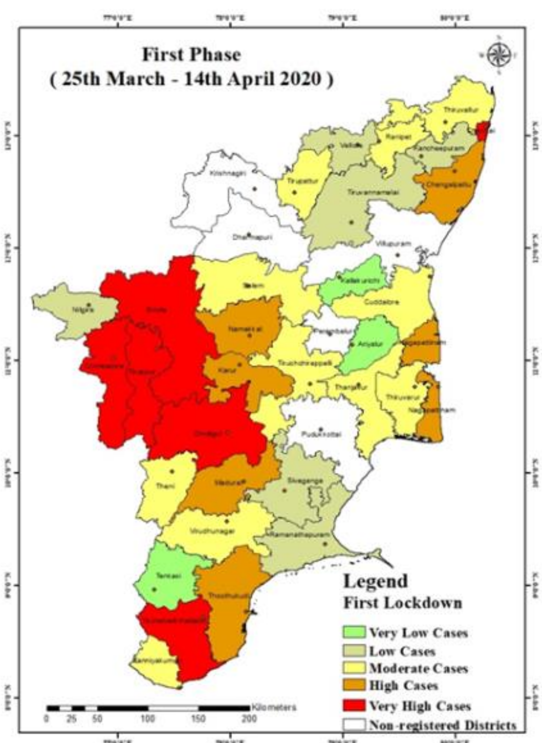

Figure 3(c): Second Lockdown Map

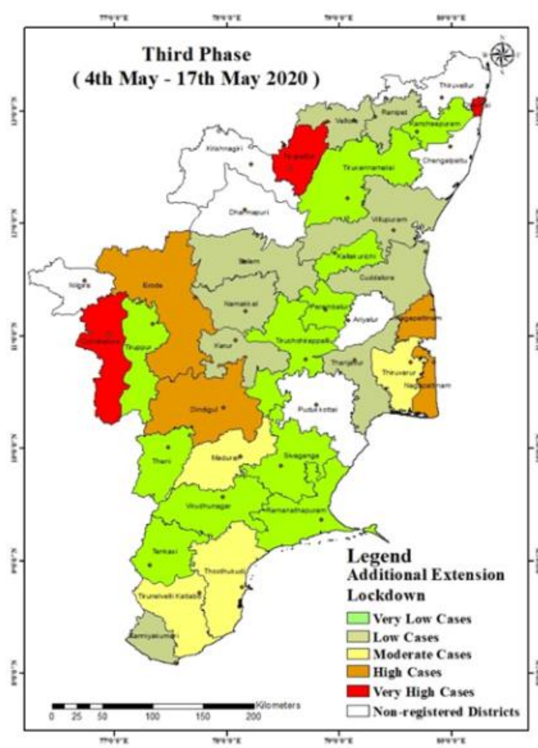

Figure 3(d): Third Lockdown Map

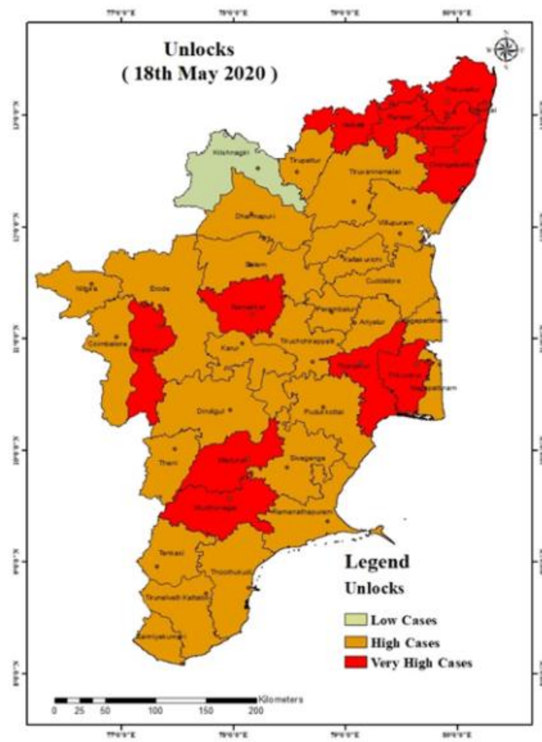

Figure 3 (e): Unlocks Map

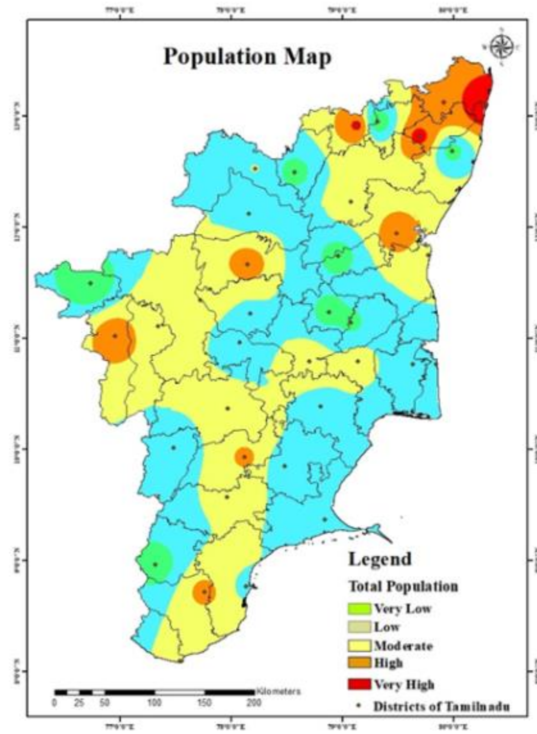

Figure 3 (g) : Total Population Map

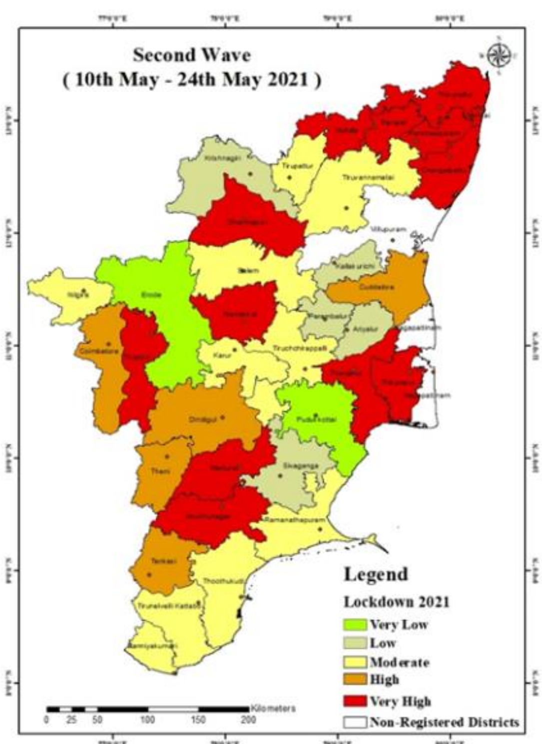

Figure 3(f): Second Wave Map

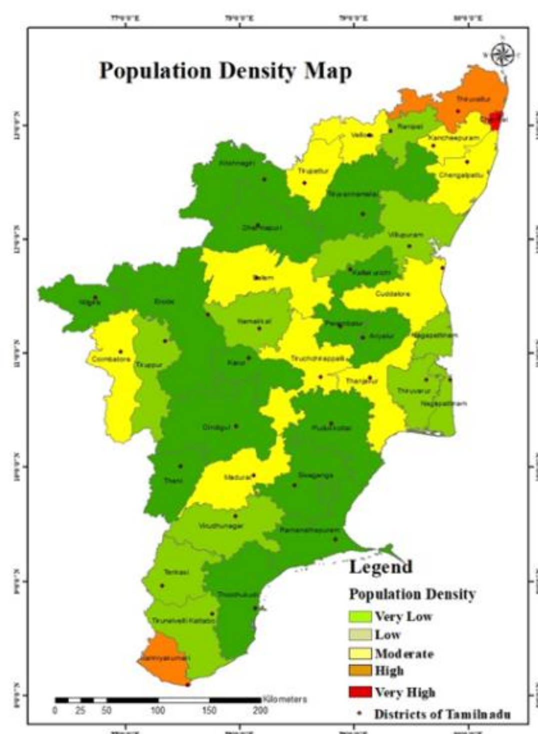

Figure 3(h) : Population Density Map

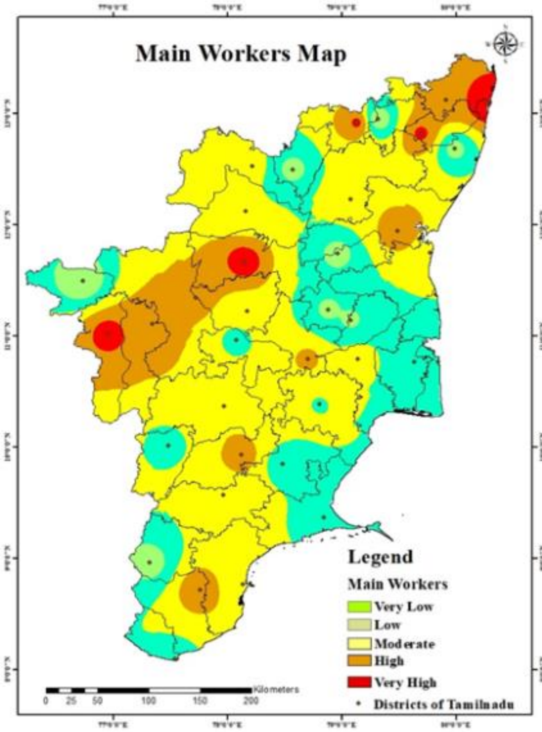

Figure 3 (i) : Main workers Map

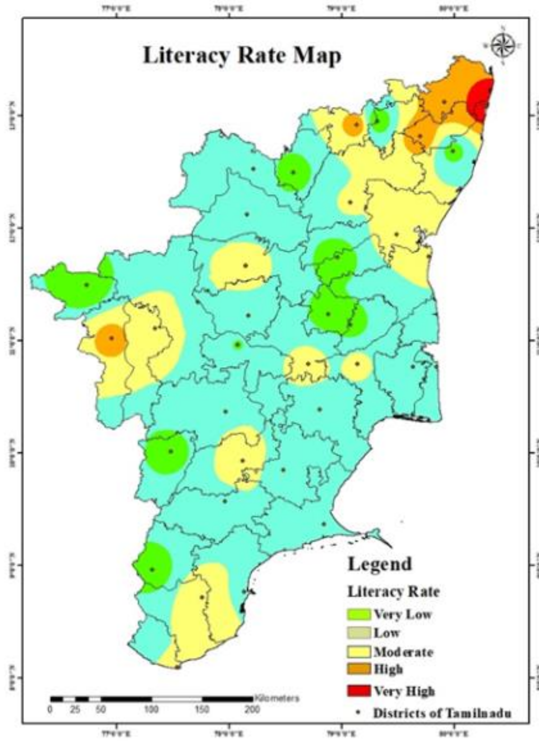

Figure 3(k): Third Wave Expectation Map

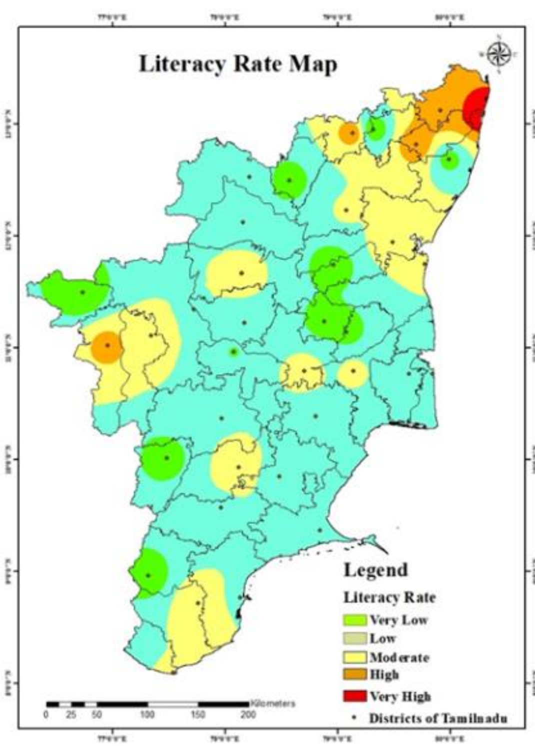

Figure 3 (j) : Literacy Rate Map

Thoothukudi, Madurai Nagapattinam highly infected (refer figure 3 (b)). During Second Phase of the Lockdown, the districts Krishnagiri, Dharmapuri, Nilgiris and Pudukkottai are considered Safe. Chennai and Coimbatore were constantly considered as a danger zone. Rest of the districts Fluctuating between Low and Moderate zones. In the third Phase the district Tirupattur was Predominantly changed to danger Zone. There are no changes in rest of the districts. After the unlocks, the entire Tamil Nādu was considered danger as there were a greater number of covid cases registered. Even the district Krishnagiri which was consistently safe during the entire year was registered with covid cases and marked as low risk zone.

Upon keen observation, The Researchers can identify that Chennai & Coimbatore districts have been consistently in high alert. On the contrary, Krishnagari district has been a denoted as safe zone all through the pandemic.

4. Discussion and Conclusion:

The key observation from the derived graph (refer Figure 5 (a)) is that; though it is really logical to implement lockdowns on districts based on its number of cases registered, the release of lockdowns with same ideology has impacted the socio-economic conditions of the middle and lower middle-class workers / labours and their dependent family members to a greater extent. Especially in districts where the total number of workers population dependent on the primary occupation of the districts is higher in ratio with that of the total population of the district are the ones who were intensely affected due to the lockdowns and the lack of job opportunities to earn the daily breads for themselves and their families.

Though The Researchers whole heartedly appreciate the strategy devised by the government of Tamil Nādu in implementing the lockdowns and releasing them based on the Zones (i.e., Green first, followed by Orange and Red at last); the undeniable fact is that, The Researchers would have certainly experienced a significant amount of lesser damage to the individual and the states economy, if The Researchers had considered the socio-economic consequences as derived in this study. In a nutshell, the red zone districts declared by government of Tamil Nādu, which were the last ones to be released from lockdown are Chennai, Coimbatore, Madurai, Ramanathapuram, Ranipet, Tiruppur and Vellore. Whereas, the above graph evidences that these are the districts with high ratio of middle and lower middle class workers vs the total number of population and the delayed release causing severe socio-economic damages to both individuals and our society.

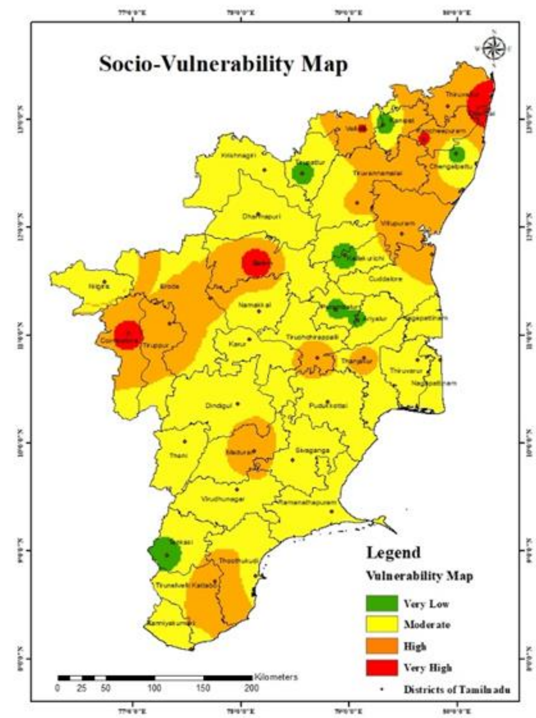

Figure 4 (b) : Socio-Vulnerability Map

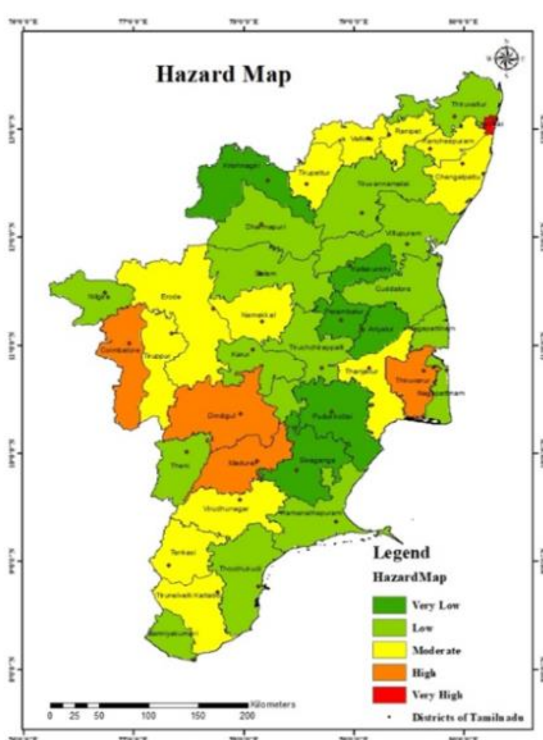

Figure4 (a) : Hazard Map

As part of this study, The Researchers have also developed hazard parameters and vulnerability components to predicts the Third wave of Covid 19 and to identify the potential risk population and high alert zones/districts across Tamil Nādu. The hazard parameter selected is based on current status of districts in Tamil Nādu (unlock status and number of covid cases) and the vulnerability component is derived based on the total number of children population between the age 0-6 across all districts within the state.

The below map (Figure 6 (a): Predicted SP-ERA Index Map) portrays the predicted impact levels in each district, where the general public shall take at most precautionary and safety measures to protect/ safeguard their children from being infected as the third wave is expected to infect kids on a larger scale. Also, The Researchers request the government of Tamil Nādu to pay the kind attention and consider to review this prediction before devising state level strategy to fight our common enemy “The COVID 19 “.

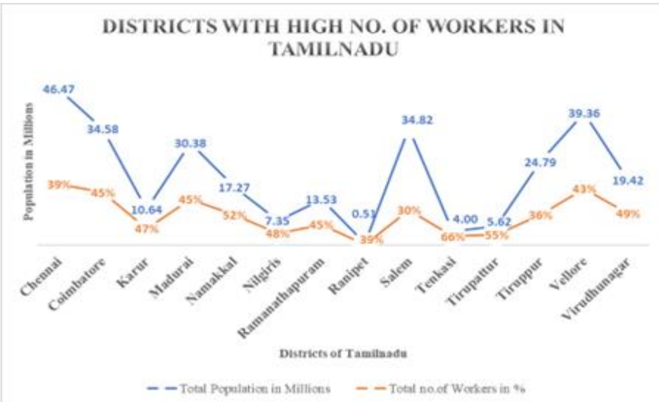

Figure 5(a) : Graph Showing the Districts with high no. of workers in Tamil Nādu

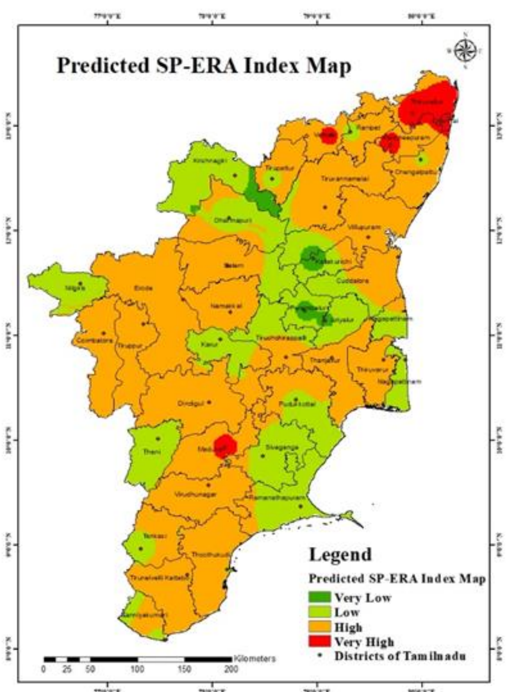

Figure 6 (a): Predicted SP – Index Map

Acknowledgements

The authors wish to express their gratitude to Avakaza Geo-Science Research & Technologies for the support in the completion of the study

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Spatial modelling on the incidence with socioeconomic aspects during the pandemic at India

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Abstract

Coronavirus disease (COVID-19) caused by the SARS-CoV-2 virus, is a global health concern due to the rapid spread of the disease, posing unprecedented socioeconomic burden to the country. The thematic aspect of COVID-19 requires analysis that adopts an interdisciplinary approach, and geography is one of the few disciplines that purports to offer a synthetic approach to the interplay between the biophysical and human variables, by approaching the environment from a holistic perspective with a focus on the forms and processes that concur in a geographical space. The study investigated county-level variations of disease incidence across Metropolitan city of India. The research compiled a geodatabase of environmental, socioeconomic, topographic, and demographic variables that could explain the spatial variability of disease incidence. Further, employed spatial lag and spatial error models to investigate spatial dependence and geographically weighted regression (GWR) and multiscale GWR (MGWR) models to locally examine spatial non-stationarity. Mapping the effects of significant explanatory variables (i.e., income inequality and median household income) on spatial variability of COVID-19 incidence rates using MGWR could provide useful insights to policymakers for targeted interventions.

Keywords: COVID-19, Socioeconomic, regression, GIS

1. Introduction

The World has been suffering by a pandemic from first quarter half of 2020. It was identified as a new coronavirus (severe acute respiratory syndrome coronavirus 2, or SARS-CoV-2), and later named as Coronavirus Disease-19 or COVID-19. While COVID-19 originated in the city of Wuhan in the Hubei province of China, it has spread rapidly across the world, resulting in a human tragedy and tremendous Social economic damage. By mid-June, there had been over 8 million cases of COVID-19 globally, with over 436,000 deaths.

Given the rapid spread of COVID-19, countries across the World have adopted several public health measures intended to prevent its spread, including social distancing (Fong et al. (2020)).1 As part of social distancing, businesses, schools, community centres, and nongovernmental organization (NGOs) have been required to close down, mass gatherings have been prohibited, and lockdown measures have been imposed in many countries, allowing travel only for essential needs. The goal is that through social distancing, countries will be able to “flatten the curve”, i.e., reduce the number of new cases related to COVID-19 from one day to the next in order to halt exponential growth and hence reduce pressure on medical services (John Hopkins University, 2020a).

The spread of COVID-19 is expected to result in a considerable slowdown of Social economic activities. According to an early forecast of the International Monetary Fund (2020a), the global economy would contract by about 3 percent in 2020. The contraction is expected to be of far greater magnitude than that of the 2008-2009 Global Financial Crisis. OECD (2020) forecasts a fall in global GDP by 6 percent to 7.6 percent, depending on the emergence of a second wave of COVID-19. 3 uncertain, with different effects on the labor markets, production

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supply chains, financial markets, and the World economy. The negative economic effects may vary by the stringency of the social distancing measures (e.g., lockdowns and related policies), its length of implementation, and the degree of compliance. In addition, the pandemic and the government intervention may lead to mental health distress, increased economic inequality, and affect some socio-demographic groups particularly adversely.

The goal of this piece is to survey on the Social economic consequences of COVID-19 in Major south Indian states in India. This paper will focus on five broad areas: 1) Population 2) Banking 3) Literacy and 4) Water.

2. Literature review

In an earlier contribution, Joe et al. (2020) conducted a detailed statistical study of factors associated with the COVID-19 pandemic mortality in India using crowd-sourced data to provide estimates for age-sex specific COVID-19 case fatality rate (CFR) and the percentage of confirmed deaths in total confirmed cases. The authors concluded that (1) males have higher overall burden, but females have a higher relative-risk of COVID-19 mortality in India, and (2) elderly males and females both display high mortality risk and require special care when infected. As the period that this study covers ends on May 20, 2020, well before the huge surge in COVID-19 cases—inevitably constrained by the availability of data—there is a need for covering a more recent period.

As reviewed by Das et al. (2021), recent studies on the correlates of COVID-19 predominantly focus on the meteorological variables (e.g., Ma et al., 2020) and few studies focus on socioeconomic correlates. After controlling for temperature and moisture indices, Das et al. have found that the living environment deprivation (in terms of housing conditions, asset possession and water access/population and household density) was an important correlate of spatial clustering of COVID-19 hotspots in Kolkata megacity, the capital of West Bengal. While we cannot include such detailed data for our study at the national level, we control for weekly temperature and rainfall as well as the ratio of urbanization at state levels.

It is evident that socioeconomic factors influence the COVID-19 pandemic and infections, but virtually no studies have considered them in India,7 particularly at the national level. An important exception is Olsen et al. (2020) who have estimated a hierarchical and multilevel model to estimate the correlates of the risk of death because of COVID-19 in 11 states of India, considering the factors at both individual and district levels. The authors combined the National Family Health Survey for 2015/16, Census data for 2011, and estimates of COVID-19 deaths cumulatively up to June 2020 from How India Lives. Olsen et al. found that people living in urban areas, belonging to the scheduled caste, being smokers, who are males with more exposure to activities outside home, and above 65 years have a higher risk of the COVID-19-oriented death. While our study cannot incorporate all the factors, it will cover a few important variables, such as urbanization, the morbidity above 60 years, and income per capita.

3. Method and Materials

3.1 Materials

From the government and Census of India the data was collected

3.2 Methods

We in the current study used Weighted Overlay Method to get the effected percentage (%) for Banking, Literacy, Population and Water because of Covid-19 in few Major south Indian states those are Karnataka, Kerala and Andra Pradesh states.

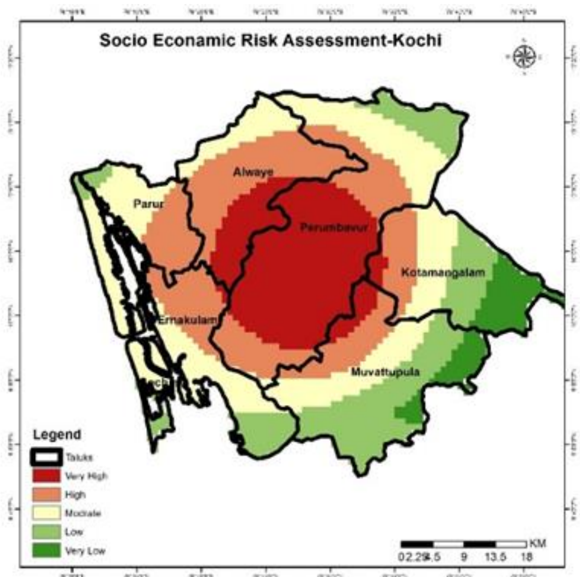
The weighted overlay analysis was performed to identify the Impact on Banking, Literacy, Population and Water because of Covid-19. With the inclusion of four thematic layers such as Banking, Water, Population and Literacy.

Kochi is the capital of Kerala, the below map shows the impact on the Taluks. Those are categorised as Very high, High, Moderate, Low and Very low.

4. Results and findings

Kochi-Kerala

Kochi (also known as Cochin) is a city in southwest India's coastal Kerala state. It has been a port since 1341, when a flood carved out its harbour and opened it to Arab, Chinese and European merchants. Sites reflecting those influences include Fort Kochi, a settlement with tiled colonial bungalows and diverse houses of worship., the below map shows the impact on the Taluks. Those are categorised as Very high, High, Moderate, Low and Very low.

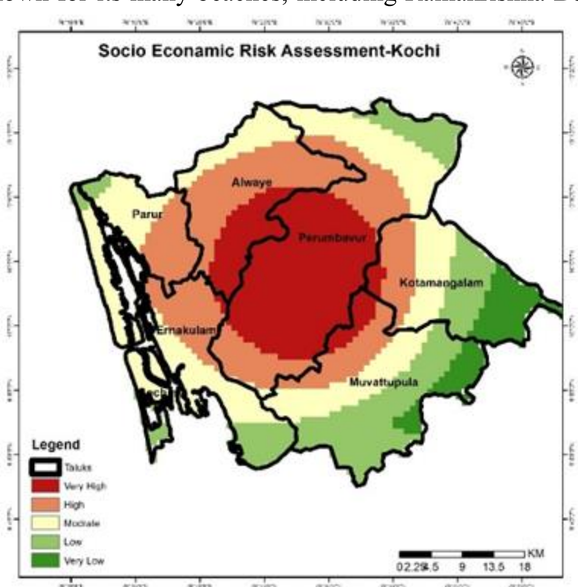


Karnataka-Bangalore

Bengaluru (also called Bangalore) is the capital of India's southern Karnataka state. The centre of India's high-tech industry, the city is also known for its parks and nightlife., the below map shows the impact on the Taluks. Those are categorised as Very high, High, Moderate, Low and Very low.

Visakhapatnam - Andhra Pradesh

Visakhapatnam is a port city and industrial center in the Indian state of Andhra Pradesh, on the Bay of Bengal. It's known for its many beaches, including Ramakrishna Beach,

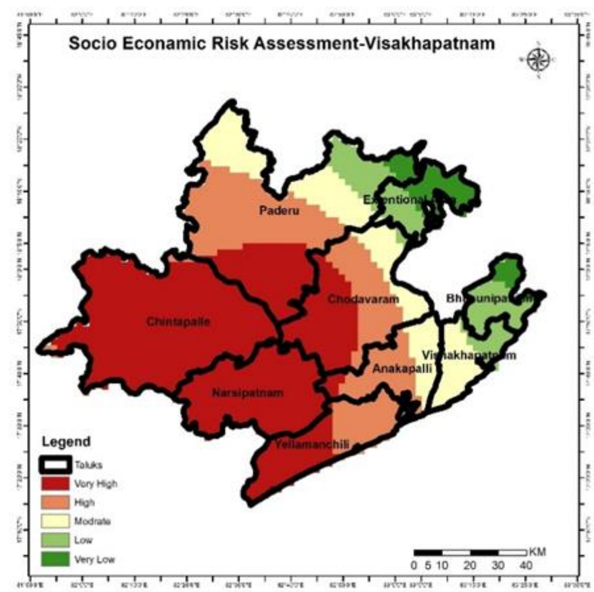


home to a preserved submarine at the Kursura Submarine Museum. Nearby are the elaborate Kali Temple and the Visakha Museum, an old Dutch bungalow housing local maritime and historical exhibits. The below map shows the impact on the Taluks. Those are categorised as Very high, High, Moderate, Low and Very low.

5. Discussion & conclusions

Discussion

India needs to rethink on its developmental paradigm. Equal access to Health and Education is an important condition for equitable development. An important lesson that the COVID-19 pandemic has taught the policymakers in India is to provide greater impetus to sectors which make better



allocation of resources and reduce income inequalities. COVID-19 has also taught a lesson that in crisis the population returns to rely on the farm sector. India has a large arable land, but the farm sector has its own structural problems. However, directly or indirectly, 50 per cent of the households still depend on the farm sector. A greater support to MSMEs, higher public expenditure on health and education and making the labour force a formal employee in the economy are some of the milestones that the nation has to achieve.

One of the imminent reforms to be done in the country is labour reforms. Labour laws are outmoded in India, and some of these date back to the last century. India's complex labour laws have been blamed for keeping manufacturing businesses small and hindering job creation. Industry hires labour informally because of complex laws and that is responsible for low wages. The unemployment rate in India peaked in 2018, at 45 years high of 8.1 per cent (The Hindu, 2019). A rise in wages as a result of simplified labour laws will boost demand and provide inducement to invest. The COVID-19 pandemic has provided an opportunity to expedite the process of labour reforms. Financial inclusion with labour reforms will help in increasing wages and reducing unemployment.

Before the advent of modern state, social security was largely community based in India. The community (in villages and cities) used to take care of the old, poor and vulnerable. Sharing food or giving food as alms was a part of daily routine and was an important part of our culture. Many charitable works for the community were undertaken by those who had resources within the community. At the time of crisis, the state provided help, but a large part of help came from local philanthropists. After the creation of modern state, community-based social security measures were discontinued. State-sponsored social security net for all is yet to be developed in India. Social security measures are segregated. It is time to provide a social security card (with a unique identification number) to everyone in the country, along with a 100 per cent financial inclusion. Availability of advanced digital technology can easily make this possible in India. Massive exodus of migrant labourers, news of some of them dying as a result of walking miles in the scorching sun, and many remaining hungry for days are some of the most disturbing images of lockdown. Duplication of relief efforts in the absence of a formal social security net and having no way to reach the last mile where a part of the population remains left out are some of the realities that have been brought forward by the pandemic. It is time to create a robust state-sponsored social security net for every citizen of the country.

Conclusion

In the present study, we calculated the effect on Socio Economic of Indian major South Indian States. And we tried to show the effect as different categories. Moreover, the based on weighted overlay, the effected areas like Water, Population, Literacy and Banking are classified into very high, high, medium and low and very low risk zone of COVID-2019. It's a great Spatial Analyst Tool. But initially I faced few difficulties getting the output.

6. Acknowledgements

First I would like to thank Kathmandu University, Nepal and FOSS4G team for given this great opportunity.

I also would like to thank AGSRT, Bangalore. Am very thankful to Salghuna, The Research Head, AGSRT, Bangalore. Thanks for your tremendous support, guiding me through out and when ever needed.

7. References

Census India, 2011 data were used to emphasize population and population density of the study area.

Also used

https://censusindia.gov.in/2011census/Hlo-series/HH12.html (Banking Data)

https://censusindia.gov.in/2011census/Hlo-series/HH06.html (Drinking Water data)

https://www.indiacensus.net/literacy-rate.php (Literacy Data)

AUTHOR/S BIOGRAPHIES

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GIS Modelling to Decentralize Examination Centres to Maintain COVID-19 Protocol

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Abstract

The COVID-19 pandemic related lockdown has brought the teaching and learning methods as well as examination system in a perplexed situation. The Hon'ble Supreme Court of India made it compulsory to hold the Final Semester Examination. As per COVID-19 protocol, the movement and gathering of the students in large number are restricted; therefore universities cannot conduct the examination on the university campus. In the present study, a QGIS based model has been created to conduct the Final Semester Examination in a decentralized manner. The model will use the location of affiliated institutions/colleges and the location of students. Using this location data the model will allocate the nearest examination center to the student so that the minimum gathering and movement of the students are involved. The catchment area of each examination center was calculated by generating Voronoi polygons, using the locations of the affiliated colleges (examination center). The students falling within the catchment polygon were allotted the respective center. The model also takes care of the overflowing catchment polygons by redistributing the excess students to the adjacent under capacity catchment polygon. It was done by selecting and shifting the excess students by creating an intelligent-buffer with variable (minimum) distance along the edges between the catchment area in question and the adjacent under capacity catchment polygon. To test the model the actual locations of colleges affiliated with The University of Burdwan, WB, India was used. Students' locations have been identified using a random point generator. The seating capacity of the examination center has been considered 200. QGIS python script was developed to allot the nearest examination center to the students. As per the data used for the model, the maximum linear distance to the examination center of students would be less than 20 Kms. This shall be helpful to maintain the COVID-19 protocol as well as to conduct the Final Semester Examination of any University or Institute.

Keywords: COVID-19, GIS, Examination, Voronoi Polygons, Python

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Surface Runoff Estimation by SCS Curve Number Method in an un-gauged Usri River Basin using GIS

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Abstract

Estimating volume of surface runoff with respect to available rainfall is necessary for sustainable water resource planning and management at river basin scale. In India, there are a few manually operated fixed gauging stations to measure river discharge (Q). Geographical Information System (GIS) based Soil Conservation Service - Curve Number (SCS – CN) model has been employed in this present study to estimate the runoff of an un-gauged Usri River Basin, located in the Giridih District of Jharkhand (India). The river basin covers 865.74 sq km area. The model generates CNii as a primary factor for runoff estimation. CNii value is calculated based on the basin scale land use land cover (LULC) types and hydrological soil group (HSG). The LULC type has been downloaded from openly shared "Decadal Land Use and Land Cover Classifications across India, 2005" which follows International Geosphere-Biosphere Programme (IGBP) classification. While the HSG data has been downloaded from "Global Hydrologic Soil Groups (HYSOGs250m) for Curve Number-Based Runoff Modeling". While the monthly average rainfall data has been downloaded from the India Meteorological Department (IMD, GoI) using India-WRIS portal. The SCS-CN model finds seven zones based on CNii in the basin area like 71, 78, 81, 83, 86, 87 and 100. The CNii zones cover 16.66, 2.65, 1.24, 68.14, 1.43, 8.05, 1.85 percent of area of the total basin area respectively. Weighted average CNii of the basin with "Antecedent Moisture Condition (AMC) II" is 81.52. The monthly average rainfall data in the Usri Basin region (Giridih District) in the year 2020 (January-December) was 101.30 mm. This rainfall can generate discharge (Q) in the Usri River drainage basin amounting 16.39 cumec. The correlation-coefficient between rainfall and discharge is 0.994.

Keywords : Surface runoff, SCS-CN, river drainage

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THEME 8

Geospatial Applications in Citizen Science (GCS)

Use of Geographical Information System (GIS) on Public Police Partnership (PPP) in Nepal

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Law enforcement agencies in Nepal especially Nepal Police is serving public on different social problems such as crime, racism, earthquake, flood, pandemic and many more. A public may be victim or witness of the problems. In both cases, cooperation from public is always vital for Nepal Police to respond on those problems where partnership between public and police is anonymously established, termed as Public Police Partnership (PPP). PPP is a concept where public and police work together to mitigate such problems. Nepal Police always seeks continuous inputs and quality information from public to respond them quickly. Foremost, requirement for prompt response is to find the answer of, "Where did an incident happen?" In such case, Geographical Information System (GIS) as the 'science of where' is adopted. GIS enhances the collaboration between public and police by minimizing the response time and locational matters. Development of free and open-source software (FOSS) based GIS platform including web server and database management system show numerous possibilities of GIS in police operation and in the PPP. Use of GIS based mobile application along with PPP has been used frequently throughout the world in law enforcement agencies. Such system allows public to report an incident using mobile app with the time stamp, location information along with text, audio and video information. In this way, collectively using the concept of PPP and Mobile based GIS technology on receiving an incident or problem information is really important to respond promptly for social justice. This collective effort has been not used yet explicitly in Nepal Police. Thus, based on this concept, Nepal Police receives an incident information from a citizen via GIS based mobile technology. The received information is monitored closely and responded promptly. The time elapse between the incident reporting and incident response can be drastically reduced by using the proposed concept of web and GIS based mobile platform where public and police both are active and main actors of the system. The system allows police and public to work together for the same reason to strengthen the relationship which brings harmony in the society as well.

Keywords: Social Problem, Public Police Partnership, Police Response, Crowdsourcing, GIS, Mobile Application

Introduction

Nepal Police is an organization, dedicated to the nation & committed to the protection of human rights by establishing peace in society through effective crime control and investigation so as to maintain law and order in the country (Police Act, 2012 (1955), 2020). Getting notified quickly on the information about different social problems such as crime, racism, earthquake, flood, pandemic and many more are always crucial for the police organization to provide prompt and instant services. Generally, police organization usages their own means, for example Walkie-talkie, for gathering such information. However, due to various hindrances they can't make their presence in all areas of responsibility (AOR) at a single point of time. In consequences, there is difficulty to get all information promptly regarding such problems. In such scenario gathering or receiving information from the community is always paramount importance where 'Public Police Partnership (PPP)' or 'community policing' coexists. (Trojanowicz & Bucqueroux, 1998) defined community policing as "new philosophy that develop a harmony

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between people and police by working hand in hand to identify and solve contemporary social problems as such providing quality life in the neighbourhood". According to (Palmiotto, 2011) crime prevention, public expectation, police image, and ethics in law enforcement are some of the major areas where community policing can contribute. Nepal Police adopted the concept of community policing first on 1982 "to adopt a proactive approach to mitigate possible incidents and threats" (Community Police, 2014).

In today's world Information Technology (IT) is used in every sector and also plays significant role in policing as well. (Chu, 2001) highlighted that IT can be used to improve police response ability on an incident which helps on crime control and investigation. It indicates that IT can be used in the community policing to gather information and enhance communication between public and police so as to provide effective response. Involvement of community on online collection of various information (spatial, non-spatial) that is 'crowdsourcing' is gaining popularity because it allows us to collect too much information in short period of time. (Goodchild, 2007) emphasized Wikimapia and OpenStreetMap as an outcome of crowdsourcing specifically volunteered geography and reviewed the massive use of crowdsourcing to receive and disseminate GIS based data. Currently, along with the development of IT, mobile devices are used frequently for crowdsourcing. Based on the concept of PPP, (Salim, Cheng, & Choy, 2011) used mobile platform for crowdsourcing to analyse and monitor public perception regarding the social crimes. It shows that there is huge possibility of using PPP and 'Mobile platform' on collecting information about a social incident.

Police organization always seeks answers of the questions: What, Where, When, Why, Who and How during various situations (Gavin Eric Oxburgh, 2010). Among those, WH questions helps to find the answer of 'Where' and is always kept first priority to response immediately. It indicates the importance of 'Geographical Information System (GIS)' in Policing. To find the answers of the questions such as where is an incident location? where is a suspect location? Where is the location of a criminal? Where are escape roots on particular geographical area? Where is the place of higher crime rate? Where is the vulnerable place for natural catastrophe? Where could be the secure place for criminal to hide? Where are the places the suspect recently travelled? Where is the nearest patrol troop to assist in a particular incident? are always important queries from policing point of view. This indicates that law enforcement agencies and police can use GIS for filed operation, crime investigation and prevention, planning tool and as communication tool (Wang, 2012).

This paper mainly emphases on PPP by using Mobile based GIS system in Nepal Police to assist on filed operation specifically for responding to the incidents which have not used yet explicitly in Nepal Police. Thus, based on this concept, Nepal Police receives incident information from a citizen via GIS based mobile technology. The received information is monitored closely and responded promptly. The time elapse between the incident reporting and incident response is drastically reduced by using the proposed concept of web and GIS based mobile platform where public and police both are active components of the system and both entities work together for the same reason to strengthen the relationship which brings harmony in the society as well.

Literature Review

The collective effort on an accomplishment of a task is always effective and efficient comparison to single mindset which has been analysed by (Malone & Bernstein, 2015) in various fields including IT, Biology, economics, law and communication. Here, authors emphasized on "interconnected groups of people and computers, collectively doing intelligent things". The concept of PPP also implies the collective intelligence on an incident response. The PPP can be valuable tool for law enforcement agencies on receiving crime incident information and to build safer society which has been reviewed by (Estellés-Arolas, 2020). The paper reviewed initiatives like PPP and tried to characterize different associated elements that can help on its successful completion. It indicates that the concept of the PPP is convenient and effective idea to get information of social events which finally leads police organization to respond quickly. Use of GIS based mobile application along with the PPP, has been used frequently throughout the world in law enforcement agencies (TRILLION project, 2018) . The Trillion project where public can report an incident using mobile app with the time stamp, location information along with text, audio and video information. The major objective of the project is to 'use innovative sociotechnical system (STS) like social networks, mobile applications to build strong harmony between citizen and law enforcement agencies'. It indicates that GIS based mobile technology along with the concept of PPP provides valuable pin point information of an incident and there are possibilities to get additional related audio and video information with the same platform. This type of additional information provides clear insights of the situation which again assist police organization for a quick response. Only receiving information from public regarding an incident is not sufficient. When the police able to do a prompt response on a received information that leads the public trust towards the police and also brings harmony between police and public. Whenever we talk about the prompt police response the 'Computer Aided System (CAD)' come into existence. The role of CAD system and its impacts to support community policing has been defined by (McEwen, Ahn, Pendleton, Webster, & Williams, 2002). CAD system helps to reduce the time taken to dispatch police officer in an incident. They highlighted major two objectives of CAD system, "the first one is to satisfy citizen by prompt response and second to effecting arrest so as to reduce crime". Moreover, CAD system have capability to integrate different source of information including mobile app such that dispatcher can get a holistic view of the problem in the single dashboard. (Brewer, 2008) defined CAD system for law enforcement agency which can be easily integrated with different law enforcement related information system to deliver prompt response, proper record keeping and reporting. In this way, the paper highlights that the proposed concept have various other benefits by which we can get the answers of the questions such as which incident responded by which police officer in which date and time? That keeps records of each individual personnel and assist on performance evaluation as well. Similarly, the information received from the CAD system is associated with longitude, latitude, which can be easily published into map along with incident category, time and number information. The same ideologies where the role of computerized crime mapping on crime prevention and control has been highlighted by (Vigne, 1999). The paper highlights on the role of digital map for pro-active response from law enforcement agencies by doing analysis of digital map including heat map. These maps allow quick decision making on the problem identified and also turn out to be a source of incident/crime information as awareness for public themselves. Besides this, base maps like OpenStreetMap (OSM) may add more values on such developed maps. (Arsanjani, Zipf, Mooney, & Helbich, 2015) defined different applications of OSM in the GIScience. So with the support of OSM these maps attract public concern and allows them to know the status of crime in their neighbourhood which leads to safer society. GIS based mobile app CAD System to support PPP has been in operation in different developed countries. Law enforcement agencies related to different nations are using the system to perform data driven policing, smart policing and intelligence led policing. (Nesbary, 2001) examined CAD system in Boston Police department and explore its effects in different stakeholders.

The proposed concept of GIS based mobile technology along with PPP is same as CAD where the precise location information of an incident is received via mobile technology from citizen and the police responds back promptly via verifying associated incident location and the police in the field in web dashboard. This system allows dispatcher to visualize different patrol troops with their geolocation in dashboard as well. It also allows dispatcher to chat with the public, who reported the incident, regarding the further information and allows him/her to acknowledge on the incident or assign incident to patrol troops or reject the incident. The system allows each responsible patrol troops to visualize the assigned incident by dispatcher. It allows them a GIS based environment to reach at the assigned incident location where patrol troops can observe the required time to reach the incident location along with efficient route. So the paper describes the concept of GIS based mobile app CAD System along with PPP in the context of Nepal Police for regular operation. It has a capability to cope with existing infrastructure, human resource, working pattern and our culture. The system processes a complete cycle of request form a citizen. It means the system receives the information along with associated information from citizen and then it is acknowledged, responded and rejected based on the situation. Besides this the paper conceptualize the development of a web- and mobile-based geo-crowdsourcing platform, empowered by web-mapping for data visualization, aiming to document GIS based Computer Aided Dispatch (CAD) system. This system allows reported incident to visualize in the dashboard with geo-location and other related description including text, audio and video details so as to help on prompt response. Finally, effective mobilization of police personnel results positive impacts in the society and support to gain public trust as well.

Methodology

There is a need to focus on technological and administrative areas to develop and implement the proposed mobile based GIS system in coordination with PPP. These areas are also useful to implement it effectively throughout the nation and to reinforce PPP. According to (O'Brien & Marakas, 2011), every Information System have major five components which works together to meet its objective. These components are 'software', 'hardware', 'Network', 'data (database)' and 'people'. Technological and administrative areas are evolved to manage those five components.

Technological Framework

Following technologies are used to operationalize the system.

i. Geographical Information System (GIS)

Since GIS deals with location information, the system focuses on incident location, user location and patrol troop's location and their routes. A web based GIS map is used to assist user on pin pointing an incident location, user can search the location or can find it by pan, zoom in, zoom out features. The system enforces user to enable Global Positioning System (GPS) on the mobile device to locate his/her location while reporting an incident. As such the system automatically tracks the location of user during an incident reporting which finally helps on police response. Similarly, the system tracks patrol troop's location and their routes in real time along with their Call Sign Number which is a unique identity. There is a need of uninterrupted internet connection to track patrol location in real time and update their location regularly to the server. In gist, a CAD system is integrated in the system for prompt response.

A web GIS platform constructed by (Xia, Xie, & Xu, 2010) using free and open-source software (FOSS) Linux as Operating System, Apache and Geo-Server as web server, PostgreSQL/PostGIS as database management system (DBMS) shows immense and indispensable possibilities of FOSS based GIS in development and implementation of the system. Similarly, the study carried out by (Farkas, 2017) regarding open-source web GIS client libraries to accomplish web-based GIS system also highlights the importance of FOSS based GIS applications.

ii. Mobile Application

A mobile system equipped with above GIS technology is developed to provide reporting incident environment. The mobile system allows user to report location based incidents along with relevant attachments like audio, video and text. These attachments provide holistic view of the situation and assist patrol troop for verification and prompt response. In addition to this, the system allows public to locate nearest police station with respect to their own location. This allows public to reach quickly to police in emergency or can contact easily. Moreover, the system has capability to disseminate various information as awareness and guidelines for public safety as well. Besides this the system incorporates a 'panic mode' feature which enable user to pass his/her location and cell number to the police control and operation centre (C & O Centre) in the major emergency like the threat of life. Further, a user can search his or her all past reported incident details and their status which allows a fair judgment from the user perspective towards police service. Similarly, the system allows patrol troop to input their Call Sign Number before they start patrol that helps to uniquely identified them. Also, the system allows each responsible patrol troops to visualize the assigned incident and allows mobile based GIS environment to reach at the assigned incident location with the information of route and time required.

iii. Web Dashboard

A web dashboard is incorporated in the system to monitor reported incidents and patrol troops by dispatcher in the control and operation centre. It also allows dispatcher to chat with the public, who reported, regarding the further information to follow up the incident. It also allows to acknowledge on the incident, assign incident to patrol troops based on nearest distance or AOR or reject the incident if it is fake. This web dashboard has zoom in, zoom out, pan features with background base map along with satellite view which allow dispatcher to know details about the incident location. Besides this it has search location facility to move quickly on the incident location. The platform has report generation facility based on the incident category, reported time duration along with description details. It is equipped with graphical representation of reported incidents in the form of pie and bar chart. The distance covered by patrol troops within the specified time period can also be monitored via the platform. Besides this the web dashboard is flexible enough to adjust itself based on the access level of user. User has different access level on the data obtained via mobile platform and access level is assigned based on incident category and responsible geographical area. This dashboard allows administrator to add incident category which is also reflect on the mobile app easily. Besides this it allows administrator to disseminate awareness and guidelines information to public at once anytime. Moreover, it emphasized specific signal for the user who are in panic situation where dispatcher need more attention or highest priority. This dashboard serves as CAD system which is shown below in the Figure 1.

iv. Database Management System

A PostgreSQL/PostGIS is used as database management system (DBMS) to manage spatial and non-spatial data belongs to the system. The DBMS has capability to incorporate coordinate system in the context of Nepal and other major referenced model. The DBMS should have capability of Unicode support mainly for Nepali language. Besides this, it has features like data backup and recovery, audit trail, multi hardware and operating system support etc.

Figure 1: Web dashboard to monitor incidents

Administrative Framework

i. Control Room Vehicle (CRV) and Patrol Troops

These are special vehicles used to patrol regularly in the AOR. These vehicles are equipped with mobile device or rugged tablet which have capability to run the required mobile application. Nepal Police concerned office manages such patrol troops in required number. Similarly, the related office provides proper training to patrol troops regarding the system.

ii. Control and Operation Center (C & O Center) with dispatcher

This is a place for monitoring the web dashboard 24/7 hours along with skilled dispatcher group. Police personnel having some IT skill are selected and trained for the purpose. Dispatcher group operates in the three shift schedule within 24 hours' time period. The C & O Centre with dispatcher establishes based on the requirement of different police offices.

iii. Responsible Police Offices

These are police offices which observe regularly the incident of interest and assist dispatcher to dispatch police patrol. For example, there might be an office which take care of only cybercrime issues within a certain area as such it regularly observes its web dashboard concerning cybercrime issues. The system admin has capability to assign respective privileges to those offices. These offices are selected based on the type of incident they handle in their AOR i.e., geographical area. The system is flexible enough to adjust in such scenario.

Major components of the system within technological and administrative framework which encompassed the whole system is shown below in the Figure 2.

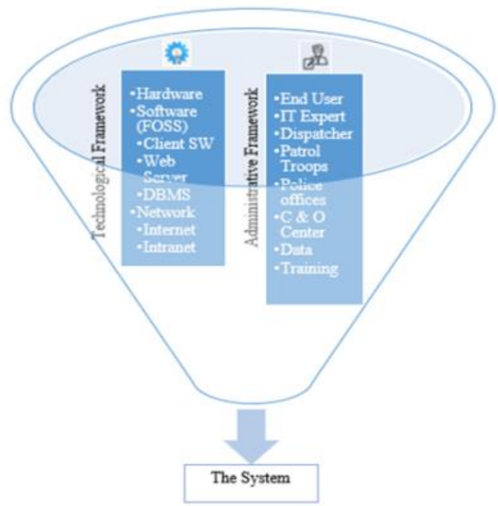

Figure 2: Components within technological and administrative framework

Conceptual Data Flow

The overall data flow of the system is illustrated below in Figure 3.

The above figure describes overall data flow in the system. Public reports incident first via the mobile application. After the successful submission of the report in the system, the system notifies it to the responsible office via dashboard. C & O centre in the responsible office observes it and acknowledges the report which appears in the user's mobile. Besides this dispatcher in the C & O centre command the suitable CRV officer to handle the reported incident. The system notifies and provides details about the incident to CRV. The CRV officer reports the details about the incident after reached at the scene which is noticed by the C & O centre. The system allows user to send feedback or further information, as such the C & O centre able to monitor the incident more closely.

Figure 3: Conceptual Data Flow

Implication

The use of the system helps on digital transformation within Nepal Police and people of Nepal for incident handling. The system provides positive impacts on Nepal Police operation and administration, Police communication network and strengthening relation with citizen of Nepal.

Nepal Police Operation & Administration

It allows Nepal Police to mobilize its human resources effectively in the field operation to provide quick response on public request. It can record the details associated with reported incident such as type of incident, reported date and time, reported by, respond by etc. that helps managerial officer to make different decisions. The system allows manager to keep the performance history of each and every personnel which guides him/her on fair duty deployment that encourage personnel in the field. Besides this, it provides the clear visualization of incidents occurred in different geographical areas that helps again officers to make analysis for preventive measures. Moreover, reported incident data from the public are managed with DBMS helps on data driven, evidence based policing and predictive policing as well in future. Since the vehicle used by CRV are monitored in real time, that helps to identify the distance travel and fuel consumed by them within certain time period. That allows officer to estimate budget regarding the police patrol as well. It also helps on improving the communication channel of Nepal Police by receiving the incident information along with text, audio, video which couldn't be possible with the traditional channel (Walkie-talkie). Since the system saves incident reported and responded time stamp, it allows Nepal Police to improve its performance on responding the incident as well. So the time elapse between the incident reporting and incident response is drastically reduced by using the proposed web and mobile -based geo-crowdsourcing platform.

Amplify Public Participation

Public have a mobile application, a very convenient platform, to report an incident. Public can do it easily by using of smart mobile connected with internet. Due to this platform, public do not require to go physically in a police station which saves their time as well. In general, public feels hesitation to personally go into the police station to report an incident and this platform is very useful in such case as well. Moreover, in the case of pandemic like Corona the platform is really remarkable from the public perspective to reach to Nepal Police. The platform allows public to share text, audio and video content along with precise location of an incident that boost police operation for response. The system allows public to remain in close contact with Nepal Police by using chat facility. Besides this the 'Panic Mode' feature allows public to share their exact location and contact number in the critical situation such that Nepal Police considered it in highest priority to response. Moreover, public can receive security awareness or guidelines dispatched from Nepal Police side easily.

Public Police Participation

Public and police are become an active components of the system. Police get complete situation report of the incident via public and can respond accordingly. They work together to solve social problem efficiently and effectively which leads to bring harmony in the society, reduce crime rate and secure society. Hence the process strengthens the PPP.

Discussion & Conclusion

Based on the current situation it is difficult for Nepal Police to promptly know the precise information about social problems or incidents occurred in the society. As such the prompt response is impossible. This means the time elapse between receiving an incident information and police response is too large. This study conceptualizes the same issue with the concept of web and mobile-based geo-crowdsourcing system. The system operated in the concept of the PPP where two major actors: public and police works together within same platform in a tandem arrangement. Due to the use of GIS and Mobile application, the system helps to drastically reduce time elapse on incident response by allowing public and police to work together as such strengthen the relationship. Moreover, it helps to reduce crime rate, maintain public safety and bring harmony within society as well. The proposed system incorporates two major components and they are technical and administrative framework. Technical component incorporates software, hardware, computer network, mobile application including GIS whereas administrative component incorporates identifying and managing responsible offices to operate, selecting suitable human resource for monitoring information obtained from pubic, dispatching CRV in time, executing task at the scene and performing overall supervision. Moreover, managing quality data, providing suitable training to police personnel, entertaining feedback to improve the system are some of the issue addressed within administrative component. Specially, the use of GIS and mobile based technology add further value to strengthen PPP by reducing the time elapse on police response. Along with increasing number of mobile based users in Nepal and cheap Internet bandwidth (MIS Reports, 2021) there is huge possibility to success the concept. Besides this, recommendations provided by (Nesbary, 2001) regarding the implementation of CAD system in Boston Police Department shows its possibility in the context of Nepal Police as well.

As mentioned earlier such system is not a new concept and adopted by different countries throughout the world. Successful implementation of such system in a particular nation does not imply that it is same for Nepal as well. In the context of Nepal above mentioned technological and administrative factors may influence in its successful implementation. The major component among the five components defined by (O'Brien & Marakas, 2011) is 'People' which may affect the successful implementation of the system in the context of Nepal. The 'People' component includes end user or public who uses the system, data entry operator who enters quality data into the system, supervisor who monitors entered data into the system, IT expert (database administrator, programmer, network and security expert etc.) who solves technical problem, patrol troops who response promptly in the system and dispatcher who monitor reported incident regularly and timely dispatch patrol troops accordingly. In this way, managing people component especially public and police under administration categories is an important factor. Besides this, lack of quality data which is another component may also affect the system for the successful implementation. Regarding the quality of information, (O'Brien & Marakas, 2011) define 'form', 'time' and 'content' dimensions as quality of an Information. They highlighted that only getting information is not sufficient until unless the information has one of them quality based on the situation. In the proposed context, if an end user provides data with precise location, clear description, accurate time and date stamp along with additional information using audio and video details then the response from police is comparatively more fast than the information without these parameters. Quality data leads to meet the objective of the system easily. Another important factor which completely affects the system during implementation is end user training. As suggested by (Cronan & Douglas, 2015), end user training is most important part for the effective implementation of an information system that increases the productivity, saves time and increases the degree of satisfaction. All above components along with two dominant components 'People' and 'Data' are shown below in the Figure 4.

Since the information obtained from the proposed system equipped with location information, there are lots of future extension possibilities such as crime mapping, resource allocation, dissemination of crime information to public in their vicinity are some of them. These activities help again to build safer society and boost the PPP concept.

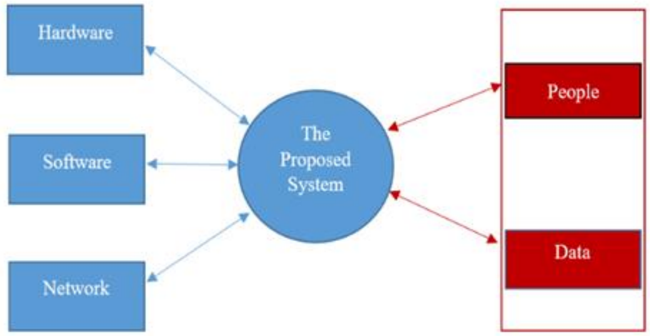

Figure 4: Required components along with possible dominant components.

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Integrated PGIS for the Sustainable Development of Tourism of Machhapuchchhre Model Trek Route and Development of Mobile Based Application

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Abstract

The purpose of the study is to enhance the newly explored Machhapuchhre trek route. It means to bring sustainable development to the tourism site by the use of Participatory GIS for decision-making and provide the information which is yet to be known by many trekkers and backpackers. Along with the use of GIS and Remote Sensing, PGIS is used to research the local resources more precisely and at ground level. Our study aims to deduce the suitable trek route with the use of Multicriteria Decision Analysis (MCDA). One of the MCDA methods, the Analytical Hierarchy Process (AHP) method is used to calculate weightage to each criterion. Weightage is used in decision analysis to select a suitable and sustainable trekking route. The weighted overlay is carried, a GIS suitability map for trekking was obtained. Optimal route planning is a big environmentally and economically challenging issue in high terrain mountain areas. Even the treks which are available at the time are not sustainable ones. Many of the trek routes have been opened for the benefit of some stakeholders. So, the project is focused on systematic and professional methods to ensure a sustainable route with the concepts of ecotourism. To deduce the optimum route, the Least Cost Path Analysis (LCPA) was used, which evaluated the eight neighbors of a raster cell. This generated the path, which moved to the cells with the smallest accumulated or cost value. This process was repeated multiple times until the source and destination were connected. The completed path is the smallest sum of raster cell values between the two points and it has had the lowest cost. Thus, the least-cost path from our study is generated below the existing route, passes above the existing water source near the starting point, passes through the forest in between, and reaches the basecamp, which is our destination. This generated least cost from our study could be used for generating alternative scenarios of ecotourism management based upon resource management and biodiversity conservation, which helps to achieve the sustainable goals. Use of mobile-based application makes easier to disseminate the information deduced from the study of the trekking route. So, the Machhapuchhre Model trekking application is developed, which shows the hotels, motels, attractions, parks, tourist-hubs, risky areas, etc.; this ease anyone for trekking in the route with safety.

Keywords: AHP, Ecotourism, Multicriteria Decision Analysis, Least Cost Path Analysis, Participatory GIS, Trekking

1. Introduction

1.1 Background

Tourism has been one of the major backbones of the economy in Nepal. Every year Nepal earns a foreign currency equivalent of about Nrs 16,825 million. In the year 2014-2015, the highest forex earning was Nrs. 46.370.90 million. (Jaiswal, 2020) The tourism sector has a high potential to carry Nepal into a new economic dimension. As per the statistics, published by the Nepal tourism board, in the fiscal year 2075/76, it is found that 1,71,542 tourists have visited Nepal for trekking purposes. Mardi Himal Trek,

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Ghorepani Poon Hill Trek, Siklesh Trek, Ghandruk Village Trek, etc. are some of the major trekking routes in Kaski districts. Out of which, Machhapuchchhre Model Trek is one of the newly identified trekking trails. The Machhapuchchhre model trek covers seven major rural municipalities and holds immense potential for trekking and hiking activities. The trek region consists of diverse ethnic groups like Gurung, Tamang, Magar Damai, Kami, Sarki, Chhetri, Newar, Brahmins, etc. along with the eye-catching views of snow-capped mountains like Mt. Mardi, Mt. Machhapuchchhre, and Annapurna Himalayan ranges. Machhapuchchhre model trek being a new trek route possesses a lot of opportunities and also difficulties. Machhapuchchhre model trek needs to adopt the model of sustainability and ecotourism for its promotion and increase in the visit of the trekkers. The sustainable development of ecotourism can be achieved by integrating the public participatory approach of geographical data acquisition, known as PGIS.

In tourism and sustainable tourism development, particularly, GIS can be used for various analyses, planning, and mapping purposes, such as inventory of tourism resources, monitoring of specific indicators, mapping recreational conflicts, recreation-wildlife, identifying suitable locations for tourism and recreation development, simulating and modelling spatial outcomes of proposed tourism development. GIS can also serve for integrating socio-economic and environmental datasets within a decision support system. (Boers & Cottrell, 2007). Even though the GIS is characterized as the advanced technology for the development of tourism, the participation of the public in decision-making is a must for the sustainable development of ecotourism. Participatory GIS has been widely used to support community resource mapping to secure sources of community livelihood and their cultural value areas (such as sacred sites, historical places, ancestor routes). (Sulistyawan et al., 2018)

1.1 Statement of Problem

Machhapuchchhre model trek is a new trekking route and is not a proper sustainable trek route. Lack of scientific knowledge and tools in designing the route has led to a fewer number of visitors. Recently the route lacks the local people and stakeholder's emotions, suitable geographical and topographical properties, and socio-cultural values of the ethnic group. Due to this reason, tourism in that region is not enhanced as planned. So, to bring sustainability in the Machhapuchchhre model trek by enhancing the public participation in decision making, using advanced technology and concepts like PGIS, and sharing the information using the mobile-based informative android application, this project is initiated.

1.3 Objectives

i. Specific Objective:

- To establish the Machhapuchhre Model Trek Route and develop a mobile-based application to disseminate the information.

ii. General Objective:

- To assist in the sustainable development of tourism in the Machhapuchhre Trek Route Region.
- To promote the social and cultural value of the region.
- To develop the economy of the local people and stakeholders.

1.2 Study Area

The study area lies in the Annapurna Conservation Area We are mainly focused on the administrative division Machhapuchhre and Annapurna Gaunpalika of Kaski district, Gandaki province. Our main purpose is to establish a model trek route named the Machhapuchhre trek route

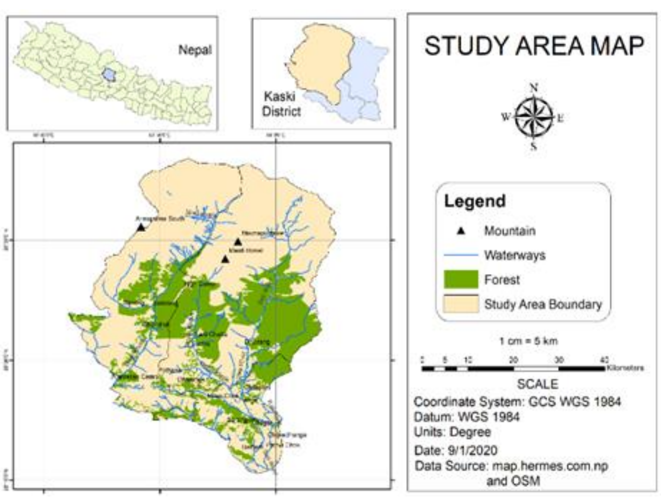

Figure 1 : Map of Study Area

which starts from Sainti Ghatta. Sainti Ghatta is located at the height of 1300 m from sea level. The starting point of our trekking route is about 25 km far from the Pokhara airport via Lhachowk- Lwang road. The trekking route is encircled between the two rivers Mardi and Kaligandaki. Different ethnic groups like Gurung, Tamang, Magar, Kami, Damai, Sarki etc. with their own rich culture and traditions live here.

2. Literature Review

2.1 Concept of Ecotourism

There are several definitions of ecotourism given by the different organizations, agencies, institutions, intellectuals. It is one of the hot topics which is discussed in international, national, and regional meetings, conferences, and seminars. The definition of ecotourism consists of just two words; one that originates from 'ecology' plus 'tourism' (Anomasiri, 2004). The International Ecotourism Society (TIES) (previously known as The Ecotourism Society (TES) in 1991 produced one of the earliest definitions, which states that "Ecotourism is a responsible travel to the natural areas that conserves the environment and sustains the well-being of the people". Ecotourism guarantees the sustainable use of environmental resources while generating economic opportunities for the local people (Kiper, 2013). Ecotourism is about uniting conservation, communities, and sustainable travel. This means that those who implement and participate in ecotourism activities should follow the ecotourism principle of minimizing the impact on natural resources. (Acharya, n.d.) In the context of Nepal, ecotourism has marked its impact. In Nepal, ecotourism helps in environmental conservation, social enhancement, and economic development of a particular area where ecotourism is being promoted. It had helped in controlling antisocial activities, conserving religious and cultural heritage, maintaining peace and prosperity, and increase in cooperation of people with religious beliefs and religious tolerance. Poverty alleviation, rural development, agricultural transformation, and community enrichment are promoted by ecotourism in Nepal (KC, 2017). The government of Nepal has also identified ecotourism as a part of contributing to environmental conservation and economic development in a significant way.

2.2 Concept of Trekking and Trekking in Nepal

Trekking is a recreative activity, mainly performed in outdoors, natural areas, and protected areas. It is practiced in difficult terrain and climate, requires special equipment, clothing, and food, involves risk, jeopardy, and wilderness. Trekking is done on the foot in remote areas or destinations such as natural, rural, and undeveloped areas. Trekking is a multi-day trip through the trails of relatively unspoiled natural areas. The purpose of trekking is to explore and enjoy the untouched natural scenery (Rashidul Hasan, 2015). Nepal is a land full of natural paradise tucked between the skyline of mountains and the greenery jungles of terai where trekking is a popular activity. Nepal has attracted trekkers from around the world (Trekking in Nepal, n.d.). The trekking trails of Nepal range from lush, subtropical lowlands through fertile Himalayan foothills and up to spectacular mountainous highlands revealing a paradise of majestic natural scenery along with magnificent cultural experiences. Nepal's trails take trekkers up close to be face-to-face with the highest peaks on the planet—the glorious Himalaya towering into the skies. Along the way on Nepal's trails, trekkers can enjoy continual natural beauty at nearly every turn of the journey while experiencing meaningful cultural interactions, historical treasures, spiritual activities, and much more (Trekking in the Nepal Himalaya, n.d.). Machhapuchhre Model Trek is a relatively new trekking route in the Annapurna Conservation Area. It is perfect for trekkers seeking an unspoiled and less crowded trail for trekking. The trail encompasses gorgeous terrace farmlands, beautiful waterfalls, mountains, landscapes, and green vegetation. Also, it incorporates knowing about the amazing people living in the region and their lifestyle and culture. These include several communities, including Gurung, Magar, Tamang, Newar, and Brahmin, among others (Machhapuchhre Model Trek: Experience Culture at Machhapuchhre, n.d.). The eye-catching views of mountain-like Machhapuchchhre and Annapurna Himalayan range from the proximity, the opportunity to experience the combinations of rice flora and fauna mountain forest, varied birds special, wildflower wild animals and natural hot spring are supplementary attractions for the visitor of all kinds (Machhapuchhre Model Trek, n.d.)

2.3 Review on PGIS

Participatory approaches regarding the creation of maps and their interpretation started in the late 1980s. Development practitioners at that time were inclined to adopt participatory rural appraisal methods, giving preference to eliciting local knowledge and building on local dynamics to facilitate communication with all stakeholders. Technologies in mapping changed in the 90s with the diffusion of modern spatial information technologies including geographic information systems (GIS), GPS, remote sensing image analysis software, and open access to spatial data via the Internet. The new environment and drive towards local participation have facilitated the integration of geospatial information technologies and systems with community-centred initiatives. This merging for the empowerment of all stakeholders has come to be known as participatory GIS (PGIS) (Bhattacharyya, 2006).

The PGIS practice is the result of a spontaneous merger of Participatory Learning and Action (PLA) methods with Geographic Information Technologies and Systems (GIT&S). PGIS combines a range of geospatial information management tools and methods such as sketch maps, Participatory 3D Models (P3DM), aerial photographs, satellite imagery, Global Positioning Systems (GPS), and Geographic Information Systems (GIS) to represent peoples' spatial knowledge in the forms of virtual or physical, 2 or 3-dimensional maps used as interactive vehicles for spatial learning, discussion, information exchange, analysis, decision making, and advocacy. Participatory GIS implies making GIT&S available to disadvantaged groups in society to enhance their capacity in generating, managing, analyzing, and communicating spatial information (Rambaldi et al., 2006). As GIS becomes widely used in spatial decision-making, there is concern that top-down development planning will be reinforced. This is because GIS hardware, software, and data are expensive, require a high level of technical expertise, and are usually seen as 'expert' systems. Participatory GIS is, therefore, an attempt to utilize GIS technology in the context of the needs and capabilities of communities that will be involved with, and affected by, development projects and programs (Porter, 1998). Participatory GIS involves communities in the production of GIS data and spatial decision-making.

(Satar, 2005) uses participatory GIS to identify local land-use zoning for conservation in Merauke District, Papua, Indonesia. Community mapping and field survey including GPS point gathering was done. To get a land-use zone a community workshop was conducted. The Land-use zone drawn by the local community in a sketch map was based on local knowledge. Besides the workshop, the facilitator and community defined important areas in topographic maps and Landsat maps, brought by the facilitator. After field data collection using a participatory approach, an important area for conservation based on community knowledge was developed. These steps combined participatory approach with GIS process using ArcView™ and Image Analysis™. All the important conservation areas based on community sketch maps, a manual plot in paper-based into Landsat 7 etm digital format were identified. This process started with identifying land cover using bands 5,4,2 to shown natural coverage of all areas. GIS analysis was conducted to determine areas that were not conserved and need further action to develop a conservation plan.

Participatory mapping (PGIS) combined with interviews, geo-coded transect walks, observation, and focus group discussion were used to understand actual livestock keeping practices as a source of livelihood. The spatial and non-spatial data obtained facilitated identification of actual situations in grazing practices, resources, and their changes as well as hidden grazing-related conflicts that involve agro-pastoralists and other actors at local to district level and indirectly at the national level. Conflicts are spatially distributed in the forest areas, around water sources, and along with water bodies because of incompatible interests and goals over those areas. Due to the conflicts, there are social, economic, and environmental effects. It was found that decisions that lead to changing land uses are made with less or no participation of actors who are directly or indirectly affected by the decisions. Essentially community mapping and PGIS proved to be useful tools for examining conflicts and their spatial-temporal distribution (Mandara, 2007).

(Bhandari, 2012) used PGIS for soil conservation in the Phewa watershed of Nepal, to reduce soil erosion by formulating the general rule by the participation of the stakeholders. The poster was prepared by satellite image, topographic map, and Arc GIS software including the local knowledge. The data were collected from the focus group discussion and the individual questionnaire to incorporate the local knowledge and use it to find the risk map based on economic, social, and manageable physical factors for the sensitivity analysis. The soil erosion risk map was prepared by the physical factors Rainfall-runoff erosivity, soil erodibility, Slope length, Slope steepness, Cover-management, Conservation practice using the RUSLE model. After the comparison and discussion among stakeholders, the researcher and export group, and the soil erosion risk map showed that socioeconomic, social, and manageable physical factors management can reduce soil erosion. The study showed that the preparation of the poster GIS map and implementation of this in the watershed area could reduce the soil erosion in the study area compared.

2.3 Review on Least Cost Path Analysis

The least-cost path analysis is raster-based and has a narrower focus. Using a cost raster that defines the cost of moving through each cell, it finds the least accumulated cost path between cells. Least-cost path analysis is useful, for example, as a planning tool for locating a new road or a new pipeline that is least costly (optimal) in terms of the construction costs as well as the potential costs of environmental impacts. A least-cost path analysis requires a source raster, a cost raster, cost distance measures, and an algorithm for deriving the least accumulative cost path (Chang, n.d.). LCPA is a powerful GIS tool to integrate user information and replace the conventional methods of road planning. It can minimize the cost and time of a project (Balogun et al., 2012).

The Least-Cost Path Analysis (LCPA) method provides designers with a way to find the cheapest technique to connect two locations within a cost surface, which can be computed by combining multiple criteria. This analysis used topography and functions related to the slope, land use, and the cost data layers. LCPA model is developed from the accumulated cost surface obtained from the criteria and their applied weightages derived from the pairwise comparison of the decision-makers preferences. Finally, suitable cost-effective pipeline routes were created in GIS (Gyabeng, 2020). The Least Cost Path analysis (LCP) model applied for the route was quite successful in avoiding high slopes, expensive areas, zones of ecological values (Sunusi et al., n.d.).

3. Methods and Materials

The detailed methodology can be described in six major parts. The software used during the whole project were QGIS, Android Studio, etc.

3.1 Data Collection

To design an appropriate trekking route, both quantitative and qualitative methods of data collection were used based on their applicability and usefulness towards achieving the project objectives.

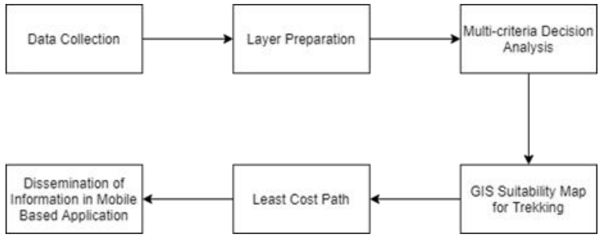

Figure 2 : Flowchart for Project Work

i. Primary Data

Mostly the qualitative data were collected through the Participatory GIS approach. The primary data were collected from the local people, stakeholders, and local government officials via the interview through the onsite visit and online medium, questionnaires, focused group discussions, etc. These primary data are especially about the local culture, traditions, historical monuments, scenic views, and many others. They are qualitative in nature.

ii. Secondary Data

Quantitative data were extracted from OpenStreetMap like road, contour, houses, river, amenities, etc. Similarly, Landsat image with minimum cloud coverage, Digital Terrain Model was downloaded from EarthExplorer (usgs.gov). From these satellite image and Digital Terrain Model, LULC map, slope and aspect map was extracted. These data can be expressed in definite standards and don't differ from individuals to individuals.

3.2 Layer Preparation

After all the data were collected, datasets were checked for missing, duplicate, incomplete data, and outliers. Similarly, information obtained through research articles, phone calls, related documents were transcribed and open coded to categorize key themes and identify patterns. Then all the necessary layers were prepared using GIS. At first, the boundary of the study area was extracted. Then all the layers prepared were classified on the different reclassifying classes and assign certain scores based on interviews/ questionnaires with the experienced owners, local people, and the stakeholders.

3.2 Multicriteria Decision Analysis

There was a matter of selecting a sustainable trekking route. For making it sustainable, different criteria were considered in decision-making. The major criteria were LULC, Accessibility, Amenities, Topography, Water bodies, Tourist spots, etc. Analytic Hierarchy Process (AHP) is one of the traditional MCDA methods developed by Saaty. Analytic Hierarchy Process was developed by Thomas L. Saaty in the 1970s and has been extensively studied and used in decision making for complex scenarios where a group of people works together to make a decision when human perceptions, judgments, and consequences have long -term repercussions (Bhushan & Rai, 2004). It is one of the most inclusive systems considered to make decisions with multiple criteria because this method gives to formulate as a hierarchical and believe a mixture of quantitative and qualitative criteria as well. (Taherdoost, 2017). AHP consists of four major steps which are developing a hierarchical problem model, pair-wise comparison of the criteria assigning relative importance using the Saaty scale of importance, calculation of local criteria, sub-criteria, and alternatives, and finally, sensitivity analysis is done.

3.3 GIS Suitability Map for Trekking

Previously prepared raster layers were assigned a percentage influence. Percentage influence is calculated by AHP as discussed above. The cell values were multiplied by their percentage influence, and the results were added together to create the output raster. This whole process is called a weighted overlay. After multiplying the LULC layer which was not reclassified with weighted overlay, a GIS suitability map for trekking was obtained. The algorithm for the suitability map preparation is shown below in figure 3.

3.4 Least Cost Path Analysis

After the suitability map for trekking is prepared, the Least Cost Path tool is used to delineate the shortest route to the Machhapuchchhre Base Camp on the basis of cost. In our case, the cost was the function of multiple criteria defined by the local people, stakeholders, and experienced one. All the requirements like Source raster, Cost Raster, Cost distance measure, and algorithm were assigned for deriving the least cost path.

Table 1 : Layers

SN	Layer	Reclassifying Class	Score
1	Slope	0-30 30-40 40-50 50-60 >60	9 7 5 4 2
2	Aspect	S, Flat, SW, SE N, NW NE E, W	2 7 9 4
3	Proximity to Existing Route	0-350 350-500 500-800 800-100 >1000	9 8 6 5 4
4	Proximity to Cultural and Religious Site	0-350 350-500 500-800 800-1000 >1000	9 7 6 4 2
5	Proximity to Settlement Area	0-250 250-500 500-800 800-1000 >1000	10 8 6 4 2
6	Proximity to Steep Areas	0-20 20-40 40-60 60-80 80-100	1 3 5 7 9
7	LULC	Settlement Water bodies Snow Barren Land Vegetation	7 1 6 5 9
8	Amenities (Hotels, Shop, etc.)	0-300 300-600 600-750 7500-1000 >1000	9 7 5 3 2
9	Water bodies (River, Stream)	0-100 100-200 200-400 400-800 >800	3 8 6 4 2
10	Tourist Spots	0-100 100-200 200-400 400-800 >800	9 8 6 5 3

3.5 Dissemination of Information in Mobile-Based Application

A mobile-based android application designated to ease the trek in the Machhapuchchhre Trek Route was developed using the Android Studio which is the android based free and open application development kit. We used XML, and Java to develop the application. The XML stands for the Extensible Markup Language and is used to develop Android User Interface. Similarly, Java is Object Oriented Programming language with the help of which we link the user interface with the backend. Also, the Mapbox which is used which is the developer platform that is used to create a custom application that can be used to display maps, solve problems with maps, data, and spatial analysis. We have used the Mapbox SDK for android for the development of the android-based application. With the help of the Mapbox, we have been able to display the global map, the user

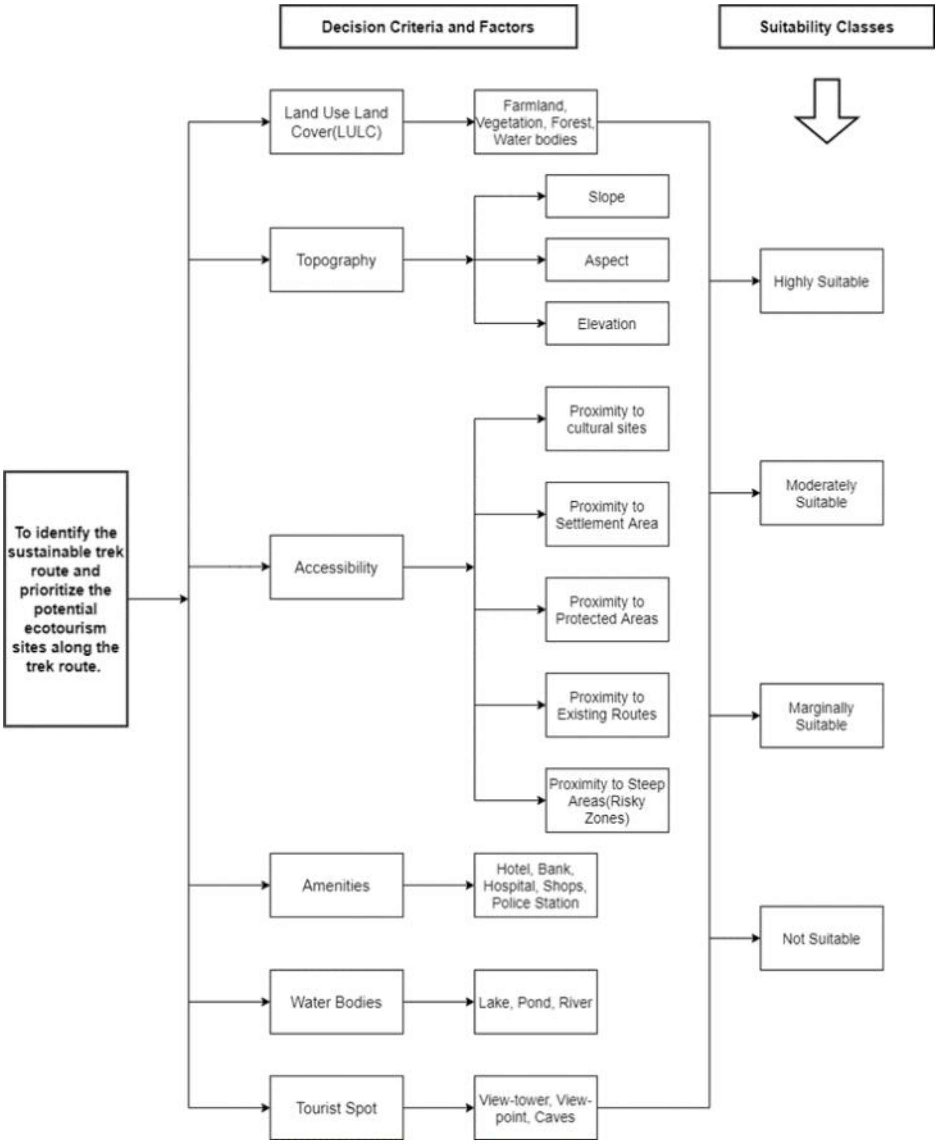

Figure 3 : Process of creating Suitability Map

location (device location), track the user location. We have used the device's location sensors to get the user's recent location. The functionality to show the user location is added on the Mapbox map, which fetches the required user location from the GNSS sensors and indicates on the map. The nearest hotspots, foods and hotels, and shops will be shown directly on the map to notify the trekkers about them in their trek route.

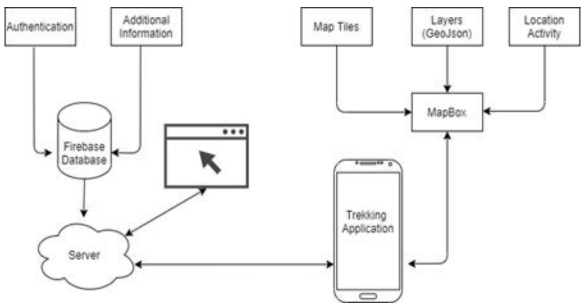

Figure 4 : Android Application Working

The final output, android based trekking application will be the combined use of the GIS, Android Studio, and Web-based application. GIS will be assisting to find the perfect trek route for Machhapuchchhre Trek Model. With the help of the android studio, we will be able to create different activities like the bottom floating action button, and activities in the android app. The application is accompanied by its firebase database which stores the shapefiles, GeoJSON files, and also the user's activities. The database is connected to the server from which it is connected to the web database. Also, the Mapbox SDK is used for loading the map tiles, geocoding, searching the map data, navigation, etc. The Mapbox is authorized to use only after accessing the private secret key called access token.

4. Results and Findings

4.1 Analytical Hierarchical Process (Weightage)

Choosing the best trek route is a multi-criterion decision problem, where the different local people, stakeholders, and business houses are involved. This could bring conflict between factors of decision. Here a mathematical model AHP is used to bring solutions in these conflict situations.

For easiness, criteria and alternatives are marked with abbreviations. The abbreviations for the criteria are as follows:

A1 Slope
A2 Aspect
A3 Proximity to Existing Route
A4 Proximity to Cultural and Religious Site
A5 Proximity to Settlement Areas
A6 Proximity to Steep Areas (Risky Zone)
A7 LULC
A8 Amenities (Hotels, Guest House, Police Station, Hospital, Banks, Shops)
A9 Water bodies (Lake, Ponds, River, Waterfall)
A10 Tourist Spots (View Tower, View Points, Caves, etc.)

Then the pair-wise comparison matrix is formed to compare each criterion with all other criteria. After that normalization is done followed by the various mathematical calculations to find the criteria weights.

Table 2 : Calculation of Criteria Weights

Criteria	Weighted Sum Value	Criteria Weights
A1	0.27	0.03
A2	0.17	0.02
A3	3.50	0.29
A4	0.89	0.08
A5	1.13	0.10
A6	0.47	0.04
A7	0.65	0.06
A8	1.85	0.15
A9	0.22	0.02
A10	2.73	0.22

Also, the Consistency check was done by calculating the

Consistency Ratio (CR), which is found to be CR = 0.0991. The CR was found to be less than <0.1, and the calculation was considered to be consistent.

4.2 GIS Layer Prepared

All the layers like Slope, Aspect, Risk Areas, Proximity to Existing Route, Cultural and Religious sites, Amenities, Water bodies, Tourist spots, etc. were prepared in GIS software based on the methodology described above. Each of the layers/criteria is prepared with great care and classified and assigned scores respecting the local people, stakeholders' sentiments.

4.3 Site Selection for Base Camp

A probable base camp for the Machhapuchchhre Trek Route is assumed by the viewshed analysis in Google Earth. From the base camp, we got the synoptic view of

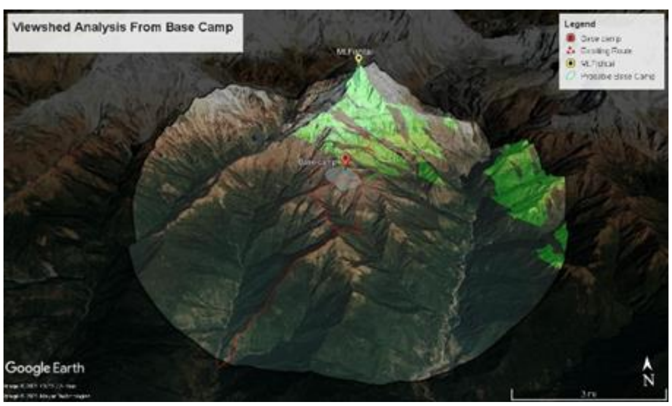

Figure 5 : Viewshed Analysis of Basecamp

Machhapuchchhre Mountain. The mountain's base is just about 4.5 km far away from that base camp point. A base camp is a destination for the least cost analysis done in our study.

4.4 Weighted Overlay

The Weighted Overlay tool applies one of the most used approaches for overlay analysis to solve multicriteria problems such as site selection and suitability models. In a weighted overlay analysis, each of the layers is overlayed and are given the appropriate weights calculated from AHP, to generate the weighted overlay raster. Here the weighted overlay is done for suitability modelling to locate suitable areas sites for the trekking where the higher values indicate

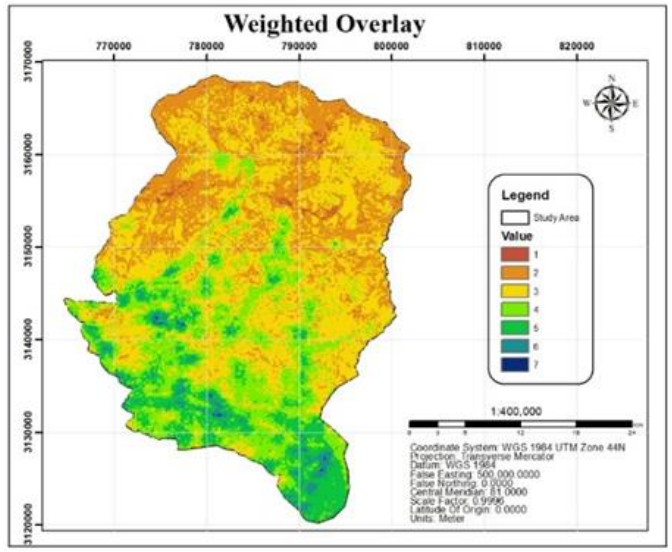

Figure 6 : Weighted Overlay

that a location is more suitable for trekking.

4.5 Cost Distance Raster

After the weighted overlay was done, cost distance raster is generated as shown below which calculates the least accumulative cost distance for each cell from or to the least-cost source over a cost surface, where the input raster or the feature source data was the starting point and the input cost raster was the raster obtained from the weighted overlay. The cost distance measure portion of the least-cost path

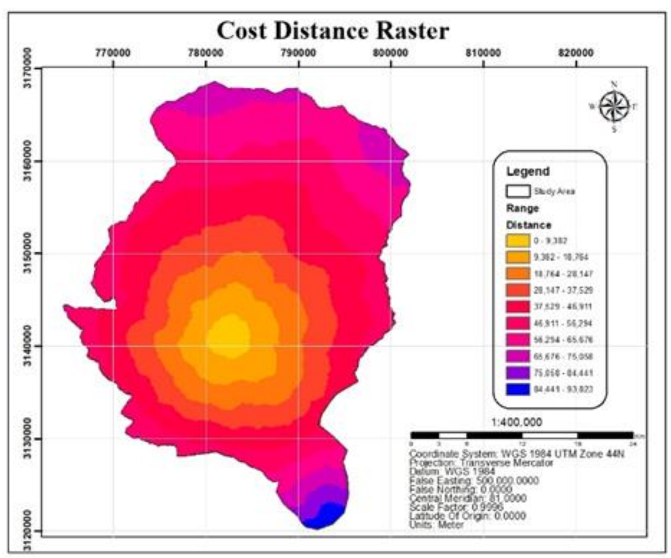

Figure 7 : Cost Distance Raster

analysis was cantered on the node-link raster cell representation. In this representation, a node was the center of the raster cell and the link connects the node to its neighbouring cells. A lateral link was also included to connect a cell to one of its four nearest neighbours and a diagonal link connects the cell to the corner neighbours. The cost distance is the cost that it takes to travel from the node to these links and the least-cost path was based on these least costs.

4.6 Cost Back Link Raster

Cost backlink raster defines the neighbour that is the next

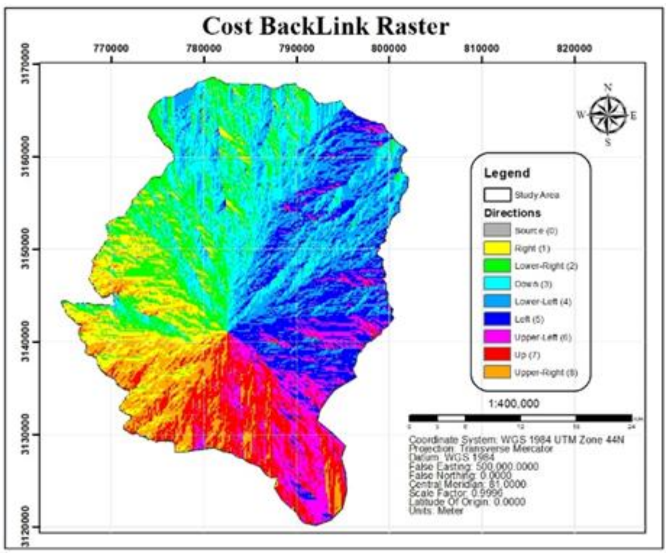

Figure 8 : Cost Back Link Raster

cell on the least accumulative cost path to the least-cost source, where the input raster or the feature source data was the starting point and the input cost raster is the raster obtained from the weighted overlay. The cost backlink raster generated is as given below.

4.6 Cost Path

Cost path calculates the least-cost path from a source to a destination, where our proposed base camp was given in the input raster or feature destination data, cost distance raster was given in input cost distance raster, and cost backlink raster was given in the input cost backlink raster. Cost path used an algorithm, which is an important component of least-cost path analysis because accumulative cost between two cells can be calculated by adding the costs of connecting the two cells. Thus, obtained least cost route passes below the existing route above the existing water body, passes through the forest areas in between, and finally reaches the base camp

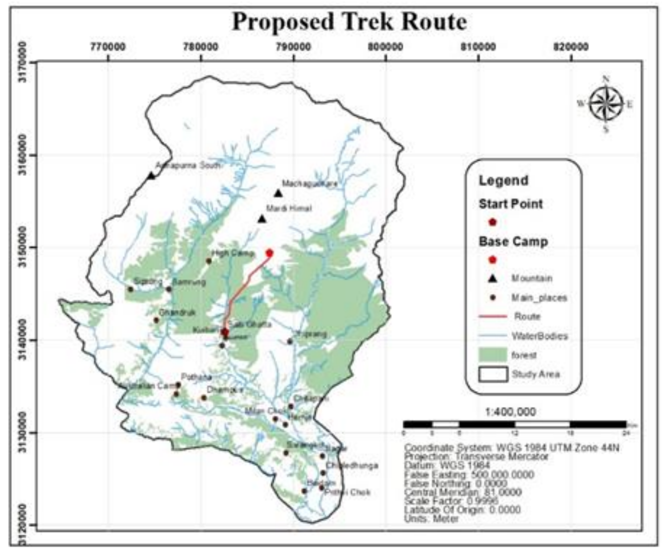

Figure 8 : Proposed Trek Route

as shown in the map below.

4.7 Android Application Development

The android based trekking application was developed by using Android Studio Software Development Kit. The programming language used for developing the app is JAVA and Extensible Markup Language (XML). XML is used for the front-end development and the backend was developed by using JAVA. The major external library used is the Mapbox. Mapbox is a location data platform that powers the maps and location services used in many popular apps. The Mapbox here is used for rendering the dynamic map, tracking the user location, displaying the amenities, cultural and religious points, and the risk areas. The architecture of android based consists of an interactive web map where the user can perform spatial operations like viewing, navigation, distance calculation, risk notifications, nearby tourist and hotels spots notification, etc. It allows the user to see the user's or trekker's current location. The system also consists of a login function, where each user is assigned the functionality to download the trek routes and update the trekkers' information. It mainly focuses on navigating the user to the route, tracking the user location, showing the nearby location, and notifying about the risk areas. The architecture of the application is described below.

- **User Login**

  The user login was made to authenticate the user and also to gain the information of the user. After the login of the user, the user can download the available updates of the trekking route.

- **User Location Tracking**

  In the application, one of the main tasks was to display the user's location on the map. The device's GPS sensor was used to acquire the latitude and longitude. Since the trekker is always carrying the mobile device, the location of the device was taken as the location of the trekker.

- **Showing Nearby Amenities, Tourist Spots, and Cultural & Religious Places**

  Amenities like hospitals, shops, money points, hotels, tea shops, etc., and tourist spots like a cave, waterfall, religious and cultural places are shown on the map. Also, the nearby amenities and tourist spots are notified via the notification.

- **Showing the Risk Areas**

  Risk areas were those areas with high slopes. The slope greater than and equal to 65 degrees was taken as a risk area. The trekker is informed about the steep areas when he moves nearby the steep areas and can see those risk areas on the map.

5. Discussion and Conclusion

The purpose of this study was to develop the Machhapuchhre Model Trek Route, which has the least costs and meets the sustainable development of ecotourism in an area. Also, this project disseminates the trekking route, amenities, viewpoints, tourist hotspots in route in the mobile -based android applications and warns the trekkers about the steepness or risky areas in the route. To develop the Machhapuchchhre Trek Route, this study first identifies and prioritizes the potential ecotourism sites, suitable for trekking in the land ecosystem of Machhapuchhre Trek Route Region, and then the least-cost path analysis is done to generate the least cost optimum path. This study here presents an integrated approach of PGIS with AHP combination to assess the suitability for trekking and to develop the least cost path, by matching the characteristics of an area with those attributes most appropriate for trekking. These integrated approaches were capable to handle complex issues like sustainable development of trekking tourism, biodiversity conservation, and conservation area management in a mountainous and developing country like Nepal.

The main contribution of this study was the generation of the least-cost path for trekking, which is developed after the development of the suitability raster, obtained by the weighted overlay of the various layers. To generate the suitability raster various criteria were identified and were assigned a unique score value and weight for each by applying the hierarchical structure of AHP in a geospatial environment. It was started by the calculation of weighting and rating from the AHP analysis where experts were asked to determine the relative importance of each criterion and factor. There were ten criteria (factors) in the form of ten GIS-based layers incorporated for determining suitable sites for trekking and to develop the least cost path. These are slope, aspect, proximity from the existing route, proximity from cultural and religious sites, proximity from settlement areas, proximity from steep areas, land use land cover, proximity from amenities, proximity from water bodies, proximity from tourist spots. To generate the least cost path, the suitability raster was fetched respectively for the least cost path analysis, where the feature source and destination were given. Also, a mobile-based android application was developed, integrating the tourist route, available tourist spots, hubs, viewpoints, steep areas, amenities; this will help to ease the trekking with safety.

Based on the results of the analysis, the least path or route passes below the existing route. Here the cost was the function of the various factors such as slope, aspect, proximity from existing route, cultural and religious sites, tourist spots, settlement, steep areas, water bodies, amenities, and LULC. Then for the least cost path analysis, the eight neighbours of a raster cell were evaluated and the generated path moves to the cells with the smallest accumulated or cost value. This process was repeated multiple times until the source and destination are connected. The completed path was the smallest sum of raster cell values between these two points and it had the lowest cost. Thus, generated least cost passes below the existing route and above the water bodies near the feature source (starting point) and from the forest areas in between, passed the barren land and reached the base camp (destination) as shown in the map above.

In conclusion, the result of this study appears practically useful for the development of tourism facilities (hotels, motels, lodges, restaurants) and ecotourism resource utilization, which no doubt helps in sustainable ecotourism development. Additionally, the final output of this study, i.e., the least cost path, could be used for generating alternative scenarios of ecotourism management based upon resource management (establishment of tourist spots, hubs, view towers) and biodiversity conservation. In the same way, trekking is a complex phenomenon of tourism, involving besides its spatial dimension, social and environmental implications. Thus, a further study should be done with the implementation of other related sub-models such as the carrying capacity model in establishing a comprehensive trekking resources management plan. These integrated approaches were able to handle complex issues like sustainable development, trekking tourism, biodiversity conservation, and conservation area management in a mountainous and developing country like Nepal.

Finally, the application of this paper can be useful for managers and planners working in the local, provincial and central governments and other non-governmental organizations. GIS can play a key role in documenting natural conditions, developments and documenting the suitability of resources, path for trekking, tourism. Moreover, GIS is a new tool for ecotourism management.

Additionally, AHP analysis reflects the real situation of the study area. This analysis was effectively used to calculate the details of the factors and class weights for trekking. Therefore, the integration of the GIS with AHP combines decision support methodology which in turn finally facilitates the creation of the least-cost path for trekking tourism. Furthermore, this study should be useful to those who are interested in the GIS technique, mapping, and ecotourism sustainable development.

6. Acknowledgment

We would like to thank the Department of Geomatics Engineering, Pashchimanchal Campus, Institute of Engineering, Tribhuvan University for giving us the chance to do this project. We would also like to show our gratitude to the Head of Department Er. Bikash Sherchan, of Department of Geomatics Engineering. We are deeply grateful to our supervisor Assoc. Prof. Dr. Krishna Prasad Bhandari and co-supervisor Er. Pradip Aryal for their knowledge, time and support; with their guidance, it has been much easier for us to initiate this project and complete the project. We are also thankful to the Center for Space Science and Geomatics Studies, Pashchimanchal Campus for letting us carry our work and helping us throughout the project.

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Volunteered Geographic Information (VGI) for Agriculture Crop Classification- A Case Study of Nepal

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Abstract

VGI's contributions in many applications are widely recognised. Crop classification is crucial for crop management, food security planning, and the development of agricultural policies. Freely available remote sensing images and machine/deep learning techniques have showed significant promise for crop type identification. However, heterogeneous crop types with the mix of paddy, maize, millet, sugarcane and others, bundled with smaller farm size make the crop-type discrimination more complicated. A tremendous amount of in-situ reference data is required to get adequately accurate crop type classification. Collecting the reference data by technical experts is not only costly but is a time-consuming task as well. It may not be possible to collect such data by the experts when mobility is restricted such as in the COVID-19 pandemic. Farmers and local volunteers may collect and provide such data in low cost for wider use even during transportation blockage. Open Data Kit (ODK), a free and open-sourced data collection tool was used by the volunteers to collect Land Use/Land Cover (LULC), crop types, the geo-location, and the image representing the LULC/crop type for verification of the same by an expert. The study collected more than 1700 reference data. About 99% of the collected LULC reference samples were and some 96% of the crop type samples were matched with the accompanied photographs. The paper assesses also discusses the role of an online feedback system for improving the data quality gathered by the volunteers, and evaluates its applicability for agriculture crop classification in Nepal where farm sizes are small with heterogenous crop types.

Keywords: Volunteered Geographic Information (VGI), Agriculture, Crop type, Open Data Kit (ODK), COVID-19

Introduction

Providing food security to all is one of the most challenging tasks for the world (Ehrlich & Harte, 2015; UN, 2015). About 8 billion population of the world (worldometers, 2021), which is ever growing, has elevated demands on food production systems (Ehrlich & Harte, 2015). Ending hunger and all forms of malnutrition by 2030, i.e. meeting the SDG Goal 2: Zero Hunger (the United Nations Sustainable Development Goals) (UN, 2015) is still a big challenge to meet. Over 2 billion people do not have regular access to safe, nutritious, and sufficient food (FAO, IFAD, UNICEF, WFP, & WHO, 2019). About 822 million people globally are estimated to be undernourished, out of which more than 278 million people belong to South Asia (FAO et al., 2019). To fulfil the global food demand, the agricultural production will have to increase by at least 50%

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(Alexandratos & Bruinsma, 2012; Chakraborty & Newton, 2011; Godfray et al., 2010) by 2050, most of which is anticipated to originate from enhanced agriculture yields (Alexandratos & Bruinsma, 2012).

Although Nepal is gifted with the resources needed for high agriculture productivity, many households predominantly in the mountainous regions experience food shortages for 4 to 9 months a year. The Ministry of Agriculture, Land Management, and Cooperatives (MOALMC) estimate that 12 high hill districts are food deficit (MOALMC, 2018). Ballooning population and stagnant local agricultural production are the major cause of food insecurity in the country. Fragmented subsistence farming, unavailability of the expert's knowledge, insufficient irrigation facilities, irregular weather patterns, and pest epidemics are some of the prominent barriers to increasing the agricultural productivity in the country (FNCCI, 2019). Nepal has been facing a negative trade balance in agriculture for a decade. The country's agricultural imports were USD 400 million in the fiscal year 2012/13 (FNCCI, 2019). The agricultural imports from India have been growing at an alarming rate of 40% annually for the past 7 years (FNCCI, 2019).

Accurate and up-to-date mapping of crops is the first and the foremost step for informed crop management, food security planning, and the development of agricultural policies. Freely available remote sensing images and machine learning techniques have proved their useability for crop classification (Belgiu & Csillik, 2018). However, the approach demands vast amount of in-situ data for training the machine learning algorithms (Karra, Kontgis, Statman-Weil, Mathis, & Brumby, 2021). Collecting such information by the experts in the COVID-19 lockdown and transport bans are almost impossible. However, the local youths when appropriately trained can collect such information with free software using smartphones.

The reminder of the article is structured as follows. The review of the literature is presented in Section 2. Section 3 encompasses methods and materials of this research. The major results of this research are presented in Section 4. The findings from this research are discussed and the conclusions of the research are presented in Section 5.

Literature Review

Efficient and up-to-date mapping of crop types is mandatory for informed decision making and planning food security situations (Belgiu & Csillik, 2018). As agricultural lands are highly dynamic in terms of crop growth and vegetation cover, high temporal monitoring and mapping is required. Cost of monitoring and mapping crops with high temporal resolution would be a crucial parameter for its sustainability. Use of freely available high spatial and temporal resolutions satellite images from Copernicus (Copernicus, 2021; Nguyen & Wagner, 2017) and Landsat (Gumma et al., 2020; Park et al., 2018) would greatly reduce the mapping cost. Further, the use of machine learning and deep learning techniques has not only reduced the human intervention but has drastically reduced the classification time (Karra et al., 2021). However, it needs to be accompanied by suitable in-situ data measurements to build a suitable synergy between remote sensing and in-situ measurements (Pratihast et al., 2014). Further, machine/deep learning classification methods are data hungry and demands thousands of in-situ reference samples to train the algorithms. For example, Land cover land use (LULC) classification using Sentinel-2 images and deep learning techniques utilized over 5 billion manually-labelled Sentinel-2 pixels, sampled from over 20,000 sites distributed across the world to categorize the world into 10 classes (Karra et al., 2021). Collection of such tremendous amount of in-situ reference samples data by the experts would not only be highly expensive but also would consume a lot of time to collect the data. Further, collection such reference data in lockdowns and transport bans would be impossible to achieve.

Alternatively, citizen-science approach has the potential of collecting tremendous amount of in-situ data in parallel mode, saving time, cost and is practical even in cases of mobility restrictions. Local participation has been proved instrumental in forest monitoring (Ananda, 2007; Pratihast et al., 2014, 2013) and land use planning (Hessel et al., 2009; Hewitt, van Delden, & Escobar, 2014). However, the procedure for citizen's participation, technology selection as well as the quality of data collected by non-professionals are unclear. Therefore, the objective of this research is to design a method to test and enhance the role of local youths for collection of crop type in-situ data in the aim of classifying crops.

Methods and Materials

Study Area

Terai and inner region of Nepal covering 17 districts that lie on the southern parts is covered in this study (Figure 1). The area is stretched covering the entire Nepal in the East-West low land area. The region is very fertile and is known as the Food Bank that hosts large area of crop lands, rain forests and some wet lands. The region experiences a tropical savanna climate type with dry winters and hot summers with a mean annual temperature of 20-28 °C, a mean annual rainfall of 1,600-1,800 mm in the west and 2,500-3,000 mm in the east (Karki, Talchabhadel, Aalto, & Baidya, 2016).

Paddy rice, maize and millets are the major crops in the summer while wheat, legumes and pulses are the main winter crops. While chief annual crops in the area includes sugarcane and orchids, vegetables and spices are not grown at scales.

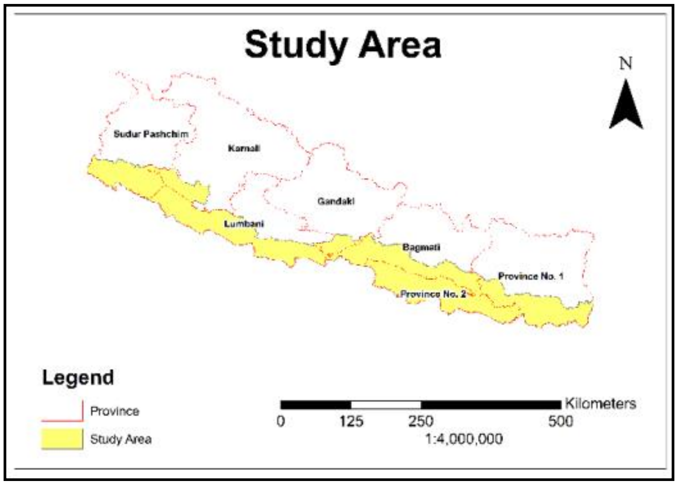


Figure 1 - Study area

Methods

Volunteers collected land use/land cover and crop type data using free and open-sourced software Open Data Kit (ODK). The ODK form as well as the data collected by the participants were hosted on the Google Drive to cut down the cost. Individual data were continuously reviewed and feedback were communicated virtually to each individual and the group of volunteers. The overall workflow adopted in the research is presented in Figure 2. Each step of the workflow is briefly presented in the following sub-sections:

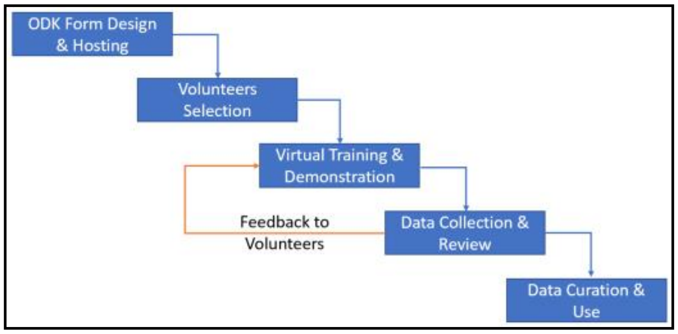


Figure 2: Method adopted

ODK Form Design and Hosting

A form was designed using ODK Build (https://build.getodk.org/). The form contained fields for collecting land use/land cover and crop type information along with locational information and a picture necessary to support verification of the collected data. Pre-defined categories for land use/land cover as well as crop types were presented through drop down menu for the purpose of efficiency in data collection and consistency in values. The form also contained automatically collected fields like survey start and end times to estimate the survey time of individual samples for statistical analysis. Other information included in the form include volunteer's name, email, and device ID. These fields were configured once during setting up the form for individual user. These data were collected to know individual volunteer's contribution and to provide personalized feedback so that better quality data are obtained the next time from that volunteer.

The designed form was validated and converted into XML using XLSForm Online v2.x (https://getodk.org/xlsform/) and was hosted at Google Drive Sheet where the collected data were also stored.

Volunteers Selection

People with at least 10 years of formal education having basic experience of operating android phones who were residing in the study area were selected as the volunteers.

Virtual Training and Demonstration

The selected volunteers were communicated through Facebook Messenger groups, emails and phone calls. The people who were willing to voluntarily contribute in the study were trained on setting up the ODK form, fill up the contributor's profile and collect data. They are demonstrated with the data collection tricks and techniques for minimum mapping unit (MMU), homogeneous number of samples per LULC and crop type classes, accuracy of data collection, convenience, and efficiency issues. Further, consequences of inappropriately collecting GPS information were also demonstrated during the training. Art and science of capturing photographs were also demonstrated and they were fully informed on how to capture the photographs so that the researcher can efficiently verify the data.

All volunteers were asked to send only a couple of samples in the beginning to ensure that they have had the hands on and are collecting and categorizing the information appropriately. Their inputs were continuously monitored by the researcher and feedback to the volunteers were provided individually and in groups. Wherever necessary, further training and demonstrations were also conducted to the needy ones.

Data Collection and Review

Data were collected using ODK on offline mode which does not require an internet connection to acquire data. When the collector gets an internet connection, they sent the data in batch. The researcher continuously monitored and reviewed the data which were stored on a Google Drive Sheet against the photograph sent by the collector. Any feedback and recommendations were communicated to specific user/user group. This help get data with improved quality.

Data Curation and Use

Finally, the obtained data were assessed against the photographs of the sample location. LULC and crop type categories which differed than what existed in the photograph were corrected as per the photograph. In cases where the correction is not possible to correct with the help of photographs were discarded from further use. The curated LULC and crop type samples are aimed to be used as reference data to classify satellite images using machine and deep learning algorithms.

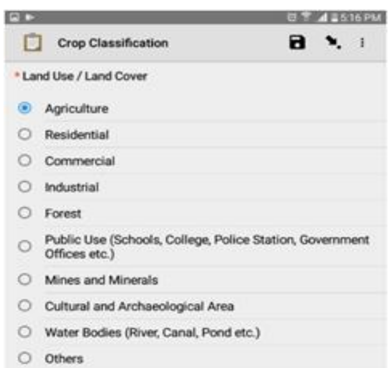
Results and Findings

The form was designed in two languages: English and Nepali (Figure 3). Any participants may choose the language during setting it up. They may also switch to another language any time they want. This is especially useful when a user is confused about the name of any crops in either language. While majority of the participants used English version of the forms, few preferred one in Nepali language. The forms in Nepali language may be more helpful when grass roots farmers will themselves collect and send the data.

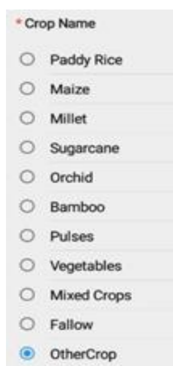
Out of about 150 participants approached though email, Facebook groups and telephone, 83 of them voluntarily collected 1701 samples in total between 22nd October 2020 and 17th February 2021. Each collected samples are accompanied by an image (few samples are presented in Figure 7) of the location depicting a particular land use type and crop type (in case of the agricultural land use type). The image is later used by the researcher to verify the LULC and Crop type information collected by the volunteer. The collected samples are visualized on a map in Figure 5.

A volunteer contributed 20 data samples on average, with minimum of 1 sample and a maximum of 114 samples (Table 1). While 29 volunteers collected more than the average number of samples, 49 users contributed less than the average number of samples. The contribution from the volunteers is presented in Figure 4. In general, the collected data is well distributed over the study area (Figure 5). However, no sample from Makwanpur District of Bagmati Province was received. Instead, about 50 samples were obtained from outside the study area. About 65% of the samples were captured from the agriculture land use, 9% represents public use, 8% water bodies and 7% have residential land use samples. About 99% of the samples were verified from the image collected by the volunteers, however, the rest of the 1% (14 samples) data could not be verified by the supporting image.

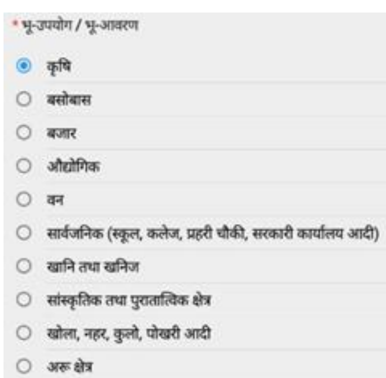
As data on summer crops were collected and Terai area is known basically for growing paddy in the summer, the majority of the samples (47%) are from paddy fields. Nine percent of the samples is represented by vegetables, 6% by bamboo, 5% by sugarcane and 18% by other crops (Table 3).



(A)



(B)



(C)

(D)

Figure 3 - Snapshots of data collection forms. LULC types (A and C) and Crop Types (B and D). Snapshots on the top are in English and ones at the bottom are in Nepali language.

Table 1 Participants' contribution statistics

SN	Description	Value
1	Total samples collected	1701
2	Number of participants	83
3	Minimum number of samples per participant	1
4	Maximum number of samples per participant	114
5	Average number of samples per participant	20

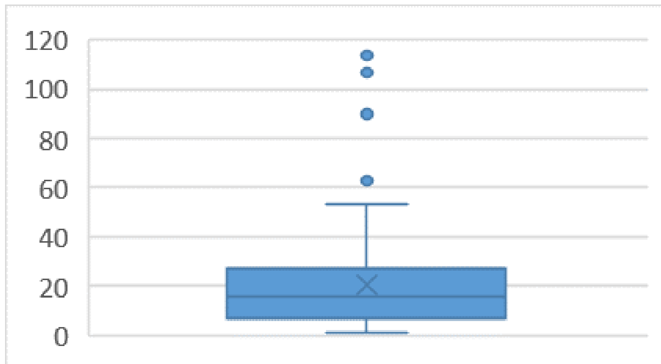


Figure 4 - Box plot of sample count collected by individual

Discussion & Conclusions

Discussion

Due to the COVID-19 pandemic lockdown, it was not possible for experts to visit different parts of the country to collect reference data samples to support classification of remote sensing images for delineating crop types area. However, many young students and office bearers were in their home town. This presented

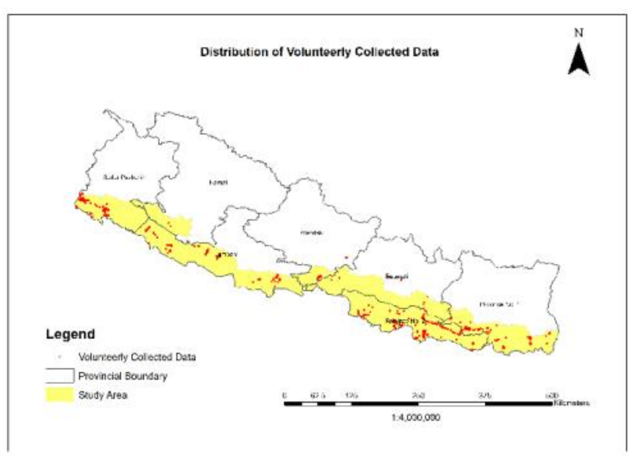


Figure 5 Distribution of collected data

a good opportunity for data collection through a citizen science approach. However, training the participants were challenging as it had to be conducted in a distant mode. Demonstration and continuous feedback to the individual and group feedbacks via conferencing tools and social media groups (Figure 6) were very crucial in getting good quality data and images.

Table 2 - Categories of LULC data

SN	LULC Types	Collected Samples	Verified Samples	Remarks
1	Agriculture	1099	1097	Samples were verified and corrected as per the image of the samples
2	Commercial	54	55	
3	Culture & Archaeology	28	28	
4	Forest	73	70	
5	Industrial	11	11	
6	Others	19	15	
7	Public Use	152	158	
8	Residential	122	120	
9	Water Bodies	143	133	
10	Unverified Sample		14	Not verifiable images
	Total	**1701**	**1701**	

The image of the sample location was vital in verifying the identified LULC and crop types identified by the volunteers. This also helped know the crop calendar and spatial variation. During the data collection, it was known that the paddy in the western part was planted and harvested few weeks earlier than those in the eastern parts of the country. This was revealed from the field sample pictures where the paddy was already harvested in the western part (Figure 7 A) while those on the eastern side were still on the ripening stage (Figure 7 B). Moreover, variability in harvesting was also prevalent at the same location (Figure 7 C) where the neighbour farms show different crop status. While on the left, the crop is at the ripening stage while it has been harvesting on the right. This difference may be attributed to the plantation of different crop variety and possibly early and late plantation as well.

Table 3 Categories of crop types

SN	Crop Types	Collected Samples	Verified Samples	Remarks
1	Agro-Forestry	1	7	Samples were verified and corrected as per the image of the samples
2	Bamboo	63	61	
3	Fallow	1	1	
4	Maize	13	11	
5	Millet	3	2	
6	Mixed Crops	29	32	
7	Orchid	46	37	
8	Other Crop	206	197	
9	Paddy Rice	530	523	
10	Pulses	42	38	
11	Sugarcane	58	55	
12	Vegetables	105	98	
13	Unverified		42	Not verifiable images
	Total	**1097**	**1104**	

Despite communication during the online raining, few volunteers had ambiguities regarding the relationship between detectable object size from satellite image (e.g., Sentinel 1 (Nguyen & Wagner, 2017) with 20m and Sentinel 2 with 10 m spatial resolutions of visible and NIR bands (Copernicus, 2021)) and their spatial resolution. This can be visualized in Figure 8 (A and B)

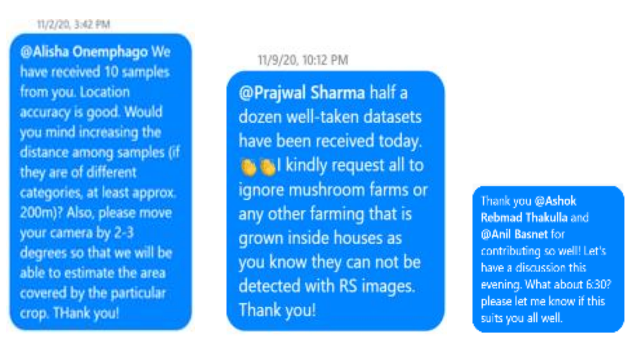
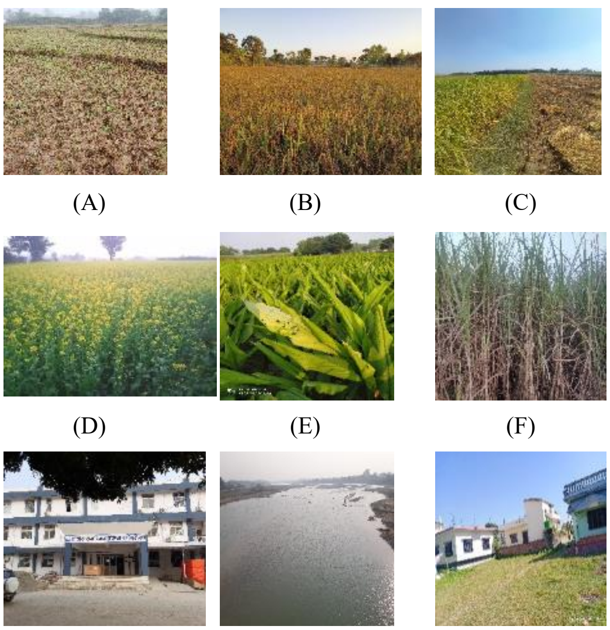


Figure 6 Few snapshots of the feedback provided to individual and volunteers' group

where the former was misidentified as paddy field despite the sample being a good representative of a public use (road) category. Similarly, the narrow canal cannot be detected from the mentioned satellite image (Figure 8 B). Another problem was capturing the image in very low lighting condition (late evening). It was not possible to use the image in verifying the class identified by the volunteer. These issues were well discussed in the groups and with the individuals who collected such data and the issues were sorted out.



(A) (B) (C)
(D) (E) (F)
(G) (H) (I)

Figure 7 Sample images collected which were used to verify LULC and Crop Type classes

The form was designed such that the reference samples collected by the volunteers could be used for land use land cover (LULC) as well as crop types classification/ delineation. However, the ultimate goal was to delineate crop types area. The distribution of samples is basically distributed as per the size of the actual availability of the LULC and crop types in the study area. Hence, about 65% (Table 2) of the samples were collected from the agricultural land use. Further, 47% (Table 3) of the agricultural samples represented paddy field as paddy is the major crop grown in the Terai in the summer.

Conclusions

Crop classification requires a large amount of in-situ data which is almost impossible to collect by the experts during lockdown and transport bans. However, local youths can fulfil the demand when they are equipped with the appropriate tools. In this study, the local youths collected good quality in-situ data to classify satellite image for delineating crop types.

(A) (B) (C)

Figure 8 - Misinterpretation and band quality image for LULC and Crop Type class verification. Misclassification (A), undetectable narrow canal in satellite image (B) and poor-quality image (C)

The same tools may be used by the farmers to gather such information. Likewise, these data may be used to validate the global land use land cover products (Gumma et al., 2020; Karra et al., 2021) for their useability at the national level. Moreover, the farmers can collect further information like image of their fields and send them to the exports, who are not available at their farms, to get their expert's recommendations in dealing with crop diseases, for example. However, more training, physical demonstrations and probably feedback from local youths may be required for obtaining good quality data. Further, availability of internet connection, at least at community centres may further support the approach applicability and sustainability.

Acknowledgements

The authors would like to humbly acknowledge the contribution of all the volunteers. The authors thank Tanka Prasad Dahal, Reshma Shrestha, Surendra Yadav, Basanta Awasthi and Dinesh Prasad Bhatta for testing the ODK forms and helping communicate with the volunteers.

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THEME 9

Geospatial Plugins, Packages and Platform development (GPPPD)

PySLD: An Open-source Python Package for Generating the Symbology of Geospatial Data

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Abstract

This work describes the pySLD, an open-source python package generating the Style Layer Descriptor (SLD) dynamically. The SLD can be used to represent the visual appearance of the map by representing the features by visual variables like shape, size, and color. Currently, the package can generate the four different types of style files as, 1. Simple style, 2. Categorized style, 3. Classified style, and 4. Raster style. Simple style is the very basic representation of the feature by one set of visual variables. It is mainly used for denoting the location of the object. Categorized and Classified style is used for the representation of thematic maps which provides specific information about the particular location, general information about spatial patterns, and compare patterns on two or more maps. The categorized style will be generated based on the data category whereas the classified style needs the classification of the data into multiple classes. The package supports the five classification methods, natural break, equal interval, quantile, standard deviation, and geometrical interval. The generated map from categorized/classified style will represent the features into multiple categories/classes and represented by the multiple set of visual variables. Raster style is the representation of the raster dataset based on the pixel values of the raster. The raster style might be based on single-band grey, single-band pseudocolor, or palette/unique values. The package also supports the feature labelling for making more informative maps. The package is successfully used to visualize the disaster dataset on the RiskChanges web-GIS portal. The RiskChanges is the web-based spatial decision support system for analysis of the changing risk to natural hazards. The main aim of the RiskChanges is to analyze the current label of the risk (both physical and population) for multi-hazards, to analyze the best risk reduction alternative, to analyze how risk could change under possible future scenarios, and to determine the best “change proof” risk reduction alternative. The pySLD package helps to generate the SLD style dynamically which can be used for the visualization of the geographic data in the Risk Changes portal.

Keywords: pySLD, SLD, RiskChanges, web-GIS, symbology, python, geospatial data

1. Introduction

The symbology of a layer is the visual appearance of the map. In cartography, symbology is the graphical representation of geospatial data on a map. Visual variables like shape, size, and color are part of map symbology. The cartographer generally combines these variables, a symbol (e.g., a solid 3px red line) to represent a certain class or category of the geographic feature(s). In the case of the spatial dataset, it is the representation of points, lines, polygons, and rasters. Such symbology needed for the users and software can be controlled by the Styled Layer Descriptor (SLD) (Lupp, 2007). The SLD is the XML schema specified by the Open Geospatial Consortium (OGC). It allows user-defined symbolization and coloring of the raster and vector dataset(s). The rules assigned to the SLD needed to be understood by both client and server. The main motive of developing this library is to generate the map style and legend without using the GIS software and provide an easy and meaningful way to visualize the geospatial data.

The geographic data doesn’t contain the visual components by default. To visualize the data, it must be styled. The style

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specifies the visual variables and other visible attributes. A Web Map Service (WMS) (de La Beaujardiere, 2006) will provide the set of style options for each set of data; however, these are preconfigured by the server and users cannot create, inspect, and modify the style. To solve such issues, the SLD standard was invented by the OGC which enables the application to configure the geographic style in an XML schema. The SLD is not only used for the WMS support servers, but it can also be used with the other standalone desktop software as well. The SLD is used by lots of GIS software like QGIS, uDig (Abera, Antonello, Franceschi, Formetta, & Rigon, 2014), OpenJUMP (Steiniger & Hunter, 2012), and servers like GeoServer (Iacovella, 2017), ncWMS (Blower, et al., 2013), ArcGIS server to manage the symbology of geographic data.

(a)

```
<FeatureTypeStyle>
    <Rule>
        <Name>Rule for polygon</Name>
        <Title>Red polygon with Blue outline</Title>
        <PolygonSymbolizer>
        <Fill>
            <CssParameter name="fill">#ff0000</CssParameter>
        </Fill>
        <Stroke>
            <CssParameter name="stroke">#0000ff</CssParameter>
            <CssParameter name="stroke-width">5</CssParameter>
        </Stroke>
        </PolygonSymbolizer>
    </Rule>
</FeatureTypeStyle>
```

(b)

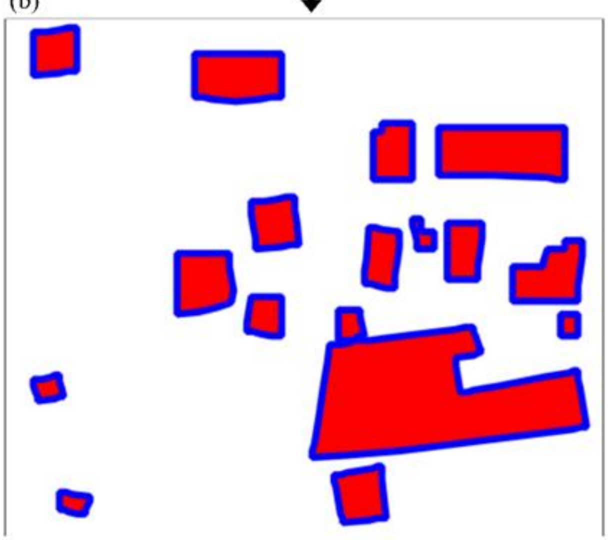

Figure 1: (a) SLD file generated from pySLD package for polygon dataset, (b) Visualization of polygon dataset using WMS

PySLD is the open-source SLD generator library written in python. Python is the chosen language because it is an object -oriented programming language which is easy to use and runs on all the major operating systems. It already has thousands of libraries and frameworks. Any type of software and web applications can easily be made using python. The generated SLD from pySLD can be easily integrated into python applications. Based on only a few parameters, it will dynamically generate the SLD file which can be linked further with the geospatial data to generate the symbology of geospatial data. One of the common ways of linking the SLD with geospatial data is using WMS. Fig 1. (a) Shows the structure of the simple style generated from pySLD and (b) polygon dataset using the same style. Here, the dataset is visualized using the WMS service from geoserver. The package is unique for automation for geospatial data visualization and legend generation. This automation feature makes it more popular and useful in web applications and software development.

2. Literature Review

The cartographic visualization of geospatial data was applied in several software/projects. Adamec in 2014 wrote about the cartographic visualization of OpenStreetMap (OSM) data. In this paper, the author describes the OSM data model, data properties, accuracy, and quality of the data. Later, the data has been downloaded and stored in the PostGIS database and visualized using various open-source standards and map visualization techniques such as Mapnik (Artem, 2005), using CartoCSS in Tilemill (Miller, 2010), SLD in GeoServer and MapFile in MapServer. Mapnik is an open-source tool for rendering maps. The user can assign the multiple styles to one layer and Mapink will help to generate them in an XML format. Although the Mapnik mostly works with the PostGIS database, it also can directly process the osm file format. CartoCSS is a cartographic representation of the Cascading Style Sheets (CSS). The user will be allowed to add the CSS based style for representation of the geographic features symbols. Finally using the tilemill tool, the style for the osm data has been created based on the zoom level. SLD is the XML schema specified by OGC. There are mainly five types of symbolizers. For the vector data, PointSymbolizer, LineSymbolizer, Polygon-Symbolizer, for raster data RasterSymbolizer and for the text description, TextSymbolizer. All the style configurations will be stored in the XML based structure. The geoserver has been used to visualize the OSM data using SLD. The configuration file for the MapServer is MapFile which specifies the complete cartographic symbolism for the resulting data outputs. The main aim of this paper is to show the number of possible ways to visualize the interactive map for web browsers (Adamec, 2014).

Kozel in 2008 compares the SLD specification with the MapFile format. The MapFile is the configuration format for the MapServer (Kropla, 2006). The paper will mainly compare the visualization techniques for vector symbols, i.e., points, lines, and polygons. The author tried to mainly focus on the color, shape, size, pattern, orientation, and transparency of the symbols. Although SLD is a more popular and widely used format, styling is possible with the MapFile as well (KOZEL, 2008).

Web GIS technology is getting popular and widely used for geographic data visualization and analysis. Online maps have become popular for navigation as well as more specialized map functions like thematic cartography. Mobile mapping is not limited to the navigation system but also to the typical Location Based Services (LBS) like finding the nearby hotels. Traditionally, visualization of thematic maps were restricted to choropleth maps and simple point maps like dot density, proportional symbol maps. Such maps can be generated by using the SLD. But the SLD specification is not adequate enough if e.g., bar and pie charts/plots should be drawn on point maps. Thus, Dietze et. al. proposed the extension of SLD named as Thematic Symbology Encoding (TSE) schema. Along with TSE, the authors proposed the new tags as ThematicSymbolizer and DiagramSymbolizer which can be used for the preparation of the thematic map which can represent the actual data in the form of pie charts and bar charts. Figure 2 is an example of the TSE schema which supports the bar/pie charts within the map (Dietze & Alexander, 2007).

The standard specification of the SLD lacks define the rules for visualization of 3D scenes data. Neubauer et. al. in 2007 developed the extension of the SLD for 3D scene data and implemented the 3D-SLD profile in their W3DS server. The implementation of 3D-SLD has added lots of things in order to visualize the 3D scene. Some of the important parameters are the positions and displacements of the Z-axis, rotation parameter, SurfaceSymbolizer, SolidSymbolizer, material properties, 3D legends etc (Neubauer & Zipf, 2007).

Most of the GIS software rely on the SLD and Semiology Encoding (SE) specification. Both of them provide an XML based schema for describing the rules which will be applied to make a symbology of a map. Although it is a widely

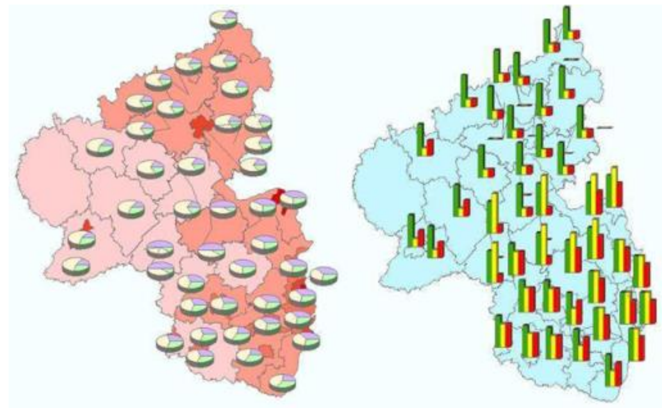

Figure 2: Choropleth map combined with diagram map/pie charts vs bar charts

popular technique and relevant for most of the cartographic purposes, it fails to describe complex cartographic and artistic styles. In order to address these issues, Christophe et.al. proposed an extension for existing SLD/SE specifications. The authors proposed the three main expressive methods: linear stylization, patch-based region filling and vector texture generation (Map style formalization: Rendering techniques extension for cartography, 2016).

3. System Architecture and implementation

PySLD is the open-source python package for creating the Styled Layer Descriptor (SLD). Thus generated SLD files can be linked to relevant layers to make an interactive map. The package is developed under the MIT license. The library has 2 main dependencies which are seaborn and psycopg2. The seaborn library can interact with the color module and generate the required color ramp. Later the required color or color ramp can be used in the visualization of the data. Psycopg2 is the most powerful python PostgreSQL adapter. This library is used to get the required information about the data from the PostGIS database.

The pySLD library is still in development mode. Currently, the library provides four types of styles: 1. Simple style, 2. Categorized style, 3. Classified style and 4. Raster style. The simple style is generally used to generate SLD files for the general reference maps, which focus on a location (more than the properties) of a feature, such as a river, roads, or buildings. Such styles have a very basic style represented by one set of variables (shape, size, and color). The representation of a map based on a particular topic or theme of geographical data is called a thematic map. The SLD file for such maps can be generated through categorized and classified style functions from PySLD. Thematic maps generally provide specific information about the particular location, general information about spatial patterns, and compare patterns on two or more maps. If the data is available based on some category (e.g., land use), then the user can directly use the categorized function. The package provides five different classification methods, natural break, equal interval, quantile, standard deviation, and geometrical interval for the classified style SLD generation. Such classification methods help to classify the data further into a specific number of classes and dynamically generate the SLD file for it. The raster style is used to generate the SLD file for the raster dataset. The style might be based on single -band grey, single-band pseudocolor, or palette/unique values. A legend is needed to explain the meaning of the symbols and make sense of the map. Such legends can be easily generated using the same SLD files. The complete documentation of this library is available here: https://pysld.readthedocs.io/.

Currently, it also supports the connection from the PostGIS database for vector data. If the data is provided through the PostGIS connection, the library can automatically read the feature from the database and generate the style based on the given attribute name.

The symbology will be different for different types of geographic features or raster surfaces. Based on the geometry type of the data, the user can choose the function. Currently there are four different types of functions available, one for raster data and the other three are for vector datasets. The symbology for the vector data can be simple, categorized and classified. Also, there is a possibility to add the static as well as dynamic labelling on a map if the user sets the feature label parameter on a function to true. The labelling feature can be applied for one layer at a time which can be single tiled as well as multi-tiled. The library doesn't solve the issue on multi-tiled layer. There are lots of default parameters assigned in each function to avoid the error, but you can replace them if required. Finally, the SLD of the required layer will be generated based on such parameters. The overview of the pySLD architecture is shown in Figure. 3.

3.1 Simple style

The simple style is generally used to generate SLD files for the general reference maps, which focus on a location (more than the properties) of a feature, such as a river, roads, or buildings. Such styles have a very basic style represented by

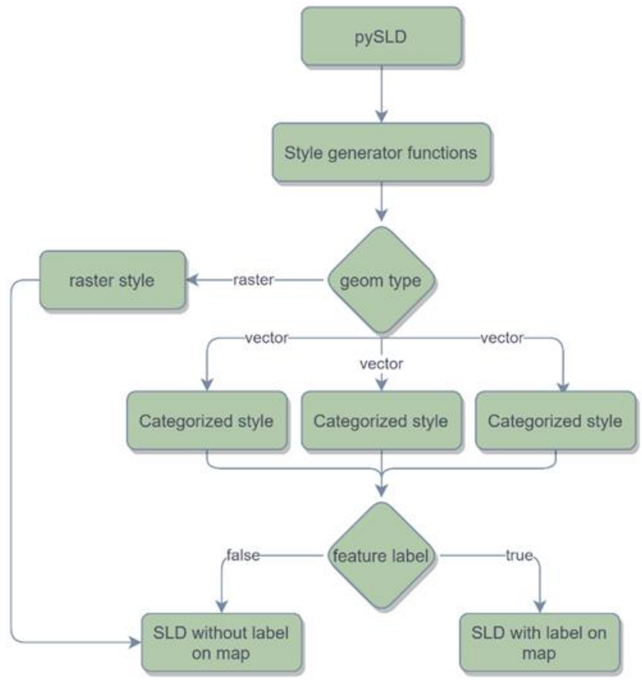

Figure 3: pySLD architecture

one set of variables (shape, size, and color). Based on the geometry type, there are different types of simple styles. The fill color, fill-opacity, stroke color, stroke width etc are the available parameters for the polygon feature, stroke color, stroke dash array, stroke linecap, perpendicular offset are the available parameters for line, whereas point size, color, point representation are the available parameters for point. Thus, generated simple styles only draw the feature according to the provided parameters. The list of most commonly used parameters are as below,

3.2 Categorized style

The categorized style can be generated based on a feature property e.g., Land use classification. It is mainly used for the thematic mapping purpose. The main parameter for this style function will be the color palette and the attribute name based on which categorized SLD will be generated. The most common way to provide the name of categories is to store the data in the PostGIS database and provide the connection parameter so that the library can automatically read it and assign the required categories into the SLD. Else, the user needs to provide the name of the categories manually in the 'values' parameter. The categorized style is inherited from simple style, it means, all the parameters for simple style will be valid for categorized style and it will add additional parameters. The 'fill_color' parameter will be

Table 1: Commonly used parameters for simple style

Parameter	Description
geom_type	The type of geometry. Available options are, point, line, polygon
fill_color	Fill color for the feature, not applicable for line
stroke_color	Outline color for the input feature
stroke_width	Outline width for the input feature
opacity	Transparency of the layer
feature_label	Determines whether to add the label or not. It is a boolean value
attribute_name_label	Name of the attribute for adding the label

ignored in the case of generating the categorized style. The list of the most commonly used parameters are as shown in table 2.

Table 2: Commonly used parameters for categorized style

Parameter	Description
attribute_name	The name of the attribute for generating the categorized style
color_palette	The color palette to represent the feature
dbname	PostgreSQL database name
user	PostgreSQL database user
password	PostgreSQL database user password
host	PostgreSQL database host
port	PostgreSQL database port
schema	PostgreSQL database data schema
pg_table_name	PostgreSQL database data table name
values	In case of not providing the PostgreSQL connection parameter, the user needs to provide all the categories. List of categories

3.3 Classified style

Classified style is also known as graduated style. It allows the user to assign the different symbols to the features of different objects in the same layer. The given feature attribute will be classified into several classes and represented by the different symbols (e.g., different colors). In pySLD, there are five different data classification methods, i.e., natural break (Jenks, 1967), equal interval, quantile, standard deviation, and geometrical interval. Such classification methods help to classify the data further into a specific number of classes. The classified style is inherited from both categorized and simple styles, which means, all the parameters from simple style and categorized style will be valid for the classified style. The main parameters for classified style are color palette, number of classes, classification method and attribute name base on which classified SLD will be generated. The list of most commonly used parameters for classified styles are as below,

Table 3: Commonly used parameters for classified style

Parameter	Description
attribute_name	The name of the attribute based on which classify the feature
number_of_class	The number of classes for classifying the feature
values	In case of not providing the PostgreSQL connection parameter, the user needs to provide all the values within the attribute name manually.
classification _method	Classification method name for classifying the feature. Available options are, natural_break, equal_interval, quantile, standard_deviation, gemetrical_interval

3.4 Raster style

The raster style can be generated based on the raster values. The raster style can be based on single-band grey, single-band pseudo-color or palette/unique values. The main parameter for this style function will be a color palette, min value of raster, max value of raster. Also, the legend for the map can also control whether the legend should be a continuous color ramp or discrete color. The list of most commonly used parameters for raster styles are as below,

4. Case study

The PySLD package was successfully used to generate the style/legend for the disaster datasets in RiskChanges web-portal. The RiskChanges web-GIS portal is still under development and is planning to lunch at the end of October 2021. The RiskChanges is the web-based spatial decision support system for analysis of the changing risk to natural hazards. The main aim of the RiskChanges is to analyze the current label of the risk (both physical and population) for multi-hazards, to analyze the best risk reduction alternative, to analyze how risk could change under possible future scenarios, and to determine the best "change proof" risk reduction alternative. The interface of the data visualization module in the RiskChanges is shown in figure 4.

RiskChanges is developed for the exposure, loss, and risk calculation, under various possible alternatives and future scenario. It will visualize the input dataset and the results generated from the system. The web-GIS portal provides the interface to user authentication, Element at Risk (EaR), hazard, and vulnerability data upload, data management, exposure, loss, and risk calculation. Only the authenticated user can interact with the site and visualize the data. The hazard data is represented by a raster format (GeoTIFF) in the system whereas, for EaR, exposure, loss, and risk, the system uses the vector format (ShapeFile and PostGIS connection). The system provides a nice user interface to visualize and edit the style of the layers based on user preferences. In the case of a raster dataset, color palette, number of classes, opacity are available options for the user to edit the symbology. For vector datasets, the user must select the style type at first (available options are simple, categorized, and classified). Depending on the selection of style type, other relevant options will be available. In the case of classified style, classification method, number of classes, attribute name, color palette, outline color, outline width, opacity are the available options. The visualization section is like a QGIS symbology interface. Such changes are instantly updated in the map visualization section. After saving the style, the style will dynamically create the SLD file and send it to the server. Later, the same SLD will be used to generate the legend for the map. The basic overflow of the portal is as shown in figure 3.

Table 4: Commonly used parameters for the raster style

Parameter	Description
color_palette	Color palette to represent the raster
number_of_class	Number of classes based on raster pixel value
max_value	Maximum value for the raster pixel
min_value	Minimum value for the raster pixel
continuous_legend	Boolean value for representing the raster whether on a continuous color palette or discrete color palette

5. Discussion

The pySLD is the first open-source python package that can manage to generate the SLD file dynamically based on a few given parameters. Thus generated SLD can be applied to the specific layer so that the feature represented by the layer will be visualized more adequately. Also, the legend of the map will be automatically generated in the case of the WMS. The main features of this package are the pythonic way of generation of XML based schema for the SLD, classification of features into the required number of classes, generating the SLD for labels on the map, reading the vector data from the PostGIS database.

There are lots of advantages to using this package as described above however it lacks to provide some of the features. One of the drawbacks of this library is that there are no functionalities to read the raster data and vector data can be read from the PostGIS database connection only. In the case of the raster, the user needs to provide the raster minimum value, maximum value, and number of classes manually. Similarly, in the case of vector data (if the data source is other than PostGIS), the user needs to provide the category/class name, category/class values. Such issues can be solved with the help of GDAL, but it will cost to add the dev dependency on the pySLD.

Coöperatieve Vereniging OpenGeoGroep U.A. in 2011 also implemented a similar library for generating the SLD file (Linden, 2011). But their implementation is not robust. The users need to know about the SLD before using their version of pySLD. There is no way to generate the SLD for raster. The user needs to provide the ruleset for each filter condition and the shape, size, and texture of the feature for each filter. Such work only increases the complexity and adds the chance to raise the bug on the SLD generation. It also lacks

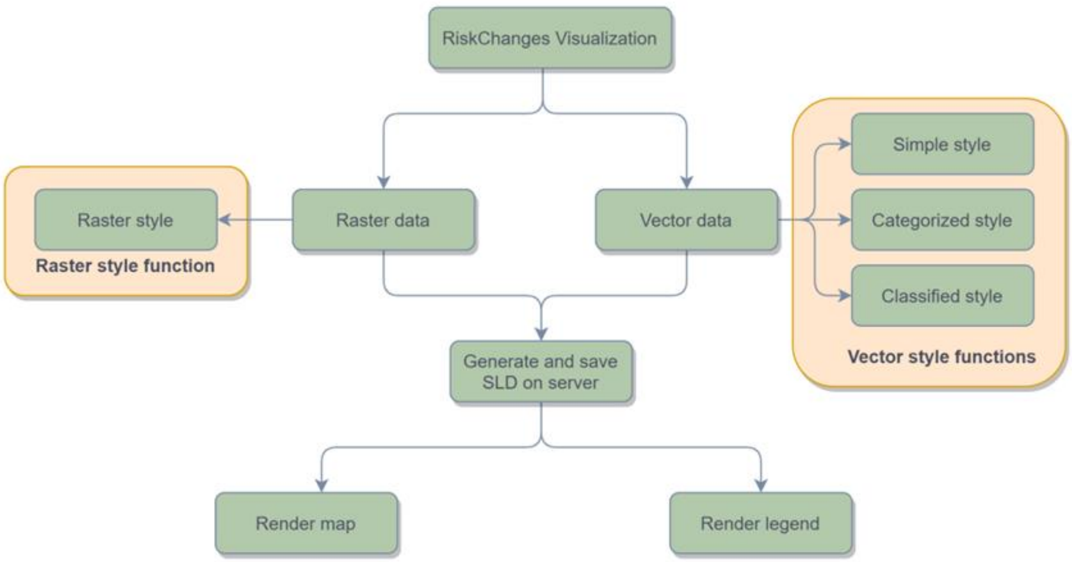

Figure 3: RiskChanges portal data visualization workflow

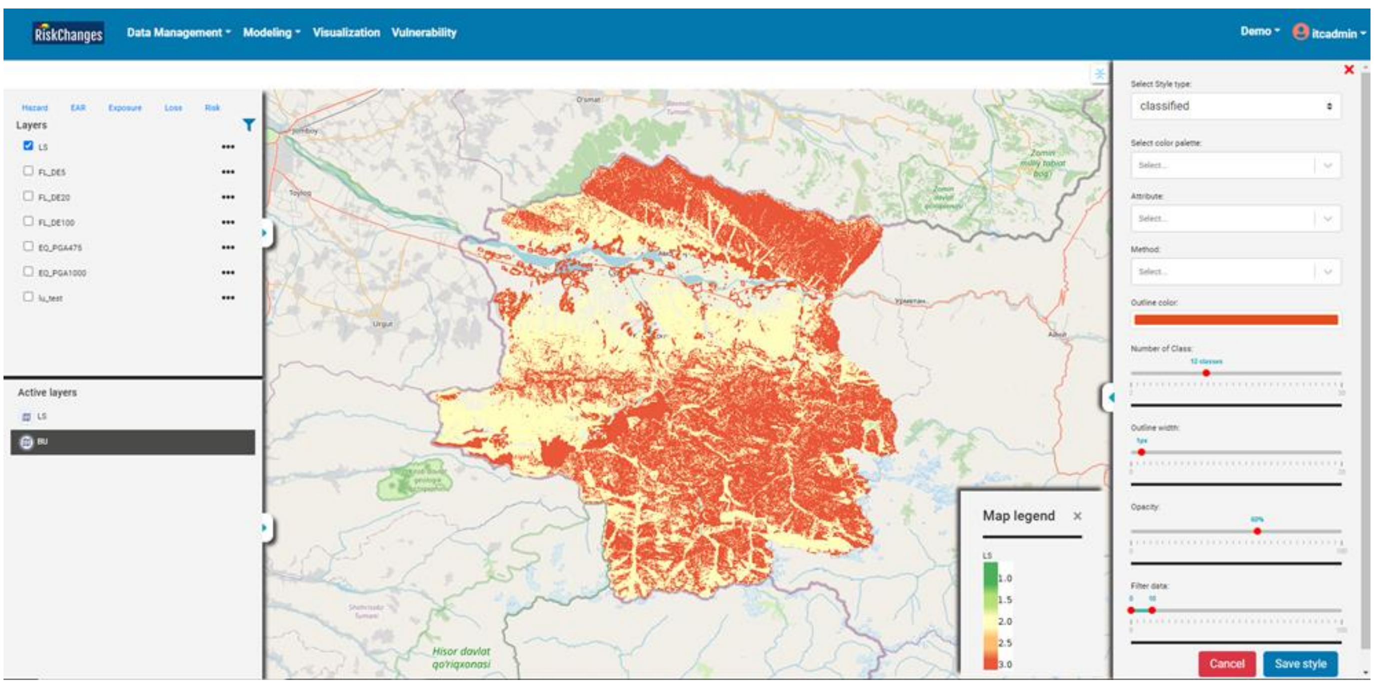

Figure 4: Data visualization interface of the RiskChanges.
The currently visualized data is the landslide data for the Panjakent district

to provide any documentation. Our package provides the proper standard documentation and solves such complexities. Our package automatically adds the filter based on the given category/class name and values.

Since the package is very easy and simple to use and fully based on the SLD specification as specified by the OGC, it also lacks the Thematic Symbology Encoding (TSE) schema proposed by (Dietze & Alexander, 2007) and 3D-SLD proposed by (Neubauer & Zipf, 2007). The main aim of this research is to provide an easy and effective way of generating the SLD dynamically for all kinds (raster and vector) of geographic data. The package is designed in such a way that it can be easily extended and add new features. The future work is to integrate such complex styling into the package and make it a more powerful symbology generation library. And the reading of geographical data from various sources will reduce the complexity and manual work for the user which will be improved in the future.

6. Acknowledgement

I would like to thank Geoinformatics Center (GIC), Asian Institute of Technology (AIT), Thailand and Faculty of Geo -Information Science and Earth Observation of the University of Twente (UT-ITC), Netherlands, for their support in developing this library.

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Developing Spatial Data Visualization System Using Open Source Tools: A Case of Mysuru City, Karnataka

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Abstract

India is one of the developing countries with the fastest growing economy. Various factors like land, workforce, transportation system, infrastructure, foreign direct investment (FDI) policies, are fascinating foreign investments in India. This has led to the development of huge industries in the urban areas, which provide employment opportunities to a large population. Importance is given to developing urban areas with basic amenities like health care facilities, educational institutions; transportation systems like roadways, railways, and even airways. These factors are the cause-root for the concentration and migration of population to *urban* areas. Increased and growing population in the cities has resulted in the scarcity of land, increasing pressure on the natural resources. There is an immediate need for a strategy that aids in efficient, planning and sustainable management of the available land resource. One such strategy is through developing updated spatial layers using open source databases and software. This communication mainly focuses on developing and analyzing spatial layers for one of the popular cities in India, Mysore, which would assist in efficient town and city planning, resulting in effective land use management. Various vector layers were developed such as health care centres, hospitals, roadways, railways, cultural and heritage sites, junctions of high traffic areas, etc., Attribute data were joined to vector layers from authentic government data sources at both municipal and state administration levels. Generation of raster datasets using open source tools included temporal land use maps from Landsat data, digital elevation model (DEM), aspect map, Hill - shade map and, slope map. The aggregated vector and raster layers show that most of the basic amenities are concentrated in the urban areas without efficient and sustainable planning. Rural areas deprive proper planning, transportation facilities, health care centres, industries, hence they lag in progress without much economic activity. Urban growth, land use pattern change over time is crucial in the management of natural land resources, biodiversity, and ecosystem. This dynamic pattern has a significant effect not only on the environment but also on human beings, an integrated part of this environment and our future generation. Hence, the results obtained act as a potential guide in planning and designing the towns and cities. The scope of this research can be further extended to integrate real-time spatial data visualization which can aid in planning people-friendly strategies at both municipal level and district level to effectively combat the current situation of distress in urban areas.

Keywords: Sustainable management, land use management, open-source, spatial data visualization, Web-GIS.

1. Introduction

Urbanization and urban growth are two important phenomena in recent times. The development of urban areas or cities, by providing them with the basic amenities like medical care, educational institutes, industries, rapid transit, services, and employment opportunities attracts the rural population. This results in the migration of people to urban areas. In 2018, according to United Nations, the world population living in urban areas which were 55%, is expected to reach 68% by 2050. Urbanization and population growth all over the world could add around 2.5 billion people, where about 90% of the contribution is by Asia and Africa (UN DESA, 2018).UN projects that by 2027 India would surpass China, and become the most populous country in the world (UN DESA, 2019). This

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rapid population growth would increase the pressure on the limited land resources, environment as well as ecosystem.

Urbanization has been accelerated by the mixed economy in India. The advantageous location of the state for industrial and commercial development has helped to progress in urbanization. Infrastructure has played an important role in urbanization (Sastry, 2008). UN Survey projects that by 2050, India will have added 416 million urban dwellers. So the land necessary for residence or shelter, health care, and other basic amenities also increases, in turn increasing the concretized surfaces, which reduces the rate of evapotranspiration (Daramola, Eresanya, & Ishola, 2018) contributing to serious environmental issues like increase in the global temperature or Land Surface Temperature (LST) (Fathian, Prasad, Dehghan, & Eslamian, 2015). This affects essential sectors like Infrastructure, Energy (Scott, et al., 1990), Water Resources, Agriculture (Bolin, Doos, Jager, & Warrick, 1986), Forest ecology, Air Quality, and Health (Raloff, 1989). Studying urban sprawl is the need of the hour. On the other hand, the urban areas where the population is migrating are not efficiently planned for sustainability management, resulting in poor governance. This is due to lack of updated geospatial data like LU maps, collection of a large set of spatial data required to prepare the necessary dataset, heavy computations and economic factors (Yang, Fu, Smith, & Yu, 2017), and lack of technical knowledge which hinders the usage of advanced technologies (Barrington-Leigh & Millard-Ball, 2017). Municipalities, especially in the developing countries, do not possess a proper amalgamated tool that aids in analyzing comprehensive information to the precise location of an asset to strategize a city with a high optical impression, without compromising the population needs (Maulik, Gaurav, Santhosh, Rahul, & Arjan, 2018). Hence there is a necessity for an action plan by the Government and concerned agencies that helps in the proper management of land resources for the burgeoning population and urban expansion.

One such action plan is developing updated spatial layers using open-source databases and software. QGIS is free and open-source software, which aids in this purpose. It's a robust, powerful desktop GIS that runs on all major platforms like Mac, Linux, and Windows. Also, QGIS enables integration with other geospatial tools and programming languages like R, Python, and Post GIS (QGIS -3.16-DesktopUserGuide, 2021)& (MicheleTobias). It gives the world of options for geospatial database processing and visualization and allows users to analyze, edit spatial information, and mapping.

Developing an updated spatial layer includes raster layers like digital elevation model (DEM), aspect map, slope map, hill-shade map, vector layer maps such as Point, line, and polygon layer map and Land-use map. Raster data is imperative for many unique real-world applications. It has a great influence on vegetation, specialized agriculture, ecology, and disaster management (GISGeography, 2021). Vector data provides a way to represent real-world features within the GIS environment. The urban environment will be composed of various land features like infrastructures, roadways and networks, vegetation, and water sources. Representation of these geographic features and land-use dynamics over time is crucial in analyzing urbanization patterns and urban sprawl. Research is carried out using the free and open software, and websites listed in Table 1. This communication mainly focuses on two significant objectives: (a) To develop and analyze a web-based spatial visualization system for the Mysuru region, (b) To understand the Land use dynamics of the study area for the years 2000 and 2020.

2. Literature review

Urbanization, urban sprawl, and population burgeoning are happening at an alarming rate all around the world. In 2018, according to United Nations, the world population living in urban areas which were 55%, is expected to reach 68% by 2050. Urbanization and population growth all over the world could add around 2.5 billion people, where about 90% of the contribution is by Asia and Africa (UN DESA, 2018). The highest number of urban dwellers is expected by 2050 and the exponential increase in urban sprawl studies since the year 2010 attributed to 72% of the total publications (Saini & Tiwari, 2020).

Urbanization is indirectly related to GHG (Green House Gases) and one has to find more precise ways to allocate responsibility. GHG emission is not affected by population growth especially in developing countries, but rather the growth in the number of consumers utilizing the GHG implications (Satterthwaite, 2009). An advantageous location for economic activities like infrastructure, industries & services are contributing to urbanization (Sastry, Emerging development issues of Greater Bangalore, 2008) Developing countries are expected to undergo a lot of changes in the sector of infrastructure development (Chandan, Nimish, & Bharath, 2020). On the other hand due to lack of updated geospatial data like LU maps, collection of a large set of spatial data required to prepare the necessary dataset, heavy computations and economic factors (Yang, Fu, Smith, & Yu, 2017), and lack of technical knowledge which hinders the usage of advanced technologies in these developing countries. As the world population is accelerating at a high rate, land use maps derived from remote sensing imagery play a vital role in strategizing & governing the terrain and monitoring landscape changes. Several free and open software like QGIS available today are user-friendly, compatible, and provides reliable spatial datasets that can be used in effective town planning and land use management. Coupled with plugins, QGIS assist in evaluating the models of the aquatic ecosystem (Nielsen, Bolding, & Trolle, 2017), parking study (Reddy & Prasad, 2017), and evaluation of SWAT and MODFLOW models (Park, Nielsen, Bailey, Trolle, & Bieger, 2019). Not only about the beatification of the city, but these spatial datasets and software can also be effectively used in the situation of distress. Geo-spatial technology and geo-based tools such as QGIS, GPS Essentials, and Open Street Map are utilized to outline the disaster exposure areas. Geo-spatial platforms focus on digitizing the disaster-prone areas exposed to flood & natural disasters. Digitizing the disease-prone areas gives a lot of information regarding the spread pattern, geographical aspects contributing to it, and hence an effective way to combat it. And aids in estimating the possible losses to infrastructure and the environment.

Land use and land cover (LULC) change has been one of the most immense and perceptible transformations of the earth's surface. Evaluating LULC change is crucial in a wide range of perspectives such as environmental conservation, resource management, land use planning, and sustainable development. Land use management is one of the major factors affecting the town & city planning, absence of which results in vivid consequences such as floods. While planning, the land must be classified into geomorphological regions and for old cities, the planner needs to be careful while choosing the land for respective use (Das, et al., 2018). The formation of a national level database in various urban planning should be incorporated by government agencies and large organizations (Saini & Tiwari, 2020)

3. Study Area

Mysuru is a city located in the southern part of Karnataka. It is also known as "Heritage City", "Cultural Capital of Karnataka" and "City of Palaces". It extends between 12° 18′ 26″ North latitude and 76° 38′ 59″ East longitude. It is situated at an altitude of 770 m (2,530 feet) above the mean sea level (MSL). It spreads across an area of 286.05 square kilometers (110 square miles).

The civic administration of the city and the Mysore division lies under the authority of Mysore City Corporation (MCC). In 2018, according to United Nations, Mysuru is the second-largest city in the state with a population of 1.162 Million.

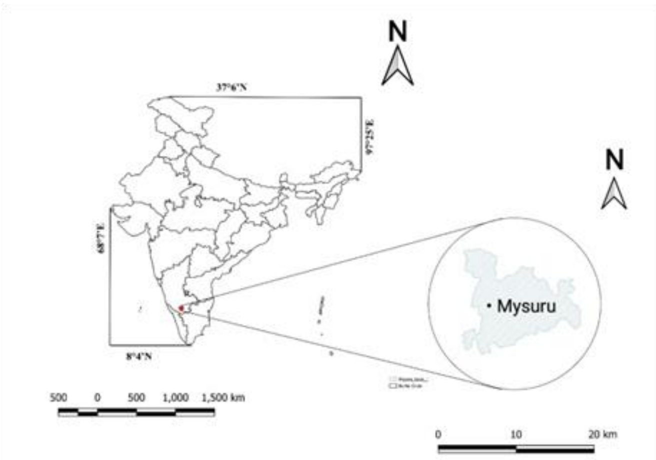


Figure 1: Study area Mysuru city - Southern India (left). Mysuru region with administrative boundary (right)

4. Methods and Materials

4.1. Materials

QGIS and external plugins like Quick Map Services (Google.cn Normal) and OpenStreetMap bridge the gap between the input, raw satellite data, and output, processed spatial dataset. Plugins add extra functionality and aids in various geospatial processes. The software and websites used are listed in Table 2.

4.1.1. QGIS

QGIS is free and open-source software, which aids in developing updated spatial layers. It's a robust, powerful desktop GIS that runs on all major platforms like Mac, Linux, and Windows. Also, QGIS enables integration with other geospatial tools and programming languages like R, Python, and Post GIS (QGIS-3.16-DesktopUserGuide, 2021)& (MicheleTobias). It gives the world of options for geospatial database processing and visualization and allows users to analyze, edit spatial information, and mapping. In addition to composing and exporting graphical maps, QGIS supports both raster and vector layers and also the software geo-reference images.

4.1.2. Google earth

Google earth is an external plugin that acts as a base layer and helps in exploring geographic data on the virtual globe.

4.1.3. OpenStreetMap

OpenStreetMap plugin also known as OSM helps in digitizing the vector layer, by providing data on the virtual earth. It gives open access to a spatial dataset like infrastructure polygons, streets, etc.

4.1.4. SCP

It is a free and open plugin that enables supervised classification of Remote sensing images, tools to download and process images.

4.2 Method: Data acquisition, pre-processing, and data preparation

Digital Elevation Model (DEM) and Landsat raster data obtained from the public repository United States Geological Survey (USGS) for the duration 2000-2020, was pre-processed and masked for the study area. Further, DEM is utilized for deriving Aspect, Hill-shade, and Slope maps.

Table 2: Software and websites used for analysis and visualization

Software/ Website	Authority	Description
Quantum GIS	Open Source Geospatial Foundation (OSGeo)	Vector and raster data development & management, Image processing, visualization & analysis of spatial data
Google earth	Google Inc.	Helps in exploring geographic data on the virtual globe
Open Street Map	OpenStreetMap Foundation	Helps in digitizing the vector layer, by providing data on the virtual earth
Semi-Automated Classification Plugin (SCP)	Free Software Foundation	Assist in the supervised classification of Remote sensing images, image processing

Various vector databases in the form of point layer, road layer, and polygon layer were digitized on the cadastral map of the study area and the corresponding updated attributes are joined. The Landsat raster data obtained is useful in deriving the Land Use Map of the study area for the years 2000 and 2020. The process of Spatial Data analysis and Land use dynamics is shown in Figure 4.

5. Results

The spatial layers of Mysuru taluk which include Digital Elevation map, aspect map, slope map, hill-shade map, and vector layer maps (point, polygon, and road) were obtained. In addition, the land-use map for the years 2000 and 2020 was analyzed, which would assist in the sustainable management of land and efficient utilization of land resources.

5.1. Raster Maps

5.1.1. Digital Elevation Model (DEM)

DEM is spatial data that represents the relief of a surface between points of known ascent and the bare ground topography of the Earth surface. The elevation data required for DEM is obtained from Shuttle Radar Topography Mission (SRTM) data, whose resolution is 1 arc-second (30 m). It was then clipped to the study area. The elevation range was split into the following 6 discrete intervals: <=

Table 3: Data Collection

Data	Year	Purpose	Source
Landsat 5 TM (30 m)	2000	Land use and Land cover analysis	USGS
Landsat 8 OLI-TRIS (30 m)	2020	Land use and Land cover analysis	USGS
Google Earth Pro	-	Geo-correction & validation, Collection of vector data	Google earth
SRTM layer	-	To create hill shade and slope maps	USGS

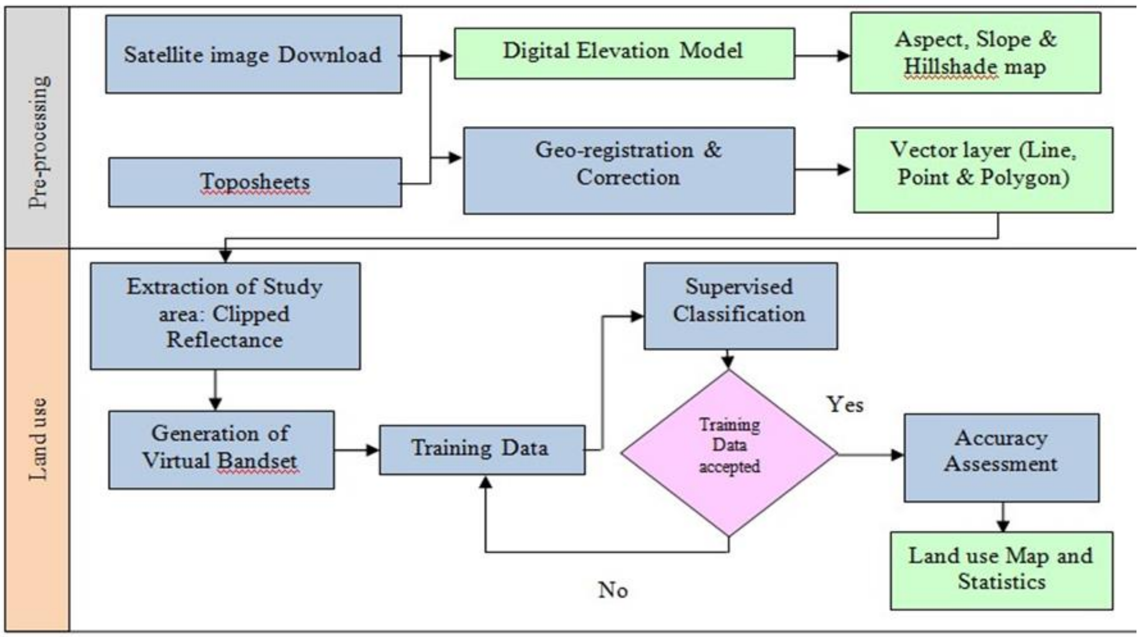


Figure 4: Process of Spatial Data analysis and Land use dynamics using QGIS

706m (level 1); 706- 776m(level 2);776- 846m(level 3); 846- 916m(level 4); 916- 986m(level 5), and >986m(level 6). DEM was represented using the inverted spectral color ramp. Figure 5 depicts the terrain feature's elevational variation of the study area.

DEM enables the extraction of topographical data that helps in the veracious quantitative measurements of terrain surfaces (Mattivi, Franci, Lambertini, & Bitelli, 2019). It provides primary and secondary terrain attributes data. Primary attributes correspond to the data that can be obtained from elevation, aspect, slope, plan, and curvature: secondary attributes are obtained with the integration of primary attributes like moisture index or solar radiation (Oksanen & Sarjakoski, 2005). It is a beneficial tool for the topographic parameterization, especially for erosion and drainage analyses, hill-slope hydrology, transport, watersheds, groundwater flow, and contaminant studies (Walker & Willgoose, 1999); (De Vantier & Feldman, 1993) (Jenson & Domingue, 1988).

5.1.2. Aspect Map

Aspect Map gives the downslope direction of the slope of a topography. It gives compass direction of slope. The value of each cell in the grid of the aspect map gives the direction in which a cell's slope faces. It is measured in the clockwise direction, in degrees. Here 0° or 360° corresponds to North; 90° to East; 180° to South; and 270° to West.

Clipped DEM was utilized for deriving the Aspect map, using the raster terrain analysis tool, (under processing tool) Aspect.

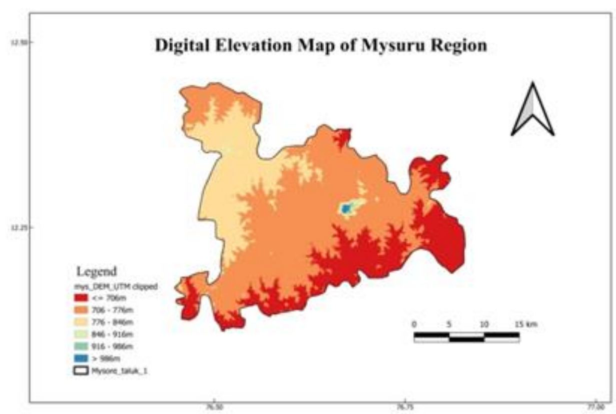


Figure 5: Digital Elevation Model showing the relief features of Mysuru city

The degree of the downslope direction was classified into 5 equal, discrete intervals.

[<=73.0187° (level1) ;

73.0187° - 144.7640° (level 2);

144.7640° - 216.5093° (level 3);

216 .5093° - 288.2547°(level 4); and

>288.2547°(level 5)].

These intervals indicate the orientation of the slope of relief features in different directions. This is represented by Figure 6. Aspect map has a great influence on vegetation and its erosion, snowpack (to prevent avalanches), and construction. It is useful in specialized agriculture which involves cultivating crops in a sheltered environment (protected from cold and dry winds), that leads to successful crop growth. (GISGeography, 2021)

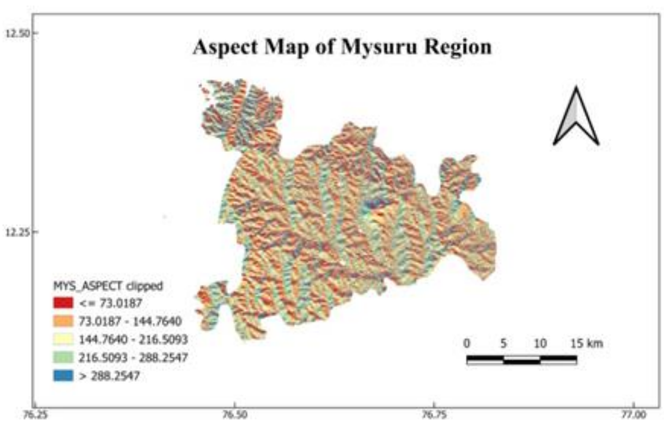


Figure 6: Aspect Map of Mysuru Region

5.1.3. Slope Map

The slope map provides a colorized representation of the slope of the terrain. This colorized slope is appropriate for visualizing the steepness of topography at all map scales. It is measured in terms of percent slope.

DEM of the Mysuru region in the UTM coordinate system was added to the QGIS working environment. Then Slope under the raster terrain analysis tool was applied. Under the properties of the obtained slope result, the rendering type of the color was changed to single band pseudo colors.

The slope range was split into 5 discrete intervals as following:

<= 6.9362% (level 1),

6.9362 - 13.8725% (level 2),

13.8725- 20.8087% (level 3),

20.8087- 27.7450% (level 4) and

>27.7450 %(level 5).

This yields the slope from lowest to the highest point, with varying colors as shown in Figure 7. The slope information is useful in understanding the topography, geomorphology, soil types and their erodability, surface drainage (Sarapirome, Surinkum, & Saksutthipong, 2002) (Reddy, Patil, & Chaturvedi, 2017)

5.1.4. Hillshade Map

Hill-shading is an approach to constitute a realistic view of a landscape by shaping a three-dimensional surface from a two-dimensional display. It generates a speculative illumination of terrain by setting a station for a light source and gives the illumination value based on the cell's relative alignment to the light illumination or based on the aspect and slope of the cell. Hillshade under raster terrain analysis tool was selected and the DEM of the Mysuru region in

UTM (CRS). Azimuth, which is the position of the sun to a required position was then set to the required value and then the data was runned to get the results. Hillshade extent for the study region is 0°- 217.752°.

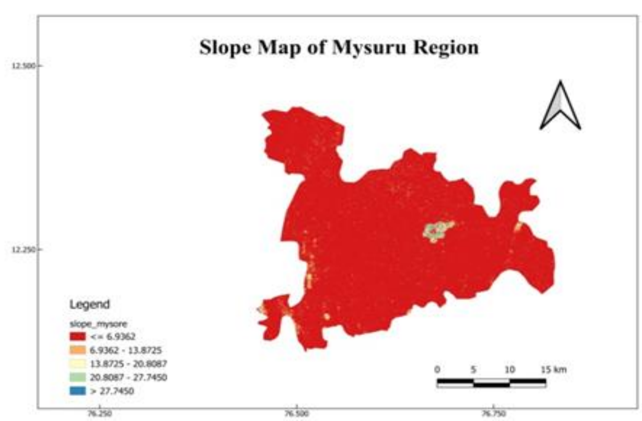


Figure 7: Slope Map of Mysuru Region

It is utilized for estimating solar radiation (Cioban, 2013). It is convenient to use the hillshade regime than aspect in ecological studies, because of its ability to capture daily and annual solar radiation regimes (Najafifar, Hosseinzadeh, & Karamshahi, 2019). Figure 8 shows the hillshade map of the Mysuru region, derived from DEM of 30m resolution.

5.2. Vector Maps

5.2.1. Road Layer Map

A polyline is employed to represent the geometry of linear features like roads, rivers, contours, footpaths, flight paths, and so on. There are special rules for polylines in addition to their basic geometry.

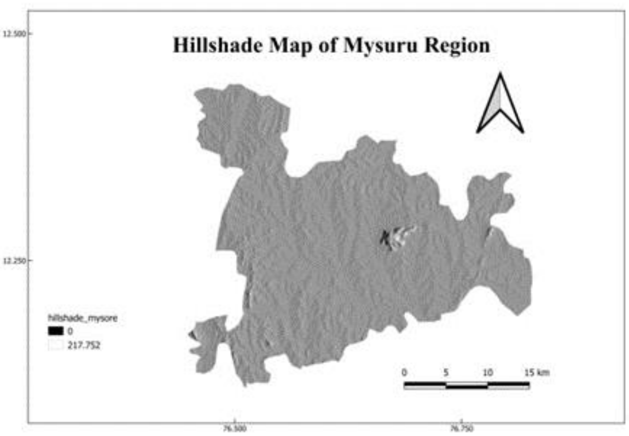


Figure 8: Hillshade Map of Mysuru Region

For the road layers created in the study area, the full dataset was downloaded using the Open Street Map (OSM) feature. Downloaded datasets from the OSM which includes NH, SH, MDR, OMR were merged to create a final road layer map of the study area. Then the corresponding attributes are joined. Figure 9 shows the road network of the Mysuru region.

5.2.2. Point Layer

A point layer overlays individual locations on a map, representing them with shapes. By default, it uses circular bubbles, but one can also make use of (several other shapes) custom images as the points in a point layer. Polygon layer map of the study area was loaded onto the QGIS working environment. Place of interest was mapped by creating a new shapefile layer under the menu toolbar, Layer. Attributes that give various information like importance, latitude, and longitude information were joined to the shape layer.

This point layer can be used to represent various places of importance. Points on the map give geospatial information like latitude, longitude, and address. It acts as a source of information for surveying in distress or pandemic situations, as it gives a clear view of the spreading pattern. Also, it

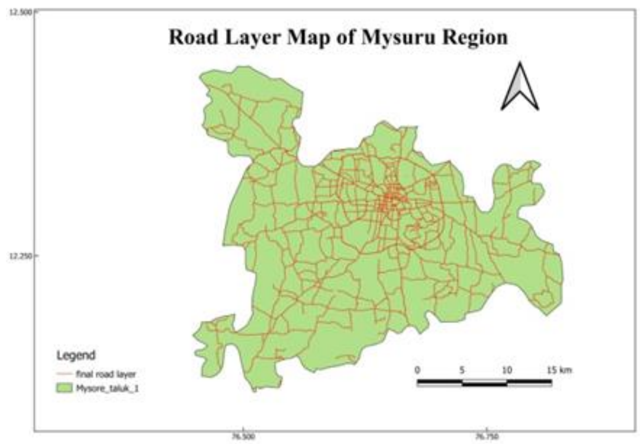


Figure 9: Road Layer Map of Mysuru Region

gives the distribution pattern of the basic amenities available. In this research, the point layer represents covid and non-covid hospitals, Primary Health Centres (PHC), Urban Primary Health Centres (UPHC), and Vaccination Centres as shown in Figure 10.

5.2.3. Polygon Layer

The map can be used to represent the various places of interest by joining series of points to form a polygon. The data of the region is extracted from Open Street Map. Places of interest of large areas were digitized on the Mysuru region map, using the polygon shapefile under layer toolbar. It can be used to represent geographies like water bodies (lake), areas of vegetation, city blocks, etc.

In this project, it has highlighted the location of various tourist spots in Mysuru like Chamundi hills, KRS, Zoological parks, and important lakes.

5.3. Land Use Map

5.3.1. Land Use Analysis

Landuse analysis for the study area was derived from Landsat5-MSS/TM (2000) and Landsat8-OLI/TIRS (2020) data, using Semi-automatic Classification Plugin (SCP) of QGIS. Band set 1-5: blue, green, red, NIR & SWIR-1 (preferred for this purpose) were stacked and clipped according to the study area to generate the reflectance. Further reflectance is utilized to create the virtual band set (FCC). From which training output can be generated by digitizing the polygon on the entire study area under four broad categories. It includes Urban, Vegetation, Water and

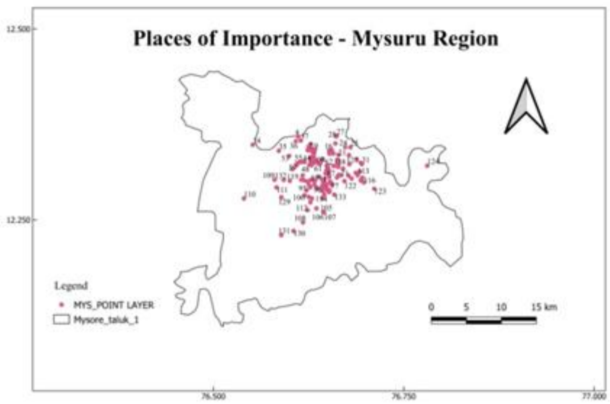


Figure 10: Point layer for Places of Importance

Other as shown in Table. And the classified map was previewed before running SCP. Verification of ground truth data is undertaken by loading the google earth into the QGIS and the final output appears as shown in Figure 12.

5.3.2. Accuracy assessment

Accuracy is calculated by extracting the appropriate data from Google Earth Pro. The classified map is compared with the validation map created by earth explorer. Two training

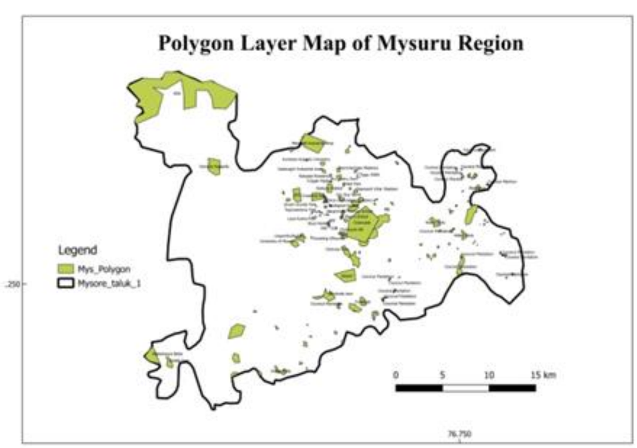


Figure 11: Important tourist spots in Mysuru

outputs are calculated to compare and validate. Once the comparison is made the accuracy is checked using the semi-automatic plugin.

6. Discussion & Conclusions

Vector map identifies the concentration of infrastructure, tourist spots, basic amenities in the city limits of Mysuru. To decentralize the basic amenities, there is a requirement of the spatial dataset in digital format which includes a raster map (DEM Map, aspect map, slope map, hill- shade map), vector map (point, line, and polygon), and land-use map. Comparison between the land-use dynamics of the years 2000 and 2020, shows the visible growth in the urban area. This is due to the advantageous location of the city and hence, the increase in population due to urban sprawl. Land-use dynamics also depict the consistency in the vegetation in the city, and a slight increase in vegetation can be observed. Initiatives undertaken by several organizations may have accelerated the rate of vegetation in the city.

Urbanization is the need of the hour. A vector map identifying the concentration of infrastructure, tourist spots, basic amenities in the city limits of Mysuru, affirms the need for proper management of land use and decentralization will decrease the urban sprawl. While planning for expanding urban areas, the concerned authorities have to ensure the proper utilization of the land using the spatial layer maps and GIS technology, which are reliable. Effective execution of the obtained results through these resources also plays a vital role, along with planning. Road network and rapid transit can be improved in the periphery of the study area, which gives access to the heart of the city and other parts, thereby encouraging the working population to reside in the outskirts of the city area. Furthermore, the raster maps can be efficiently used to improve the drainage system during the rainy season and to locate appropriate land for agriculture.

Table 14: Land use Classification category

No.	Category	Includes
1	Urban	Infrastructures, Buildings
2	Vegetation	Plantation, Dense Forest
3	Water	Lakes
4	Other	Barren Land

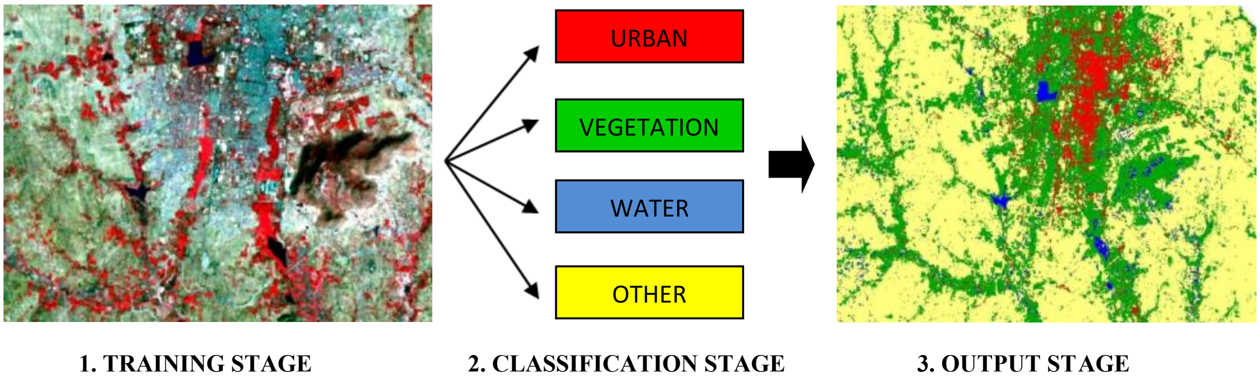
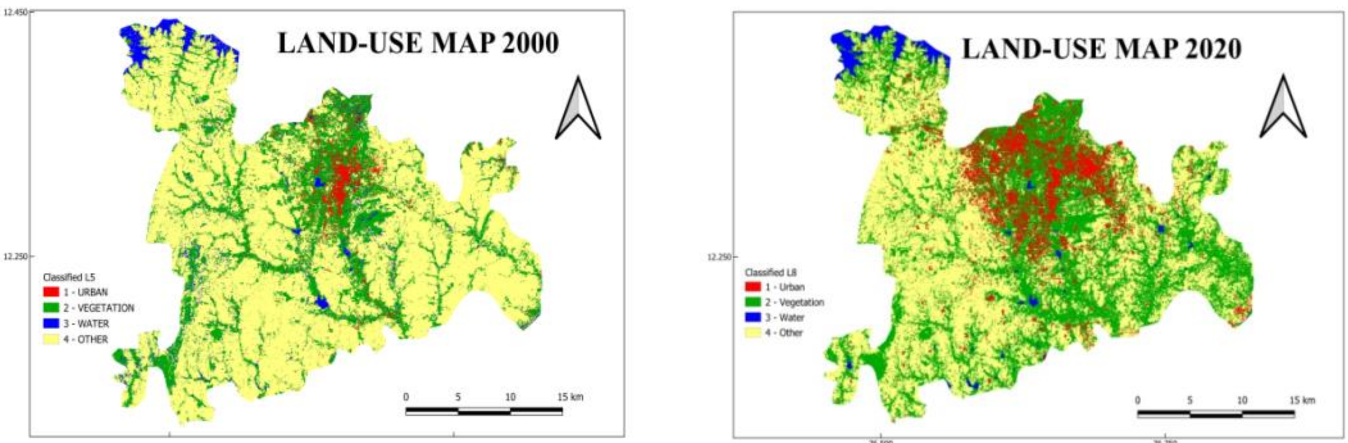


Figure 12: Land use Classification Process



(a) (b)

Figure 13: Land use Map of the year (a)2000, (b) 2020

The project provides spatial data of all the locations in Mysuru city that are currently unavailable in a source. This provides the real-time location at one single source. The outcome of this research proposed also focuses on the development of an open-source web-based spatial data visualization system aiding users to freely access various layers, analyze existing datasets, and query-based on user needs in accordance to open data standards and web-based GIS. The scope of this research can be further extended to integrate real-time spatial data visualization which can aid in planning people-friendly strategies at both municipal level and district level to effectively combat the current situation of distress in urban areas.

7. Acknowledgment

Authors are grateful to Department of Civil Engineering, The National Institute of Engineering, Mysore, for infrastructure support. Authors are thankful to OSGEO for GRASS and QGIS software and well-maintained user forms for timely answers to solve bugs in the software.

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Development of Plugin in QGIS environment for Accuracy Assessment of the Extracted Boundary

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Abstract

The convolutional neural networks (CNNs), image segmentation techniques have emerged as the key strategy to extract the boundary of the features from the unmanned aerial vehicle (UAV) data and high-resolution satellite images (HRSI). The boundary features like roads, buildings, trees, water bodies, and cadastral parcels are extensively extracted using the above techniques. However, there are limited tools for, assessment of the quality of the extracted boundary. For accessing the quality of the extracted boundary a plugin is developed using the QGIS. The plugin was developed in Python 3.0 language. The QGIS modules, functions, classes, and PyQt4 were used for the development of the application. The tool generates the length of the extracted boundary lines inside and outside a chosen buffer around the ground truth. Similarly, the plugin also extracts the length of the ground truth boundary inside and outside the identified buffer around the extracted polygon. The plugin identifies and annotates the lengths and the same is used to quantify the correctness, completeness, and quality of the extraction. The plugin will help the field engineers to access the accuracy of the extracted feature boundary.

Keywords: CNN, Completeness, Correctness, GIS, HRSI, Parcel, Quality, Segmentation, UAV

1. Introduction

With the proliferation of advanced tools, the man-made and natural features are extracted from the remotely sensed images and UAV data. But very little work has been done for qualitative and quantitative assessment of the extracted feature in comparison with the ground truth. The discrepancy measure between the extracted and reference data is attempted by many researchers to record the quality of the extraction (Neubert et al, 2008). The linear comparative analysis for accuracy assessment is presented in Seo & O'Hara, 2004. This method also uses a buffering approach for evaluation of the accuracy. Novelli et al, 2017 developed AsseSeg tool for the image segmentation quality evaluation. It is based on the potential segmentation error (PSE) and the number of segment ratios (SNR). ED2 distance is the euclidean distance associated with the PSE and NSR.

A smaller value of ED2 distance represents smaller geometric discrepancy and arithmetic discrepancy and indicates a good quality segmentation. The uncertainty of ED2 distance is also improved by using a large number of reference objects. Many authors have also indicated different indexes for the evaluation of the quality of the extraction. The details of the quality analysis are shown in reference Neubert et al, 2008.

The buffer overlay method was proposed by Heipke et al 1996. The same has been adopted by many authors (Khadanga et al, 2021, Bujar et al, 2019, Wassie et al, 2018) for quality assessment of the extracted data. Most of the authors have also used the buffer distance as recommended by IAAO, 2015. Hein et al, 2020 used the conditional generative adversarial network (CGAN) for building extraction from GeoEYE images for building

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footprint extraction. The completeness, correctness, and F1 are used to report the evaluation parameter.

The objective of this work was the development of an open-source plugin for the assessment of the quality of the extracted boundary using the recent techniques like CNN, cGAN, image segmentation, and object-based image analysis (OBIA) from the remotely sensed images and UAV data. The use of the pyhon language facilities the extension of the modules.

1.2. Plugin Development and Methodology

The plugin was developed using the QGIS version (3.16.9). The plugin graphic interface was developed through Qt Designer package. It helps to create and personalize the widgets such as combo boxes, push buttons, and labels. The TP, TN, FN as proposed by the author Heipke et al, 1997 using a suitable buffer around the ground truth, and the extracted data was used for the generation of the completeness, correctness, and quality parameters of the extraction.

1.3. Accuracy Assessment

The buffer overlay method as proposed by Heipke et al, 1997 for accuracy assessment is adopted in this study. The quality can be determined if one knows how complete the extracted boundaries are in comparison to the ground truth. Thus the completeness is a measure for what is extracted and what is not extracted. Further, it should also be known how correct is the extracted boundary in comparison to the ground truth. This correctness is also an indication of the assurance that the extracted boundary is accurate to what extent. The definition of completeness and correctness are given below.

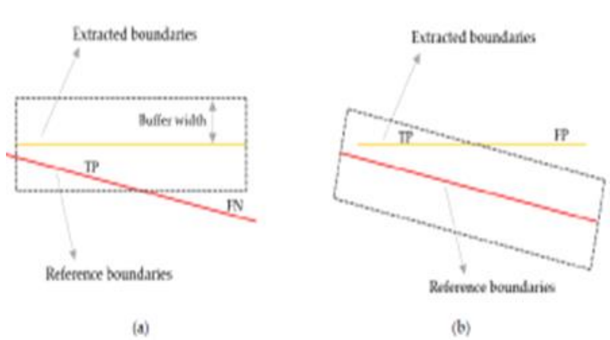

Figure 1: Buffer overlying method (Heipke et al, 1996)

$$\text{Completeness} = \frac{\text{length of matched reference}}{\text{length of reference}} *100\%$$

$$= \frac{TP}{TP+FN} * 100\% \qquad (1)$$

$$\text{Correctness} = \frac{\text{length of matched extraction}}{\text{length of the extraction}} * 100\%$$

$$= \frac{TP}{TP+FP} * 100\% \qquad (2)$$

$$\text{Quality} = \frac{\text{length of the matched extraction}}{qq} * 100\% \qquad (3)$$

qq =length of extracted data
+ length of the unmatched reference

The completeness is the percentage of the reference data which is indicated by the extracted data. This is calculated from using the plugin using the percentage of the reference data with the identified buffer around the extracted data. The correctness represents the accurately identified data. It is the percentage of the extracted data which lies within the buffer around the reference data. Quality is a measure of the goodness of the final result.

1.4. Processing Steps

The details of the input, output and the processing steps used for generation of the lengths of data inside the buffer and outside the buffer is shown below. The input ground truth data and the extracted polygon data were processed and the length of lines inside the buffer and out the buffer is saved into a CSV file. The steps followed for the calculations are shown in Figure 2.

The plugin uses the inbuilt functions as available in QGIS (Intersection, polygon to lines) for the processing of the data.

Input Data:

Ground truth vector file, Extracted vector file, Buffer width (Recommended 2M for Rural Area) and the output file name.

Output data:

The plugin generates the buffer and processes the length information and stores in the CSV file with length of the lines inside and outside the buffer with length in meters.

Algorithm

- Generates the buffer around the ground truth data/ reference data
- Converts the polygons coordinate system to WGS84 and polygons to lines
- Find the line length inside the buffer and outside the buffer using QGIS Intersection function
- Annotate the line parts inside and outside the buffer for better visualization
- Process Completeness, Correctness & Quality

Input Reference, Extracted shape, buffer in M

↓

Find Length of Line inside and outside the buffer using difference, intersection and CRS to WGS 84

↓

Annotate the line parts inside & outside the buffer

↓

Report the lengths of line inside and outside the buffer into a CSV file

↓

Process Completeness, Correctness & Quality

Figure 2: Flow Chart of the Plugin for Accuracy Accessment

The plugin uses the inbuilt functions as available in QGIS (Intersection, polygon to lines) for the processing of the shape files after converting the coordinate reference system to WGS 84. The buffer is first drawn around the reference data and then the extracted data is over laid and the lengths inside and outside the buffer was processed. Then again the buffer is drawn against the extracted data and reference data is overlaid. The output of the length information is saved to the file.

1.5 Screens of the Plugin

The screens of the plugin are shown below.

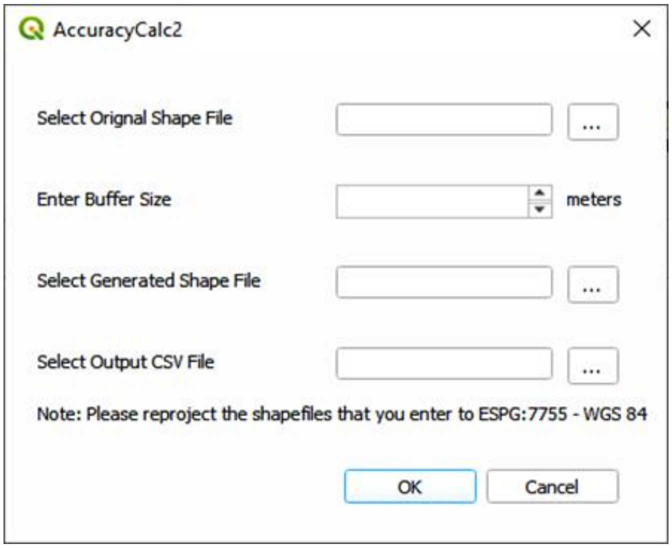

Figure 3: Input Screen of the Plugin

Figure 4: Output Screen of the Plugin

The input screen of the plugin is shown in Figure 3. The Figure 4 shows the output of the plugin. An enlarged view of the buffer is shown in Figure 5.

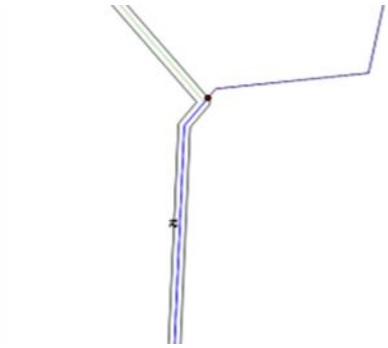

Figure 5: Enlarged view of the buffer the for a small section.

1.6 Screens of the Plugin

The input data (GT) and the sample extracted vector file are shown in Figure 6 and Figure 7 respectively. The overlay of the ground truth with the buffer of 2M and the extracted polygon is shown in Figure 8.

After processing the plugin generates the buffer data against one layer with the overlay of the other layer. Then the results of the line segments inside the buffer and outside the buffer are marked with starting point and end point. Also the line segments are shown with different color cod for better visualization. Further the individual lines inside the buffer and outside buffer with length information and cumulative length is processed and saved to the output file for better record and analysis

2.0 Results and findings

The buffer width of 2M as recommended for the rural areas by (IAAO, 2015) is taken up for the final result. Naturally, the results will be more accurate with the increase in the buffer. Thus with 2M buffer the completeness of 75 %, the correctness of 65%, and quality 53% are taken as the final result of extraction shown in Table 1

Figure 6: Input Data (GT)

Figure 7: Input Data (Extracted)

Figure 8: Overlay of GT, Extracted and Buffer

The completeness, correctness, and quality of the sample data are found to be 75%, 65%, and 53% respectively. The buffer taken for analysis is 2 M. The selection of buffer depends upon the domain and as per the recommendation of national standards for rural and urban areas. The plugin generates the TP, FP, and FN lengths and reports them into a file. The plugin also marks the line parts inside the buffer and outside buffer for better visualization of the boundary of the extracted feature.

The plugin is developed in python programming language. As most of CNN implementations are also in python programming language, the integration of these techniques with the plugin is very encouraging.

Table 1: Quality Measures of the extraction

Buffer	Complete-ness TP/ (TP+FN)	Correctness TP/ (TP+FP)	Quality TP/ (TP+ FP+FN)
2M	0.75	0.65	0.53

3.0 Conclusions

The accuracy assessment of the predicted boundaries after the usage of the CNN, image segmentation, or any other techniques is very essential. The proposed QGIS plugin allows to input reference, the extracted shapefile, the buffer, and processes the correctness, completeness, and quality. This automation will help the researchers to quantify the quality of extraction. The plugin currently uses the built-in functions as available in QGIS. The plugin can be fastened and enhanced with various python libraries and can be used to find the intersection of two features like polygon and a line.

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State of mago3D, An Open Source Based Digital Twin Platform

Shangi Shin

Gaia3D

Abstract

I'll talk about the current state of mago3D project, an open source based Digital Twin platform.

mago3D(https://github.com/Gaia3D/mago3djs) is a relatively new project first released in July 2017. The ultimate goal of mago3D project is developing an open source based digital twin platform that can replicate and simulate the real world objects, processes, and phenomena on web environment. mago3D is on its way to achieve this goal now. As a Digital Twin platform, it can integrate, manage, and visualize various kinds of data formats such as CityGML, IndoorGML, LAS, IFC, 3DS, and other popular GIS formats. It utilizes tons of open source projects as a baseline framework.. mago3D has been used in various industry sectors including ship building, urban management, indoor data management, and national defence. In this talk I'll showcase several real projects that employed the mago3D and will talk about recent improvements and new features of mago3D.

Keywords: Digital Twin, mago3D, 3D GIS, Smart City, Smart Factory

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ZOO-Project: from OGC Web Processing Service to OGC API - Processes

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Abstract

ZOO-Project is a Web Processing Service (WPS) platform implemented as an Open Source project following the OGC standards. It was released under an MIT X-11 style license and is currently in incubation at OSGeo. It provides a WPS compliant developer-friendly framework easing the creation and chaining of WPS Web services. This presentation gives a brief overview of the platform and summarizes new capabilities and enhancements available in the new version. A brief summary of the Open Source project history with its direct link with FOSS4G will be presented. The new release comes up with a brand new OGC API - Processes (OAPI-P) support. The new functionalities available in the latest release will be presented and described, further highlight their interests for application developers and users. Various use of OSGeo software and others, such as GDAL, GEOS, PostGIS, pgRouting, GRASS, OTB, SAGA-GIS, as WPS or OAPI-P services through the ZOO-Project will be presented. Then, the ongoing developments and future innovations will be explored.

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Development of enterprise level Spatial Planning and Decision Support System for Gas Asset Management in City Gas Distribution companies in India using FOSS

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Abstract

Use of natural gas through City Gas Distribution (CGD) in India has gained tremendous pace in recent years due to our commitment as per COP21 Paris Agreement to reduce CO2 levels by 33% of 2005 levels by the year 2030. This has generated the need to establish a decision support system backed up by geospatial tracking of gas assets and their lifecycle management as per mandate from the Indian gas regulator Petroleum Natural Gas Regulatory Board (PNGRB). Spatial planning and decision support system developed for CGD's is based on Geoserver as the open source GIS server, PostgreSQL as the database management system, PHP as the scripting language and Openlayers java script libraries for dynamically representing maps on the web. The core desktop GIS software Q GIS is used as an overall platform to normalize and align gas asset data (pipeline network data and point gas asset data) for GIS and gas-based topology correction through dedicatedly developed Gas Plugins. Apart from development initiatives, ground based survey using hybrid DGPS and ETS technique was used to capture gas assets and their network. All above ground assets and features were captured through these devices, however the underground assets and network were captured using the existing as-built drawings and knowledge of the ground technicians. Dense control network was established all across the area using DGPS to attain best accuracies for mapping gas assets. Ground data was processed and cleaned to obtain final network drawing. The network drawing was later converted into GIS format. The GIS format data underwent standard GIS checks and gas topology checks based on rules defined for establishing a customized gas asset and network workable on a web-based system. Based on the above architecture, modules were developed catering to the operations and management of city gas distribution. Gas asset view module in unification to land base, data sharing module to local agency and third party, network analysis for outage reporting on web browser and on desktop GIS software and incident reporting for major gas leakages or outages within the network. The proposed solution is compatible to web and android based system for easy tracking of assets by field technicians. The developed modules using FOSS are proposed to resolve more than 90% of the daily spatial tracking of gas assets by the O&M. Development is purely customized based on local CGD requirements. The proposed system is robust and through distributed architecture can take up large network and its associated assets. The solution for browser-based outage analysis and data sharing has reduced the response time from a day to less than a few minutes. This has impacted the overall performance and quick response within CGD for efficient management of customer and gas assets. The platform has also helped the CGD companies to overcome the traditional problem of locating gas assets on ground and improve their daily tracking of gas assets for their health inspection. The incident reporting module is a highly agile development module wherein dual communication between control room and ground technicians can be made in real time to establish gas leakages or breach within the gas network. The outage analysis works in parallel to the incident reporting system to predict probable affected customers both online and offline. The current system based on FOSS Tools has been widely accepted and adopted by many CGD companies in India as the New Normal, due to its modular approach, lower Capex and Opex and capability to make customizations as per local requirements. The proposed system has all the potential elements to integrate the existing SAP and ERP solution running at these CGDs.

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FOSS4G-ASIA 2021

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