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INSTITUTE OF ENGINEERING
PASCHIMANCHAL CAMPUS

A PROJECT REPORT ON

Integrated PGIS for the Sustainable Development of Tourism of Machhapuchchhre Model Trek Route and Development of Mobile Based Application

In Partial Fulfillment of Requirements for the

Bachelor's Degree
in
Geomatics Engineering

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DECLARATION

We, hereby, declare that the project work entitled “Integrated PGIS for the Sustainable Development of Tourism of Machhapuchchhre Model Trek Route and Development of Mobile Based Application” submitted to the Department of Geomatics Engineering, Pashchimanchal Campus, Institute of Engineering, Tribhuvan University, Lamachaur – 16 Pokhara is an original piece of work under the supervision of Assoc. Prof. Krishna Prasad Bhandari, Er. Saurav Gautam, faculty members and Pashchimanchal Campus is submitted in partial fulfilment of the requirements for the project work as prescribed by the syllabus. This project report has not been submitted to any other institute or university for the award of any degree.

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LIST OF ABBREVIATION

A

Analytic Hierarchy Process: AHP · 27, 28, 29, 31, 33, 51

G

Geographic Information System: GIS · 5, 10, 11, 12, 21, 22, 23, 25, 31, 35, 49, 50, 51

L

Land Use Land Cover: LULC · 25, 26, 27, 31, 33, 41, 47
Least Cost Path Analysis: LCPA · 23

M

Multi Criteria Decision Analysis: MCDA · 27

O

Open Street Map: OSM · 25, 26

P

Participatory Geographic Information System: PGIS · 1, 2, 5, 10, 11, 16, 21, 22, 23, 25, 51
Participatory Learning and Action: PLA · 21
participatory rural appraisa: PRA · 22

ABSTRACT

Trekking has been one of the major aspects of tourism to explore the natural scenario and to understand the socio-economic factors of tourism spots. Trekking routes in the mountainous region has hidden tressure and is adventurous to discover. 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 PGIS and provide the information which is yet to be known by many trekkers and backpackers. We used a participatory approach to find out information about the availability of natural resources by the participation of the public in decision making. Along with the use of GIS and Remote Sensing, PGIS is used to research the local resources more precisely and at ground level. Using the example of trek route suitability analysis for tourism development and mapping, this paper highlights some applications of GIS in tourism planning of Machhapuchhre and Annapurna Rural Municipality of Gandaki Province of Nepal.

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 out and after multiplying the LULC layer which is not reclassified with weighted overlay, 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, we 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 evaluted 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 was connected. The completed path is the smallest sum of raster cell values between the two points and it has have the lowest cost. Thus, least cost path from our study is generated below the existing route, passes above the existing water source near the starting point, passes through 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, that 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 definitely eases anyone for trekking in the route with safety.

Keywords: AHP, Ecotourism, GIS, LCPA, Machhapuchhre Trek Route, MCDA, Mobile-based application, Suitability Evaluation, Trekking

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1. INTRODUCTION

1.1 Background

The United Nations Environment Program (UNEP) and the World Tourism Organization (WTO) define sustainable tourism as "Tourism that takes full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment, and host communities." 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. Kathmandu, Bhaktapur, Lalitpur, Kaski, Chitwan, Solukhumbu, etc. are the major tourist districts of Nepal.

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. Among the various tourist spots, Pokhara is one of the famous tourist spots in Nepal. One of the major purposes of the visit to Pokhara is trekking in nearby trekking routes. Mardi Himal Trek, Ghorepani Poon Hill Trek, Siklesh Trek, Ghandruk Village Trek, etc. are some of the major trekking routes in Kaski districts. Trekking can be defined as the outdoor activity of walking for more than a day undertaken with the specific purpose of exploring and enjoying the scenery.

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, and Brahmins, etc. along with the eye-catching views of snowcapped mountains like Mt. Mardi, Mt. Machhapuchchhre, and Annapurna Himalayan ranges. Machhapuchchhre model trek being a new trek route possess 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 development of tourism in any area increases the economic development of the area also. 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)(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 techniques have been developed as a way of enhancing local peoples' abilities to share and analyze their knowledge of lifestyles and conditions thereby better enabling them to plan. Empowering people to act has been considered part of this process. Truly participatory studies have not been intended for outsiders to learn about location conditions but instead to facilitate local people to conduct their analysis and develop their agendas.(Sriboonruang et al., 2020) 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) A GIS is based on the top-to-bottom approach for the study whereas PGIS is based on the bottom-to-approach. As the local people, stakeholders, and business persons are involved in making a plan, PGIS is most suitable for the development of tourism.

1.2 Rationale

Machhapuchhre 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 Machhapuchhre 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.

1.3 Statement of Problem

Trek is a hidden gem for those who are fond of adventure and for dedicated trekkers and backpackers. As Nepal is a mountainous country with unimaginable mountain landscapes, trekking trails between the mountains and hills has become the best option for pilgrims to discover adventure in their journey. For those who plan or desire trekking, the most important part is the information regarding the tourism site. There is a lot of misinformation regarding trekking and routes, biased information is found from person to person. Our main motto is to suggest a trek route that is mostly a hidden treasure and provide information about the trekking trail and activities associated with its periphery. This work requires an android based application that includes the trek trail and attributes along the route. This kind of information helps tourists to focus on their tourism activities. Moreover, helps to explore their journey to its full extent.

There are many trekking routes in mountainous areas that are not explored properly or not found out by visitors who are mainly focused on adventurous tourism. Many hidden treasures of nature are yet to be discovered. So, our project puts concern over these sorts of problems to systemize the trekking and all other activities associated with their tourism. Machhapuchhre Model Trek is a freshly discovered route that is unexplored by many trekkers. Trekkers love such an unexplored place. This is good news for the trekking enthusiasts who are attracted to Nepal to try new trekking trails and also for the local community of that region to host the guests. We aim to develop android applications in Machhapuchhre Trek Route. Our app solves all these hindrances in their tourism (or trekking in this case) in Machhapuchhre Trekking Route. It gives map (locational)information, route for the particular tourist spots, all the associated information (accommodations, food items found, etc.) about the hotels, lodges, restaurants, tourist centres for their easy and luxurious stay. To make tourism safe and adventurous, trekkers should know about the risky areas and the zone with the high adventure. So, we give focus on exploring the risky zone near the probable path of our trekking route.

Our area of concern is to improve trekking routes in an android based application and displaying the tourism resource inventories in a wide range. Along with the path of trekking, the application shows information about the different amenities and facilities which directly concerns the longest stay of tourists in the tourism site. The success of any tourism is determined by tourism planning, tourism development and research and tourism marketing. The different tourism resources are not

properly managed. The proper management and exploration of tourism resources in a spatial way are the most in today's era.

GIS technology offers great opportunities for the development of modern tourism applications using maps. This technology integrates common database operations such as queries with the unique visualization and geographic analysis benefits offered by maps. The integration of tourism data and GIS data is a big challenge for the tourism industry, today.

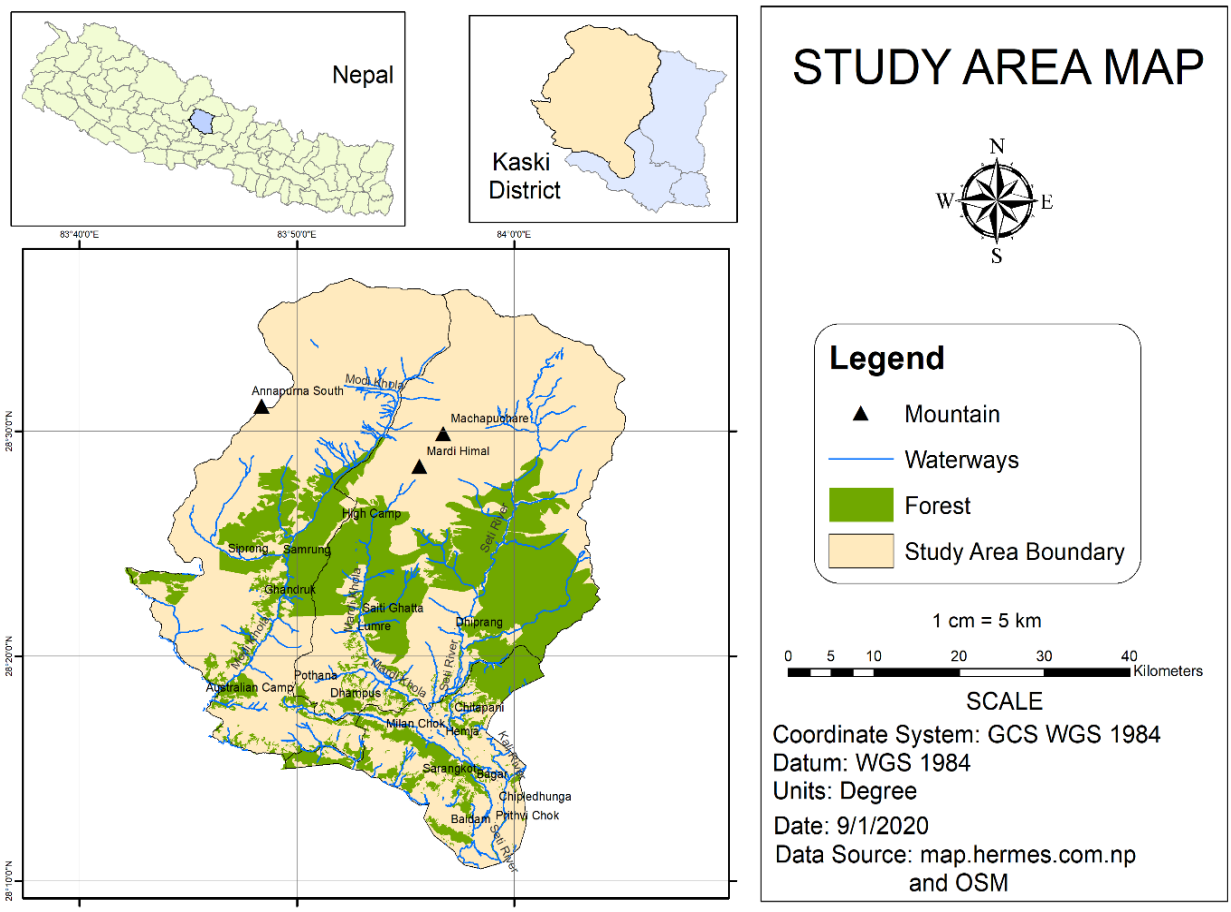
1.4 Objectives

i. Specific Objective:
   - To establish the Machhapuchhre Model Trek Route and develop a mobile-based application to disseminate the information.

ii. General Objectives:
   - To explore the hotspots in Machhapuchhre Trek Route Region.
   - To assist in the sustainable development of tourism in the Machhapuchhre Region.
   - To promote the social and cultural value of the region.
   - To develop the economy of the local people and stakeholders.

1.5 Study Area

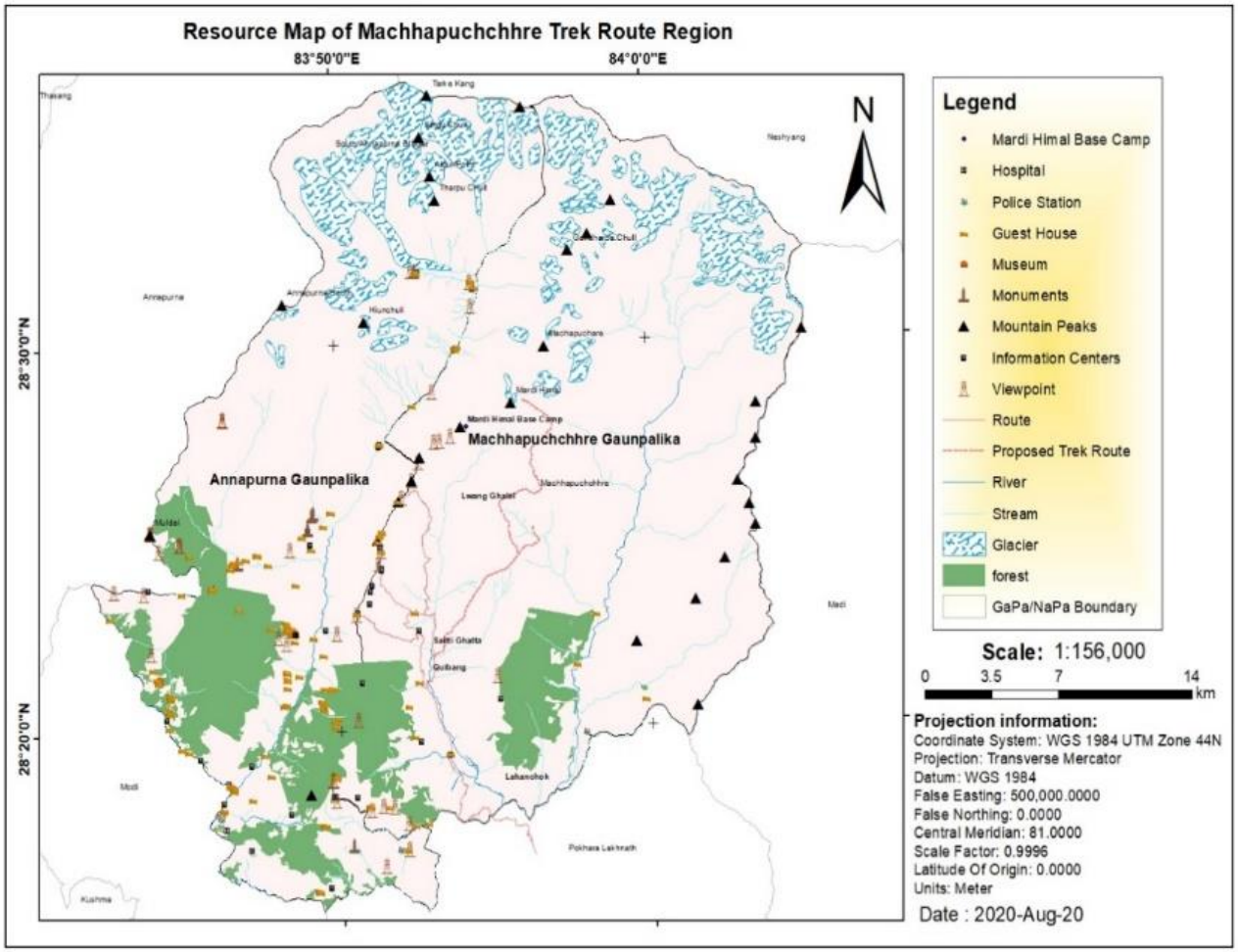
Our study area lies on the Annapurna Conservation Area which is the largest protected area of Nepal covering 7,629 square kilometres area. We are mainly focused on the administrative division Machhapuchhre and Annapurna Gaupalika of Kaski district, Gandaki province. Our main purpose is to establish a model trek route named the Machhapuchhre trek route 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. Our main focus is the mesmerizing view of mount Machhapuchhre which is ranked as the 13th most beautiful mountain in the world by the Telegraph (UK) in April 2018. Imu(1400m) is the next destination in our study area. Organic Rainbow trout and Tokro(1450m) lie on the way, which is a typical Tamang village. Purundhung (1860m), Kaltha(1890m), and Naudhoke Cave (2500m) lies on the route. The majestic view of the Himalayas and rhododendron forest are the main attraction to the Naudhoke cave, which is famous from a religious point of view. Metapurung(2600m), Coolhill(2653m) is a viewpoint before Meshroom also lies in the study area. From Korchon (3600 m) can view the majestic views of the Lamjung Himal, Machhapuchhre Range, Annapurna Range, Dhaulagiri Himal, Nilgiri Himal, and Gangapurna Himal. It is perfect for a sunrise view. From Korchon passing Lwang Ghalel via Mardi East trial, we reach our proposed Machhapuchhre Trek Base Camp, a junction points from where majestic views of the Machhapuchhre and Mardi Himal are visible and which is the only reason for the establishment of the base camp here. This trekking route seems like ridge-line trekking because most of the route passes through the ridge-line of Odane hill. It is perfect for the visitors who search for a place that is an unspoiled and less crowded



Map 1 Study Area Map

trail for trekking. Also, mountain Machhapuchhrre is worshipped by the people in nearer villages and not allowed to climb, so it has a pure and undisturbed view.

This place is rich in cultural diversity and tradition. Different ethnic groups like Gurung, Tamang, Magar, Damai, Kami, Sarki, Chhetri, Newar and Brahmins, etc. lives in the old but cultural village. Throughout the Machhapuchhre model trek, trekkers can meet warmhearted Gurung and Magar people by stopping in their cultural homestay. We travel through the villages like Machhapuchhre, Lhachok, Ghachok, Lwang, Dhital, etc. and stay at their locally prepared home. In rural and remote areas, the concept of hosting trekkers in private households i.e., the homestay has become so popular that it has increased the number of national and international visitors. This type of homestay provides or gives the local experience to the tourists. Such place should not change their natural looks so that trekkers can experience pure culture and tradition.



Map 2 Resource Map of Study Area

1.6 Scope and Limitation of Study

Some of the scopes of our project are:

- It helps to increase tourists' arrival, thereby promoting the tourism industry to the next level.
- It helps to uplift the economic status of local people providing employment opportunities as tourist guides.
- Development of necessary infrastructures including road network, tourist center, other facilities, etc. after the exploration of the prospects of tourism in the area.
- It involves the participatoy approach, i.e. the local people are participated in decision-making, thus the sustainable development is achieved.
- It motivates for the eco-friendly development, promoting the ecotourism.

Some of the limitations of the project are as follows:

- The project will be based on the open-source platform rather than the commercial one.
- This is completely an academic work.
- It may not be applicable to all villages in Nepal because of its geographical situation and the unique characteristic features of Gurung and Tamang community, which sometimes may be same as of others.
- This study focuses on ecotourism of the Machhapuchhre Trek Route Region, can not be generalized.

2. Literature Review

This chapter deals with the definition of various concepts regarding trekking, tourism/ecotourism, PGIS, least-cost path analysis, reviews all the available literature, journals, articles, books, magazines, newspapers and all other available materials related to these topics.

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, itself is the sustainable form of natural resource-based tourism. The term ecotourism was coined in 1983 by "Hector Ceballos Lascurain" a Mexican environmentalist and was initially used to describe nature-based travel to relatively undisturbed areas with an emphasis on education. Ecotourism guarantees the sustainable use of environmental resources while generating economic opportunities for the local people (Kiper, 2013). World Conservation Union (Brandon, 1996), states that Environmentally responsible travel and visitation to relatively undisturbed natural areas, to enjoy and appreciate nature that promotes conservation, has low negative visitor impact, and provides for beneficially active socio-economic involvement of local populations. According to The National Ecotourism Strategy (1994) (QuickStart Guide to a Tourism Business, 2006), "Ecotourism is nature-based tourism that involves education and interpretation of the natural environment and is managed to be ecologically sustainable".

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. It is necessary to build environmental and cultural awareness and respect for ecotourism. Ecotourism provides positive experiences for both visitors and hosts and direct financial benefits for conservation. It deals with financial benefits and empowerment for local people. Ecotourism raise sensitivity to host countries' political, environmental and social climate (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 is promoted by ecotourism in Nepal (KC, 2017).

With the presence of most of the tallest mountains in the world, Nepal has been successful to attract and welcome millions of tourists who visit for trekking and mountaineering. It has created opportunities for the successful operation of hotels, lodges and tea houses along the trails which has a direct impact on the livelihood of people of the remote area.

The government of Nepal has also identified ecotourism as a part of contributing to environmental conservation and economic development in a significant way. With the establishment of ecotourism in the protected area, the life of local people has received a great impact by uplifting their living standard and eventually their economic status on the other hand. Government of Nepal has developed many protected areas as national parks, wildlife reserve, conservation area, heritage sites for protecting wildlife and vegetation and escalating ecotourism. In remote districts like Lamjung, Tanahu, Kaski, Syangja, and Gorkha, tourism has become an alternative source of income. Tourist enjoys the intact and rare beauty of protected areas, snow-capped mountain, distinctive culture, and tradition of the remote area.

2.2 Concept of trekking

Among the various branches of the tourism industry, natural tourism (analogous with 'ecotourism' here) has been popular these days. Many tourism activities are done within the scope of nature, one of them is trekking. It is recreational outdoor activities and the combination of hiking and walking activity in nature, rural and undeveloped areas. Trekking is also known as the act of making a long journey across a difficult country on foot mostly for pleasure. (Balli & Canoglu, 2017). 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). Trekking is walking in the countryside for pleasure or sport usually meaning for a longer period than hiking. The trekking trails generally meet the needs of outdoor, nature, and adventure enthusiasts by offering pristine untouched nature and changing landscapes.

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.). Everest Base Camp Trek, Annapurna Circuit Trek, Langtang Trek, Kanchanjanga Trek, Manasalu Trek, Mardi Himal Trek, Ghorepani Poon Hill Trek, Siklesh Trek, Ghandruk Village Trek, etc. are some of the major trekking routes which are gaining popularity in the country.

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 Machhpuchhre and Annapurna Himalayan range from the proximity, the opportunity to experience the combinations of rice flora and fauna mountain forest, varied birds special, wild flower wild animals and natural hot spring are supplementary attractions for the visitor of all kinds (*Machhapuchhre Model Trek*, n.d.-b).

2.3 Development of criteria and indices suitable for ecotourism (trekking)

Based on the literature review, different suitability evaluation index systems are built. Some of the various factors for mountain adventurous tourism (includes trekking, hiking) are:

i. Resource factors:
   Aesthetic value, popularity, annual suitable period, environmental influence
ii. Difficulty condition factors:
   Difference in elevation, difference in slope, remoteness
iii. Safety condition factors:
   Transportation facility, weather variability, geological hazards
iv. Biological Safety factors:
   Elevation, slope, biodiversity, land cover types

(Wang & Yang, 2021)

2.4 Tourism in Pokhara

2.4.1 History of tourism in Pokhara

There is no proper record of tourism in Nepal before the democracy in 1951. Before democracy, Nepal had not opened the door for tourists but after the emergence of democracy, political, social and economic aspects of Nepal have developed and since then Nepal has opened the door for foreigners to visit Nepal. Mountain tourism has played a vital role at the beginning of tourism development in Nepal because tourism in Nepal began with mountain tourism. Late. Sir Edmund Hillary and Tenzing Norgay Sherpa have successfully ascended the world's highest peak Mt. Everest of Nepal in 1953, the first successful ascent exposed Nepal all over the world (Shrestha, Hari Prasad, n.d.). Nepal is a country with geographical diversity and a unique climate. The climate of Nepal differs in topographical areas. Nepal, a landlocked country situated between India and China, is divided into three ecological regions; Mountains, Hills and Terai. These all are parallel to each other, from east to west, rarely intersected by the country's river system and each region has a different natural environment and socio-cultural environment. Nepal has a diversity of structure that is contemplated within the variation of weather and climate simultaneously. Nepal is a federal democratic country, recognized as the land of Gorkhas is evaluated as bliss with glorious views of nature, mountain, multiethnic, multilingual and multicultural groups. Tourism, trekking, hiking, mountaineering, jungle safari, rafting, national wildlife parks, heritage sites, beautiful temples are the reason behind the recognition of Nepal all over the world (Sahayogee, 2018).

Pokhara is the second-largest city of Nepal, lies approximately 200 km away from the capital city, Kathmandu. Around the 1950s to 1960s Pokhara was known as the waypoint for climbers. Thousands of tourists have discovered Pokhara as a waypoint for climbing the mountain in 1962. Mount Annapurna (8091m) is the first historic climbing by French national Maurice Herzog and team on 3 June 1950. These ancient mountaineers have exposed Pokhara as a waypoint for mountaineering in the world. Another exposer of Pokhara is Thomas Cook from the United Kingdom has talked about Pokhara and its surrounding from the tourism perspective in 1966. Western hippies were the first risk bearer and thrill-seekers to travel around the new places of the Annapurna region in the 1960s and 1970s. Pokhara has become hippies favourite place in that era and their photography has helped Pokhara to become popular in the world. Thus, still, their contribution is remembered. Series of activities and consecutive ancient inclinations have made Pokhara a popular city in Nepal. There was a time when Pokhara was known only as the destination of mountain tourists but now it is at a peak of popularity for its various attributes and the increasing number of tourists in Pokhara. In 1961 Tourism information centre was established and invented the draft of the physical development plan which became the landmark for tourism development in Pokhara. Likewise, in 1968 Siddhartha highway was constructed which has connected Pokhara with the outer world. This connection has increased the flow of tourists in Pokhara. At the end of the 1970s only started the development of tourism in Pokhara. Pokhara has been recommended as the first and leading Himalayan adventure destination by PATA (Pacific Asia Travel Association) Development Authority in its developing stage. Historically, Pokhara was used as a trade route between India and China in the 18th and 20th centuries (Upreti BR, Upadhayaya PK, 2013).

2.4.2. Importance of tourism in Pokhara

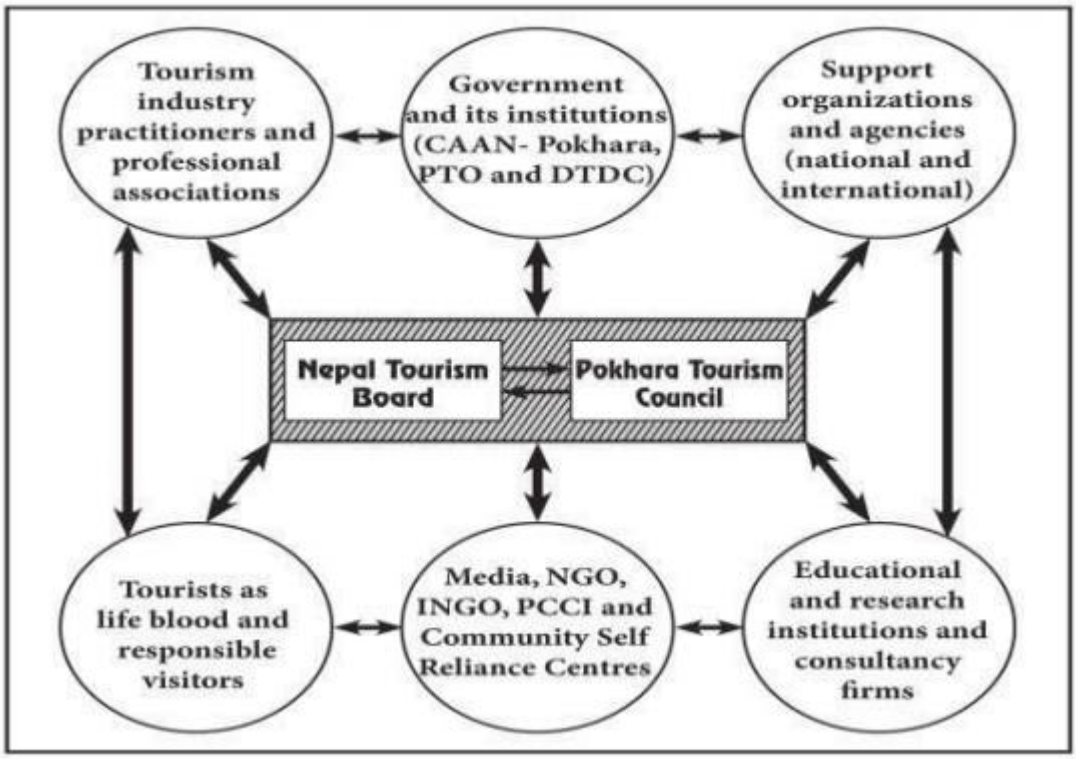
Nepal is recognized for its thrilling adventure and nature lover's ecstasy. It has panoramic views of the eye-catching Himalayas, a great diversity of landscapes, and the expeditious flow of rivers. Nepal is a beguiling beautiful country having the potential for adventure tourism such as trekking, rafting, kayaking, paragliding, jungle safari, wildlife reserves, mountaineering, hiking, bungee jumping and many more to explore adventure tourism in Nepal. Adventure tourism works as a tonic among all tourism markets (Nepali Times, 2015).

Pokhara is a touristic hub where both the international and domestic tourist enjoys the natural beauties and climate. Pokhara has more potential to develop the tourism industry using all the available resources. Tourism is not only important in Pokhara but also in the whole country. The tourism industry is one of the important factors which helps to increase national income and promote Nepal all over the world. Pokhara’s motive is not only to attract thousands of tourists with its physiographic uniqueness rather it explores opportunities for policymakers and planners to take necessary precautions and preventive measures from the possible natural disaster analyzing related risks and their effect (Upreti BR, Upadhayaya PK, 2013).

2.4.3 Related Administrative and Management organization in the Tourism industry of Pokhara

The tourism industry in Pokhara encompasses the distinct but practically compatible several sub-sectors and their performer and occupational institution to expand, handle and organize this industry. The given figure portrays the composition of sub-sectors with interdependence with each other directly or indirectly. Media, worker's tourism association, tourism-related educational institutions and other commercial associations such as Hotel, Bar, Restaurant, money exchanger, Cyber, sports, Nepal mountaineering, trekking, bus, taxi, tour and travel associations, trekking mountaineering equipment shop, Nepal Tourism Board, Pokhara Regional association and Ganesh

Laxmi Trust are functional and co-related to each other. All the association coordinates each other for the development of tourism industry in Pokhara and to promote the Pokhara as a beautiful and potential touristic destination of Nepal globally (Upreti BR, Upadhayaya PK, 2013).



Source: (Upreti BR, Upadhayaya PK, 2013)

Figure 1: Institutions and actors involved in the Tourism Industry in Pokhara

Symbols Used in the diagram: NGO- Non-Government Organizations, INGO- International Non-Government Organizations, PCCI- Pokhara Chamber of Commerce Industry, CAAN- Civil Aviation Authority of Nepal, DTDC- District Tourism Development Committee, PTO- Pokhara Tourism Office.

In the above figure 1, all the organizations and performers are classified into eight foremost parts. There are three organizations; Nepal Tourism Board (NTB), Pokhara Regional centre and Pokhara Tourism Council (PTC) have grasped the central position and working as an umbrella organization for all the organizations and perform in close coordination with each other. NTP is regarded as a public-private institution that is responsible for the development of tourism products and services and works on their marketing and promotion. Pokhara Tourism Council's role is to assist the government by providing important ideas and creative suggestions to execute the plan and policies made for sustainable development of tourism industries, on behalf of all the member organizations. Pokhara Tourism council is also involved in encouraging and saving the tourism industry in Pokhara, coordinating with government bodies, tourism associations, government, and foreign agencies. All the above tourism correlated associations are efficient and interconnected to each other(Upreti BR, Upadhayaya PK, 2013).

In the context of the Machhapuchhre Model Trek, the Machhapuchhre Model Trek Management Committee(MMTMC), established in 2073 BS with the registration number of 353 from the District Administration Office, Kaski, has been actively involved in the exploration, development of trekking routes since its inception in July 2016. Its office is located at Sainti Ghatta, Machhapuchhre Rural Metropolitan City, Kaksi (*Machhapuchhre Model Trek*, n.d.-a).

2.5 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 has 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, analysing and communicating spatial information (Rambaldi et al., 2006).

In PGIS the key lies in the 'P': 'Participation' comes first and last. The decision to map, the design, the knowledge generation, the knowledge acquisition and sharing, the validation, the analysis (as much of it as possible), the dissemination and the ownership – all are participatory. In thePGIS approach, these elements are also the property, responsibility and entitlement of the community (Mccall & Dunn, 2012). Participation and knowledge of local groups (e.g. farmers, peasants, and tribes) is understood to be a valuable resource in community-level natural resource management, decision-making and policy-planning processes.

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 utilise GIS technology in the context of the needs and capabilities of communities that will be involved with, and affected by, development projects and programmes(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.

(Nethengwe, 2007) combines a quantitative spatial analysis using household survey and traditional GIS data with qualitative methods -- mental mapping, interviews, GPS-based transect walks, oral narratives and focus group discussions -- to examine the local dynamics of flood vulnerability at Milaboni and Dzingahe villages. PGIS provides the framework to include socially differentiated local knowledge while political ecology focuses the analysis on how power relations impact household flood vulnerability. The integration of local and expert knowledge comes together as a PGIS database for flood vulnerability analysis.

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).

(Lamptey, 2009) studied to examine whether the PGIS tools can be used to map indigenous knowledge (IK) on the dynamics of customary land tenure and also examine whether the tool can be of significant help to the land adjudication processes. A combination of participatory rural appraisal (PRA) and geographic information technology and systems (GIT&S) tools like oral narrations, interviews, participatory mapping (p-mapping) and global positioning system (GPS) were used for the study. The methods adopted for the p-mapping exercises include a sketch and scale mapping, training, field reconnaissance and validation (community forum). To verify the accuracy with which the local people interpreted their surroundings and identified features on the satellite imagery, a GPS survey was conducted for some selected landmarks. A validation workshop was carried out for the Land Sector Agencies (LSA) of Ghana in which the outputs and the entire P-mapping process were validated.

(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. (Bhandari, 2012) used PGIS for soil conservation in Phewa watershed of Nepal, to reduce the soil erosion by formulating the general rule by 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 RUSLE model. After the comparison and discussion among stakeholders, 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.

2.6 Review on Least Cost Path Analysis

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).

Optimal route planning is a big environmentally and economically challenging issue in high terrain mountain areas which needs the scientific methods least-cost path analysis(LCPA) in a Geographic Information System (GIS). The LCPA for a road gives planners and engineers a way to find the best (cheapest)route from starting and ending within two locations which can be calculated easily considering multiple criteria in a GIS. (Ahmed Chandio 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-maker's preferences. Finally, suitable cost-effective pipeline routes were created in ArcGIS 10.4 (Gyabeng, 2020). The Least Cost Path analysis (LCP) model applied for the route paths were quite successful in avoiding high slopes, expensive areas, zones of ecological values (Sunusi et al., n.d.).

(Abudu & Williams, 2015) outlines a GIS-based methodology for determining an optimal pipeline route that incorporates Multi-Criteria Evaluation and Least Cost Path Analysis. The methodology allowed for an objective evaluation of different cost surfaces for weighting the constraints that determine the optimal route location.

For finding the best “cheapest” route for new hillside development, the following steps are followed to produce the least-cost path based on the spatial analysis functions of ArcGIS 9.3 and are depicted in Fig 2 as follows:

Step 1: Create Source and Cost Datasets

Step 2: Cost Weighted Distance

Step 3: Perform Shortest Path.

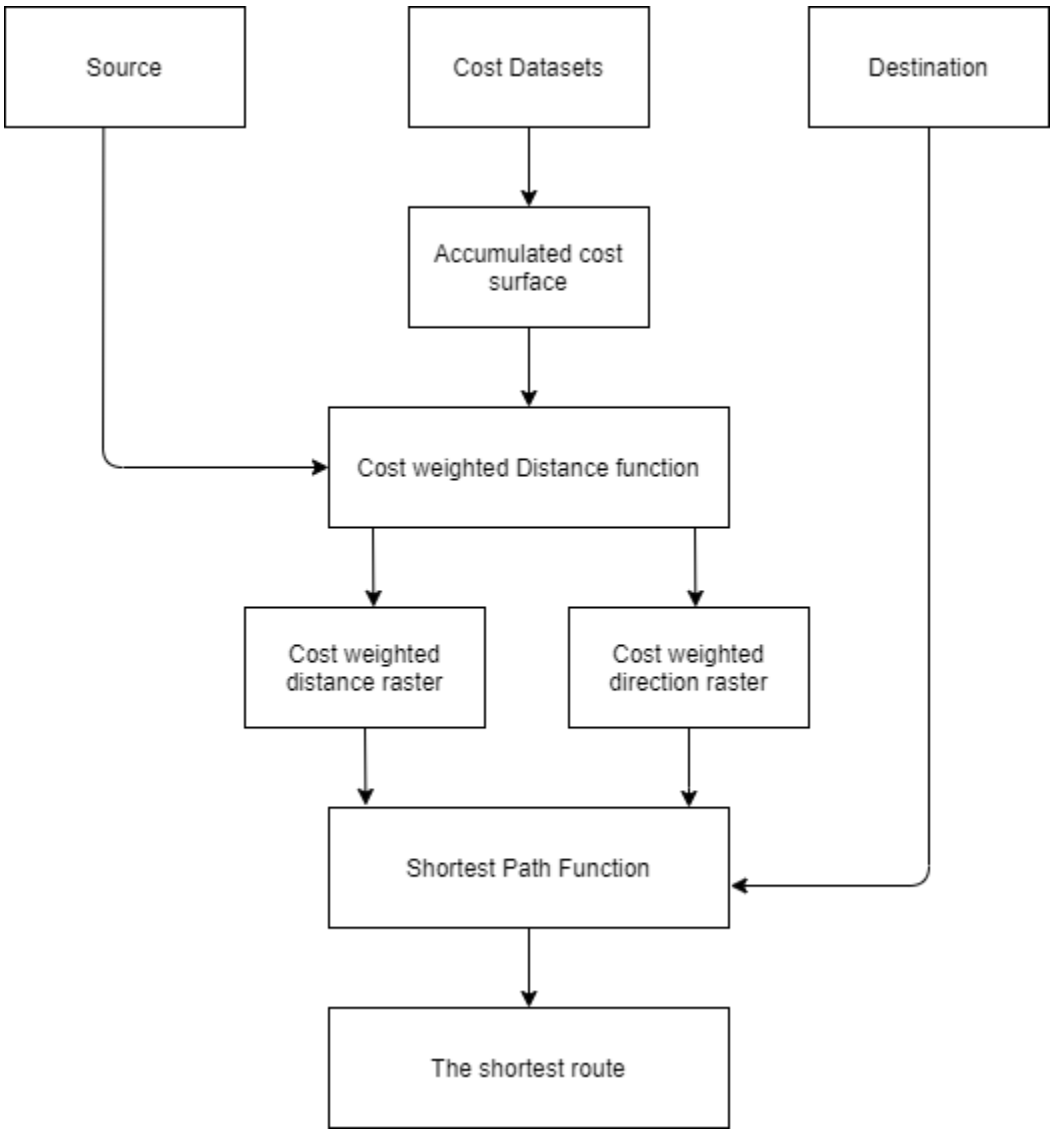


Figure 2: Methodology for the Generataion of Least Cost Path

The source is the starting point of the proposed feature for the analysis. The cost datasets or cost raster determines the cost of travelling through each cell. The accumulated cost raster surface is then generated to add the reclassified datasets together by multiply given weights according to the importance of the cost datasets. The summation of the weights must be 100%. The Weighted Summation model was applied to produce the accumulated cost surface spatial. The cost distance function (or cost weighted distance) uses the source and accumulated cost surface and produces an output raster where each cell is assigned a value that is the least accumulative cost of travelling from each cell back to the source i.e. the lower the value, the lower the cost. Every cell in the cost-weighted raster is given a value that corresponds to the total of the least travel costs which would be incurred by travelling back along the path to the cheapest way to the nearest source. The cost-weighted distance function produces the two costs i.e. the cost weighted distance raster and the cost weighted direction raster. The cost distance raster indicates the least accumulated cost for each cell to the nearest source, but it does not tell how to get there. The direction raster provides

a road map to identify the route to take from any cell, along with the cheapest path, back to the nearest source (Balogun et al., 2012).

3. Methodology

3.1 Detailed Methodology

The methodology can be described in 6 major parts:

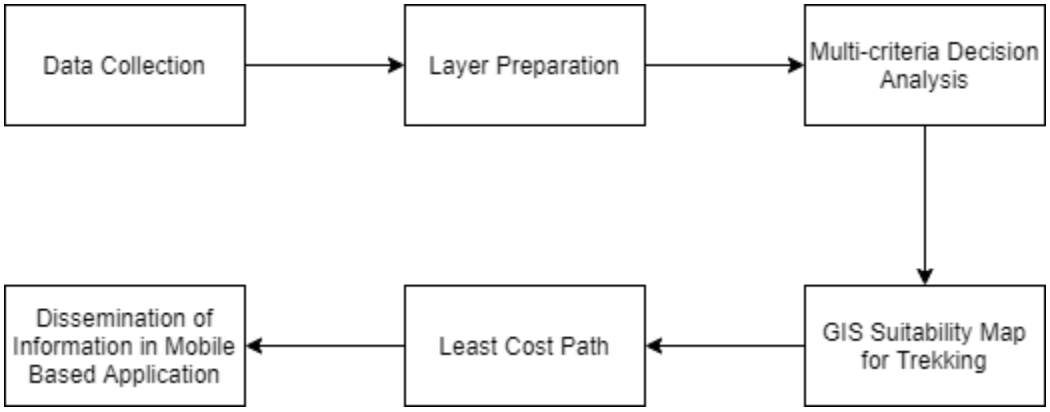


Figure 3 3 Flowchart of Project Work

Software used during the whole work was ArcGIS, QGIS, Android Studio.

3.1.1 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.

1. Primary data: Qualitative data were collected through the PGIS approach. Participatory GIS (PGIS) or public participation geographic information system (PPGIS) is a participatory approach to spatial planning and spatial information and communication management. And collected data were about local culture, traditions, historical monuments and many other.
2. 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.

Before loading the OSM data was prepared. The dataset was 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.

3.1.2 Layer preparation

Layer map preparation task was fully done on ArcGIS 9.10 software. At first, the boundary of the study area was extracted and loaded.

Then as per our criteria and sub-criteria different layer map were prepared as below:

The LULC of the study area was extracted from Landsat 8 image by supervised classification. Similarly, slope, aspect layer map was also prepared, both were extracted from Landsat DEM. Other separate layers of cultural sites, existing routes, settlement areas, protected areas, amenities facilities (hotel, hospital, police station), water bodies (lake, ponds, rivers) and tourist spots (view-tower, view-point) were prepared. For these layers, all required data were extracted from OSM. And ring buffer was carried out in all layer's maps except LULC, slope, aspect. All the layers were reclassified and as per their importance marks was given which is shown below:

Table 1 Reclassifying Classes and Score of the Criteria

SN	Layer	Reclassifying Class	Score
1	Slope	0 - 10	9
		10-20	7
		20-25	5
		25-30	4
		>30	2
2	Aspect	South, Flat, SouthWest, SouthEast	2
		North, NorthWest	7
		NorthEast	9
		East, West	4
3	Proximity to Existing Route	0-350	9
		350-500	8
		500-800	6
		800-1000	5
		>1000	4
4	Proximity to Cultural and Religious Site	0-350	9
		350-500	7
		500-800	6
		800-1000	4
		>1000	2
5	Proximity to Settlement Area	0-250	10
		250-500	8

		500-800	6
		800-1000	4
		>1000	2
6	Proximity to Steep Areas	0-20	1
		20-40	3
		40-60	5
		60-80	7
		80-100	9
7	LULC	Forest, BuiltUp	7
		Water bodies	1
		Snow	6
		Agriculture	2
		Vegetation/Open	9
8	Amenities (Hotels, Police Station, Hospital, Bank, Shop)	0-300	9
		300-600	7
		600-750	5
		750-1000	3
		>1000	2
9	Waterbodies(River, Stream)	0-100	3
		100-200	8
		200-400	6
		400-800	4
		>800	2
10	Tourist Spot (View Tower, View Point, Caves, Lake, Ponds)	0-100	9
		100-200	8
		200-400	6
		400-800	5
		>800	3

3.1.3 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 and Tourist spot.

Analytic Hierarchy Process (AHP) is one of the traditional MCDA methods developed by Saaty.

Weightage to particular criteria was assigned using AHP. In total there were 11 criteria. It is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. [en.wikipedia.org]

Criteria Weight and Class Weight

To create the suitability map, we need the factor weightage, as well as the class weights of the criteria involved in our research, to be needed. This weightage can be systematically determined using Analytic Hierarchy Process (AHP). 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 method mainly consists of 4 major steps:

a. The first step is developing a hierarchial problem model for which a decision is to be made. The objective or goal is situated at the top of the hierarchy, criteria and sub-criteria are put at the lower levels and alternatives are at the bottom of the model as shown in the figure below.

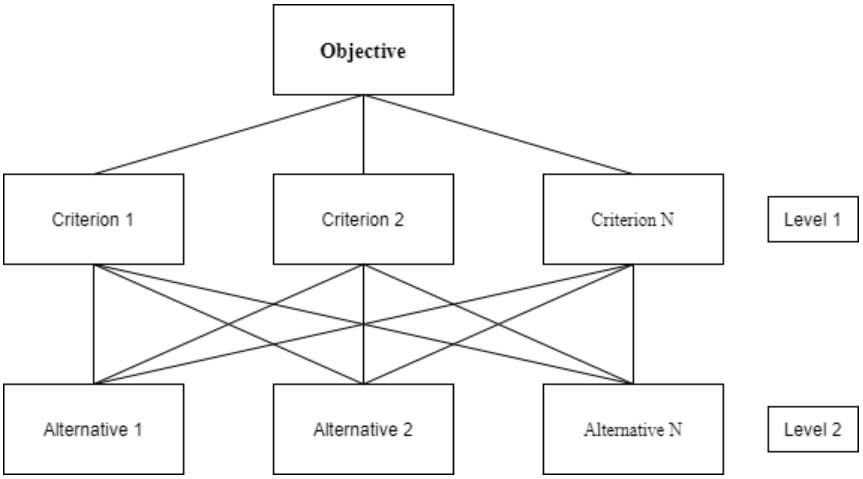


Figure 44 Example of Hierarchy in AHP

b. In each level of the hierarchy, the pair-wise comparison of the criteria is done assigning relative importance using the Saaty scale of relative importance. The scale contains the five

levels and 4 sub-levels of importance which describes the intensity. The scale ranges from 1 to 9 as given in the table below.

Table 2 Saaty scale of relative importance.

Importance	Definition	Explanation
1	Equally important	Both elements have equal contributions to the objective.
3	Moderately important	Moderate advantage of the one element compared to the other.
5	Strong importance	Strong favouring of one element compared to the other.
7	Very strong and proven importance	One element is strongly favoured and has domination in practice, compared to the other element.
9	Extreme importance	One element is favoured in comparison with the other based on strongly proved evidence and facts.
2,4,6,8	Intermediate values	

c. After the assessment of the relative importance to elements from each level of the hierarchical structure, it could be applied for the calculation of the local criteria, sub-criteria and alternatives. After that, the overall priorities of the alternatives are synthesized. The total priority of each alternative is calculated with the sum of local priorities that are weighted with weights of elements from higher levels.
d. At last, sensitivity analysis is done.

For the successful appliance of the AHP method, four axioms must be met i.e., Reciprocity Axiom, Axiom for homogeneity, Axiom for dependence, and Axiom for expectation.

Mathematical Model

Let's consider n number of criteria which are compared, the comparison results from matrix A with dimension n × m.

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$

The elements of the matrix or the ratio between compared criteria are expressed by the formula:

$$a_{ij} = \frac{w_i}{w_j}$$

From the reciprocity axiom, "If element A is n times more important than element B, then element B is 1/n times more important element of A.", we can get that,

$$a_{ij} = \frac{1}{a_{ji}}$$

The next step is to obtain a normalized matrix $B = [b_{ij}]$. The elements of the matrix B are calculated as:

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}$$

The calculation of the weights i.e., eigenvector $w = [w_i]$ forms the normalized matrix B which is formed by calculating the arithmetic mean for each row of the matrix according to the formula:

$$w_i = \frac{\sum_{j=1}^{n} b_{ij}}{n}$$

Consistency of the Comparison Matrix

Consistency implies a coherent judgement on the part of the decision-maker regarding the pairwise comparisons. Mathematically, we say that comparison matrix A is consistent if $a_{ij}a_{jk} = a_{jk}$ for all i, j, k.

As the pairwise comparison is done by human judgement, some reasonable degree of inconsistency is expected and tolerated. To determine whether or not a level of consistency is reasonable, we need to develop a quantifiable measure for the comparison matrix A. When Matrix A is perfectly consistent then it produces a normalized matrix C in which all diagonal elements are identical – that is

$$C = \begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \dots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \dots & \frac{w_2}{w_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{w_3}{w_1} & \frac{w_3}{w_2} & \dots & \frac{w_n}{w_n} \end{bmatrix}$$

It then follows that the original comparison matrix A can be determined from C by dividing the elements of column i by w_i. We thus have:

$$A = \begin{bmatrix} 1 & \frac{w_1}{w_2} & \dots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & 1 & \dots & \frac{w_2}{w_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{w_3}{w_1} & \frac{w_3}{w_2} & \dots & 1 \end{bmatrix}$$

The resulting ration comparisons are depicted in

$$\begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{w_3}{w_1} & \frac{w_3}{w_2} & \cdots & \frac{w_n}{w_n} \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} = n \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix}$$

To obtained the term n × w the matrix is multiplied by w on the right. More compactly, given that w is the column vector of the relative weight w_i, I = 1,2,….n, A is consistent if:

$$Aw = nw$$

If A is not consistent the relative weight w_i is approximated by the average of the n elements of row i in the normalized matrix C. Letting $\overline{w}$ be the computed average vector, it can be shown that

$$A\overline{w} = \lambda_{max}\overline{w}\,, \lambda_{max} \geq n$$

In this case, the closer λ_{max} is to n, the more consistent is the comparison matrix A. Based on this observation, AHP computes the consistency ratio as:

$$CR = \frac{CI}{RI}$$

Where CI is the consistency index of A and is calculated as

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

Whereas RI is the random consistency index of A and its value is taken from the table given below where the first row (n) indicates the number of rows i.e. matrix size, whereas the second row is the Random consistency index.

Table 3 Random Consistency Index

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.58

If CR ≤ 0.1, the level of inconsistency is acceptable otherwise, the decision-maker may need to reestimate the elements of a_{ij} of A to realize better consistency. We can compute the value of λ_{max} from $A\overline{w} = \lambda_{max}\overline{w}$ by noting that the i^{th} equation is :

$$\sum_{j=1}^{n} a_{ij}\overline{w} = \lambda_{max}\overline{w}\,, i = 1,2, \ldots n$$

Given $\sum_{i=1}^{n} \overline{w}_i = 1$, we get

$$\sum_{i=1}^{n}\left(\sum_{j=1}^{n} a_{ij}\overline{w}\right) = \lambda_{max}\sum_{i=1}^{n}\overline{w}_i = \lambda_{max}$$

This means that the value of λ_{max} can be calculated by first computing the column vector $A\overline{w}$ and then summing its elements.

3.1.4 GIS Suitability map for Trekking

Previously prepared raster layers were assigned a percentage influence. Percentage influence was 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.

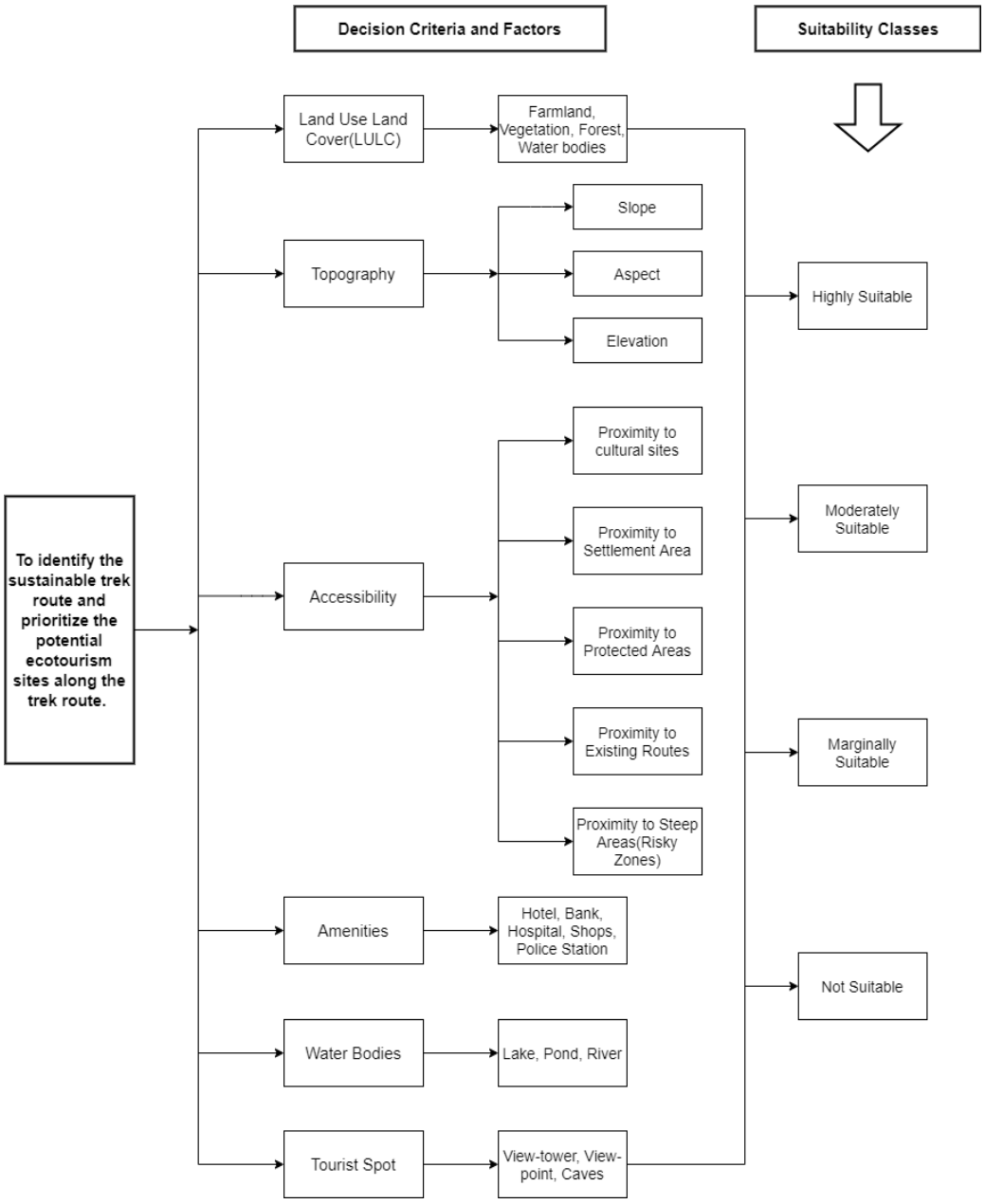


Figure 5 5 Process for creating Suitabilty Map

3.1.5 Least Cost Path Analysis

Least cost path analysis is a distance analysis tool within GIS that uses the least cost path or the path between two locations that costs the least to those travelling along it to determine the most cost-effective route between a source and destination. Cost can be a function of time, distance or other criteria that is defined by the user. When using least cost path analysis in GIS, the eight neighbors of a raster cell are evaluated and the generated path moves to the cells with the smallest accumulated or cost value. This process is repeated multiple times until the source and destination are connected. The completed path is the smallest sum of raster cell values between the two points and it has the lowest cost (*Overview of Least Cost Path Analysis - GIS Lounge*, n.d.)

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. Prior to conducting a least cost path analysis there are there are some requirements that all users must have and understand. These are a source raster, a cost raster, cost distance measures and an algorithm for deriving the least cost path (Chang, n.d.).

- ✓ **Source Raster:** A source raster defines the source cell(s). Only the source cell has a cell value in the source raster; all other cells are assigned no data. But in the context of least-cost path analysis, one can consider the source cell as an end point of a path, either the origin or the destination. The analysis derives for a cell the least accumulated cost path to the source cell or to the closest source cell if two or more source cells are present (Chang, n.d.).

- ✓ **Cost Raster:** The cost raster is the raster that defines the cost or other impedance (defined by the user) to move through each raster cell. A cost raster has three characteristics. The first is that the cost of each cell is the sum of the different costs while the second is that the cost can represent either the actual or the relative cost. The third characteristic is that the cost factors can be weighted depending on the importance of each factor (Chang, n.d.). For example if travel time is considered a more important factor than the monetary cost, it can be it can be weighted more in the analysis.

- ✓ **Cost distance measure** portion of least cost path analysis is centered on the node-link raster cell representation. In this representation a node is the center of the raster cell and the link connects the node to its neighboring cells. A lateral link is also included to connect a cell to one of its four nearest neighbors and a diagonal link connects the cell to the corner neighbors. The cost distance is the cost that it takes to travel from the node to these links and the least cost path is based on these costs (*Overview of Least Cost Path Analysis - GIS Lounge*, n.d.).
- ✓ Finally, **least cost path analysis** requires an algorithm for deriving a least cost path. An algorithm 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 but least accumulative costs are challenging because there are many different ways to connect two cells and they do not have to be immediate neighbors (Chang, n.d.). Least cost paths are derived after all possible paths are evaluated, thus an algorithm makes these complex and time consuming calculations much easier (*Overview of Least Cost Path Analysis - GIS Lounge*, n.d.).

After the four requirements for conducting a least cost path analysis are met, it is important to rasters are correctly weighted that makes up the cost raster to create the least cost path.

3.1.6 Dissemination of Information In Mobile-Based Application

A mobile-based android application designated to ease the trek in the Machhapuchchhre Trek Route is developed using the Android Studio which is the android based 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 by the help of which we link the user interface with the backend. Also, the Mapbox 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 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.

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 have been able to create different activities like the bottom navigation menu, side navigation menu, floating action button, and fragments in the android app. The application is accompanied by its local database (SQLite) 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.

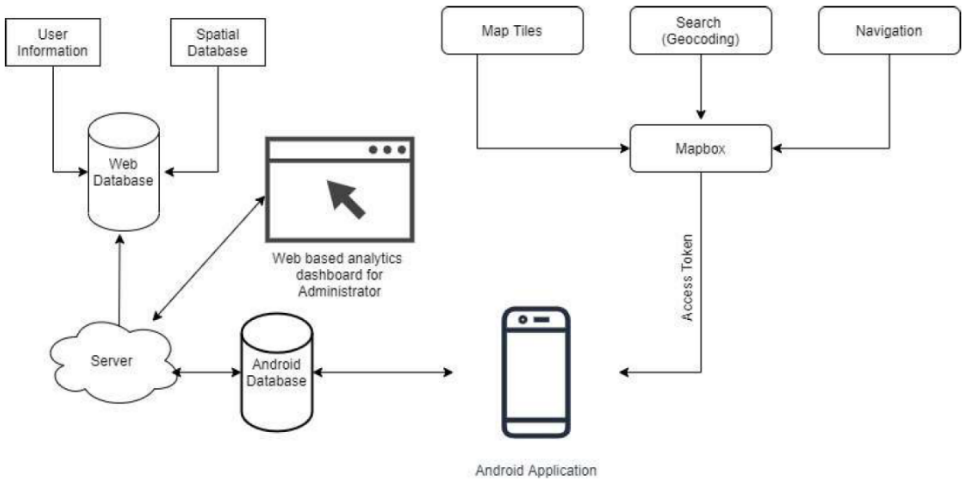


Figure 6 System Architecture of Android Application

4. Results and Discussion

4.1. Result

4.1.1. 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 can be 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)

Table 4 Comparison of the criteria for choosing the best route

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1.00	3	0.13	0.17	0.14	0.20	0.25	0.14	3.00	0.13
A2	0.33	1	0.11	0.14	0.17	0.33	0.25	0.13	0.50	0.13
A3	8.00	9	1.00	6.00	4.00	5.00	6.00	4.00	8.00	3.00
A4	6.00	7	0.17	1.00	0.33	4.00	2.00	0.20	4.00	0.25
A5	7.00	6	0.25	3.00	1.00	3.00	2.00	0.33	5.00	0.20
A6	5.00	3	0.20	0.25	0.33	1.00	0.33	0.25	2.00	0.14
A7	4.00	4	0.17	0.50	0.50	3.00	1.00	0.25	4.00	0.17
A8	7.00	8	0.25	5.00	3.00	4.00	4.00	1.00	7.00	0.33
A9	0.33	2	0.13	0.25	0.20	0.50	0.25	0.14	1.00	0.13
A10	8.00	8	0.33	4.00	5.00	7.00	6.00	3.00	8.00	1.00
SUM	46.67	51.00	2.73	20.31	14.68	28.03	22.08	9.44	42.50	5.47

Now the normalized matrix is calculated by dividing the importance of the criteria by the sum of the importance of the different criteria. The matrix can be shown as

Table 5 Normalised Pair-wise Comparison Matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	0.02	0.06	0.05	0.01	0.01	0.01	0.01	0.02	0.07	0.02
A2	0.01	0.02	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.02
A3	0.17	0.18	0.37	0.30	0.27	0.18	0.27	0.42	0.19	0.55
A4	0.13	0.14	0.06	0.05	0.02	0.14	0.09	0.02	0.09	0.05
A5	0.15	0.12	0.09	0.15	0.07	0.11	0.09	0.04	0.12	0.04
A6	0.11	0.06	0.07	0.01	0.02	0.04	0.02	0.03	0.05	0.03
A7	0.09	0.08	0.06	0.02	0.03	0.11	0.05	0.03	0.09	0.03
A8	0.15	0.16	0.09	0.25	0.20	0.14	0.18	0.11	0.16	0.06
A9	0.01	0.04	0.05	0.01	0.01	0.02	0.01	0.02	0.02	0.02
A10	0.17	0.16	0.12	0.20	0.34	0.25	0.27	0.32	0.19	0.18

At the last, the weightage is calculated as the sum of all row elements divided by the number of criteria. It is shown as

Table 6 Weightage Calculation

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Criteria Weights
A1	0.02	0.06	0.05	0.01	0.01	0.01	0.01	0.02	0.07	0.02	0.03
A2	0.01	0.02	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02
A3	0.17	0.18	0.37	0.30	0.27	0.18	0.27	0.42	0.19	0.55	0.29
A4	0.13	0.14	0.06	0.05	0.02	0.14	0.09	0.02	0.09	0.05	0.08
A5	0.15	0.12	0.09	0.15	0.07	0.11	0.09	0.04	0.12	0.04	0.10
A6	0.11	0.06	0.07	0.01	0.02	0.04	0.02	0.03	0.05	0.03	0.04
A7	0.09	0.08	0.06	0.02	0.03	0.11	0.05	0.03	0.09	0.03	0.06
A8	0.15	0.16	0.09	0.25	0.20	0.14	0.18	0.11	0.16	0.06	0.15
A9	0.01	0.04	0.05	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02
A10	0.17	0.16	0.12	0.20	0.34	0.25	0.27	0.32	0.19	0.18	0.22

Table 7 Weighted Sum Value

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Weighted Sum Value
A1	0.03	0.05	0.04	0.01	0.01	0.01	0.01	0.02	0.06	0.03	0.27
A2	0.01	0.02	0.03	0.01	0.02	0.01	0.01	0.02	0.01	0.03	0.17
A3	0.22	0.14	0.29	0.48	0.38	0.21	0.35	0.60	0.17	0.66	3.50
A4	0.16	0.11	0.05	0.08	0.03	0.17	0.12	0.03	0.08	0.05	0.89

A5	0.19	0.09	0.07	0.24	0.10	0.13	0.12	0.05	0.10	0.04	1.13
A6	0.14	0.05	0.06	0.02	0.03	0.04	0.02	0.04	0.04	0.03	0.47
A7	0.11	0.06	0.05	0.04	0.05	0.13	0.06	0.04	0.08	0.04	0.65
A8	0.19	0.13	0.07	0.40	0.29	0.17	0.23	0.15	0.15	0.07	1.85
A9	0.01	0.03	0.04	0.02	0.02	0.02	0.01	0.02	0.02	0.03	0.22
A10	0.22	0.13	0.10	0.32	0.48	0.30	0.35	0.45	0.17	0.22	2.73

λ_{max} is the average ratio of the weighted sum value to criteria weight.

Table 8 Calculation of Criteria weights and ratio

Criteria	Weighted Sum Value	Criteria Weights	Ratio
A1	0.27	0.03	10.04
A2	0.17	0.02	10.82
A3	3.50	0.29	12.10
A4	0.89	0.08	11.20
A5	1.13	0.10	11.78
A6	0.47	0.04	10.95
A7	0.65	0.06	11.09
A8	1.85	0.15	12.28
A9	0.22	0.02	10.61
A10	2.73	0.22	12.40

Therefore , λ_{max} = 11.33 Consistency Index is calculated as,

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

$$CI = \frac{11.33 - 10}{10 - 1}$$

$$CI = 0.1477$$

For n = 10, Random Index (RI) = 1.49

Now, Consistency Ratio (CR) is calculated as,

$$CR = \frac{CI}{RI}$$

$$CR = \frac{0.1477}{1.49}$$

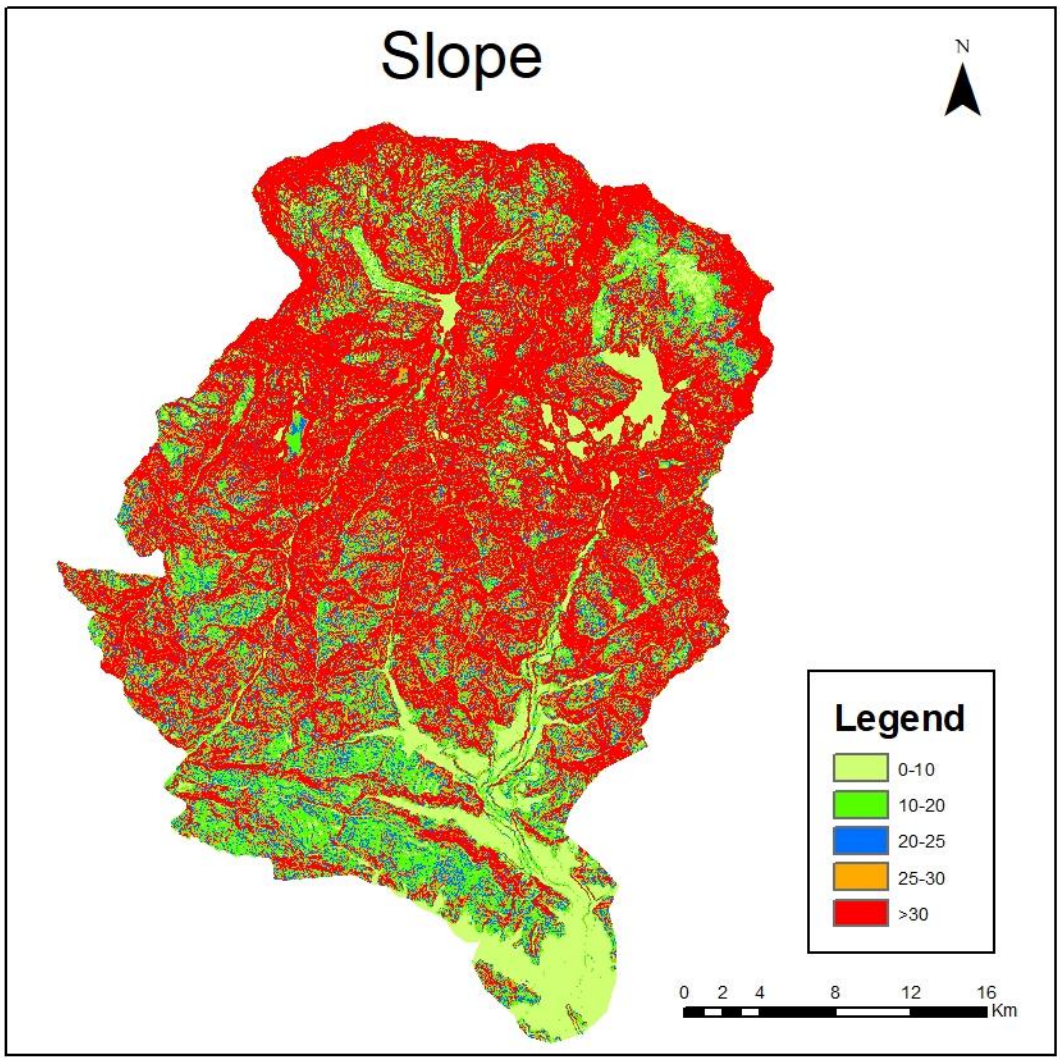
Therefore

$$CR = 0.0991$$

4.1.2. GIS Layers Prepared

i. Slope

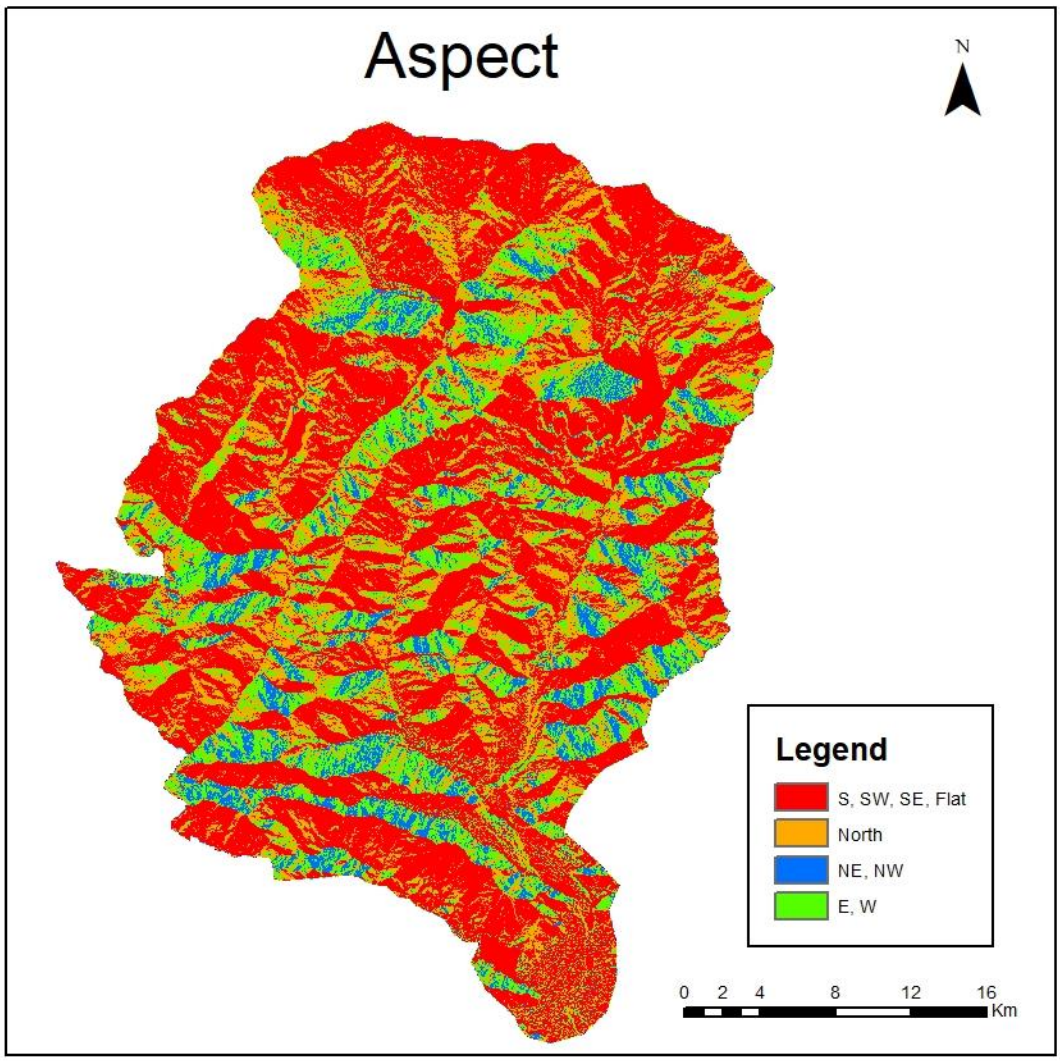
Slope is one of the most important factors responsible while making suitability analysis of trek routes. Trekking is mainly focused on walking along a route and enjoying the scenic beauty. So, more-flatter the surface or say gentler change in slope of the surface more suitable for trekking. Here also we have reclassified slope in different groups as per their suitability. It is shown in the legend below. As per the questionnaire, interviews and focus group discussion, 0-10(degree) slope is considered as highly suitable, 10-20(degree) as moderately suitable, 20-25(degree) as marginally suitable, 25-30(degree) as less suitable, above 30 as not suitable for trekking.



Map 3: Slope Map

ii. Aspect

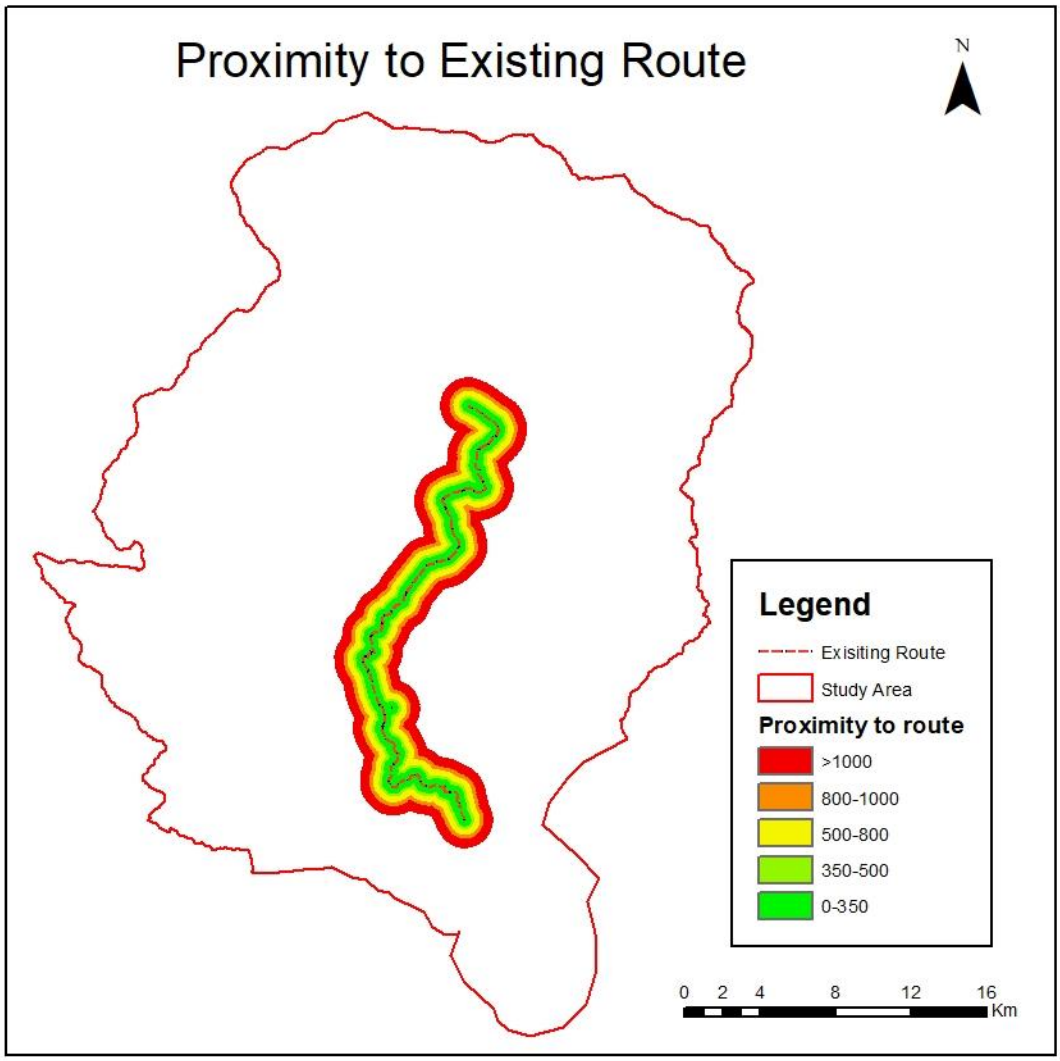
Aspect values indicate the directions the physical slopes face. The direction a slope faces with respect to the sun (aspect) has a profound influence on vegetation, snowpack and construction. This aspect also has some impact on trek route analysis. We reclassified aspect values as northeast and northwest, north, east and west and south, southeast, southwest and flat into 4 categories. As per the questionnaire, interviews and focus group discussion, aspect values with northeast and northwest were considered highly suitable, the north was considered moderately suitable, east and west were considered marginally suitable and south, southeast, southwest and flat were considered not suitable for trekking. Here legend represents the classified aspect as per their suitability.



Map 4: Aspect Map

iii. Proximity to Existing Route

Here the existing route means previously tracked route. While designing a trek route, if we find such a route at a certain distance then it will be quite economical for our project in designing the route. And nearer the existing route more suitable for us to include that existing route in our trek route. The figure below shows the proximity analysis of the existing route. Legends represent the reclassified distance to the existing route as per their suitability. 0-350 m class is considered most suitable, 350-500 is considered moderately suitable, 500-800 is considered marginally suitable, 800-1000 less suitable and greater than 1000m is not considered suitable.

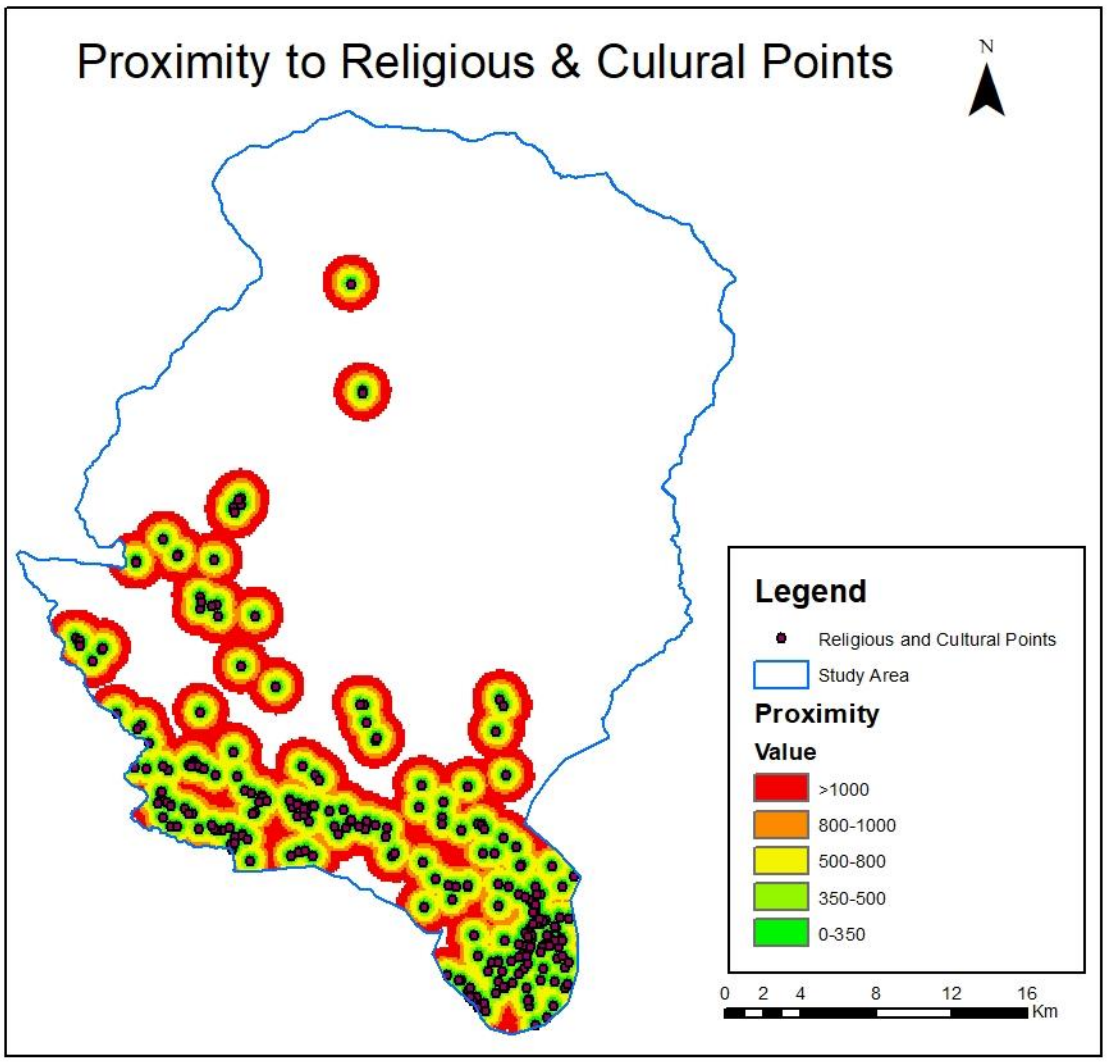


Map 5: Proximity to Existing Route

iv. Proximity to Cultural and Religious Site

Cultural and religious sites are worthy places to visit and take some rest while trekking. Another thing is their presence in the trekking route is not compulsory but if available they add some importance to the trek route. The figure below shows the proximity analysis of cultural and religious sites. We have designed our trek route in such a way that the route should include

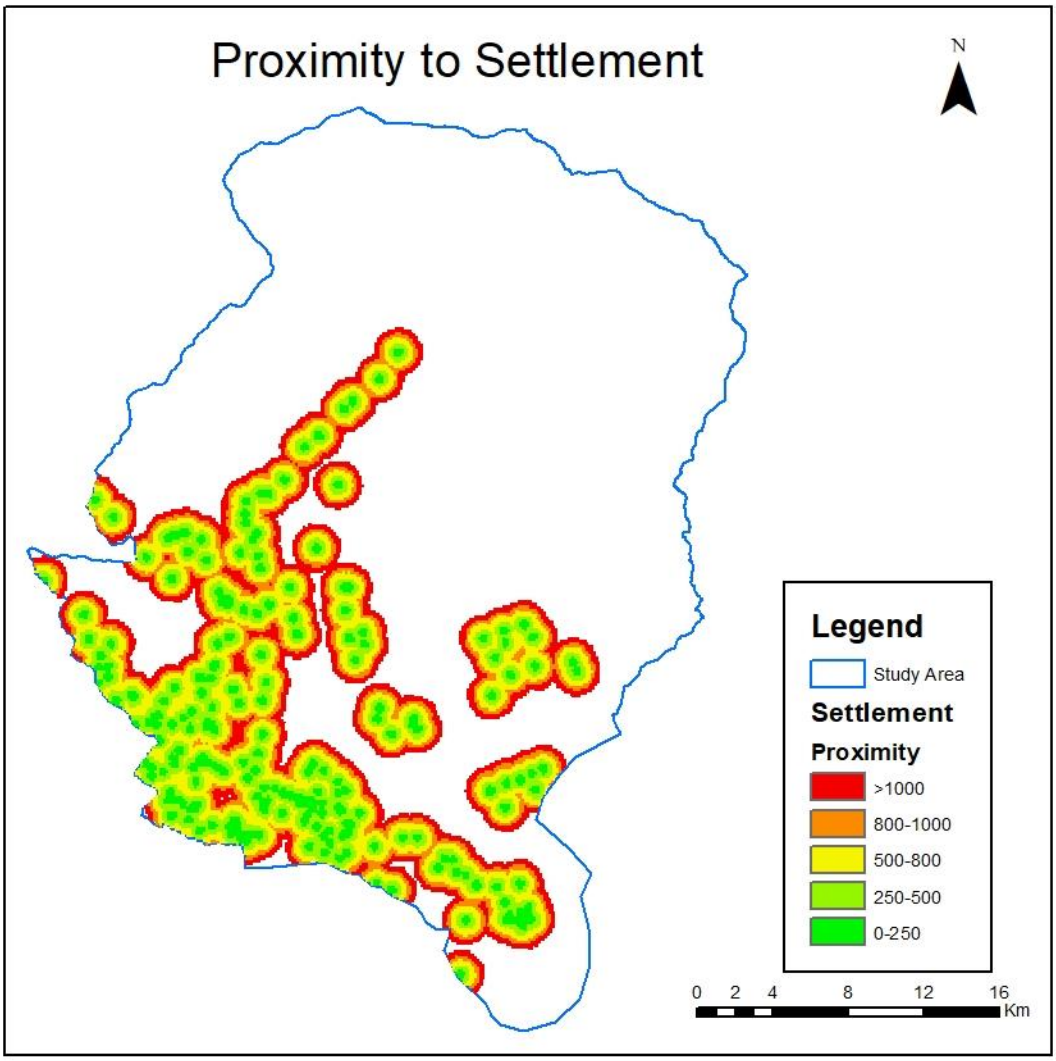
all possible nearest cultural and religious sites to make the trekking more attractive, memorable. Legend represents the reclassified distance class to cultural and religious sites. The 0-350m class is considered more suitable, 350-500m class is considered moderately suitable, 500-800m class is considered marginally suitable, 800-1000m class is considered less suitable and greater than 1000m class is not considered suitable.



Map 6: proximity to Religious and Cultural Sites

v. Proximity to Settlement Areas

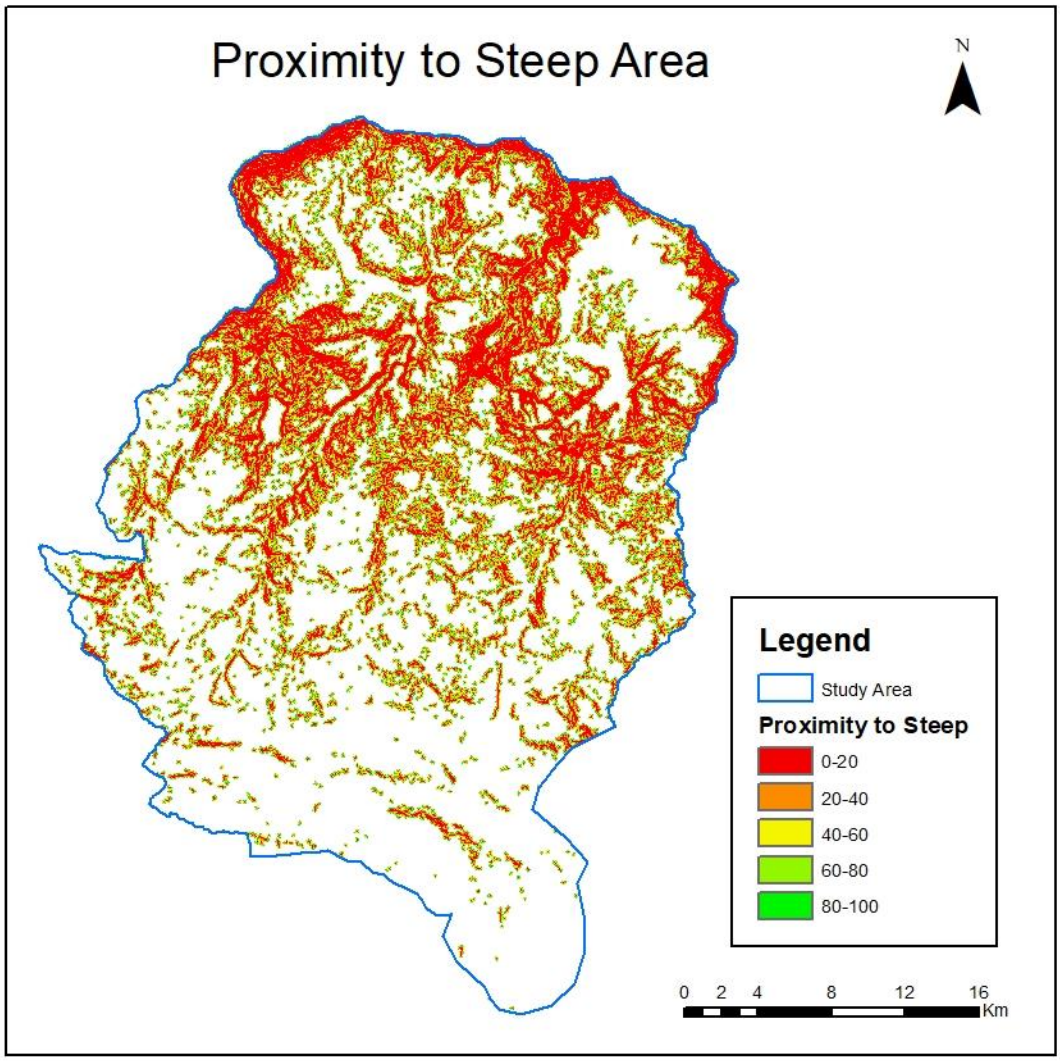
Here we are planning to pass our trek route near the settlement areas so that trekkers can enjoy local culture and tradition but not midway settlement areas since people of settlement areas may get disturbed. So for this, we have made proximity analysis to settlement areas. The legend below shows the reclassified distance class to settlement areas. 0-250 m class is considered most suitable, 250-500 is considered moderately suitable, 500-800 is considered marginally suitable, 800-1000 less suitable and greater than 1000m is not considered suitable.



Map 7: Proximity to Settlement Area

vi. Proximity to Steep Areas (Risky Zone)

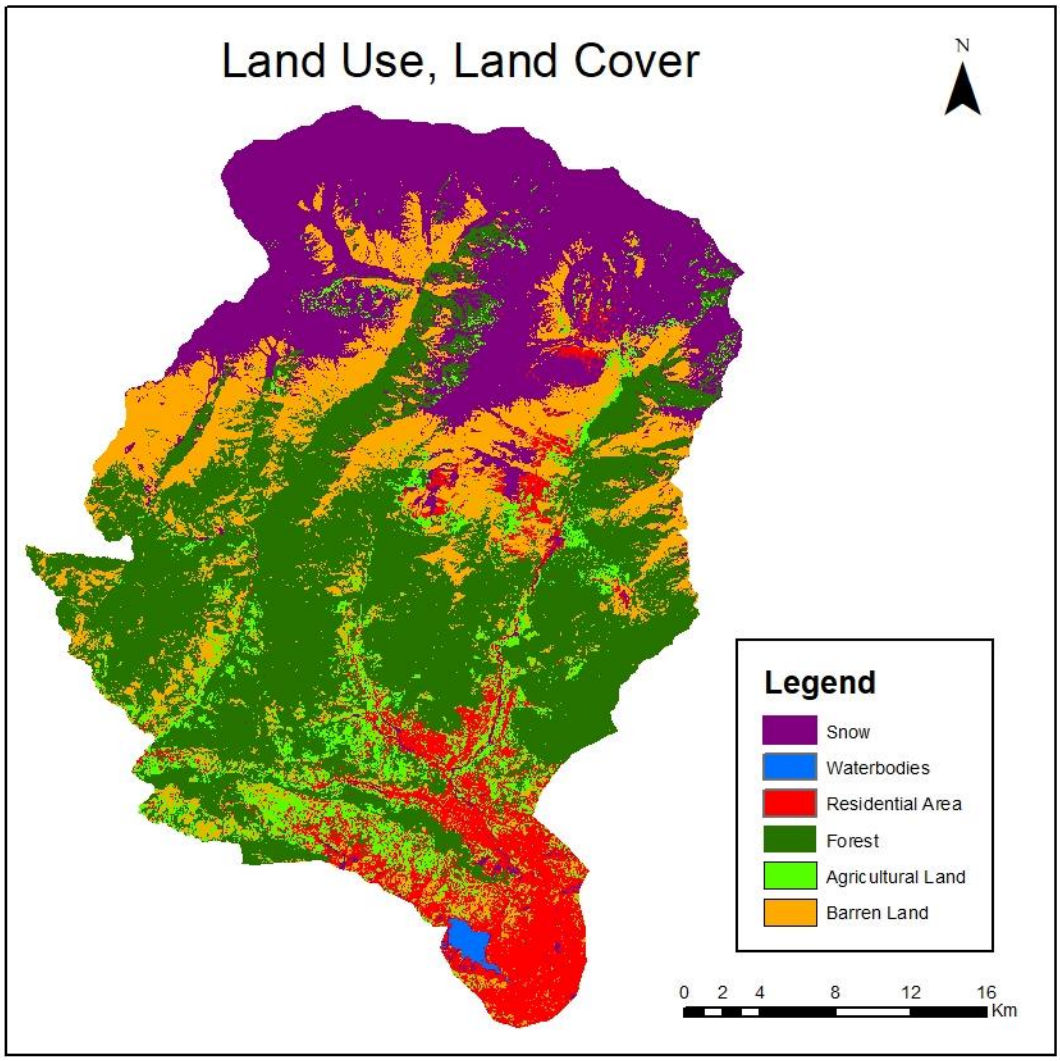
Steep area is the area rising or falling sharply; almost perpendicular. Such an area needs to be avoided in the trek route. Presence of such an area is risky for trekkers. So here we avoid such areas in our trek route. For this we have made proximity analysis to such areas. Legend below shows different distance classes to steep areas. Areas near to steep areas are not considered suitable while areas farther away are considered suitable. 80-100m class is considered more suitable, 60-80m class is considered moderately suitable, 40-60m class is considered marginally suitable, 20-40m class is considered less suitable and greater than 0-20m class is not considered suitable.



Map 8: Proximity to Steep Areas

vii. LULC

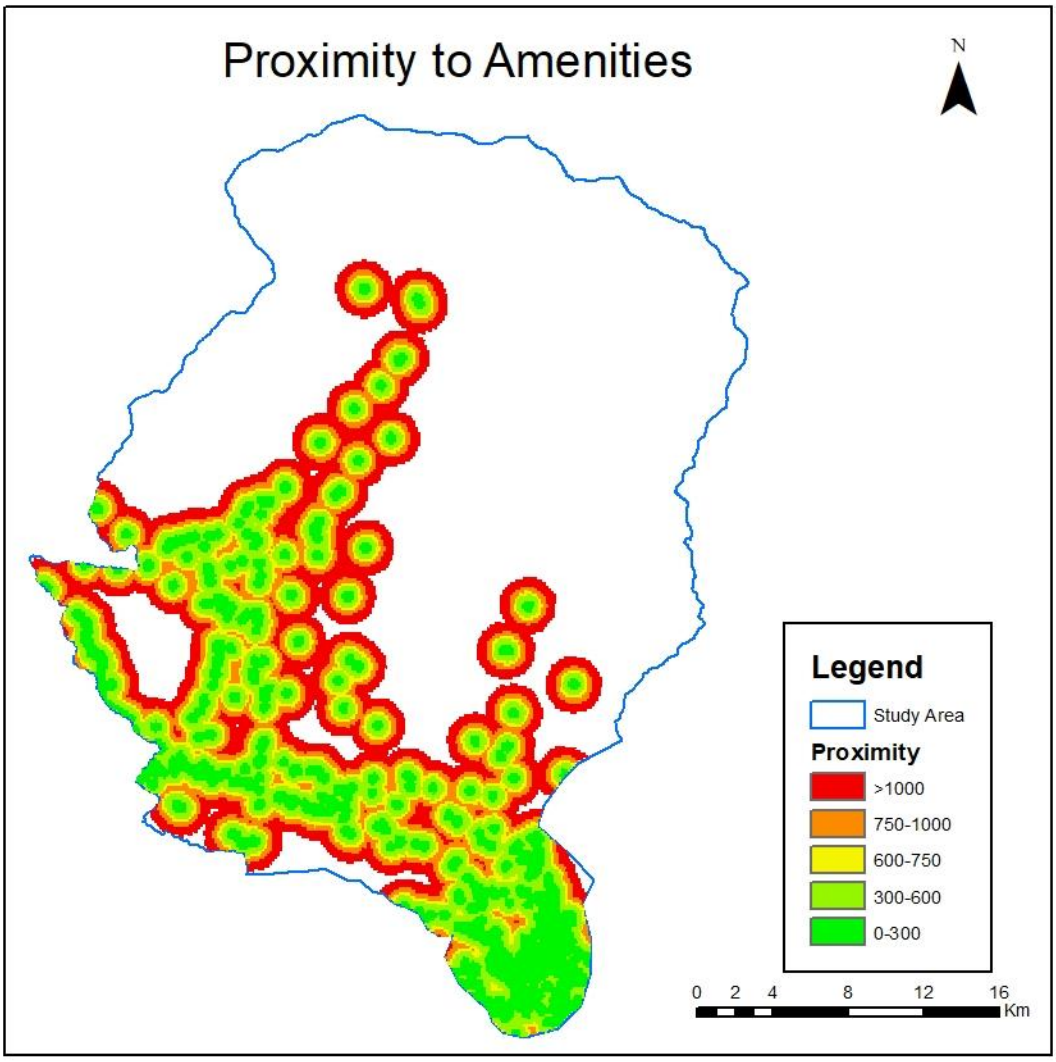
LULC stands as Land Use Land Cover. While making route analysis we must be aware about LULC of that particular region or area. For example, we have to avoid agricultural land, water bodies, etc. in our route. So, for this whole study area was classified under supervision. The legend below shows the LULC data as below in map. Purple colour in legend indicates snow covered areas, blue color indicates water bodies, red colour indicates residentials areas, dark green indicates forest cover, light green indicates agricultural land and at last light yellow indicates barren land.



Map 9: LULC Map

viii. Amenities

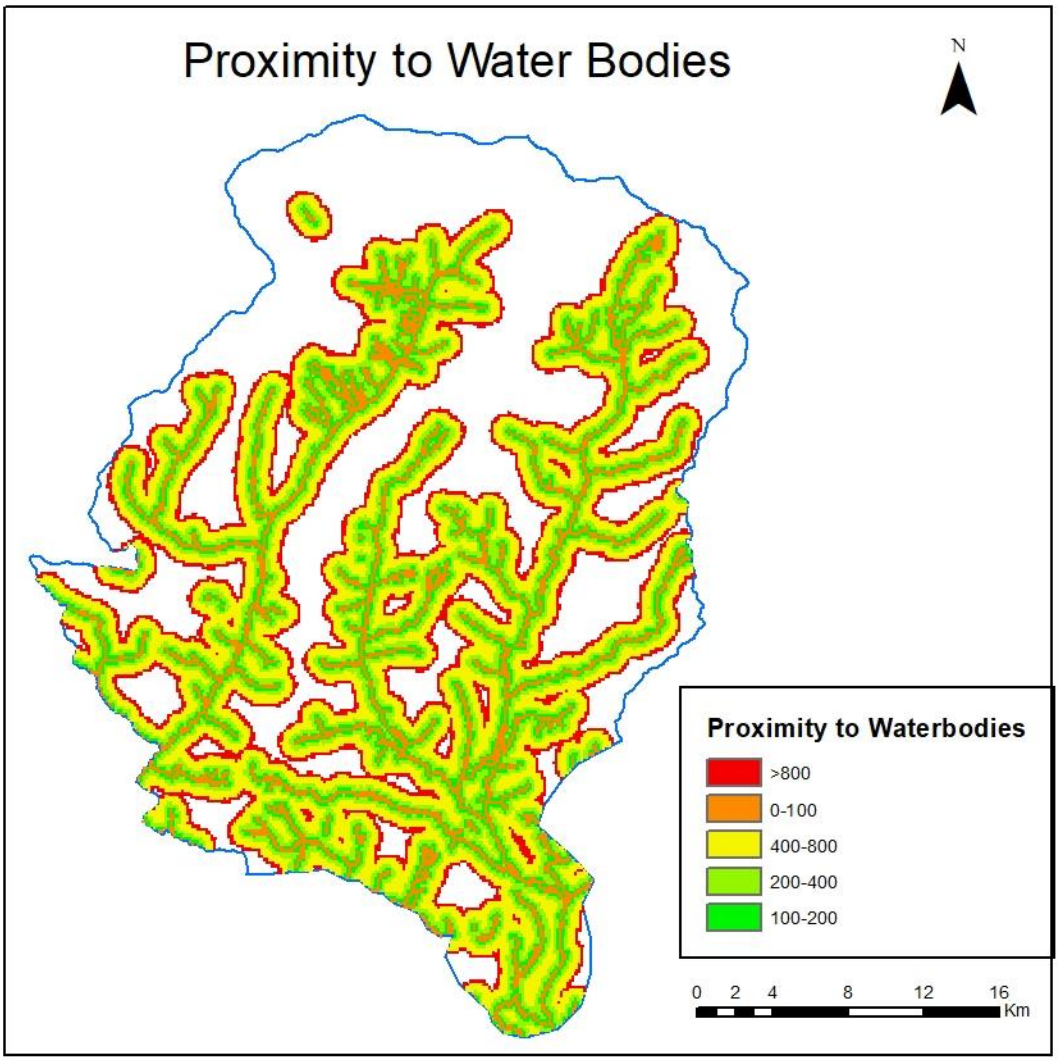
Here hotels, guest houses, police stations, hospitals, banks, shops fall under amenities. Their presence near a route adds a feeling of security and help in trekkers in case of any difficulty and emergency. Considering it, we also have tried to include available amenities in our route. For this we have made a proximity analysis of amenities. Legend below shows the reclassified distance class to the amenities. 0-300m class is considered more suitable, 300-600m class is considered moderately suitable, 600-750m class is considered marginally suitable, 750-1000m class is considered less suitable and greater than 1000m class is not considered suitable.



Map 10: Proimity to Amenities

ix. Water bodies (Lake, Ponds, River, Waterfall)

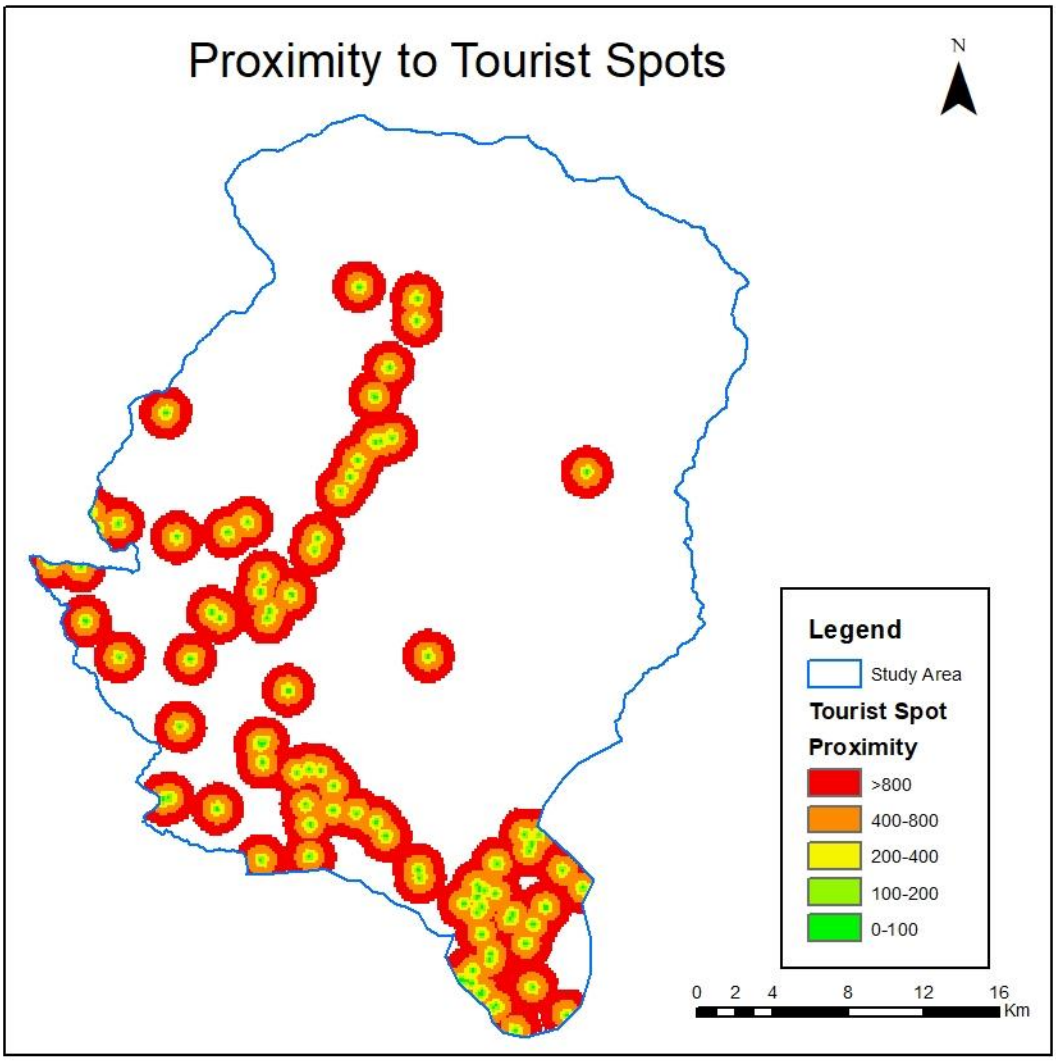
Here lake, pond, river and waterfall fall under water bodies. The sound of flowing rivers, the beauty of waterfalls, lakes, and ponds acts as energy generators while walking along a route. Their presence plays a significant role in attracting many tourists. We have tried to include water bodies in our route. For this we have made a proximity analysis of water bodies. Legend below shows the reclassified distance class to the water bodies. The 0-100m class is considered more suitable, 100-200m class is considered moderately suitable, 200-400m class is considered marginally suitable, 400-800m class is considered less suitable and greater than 800m class is not considered suitable.



Map 11: Proximity to Water Bodies

x. Tourist Spots (View Tower, View Points, Caves, Waterfall etc.)

Presence of view-tower, view-points, caves, etc. along or near the trek route is the matter of attraction for trekkers. They spent some time and enjoy there forgetting the tiredness of walking along a route. We have designed our trek route in such a way that the route should include all possible nearest tourist spots to make the trekking more attractive and memorable, meeting our major goals and objectives. The legend below represents a reclassified distance class to tourist's spots. The 0-350m class is considered more suitable, the 350-500m class is considered moderately suitable, 500-800m class is considered marginally suitable, 800-1000m class is considered less suitable and greater than 1000m class is not considered suitable.



Map 12: Proximity to Tourist Sports

4.1.3 Site Selection for Machhapuchchhre Base Camp (Probable)

A probable base camp for the Machhapuchchhre Trek Route is assumed by the viewshed analysis in Google Earth. From the base camp, we can get the synoptic view of the Machhapuchchhre Mountain. The mountain's base is just about 4.5 km far away from that point. A base camp is the destination for the least cost analysis done in our study.

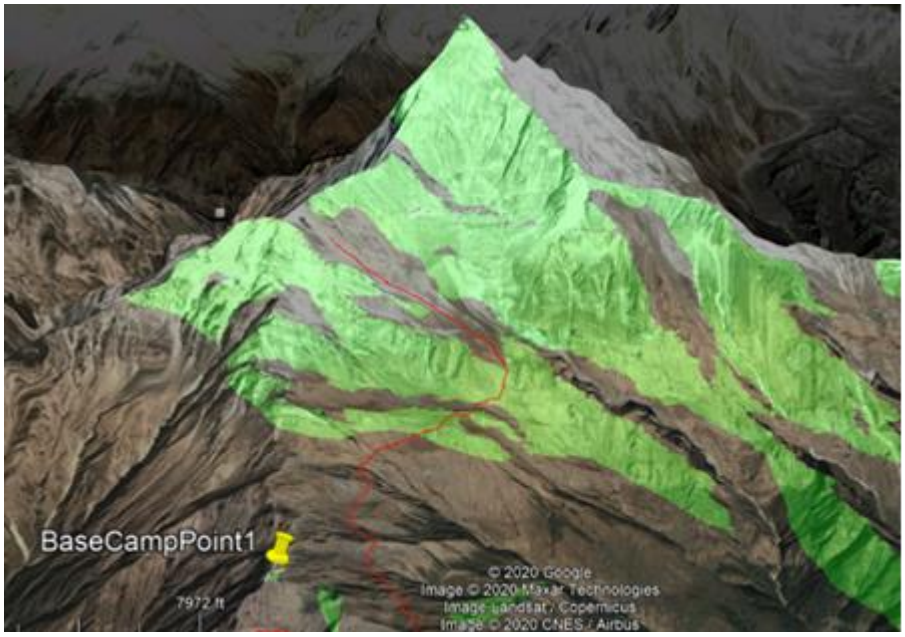


Figure 7: Viewshed Analysis in Google Earth

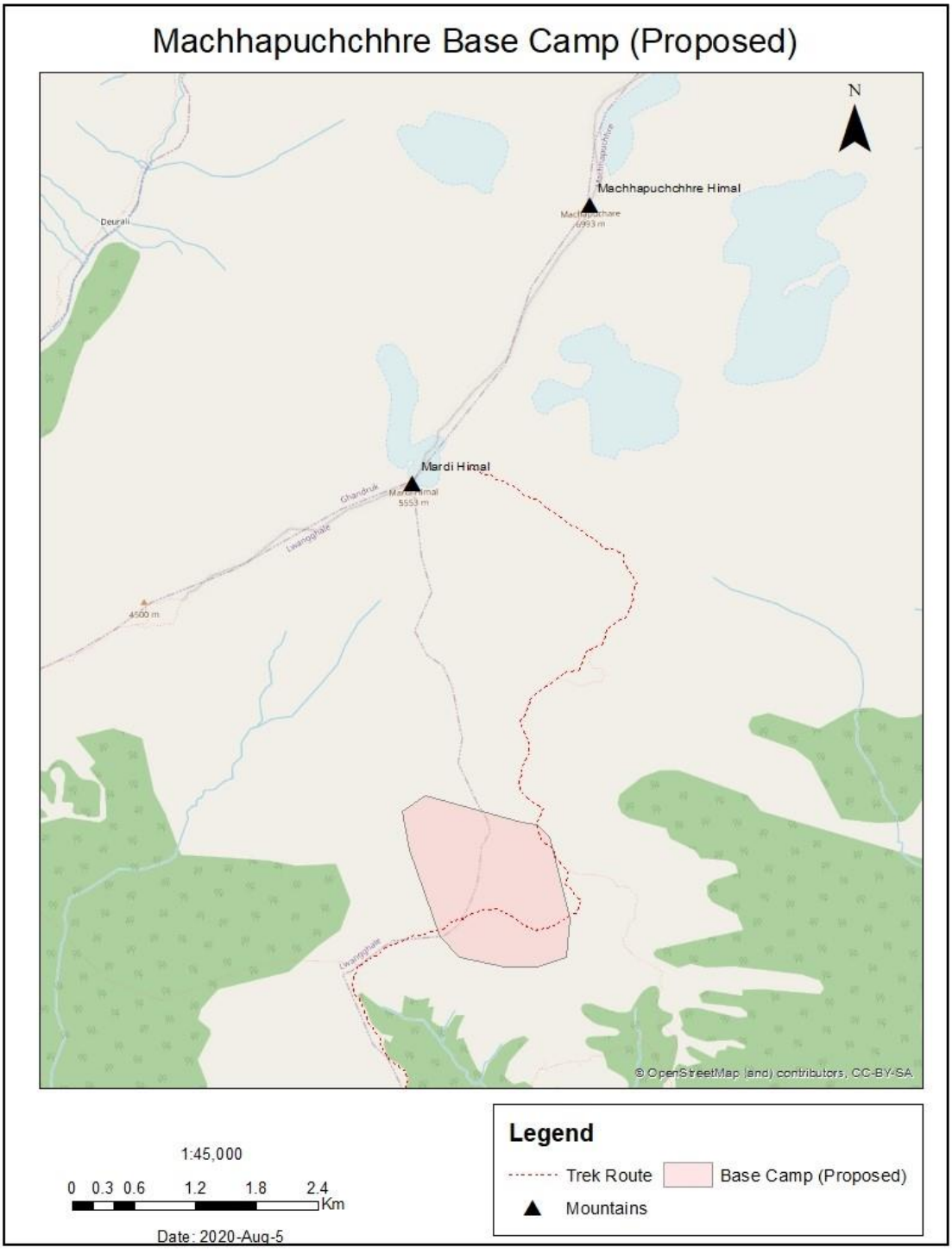
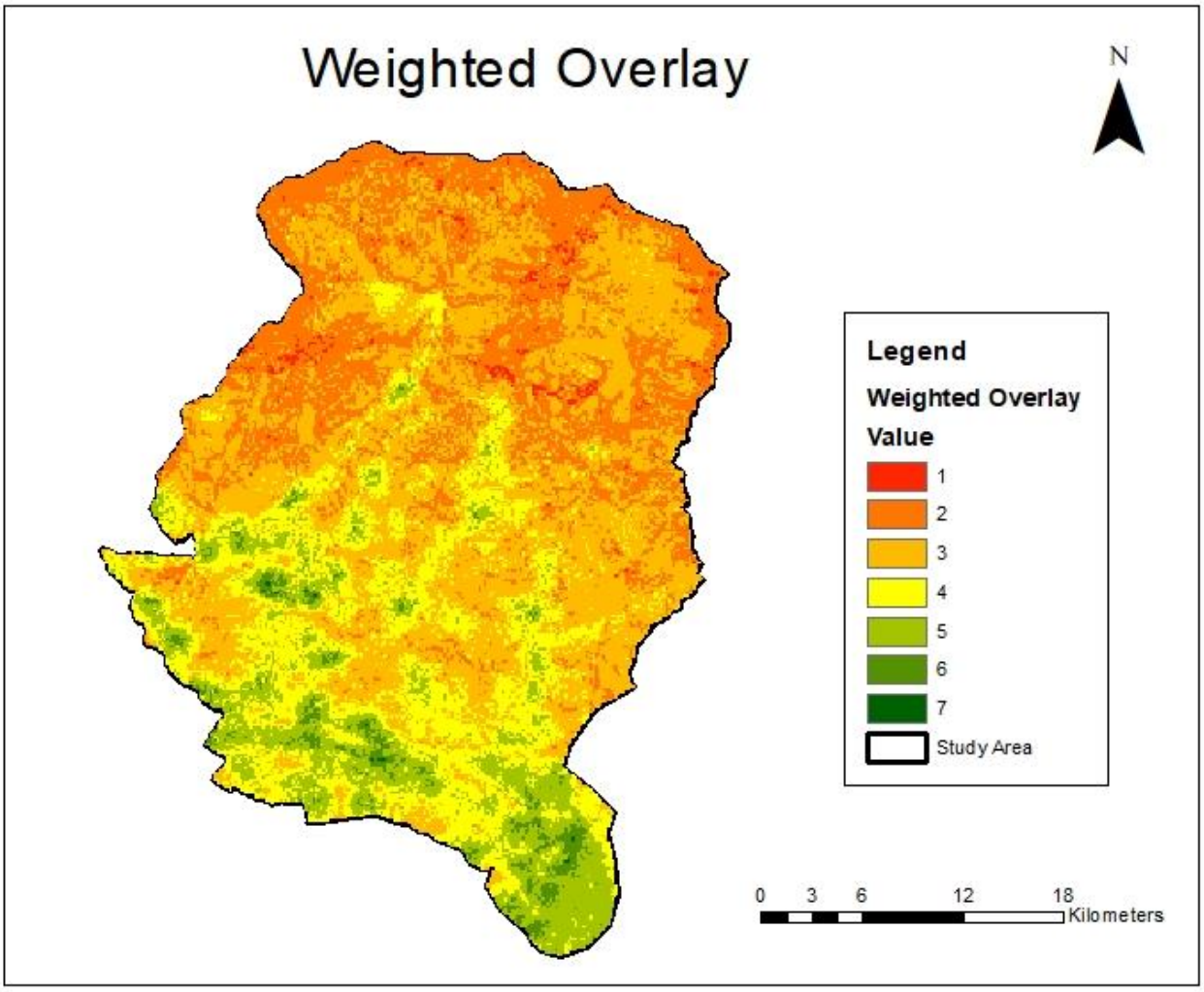


Figure 8 Proposed Machhapuchhre Base Camp

4.1.4 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 are overlayed and are given the appropriate weights calculated from AHP, togenerate the weighted overlay raster. Here the weighted overlay is done for suitability modeling to locate suitable areas sites for the trekking where the higher values indicate that a location is more suitable for trekking.

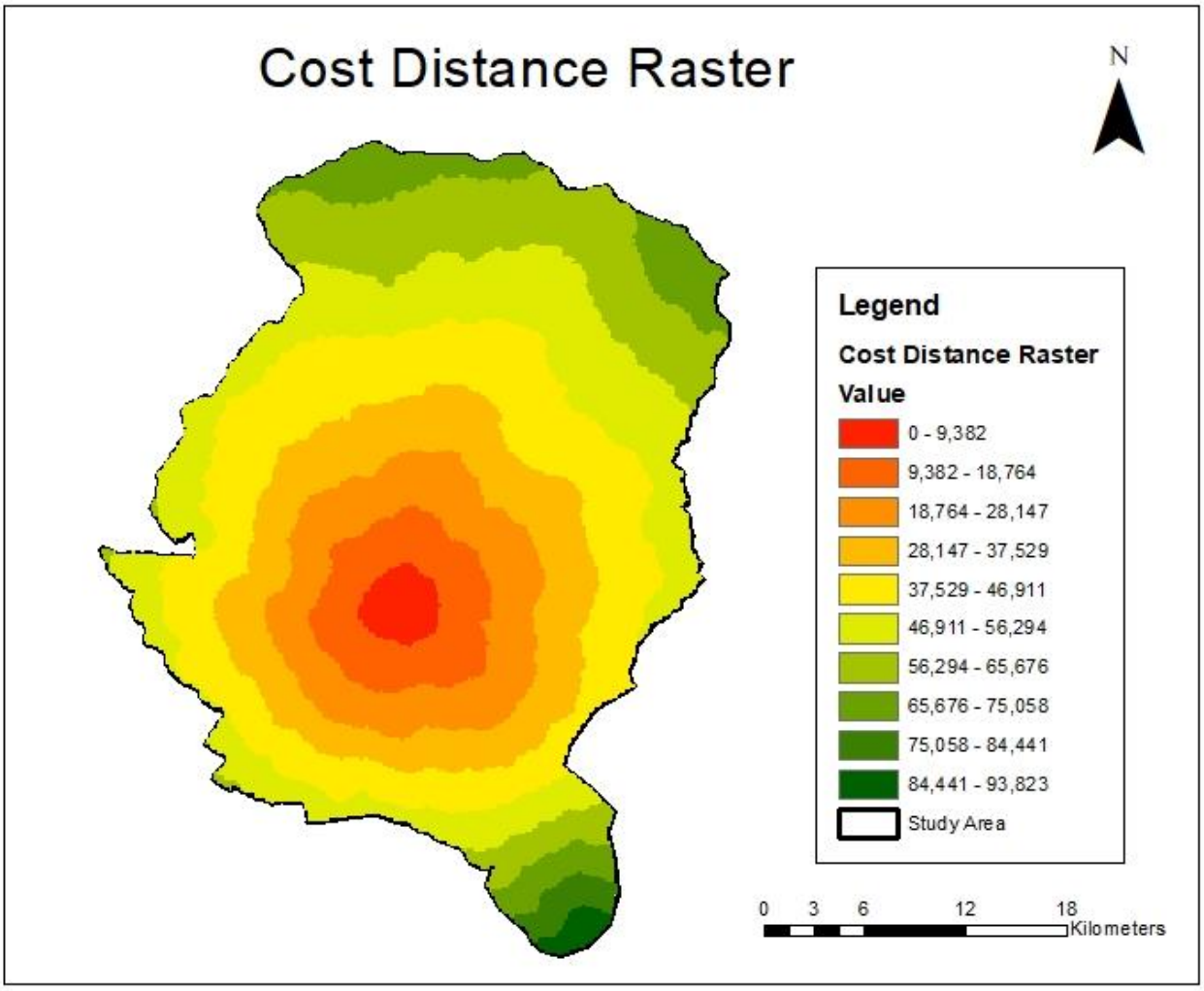


Map 13: Weighted Overlay

4.1.5 Cost Distance Raster

After the weighted overlay is 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 is starting point and the input cost raster is the raster obtained from the weighted overlay. The cost distance measure portion of least cost path analysis is centered on the node-link raster cell representation. In this representation a node is the center of the raster cell and the link connects the node to its neighboring cells. A lateral

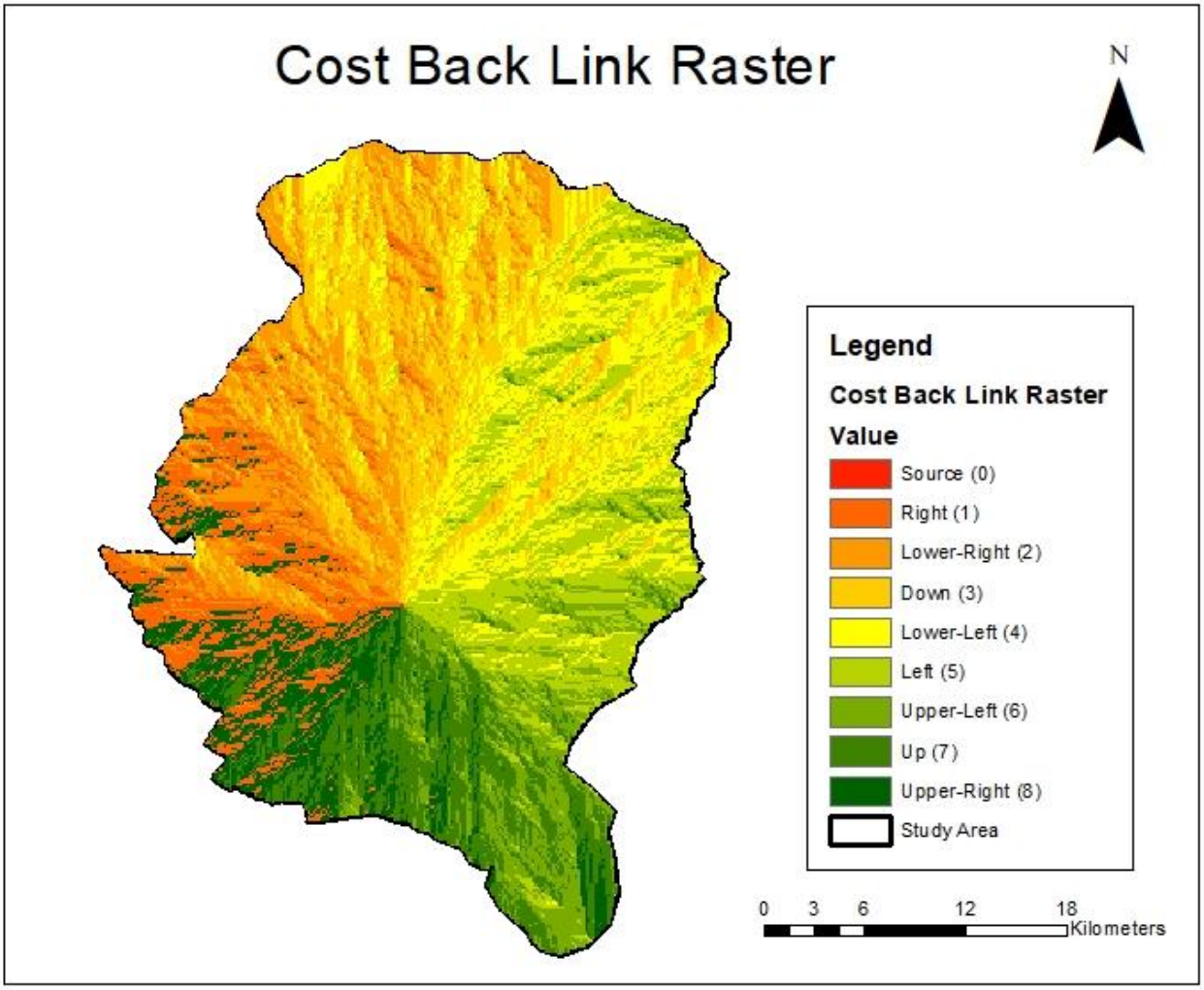
link is also included to connect a cell to one of its four nearest neighbors and a diagonal link connects the cell to the corner neighbors. The cost distance is the cost that it takes to travel from the node to these links and the least cost path is based on these least costs.



Map 14: Cost Distance Raster

4.1.6 Cost Back Link raster

Cost back link raster defines the neighbor that is the next cell on the least accumulative cost path to the least-cost source, where the input raster or the feature source data is starting point and the input cost raster is the raster obtained from the weighted overlay. The cost back link raster generated is as given below.

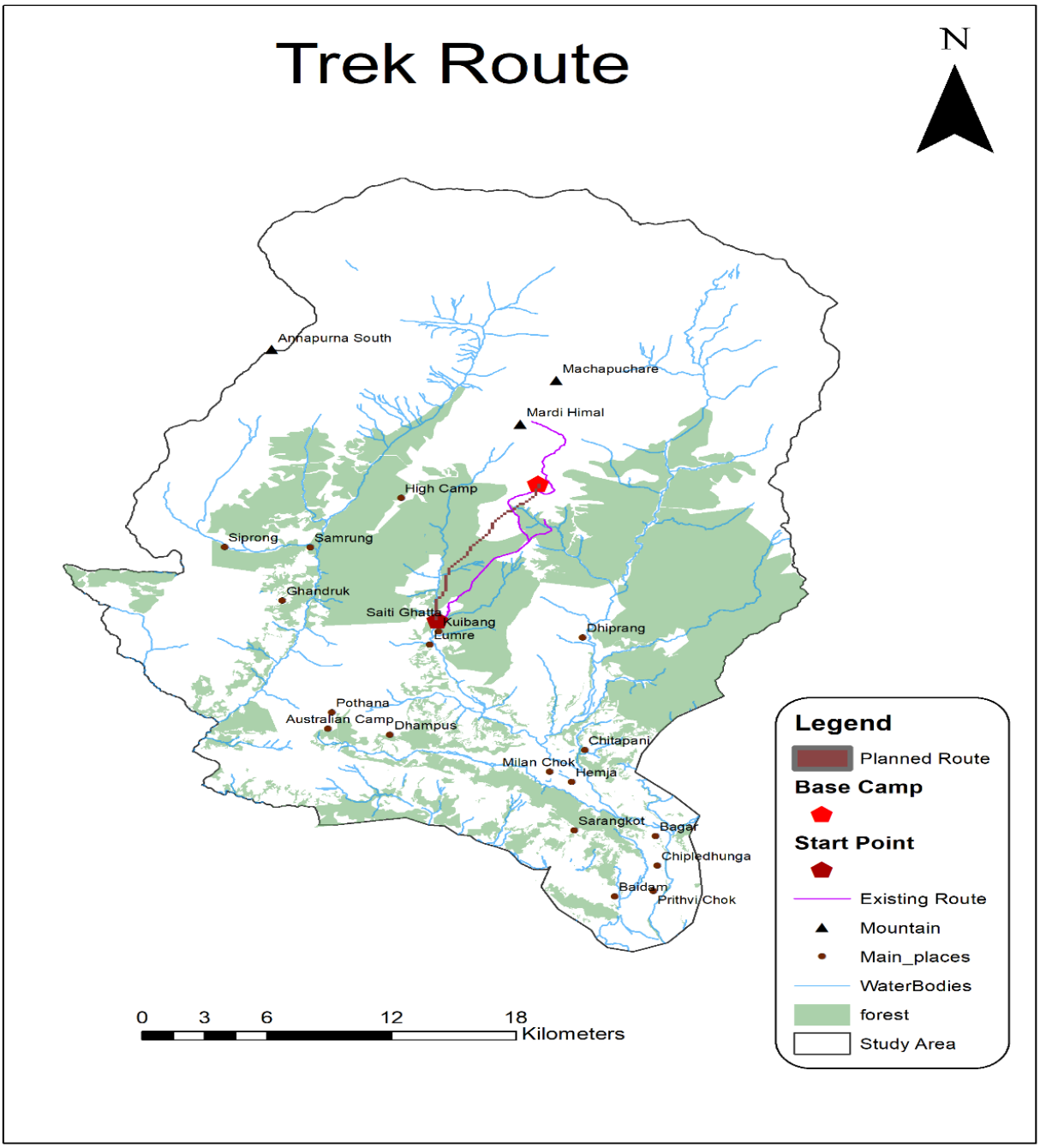


Map 15: Cost Back Link Raster

4.1.7 Cost Path:

Calculates the least-cost path from a source to a destination, where our proposed base camp is given in the input raster or feature destination data, cost distance raster is given in input cost distance raster and cost back link raster is given in the input cost back link raster. Cost path uses 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 (Goreto) above the existing water body,

passes through the forest areas in between and finally reaches the base camp as shown in the map below.



Map 17 Least Cost Path joining the Saiti Ghatta and Proposed Base Camp

4.1.3 Android Application Developed

The android based trekking application was developed by using Android Studio Software Development Kit. The programming language used for the 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 dependency 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. Also the application is used for the navigation purpose. The application provides the navigation between the use selected two points.

Figure 9 App Main Screen

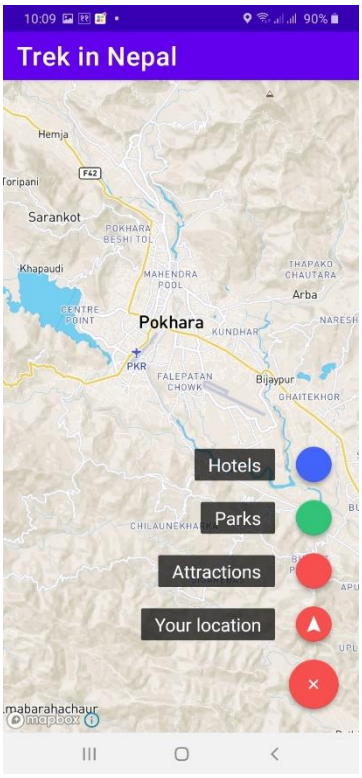


Figure 10 Floating Action Button

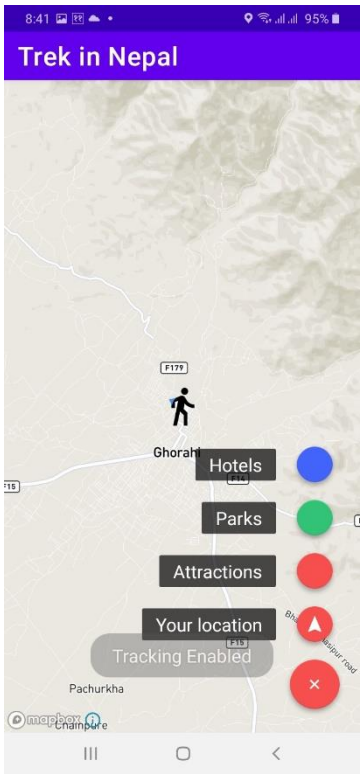


Figure 11 App Tracking the user location

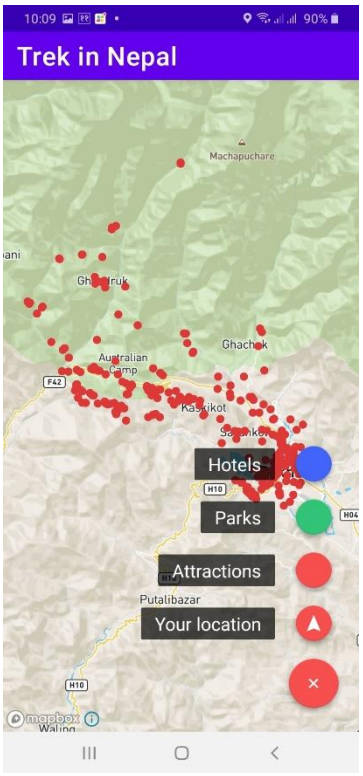


Figure 12 Displaying the Amenities

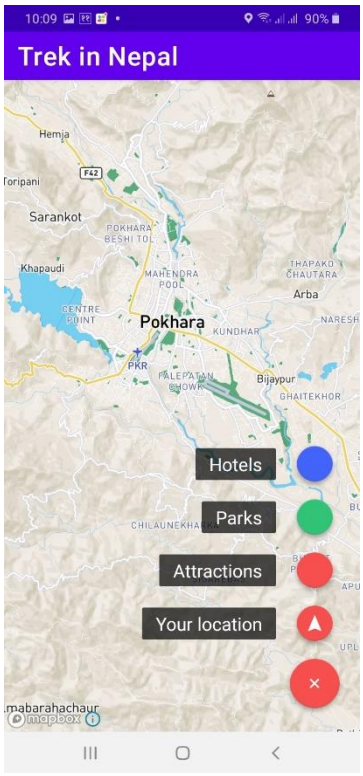


Figure 13 Displaying the features park

4.2 Discussions

4.2.1 Architecture of Android Application

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 user to see the user's or trekker's current location. The system also consists of login function, where each user is assigned with the functionality to download the trek routes, and update the trekkers information.

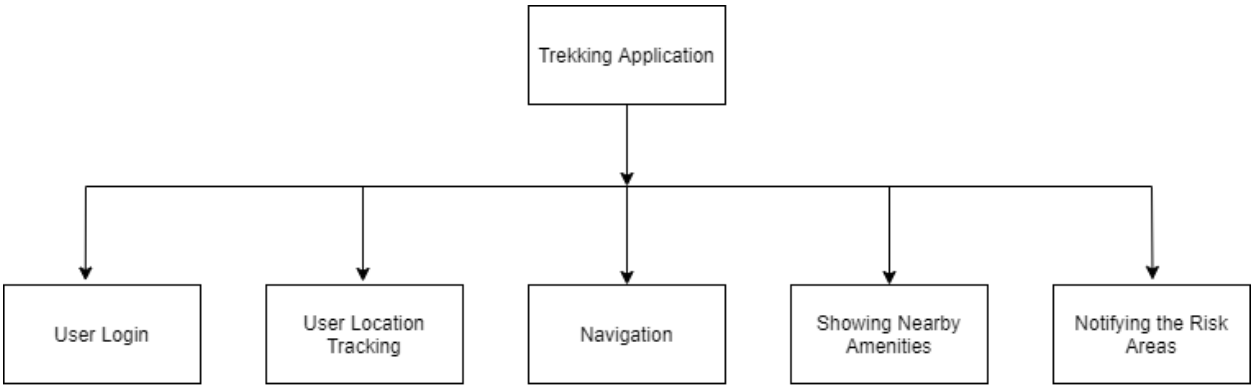


Figure 14 Architecture diagram of Android Application

Machhapuchchhre Model Trekking App is an android application used for the guidance of trekker while trekking. It mainly focuses on navigating the user to the route, tracking the user location, showing nearby location and notifying about the risk areas. The above figure describes the architecture of the application.

- ✓ **User Login**

  The user login is made to authenticate the user and also to gain the information of the user. After the loggin of the user, the user can download the available updates of the trekking route.

- ✓ **User Location Tracking**

  In the application, one of the main task is to display the user location in the map. The device's GPS sensor is used to acquire the latitude and longitude. Since the trekker is carrying the mobile device , the location of the device can be taken as the location of the trekker.

- ✓ **Navigation**

  Another task of the android application is to navigate the trekker to the Machhapuchchhre Base Camp. The application guide the trekker by turn-by-turn navigation.

- ✓ **Showing Nearby Amenities and Tourist Spots**

  Amenities like hospitals, shop, money points, hotels, tea shop etc and tourist spots like cave, waterfall, religious and cultural places are shown in the map. Also the nearby amenties and tourist spots are notifed via the notification also.

- ✓ **Notifying the Risk Areas**

  Risk areas are those are with high slope. The slope greater than and equal to 50 degree is taken as risk areas. The trekker is notified about the steep areas when he moves nearby the steep areas and can see those risk areas on map.

4.2.2 SWOT Analysis:

SWOT analysis is a strategic planning technique used to help a person or organization identify strengths, weaknesses, opportunities, and threats related to project planning or business competition. Here we performed SWOT analysis in our project too. Both internal factors (strengths and weaknesses) and external factors (opportunities and threats) play a vital role in the

development of the tourism industry, external ones like unstable political situations, e.g., war, conflict, riots, and strikes, are crucial factors particularly in case of Nepal where tourism industry frequently suffers from frequent riots and strikes called by political parties and their sister organizations (Neupane et al., 2021). It is described in the following four major parts as:

i. Strength:

Organic Rainbow trout and Tokro lie on the way to the Mahhapuchhre Model Trek Route, which is a typical Tamang Village. The majestic view of Himalays and Rhododendron forest are the major attractions to Naudhoke Cave, which is famous from the religious point of view, too. Majestic views of the Himalays (Lamjung Himal, Machhapuchhre Range, Annapurna Range, Dhaulagiri Himal, Nilgiri Himal, and Gangapurna Himal) can be viewed from Korchon. It is the perfect for sunrise. From Korchon passing Lwang Ghalel via Mardi East Trial, we reach our proposed Machhapuchhre Base Camp, from where the majestic views of Machhapuchhre and Mardi Himal are visible. This place is rich in cultural diversity and tradition. Different ethnic groups like Gurung, Tamang, Magar, Damai, Kami, Sarki, Chhetri, Newar and Brahmins, etc. lives in the old but cultural village. Throughout the Machhapuchhre model trek, trekkers can meet warmhearted Gurung and Magar people by stopping in their cultural home. The homestay has become so popular that it has increased the number of national and international visitors. This type of homestay provides local experience to the tourists.

Some of the major strength of our project can be described in the following points:

- Provides the sustainable trek route.
- The trek route and near-by facilities, amenities for the tourism is included in the android application, which definitely ease the tourism.
- The android application gives the necessary information to the trekkers about the steepy/risky areas, which to the great extent help to minimize the possible accidents and fatalities.
- The route is close to the tourist hub – Pokhara and lies in Annapurna Conservation Area.
- The route is rich in cultural and religious sites, rich in biodiversity.

ii. Weakness:

We are unable to buy satellite images, DTM instead we use freely available sources so, we lack cloud, void free satellite images. Since satellite images are the major source of data in our analysis like slope, aspect, LULC and many more. Hence error may induce in our result**.**

Some of the weakness of our project are:

- The project is based on the open-source platform rather than the commercial one.
- This is completely an academic work.
- It may not be applicable to all villages in Nepal because of its geographical situation and the unique characteristic features of Gurung and Tamang community, which sometimes may be same as of others.
- This study focuses on ecotourism of the Machhapuchhre Trek Route Region, can not be generalized.

iii. Opportunity:

Local people get the opportunity to show their culture, tradition. They can act as a guide for tourists. We can develop this route as a model route for several similar projects like this.

Some of the opportunities of the project are:

- Involves the active involvement of local people, stakeholders during the establishment of the route, thus addess the local sprit of the people.
- Foreign exchange earning.
- Preservation and promotion of tradition and cultures.
- Economic benefit to the grass- root level.
- Culture exchanage and internations between the nations.
- Rise in socio-economic status.
- Local resources like laliguras forest, lakes, temple, viewpoints, etc. will be the attraction for tourists and hence it supports mobilization of local resources.
- The sustainable trek route will attract internal (domestic), external (foreign) tourists, giving rise to the tourism industry.
- Attraction for ecotourism, trekking and rural tourism.

iv. Threats:

Some of the treats of the project are:

- Unstable political situations like strikes and riots.
- Invasion of local culture and traditions.
- Solid waste disposal and pollution issue.
- Resource deplation.
- Frequence of incidence of the missing tourists.
- Pollution and ecological disruption.
- Natural disasters like landslides, soil erosion, and flooding.
- Wildlife habitat also get disturbed.

4.2.4 Problem Encountered

We have faced the various problems during our research, some of the problems we encountered are:

1. **Covid-19 Constraints**:

The world is now victimized by the Covid-19 second wave. All the academic institutions, instutitions are running through the virtual means. The service sectors like hotels, resturants, lodges are partially closed. Public vechicles are not running (though running in intra-district). Trekking, hiking and tourism practices have been closed. Due to the fear of community transfer of the corona, strict lockdown and lack of favourable time, not go in the field in the first wave coroa pandemic also. Due to COVID-19 constraints, we are bound to work from remote from own location, using the dummy data available from web, such as osm data, elevations datasets, satellite imageries, etc. We could not work with the complete field-data), and could not analyze completely as we ought to have, however we are incorporating all of the major analysis and research.

We performed the group work connecting virtually. We used various platforms like zoom, Google Meet, MS-Team to get connected. We got a little bit difficult in joining virtually and in collaborating, which was not as if like collaborating in the physical presence. However, we managed to collaborate and to document progress in our project.

2. **Lack of Data**:

The geological and climate data of the study area have not been well maintained. So lack of the appropriate data have hindered in the further more analysis.

5. Conclusion and Recommendations

5.1. Conclusion

The purpose of this study was to develop the Machhapuchhre Model Trek Route, that has least costs, that 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 Machhapuchre Trek Route, this study first identifies and prioritizes the potential ecotourism sites, suitable for the 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 a developing country like Nepal.

The main contribution of this study was the generation of the least cost path for the 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 are identified and are assigned a unique score values and weight for each by applying the hierarchical structure of AHP in 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 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 is fethched respectively for the least cost path analysis, where the feature source and destination are given. Also mobile based android application is developed, integrating the tourist route, available tourist spots, hubs, viewpoints, steep areas, amenities; this will helped to ease the trekking with safety.

Based on the results of the analysis, the least path or route passes below the exising route (*Goreto*). Here the cost is 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 neighbors of a raster cell are evaluated and the generated path moves to the cells with the smallest accumulated or cost value. This process is repeated multiple times until the source and destination are connected. The completed path is the smallest sum of raster cell values between these two points and it has 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, passes the barren land and reaches the base camp (destination) as sshown in the map above.

In conclusion, a 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 the sustainable ecotourism development. Additionally, 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, viewtowers) and biodiversity conservation. In the same way, trekking is a complex phenomenon of the 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 the developing country like Nepal.

5.2 Recommendations

In a more specific manner, the recommendations for trekking tourism resources, facilities and services, marketing, and administration are summarized as follows:

1) Since, trekking tourism in Machhapuchhre Trekking Region is largely dependent on a natural resources and biodiversity, and it is recommended that trekking tourism be specifically addressed by regional policies that deal with biodiversity and conservation.
2) Provincial, regional, district level planning should be developed and adopted for trekking tourism. This should take into account both impacts on natural resources and local communities. In addition, villagers should be empowered to manage natural resources within the boundary of the village.
3) Facilities and infra-structures are very less in the region and their development should be in harmony with the local identity and with nature.
4) Assistance should be given for the development of ecotourism enterprises. Such assistance could include business planning, training, product development, marketing and advertisement.
5) Preparation of guidelines or frameworks for workshops to specifically address issues related to resource management, biodiversity conservation and trekking-tourism market planning should be arranged by the Pokhara Tourism Council and the Machhapuchhre Model Trek Management Committee(MMTMC).

With respect to the techniques implemented in this study, the integration of AHP in GIS techniques has been proven beneficial for supporting decision-making. The methodology is useful for identifying priority areas for ecotourism(trekking) and furthermore for the generation of the least optimum path. The development of ecotourism is further enhanced by geospatial approaches; which have proved beneficial for supporting decision-making and tourism planning (*Site Suitability Evaluation for Ecotourism Using GIS & AHP: A Case Study of Surat Thani Province, Thailand*, 2012). Trekking-tourism is an activity that strongly supports the geographical dimension. GIS has a significant potential as a tool for site source control, its implementation, analysis and quantification. GIS appears to be a significant tool for planning, managing and

monitoring of natural resources in Machhapuchhre Trek Region. Besides this, GIS could be used for ecotourism development planning for the sustainable development and policy making.

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 tools for ecotourism management.

Aditionally, AHP analysis provides reflection of real situation of 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 least cost path for trekking tourism. Furthermore, this study should be useful to those who are interested in the GIS technique, mapping and ecotourism suistainable development.

References

Abudu, D., & Williams, M. (2015). GIS-based Optimal Route Selection for Oil and Gas Pipelines in Uganda. www.ACSIJ.org

Acharya, K. (n.d.). *Thesis on Ecotourism*.

Ahmed Chandio, I., Nasir Matori, A. B., WanYusof, K. B., Aftab Hussain Talpur, M., Hussain Khahro, S., & Radin Mohd Mokhtar, M. (2012). Computer Application in Routing of Road using Least-Cost Path Analysis in Hillside Development. In *Research Journal of Environmental and Earth Sciences* (Vol. 4, Issue 10).

Balogun, A., Chandio, I. A., Matori, A. N. B., WanYusof, K. B., Talpur, M. A. H., & Lawal, D. U. (2012). Routing of road using Least-cost path analysis and Multi-criteria decision analysis in an uphill site Development. *Research Gate*, *June*, 3–6. https://www.researchgate.net/publication/263582134_Routing_of_road_using_Least-cost_path_analysis_and_Multi-criteria_decision_analysis_in_an_uphill_site_Development

Bhandari, K. P. (2012). International Archives of the Photogrammetry. In *Remote Sensing and Spatial Information Sciences*. XXII ISPRS Congress.

Bhattacharyya, A. (2006). Using participatory GIS to bridge knowledge divides among the Onge of Little Andaman Island, India. *Knowledge Management for Development Journal*, *2*(3), 97–110.

Boers, B., & Cottrell, S. (2007). Sustainable tourism infrastructure planning: A GIS-supported approach. *Tourism Geographies*, *9*(1), 1–21. https://doi.org/10.1080/14616680601092824

Chang, K.-T. (n.d.). Introduction to geographic information systems.

Gyabeng, B. A. (2020). Selection of Optimum Petroleum Pipeline Routes Using A Multi-Criteria Decision Analysis and GIS Least-Cost Path Approach. *International Journal of Scientific and Research Publications*, *10*(6), 572. https://doi.org/10.29322/IJSRP.10.06.2020.p10270

Jaiswal, B. (2020). Tourism as a Tool for Economic Development in Nepal Bhanupriya Jaiswal Jawaharlal Nehru University , New Delhi , 110067. November 2018, 0–13.

KC, A. (2017). Ecotourism in Nepal. *The Gaze: Journal of Tourism and Hospitality*, *8*, 1–19. https://doi.org/10.3126/gaze.v8i0.17827

Kiper, T. (2013). Role of Ecotourism in Sustainable Development. In *Advances in Landscape Architecture*. InTech. https://doi.org/10.5772/55749

Lamptey, F. (2009). Participatory GIS Tools for Mapping Indigenous Knowledge in Customary Land Tenure Dynamics : Case of Peri - Urban Northern Ghana. 94.

Machhapuchhre Model Trek. (n.d.-a). Retrieved June 9, 2021, from http://fishtailtrek.com/

Machhapuchhre Model Trek. (n.d.-b). Retrieved June 1, 2021, from https://marditreknepal.com/Machhapuchhre-Trek

Machhapuchhre Model Trek: Experience culture at Machhapuchhre. (n.d.). Retrieved May 31, 2021, from https://northnepaltrek.com/machhapuchhre-model-trek/

Mandara, C. (2007). Participatory GIS in Mapping Local Context of Conflicts over Pastoral Resources. *A Case Study of Duru Haitemba-Babati, Tanzania*. http://www.itc.nl/library/papers_2007/msc/nrm/mandara.pdf

Mccall, M. K., & Dunn, C. E. (2012). Geo-information tools for participatory spatial planning: Fulfilling the criteria for "good" governance? *Geoforum*, *43*(1), 81–94. https://doi.org/10.1016/j.geoforum.2011.07.007

Nepali Times. (2015). Adventure Tourism: A billion dollar industry? | Nepali Times.

Nethengwe, N. S. (2007). Integrating Participatory GIS and Political Ecology to study Flood Vulnerability in the Limpopo Province of South Africa. 242.

Neupane, R., Anup, K. C., Aryal, M., & Rijal, K. (2021). Status of ecotourism in Nepal: a case of Bhadaure-Tamagi village of Panchase area. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-021-01317-z

Overview of Least Cost Path Analysis - GIS Lounge. (n.d.). Retrieved July 23, 2021, from https://www.gislounge.com/overview-least-cost-path-analysis/?fbclid=IwAR3bjkA1J9Ufnuu1CxujNIXPvb6snVsjAcFOuoP8Jta3I1U3ou-Tz4qYTQo

Porter, G. (1998). *Participatory GIS: Opportunity or oxymoron?* https://www.researchgate.net/publication/238293890

Rambaldi, G., Kyem, P. A. K., McCall, M., & Weiner, D. (2006). Participatory Spatial Information Management and Communication in Developing Countries. *The Electronic Journal of Information Systems in Developing Countries*, *25*(1), 1–9. https://doi.org/10.1002/j.1681-4835.2006.tb00162.x

Rashidul Hasan, S. (2015). EXPLORING BANDARBAN THROUGH TREKKING TRAILS: A NEW HORIZON FOR COMMUNITY-BASED TOURISM DEVELOPMENT. In *European Scientific Journal* (Vol. 11, Issue 5).

Sahayogee, J. (2018). *Nepal - Border, Facts, Places, Information All About Nepal*. https://www.imnepal.com/nepal-tourist-tourism-places/

Satar, M. (2005). Using Participatory GIS to Identified Local Landuse Zoning for Conservation in Merauke District, Papua, Indonesia. February. http://www.iapad.org/publications/ppgis/musnanda.satar.pdf

Shrestha, Hari Prasad, P. S. (n.d.). Tourism in Nepal : A Historical Perspective and Present Trend of Development.

Site Suitability Evaluation for Ecotourism Using GIS & AHP: A Case Study of Surat Thani Province, Thailand. (2012).

Sriboonruang, K., Punkong, N., & Kumkrua, M. (2020). Paticipatory geographic information system (PGIS) for developed the online map of historical source in World War II, Pak Phraek

Road community, Kanchanaburi Thailand. *40th Asian Conference on Remote Sensing, ACRS 2019: &Amp;Amp;Amp;Amp;Amp;Quot;Progress of Remote Sensing Technology for Smart Future&Amp;Amp;Amp;Amp;Amp;Quot;*, *Acrs*, 1–11.

Sulistyawan, B. S., Verweij, P. A., Boot, R. G. A., Purwanti, B., Rumbiak, W., Wattimena, M. C., Rahawarin, P., & Adzan, G. (2018). Integrating participatory GIS into spatial planning regulation: The case of Merauke District, Papua, Indonesia. *International Journal of the Commons*, *12*(1), 26–59. https://doi.org/10.18352/ijc.759

Sunusi, A., Agrawal, V. C., Lal, D., & Suleiman, S. (n.d.). Selection of Road Alignment Location in Kano-Nigeria using GIS and Analytical Hierarchy Process (AHP) Model. www.ijsetr.com

Taherdoost, H. (2017). Decision Making Using the Analytic Hierarchy Process (AHP); A Step by Step Approach. *International Journel of Economics and Management Systems*, *2*(February), 244–246.

trekking in nepal. (n.d.). Retrieved May 31, 2021, from https://articlebiz.com/article/1051724120-trekking-in-nepal

Trekking in the Nepal Himalaya. (n.d.). Retrieved May 31, 2021, from https://www.footprintadventure.com/blog/trekking-in-the-nepal-himalaya

Upreti BR, Upadhayaya PK, S. T. (2013). *Tourism in Pokhara: Issues, Trends and Future. Prospects for Peace and Prosperity*. Pokhara Tourism Council, PokharaSouth Asia Regional Coordination Office of NCCR North-South AndNepal Centre for Contemporary Research, Kathmandu. https://pdfroom.com/books/tourism-in-pokhara-issues-trends-and-future-prospects/qjb5qvKPdxQ

Wang, C., & Yang, Z. (2021). Suitability evaluation for mountain-based adventure tourism: A case study of Xinjiang Tianshan, China.