जल शक्ति मंत्रालय
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MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES,
RIVER DEVELOPMENT & GANGA REJUVENATION

सत्यमेव जयते

BISAG-N
MeitY
Engineering to Imagineering

Project Technical Package (Volume 1.0)

for

Land Use — Land Cover (LULC)

WRIS-MIS-07

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Executive Summary

This document outlines the specification, design and development for the WRIS-MIS-07 Land Use — Land Cover (LULC) within application WRIS- Land Resources for theme Master Information System (MIS). This is among nine themes of the project “Water and Allied Resources Information Management System” (WARIMS) platform developed by the Bhaskaracharya National Institute for Space Applications and Geo-informatics (BISAG-N), led by the Ministry of Jal Shakti (MoJS).

The primary objective of the LULC is to monitor and analyse changes in land use and land cover, which are critical for sustainable development and planning.

The National Remote Sensing Centre (NRSC) has established a threefold classification system for Nationwide LULC analysis, which is updated annually and mapped at various scales. The system utilizes high-resolution satellite data for LULC mapping, employing both raster and vector-based approaches to optimize the use of optical and microwave imagery.

The LULC maps and database are intended for use in scientific research, industrial siting, land improvement, watershed and coastal zone management, water resource management, agricultural productivity improvement, and other applications. The maps are produced at various administrative levels (country, state, district, basin, sub-basin) and include temporal changes displayed through maps, charts, and statistics.

The requirement specification specifies the input data required, which includes medium to high-resolution satellite sensor images and geospatial time-series data. The process involves data preparation, interpretation, ground truthing, post-classification correction, and output generation using both vector-based on-screen visual interpretation and raster-based image classification methods.

Responsibilities for data integration and development include syncing LULC classes with existing schemas, calculating LULC area statistics, and publishing web map services. The document also addresses data validation, software requirements, dependencies, risks, and change management.

In summary, the system provides a comprehensive framework LULC mapping system, which is essential for understanding land use patterns and their changes over time, ultimately supporting informed decision-making for sustainable land management and resource utilization.

1. Introduction

The Land Use Land Cover (LULC) belongs to Application WRIS-Land Resources of the Theme Master Information System (MIS), platform WARIMS.[1]Land Cover is defined as observed physical features on the earth's surface. When an economic function is incorporated, it transforms into Land Use. Land use is a very human-centric term, (FAO, 2005).

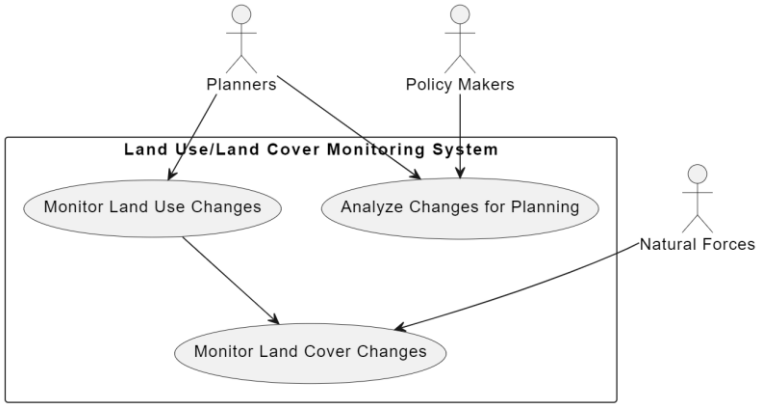


Figure-1 Flow Diagram for LULC Monitoring System

Figure-1 illustrates that the LULC mainly focuses on the activity that is being practiced on a piece of land. Changes in LULC do not always have to be driven by humans; the land can also undergo changes due to the forces of nature. Therefore, it is necessary to timely monitor the changes in land use/land cover pattern for a particular area or the whole. Monitoring and analysis of such changes gives planners and policymakers' answers to some important questions which are essential for sustainable development. Information on land use/land cover and changes over period of time attains prominence because of its primary requirement in all the planning activities.

1.1 Governance Need

The land resource related queries such as: what type of land is more severely under threat, where do forests need protection, which direction is urban centre growing, and is that posing any dangers to the natural environment, how is the changing land use affecting the atmosphere and nearby water resources, where is the best opportunity to exploit land as a natural resource and so on queries that are always asked and requires timely updated spatial database to answer.

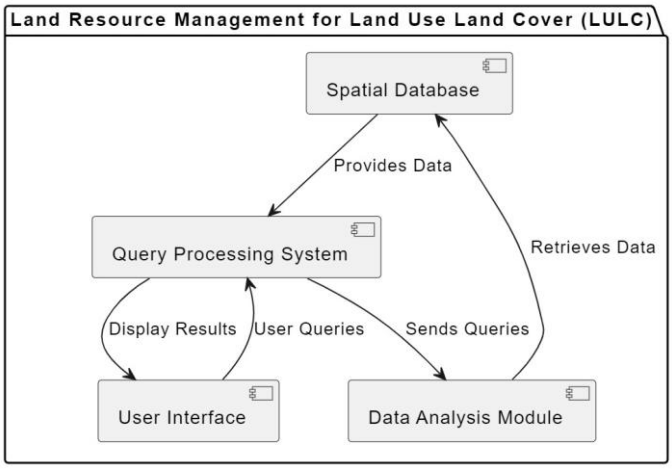


Figure-2 System flow of the Land Resource Management for LULC

Figure-2 depicts flow for the governance need about Land Resource Management for LULC.

1.2 Project Endeavour

The governance need (as stated in 1.1) highlights the necessity of an effective system for LULC monitoring that can analyse spatial data and handle queries through intuitive user interface.

[1] Annexure-1: BSR of Land Use Land Cover from NWIC

1.3 Measure of Success

To generate spatial and change database on land use/land cover. Major change areas will be specifically identified. This will enable planners and administrators to initiate the appropriate measure for preventing / arresting the degradation and development of natural resources.

1.4 Scope

The requirements specified are related to the WARIMS, theme Management Information System (MIS) for WRIS-Land Resources Application and the Land-Use-Land-Cover (LULC).

High Priority:

Land use serves as base for many applications and also as a model parameter required in many thematic studies.

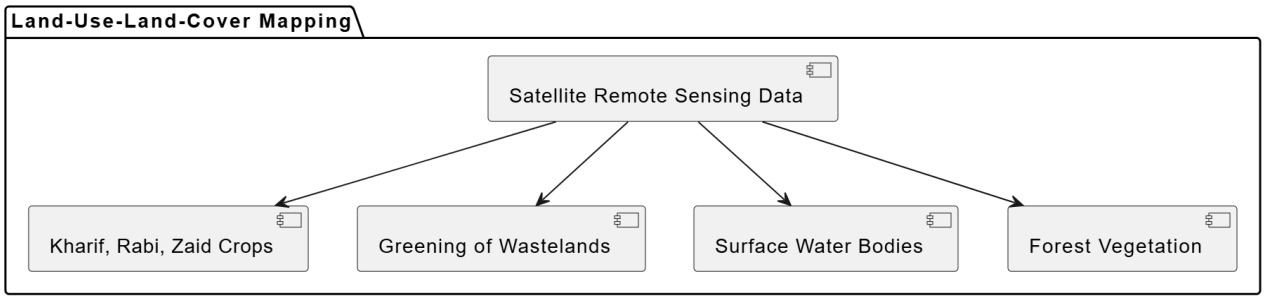


Figure-3 High Priority for LULC mapping

Land use land cover mapping addressing Kharif, Rabi and Zaid crops, greening of wastelands, seasonality of wastelands, surface water bodies, forest vegetation and other high temporal land use practices using satellite remote sensing data can provide a reliable database.

The LULC maps and database should be used at broad level for the following purposes:

- Scientific research involving carbon cycle, hydrologic cycle, energy budget studies, weather/climate prediction;
- Sitting of industries, SEZs etc;
- Land improvement programmes;
- Watershed management;
- Coastal zone management;
- Water resource management;
- Agricultural productivity improvement, etc.

1.5 End Users:

Planners, Decision makers, Administrators, Academicians, Farmers, and the Public in general.

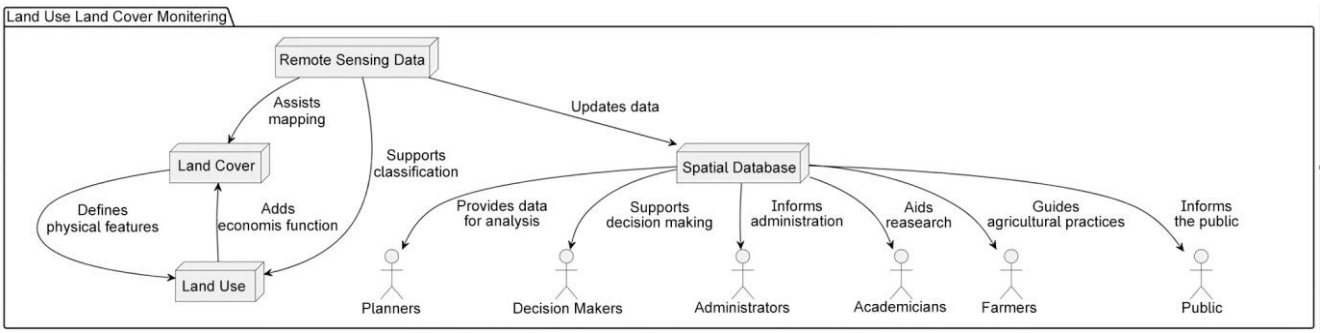


Figure-4 System Flow: End Users accessing Land Use Land Cover (LULC)

The system flow in the Figure-4 demonstrates that how the end users will utilize spatial and remote sensing data to monitor and analyse land use/land cover. The flow indicates that continuous updates and comprehensive spatial data are essential to effectively address the queries related to land resources. This data must track land use changes, threats to natural environments, urban growth patterns, and impacts on atmospheric and water resources, enabling timely and informed decision-making for environmental management and resource optimization.

2. Solutions Specification

2.1 Functional Requirements

The functional requirements are identified from the business specific requirement as received from the NWIC[2]. Based on which the flowchart as shown in Figure-5 is designed to outline the process of Land Cover and Land Use (LULC) Monitoring. The flowchart is comprehensive framework to manage the LULC dynamics and provides visual representation of the various steps involved in LULC monitoring process.

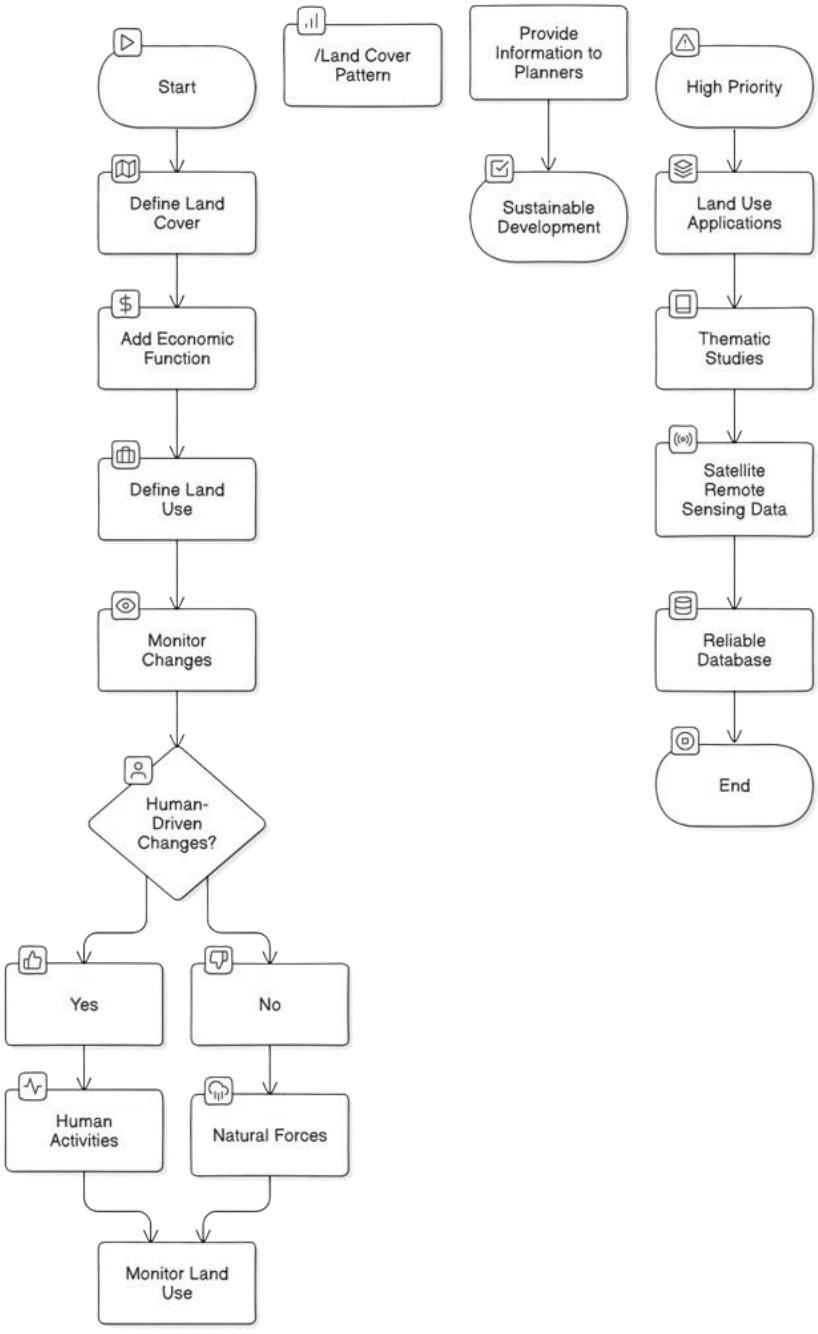


Figure-5 Flowchart: Functional Overview of LULC Monitoring[3]

The flowchart outlines the key steps involved, from defining land cover and land use to monitoring changes and providing information for sustainable development. It also highlights the importance of considering both human activities and natural forces in driving land cover and land use changes.

[2] Annexure-1: BSR of Land Use Land Cover from NWIC
[3] Application URL: https://cache.ncog.gov.in/WARIMS

2.2 Design Flow of Requirements

The design flows are represented for each feature of the requirement specifications as below:

1) Map:

i) LULC map at country to State/ District/ Basin/ Sub-Basin level from IRS LISS-III (23.5m) data on 1: SDK scale and from IRS P6 AWiFS (56m) data on 1:250K scale (NRSC)[4].

Following is the sequence diagram in Figure-6 for the tasks:

- Visualization on Map at country to State/ District/ Basin/ Sub-Basin Level.
- Filtering options for data (forest type wise) need to be obtained. Category/class wise data visualization should be admin-wise (different states up to district) or hydrological boundary-wise (basin up to sub-basin).

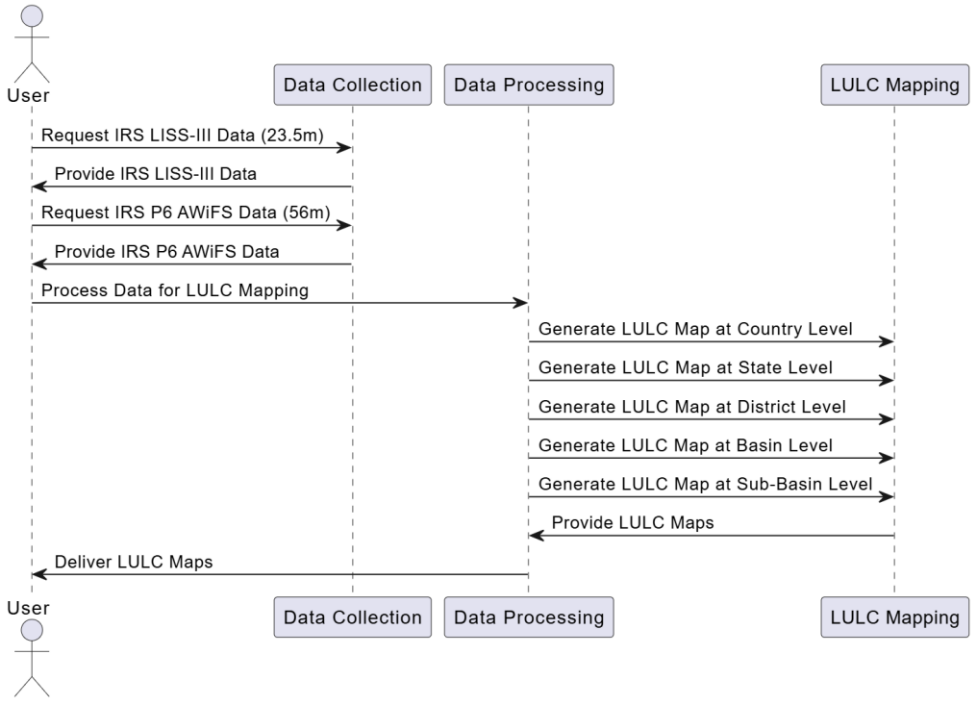


Figure- 6 Sequence Diagram for the task:
Visualization on Map at country to State/ District/ Basin/ Sub-Basin Level for Admin/ Hydrological boundary wise.

ii) High Resolution LULC Map[5]: LULC data is prepared for the area of interest using high resolution satellite images with required ground checks and disseminated with finer details and standard symbology.

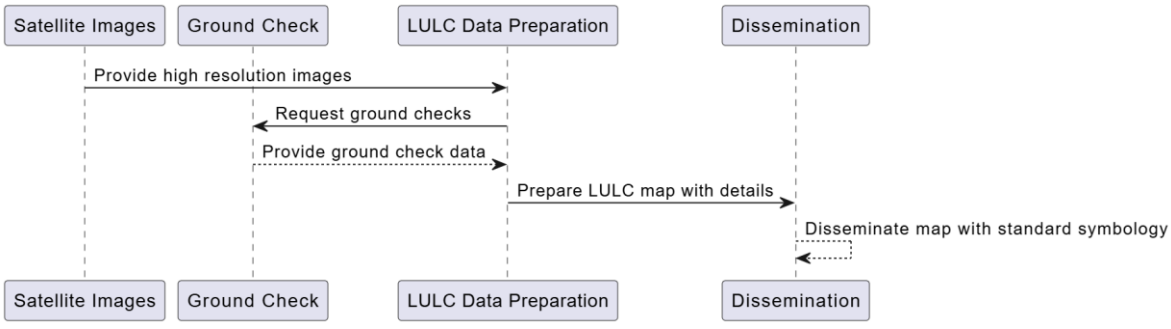


Figure-7 Sequence Flow for Expected High Resolution Map

The Figure-7 outlines the LULC mapping process. It starts with satellite images, followed by ground checks for accuracy. The data is then used to create a detailed LULC map, which is disseminated with standardized symbols.

[4] Annexure-1: BSR of Land Use Land Cover from NWIC - Map Section of Visualization Page2
[5] Annexure-1: BSR of Land Use Land Cover from NWIC - High Resolution LULC Map Section of Visualization Page2

2) Graph Charts:

Pie/Bar charts are used for administrative/hydrological setup indicating LULC classes.

i) Class wise distribution of Land use land cover area (Based upon administrative setup)[6]

The Figure-8 outlines the process of LULC analysis and presentation.

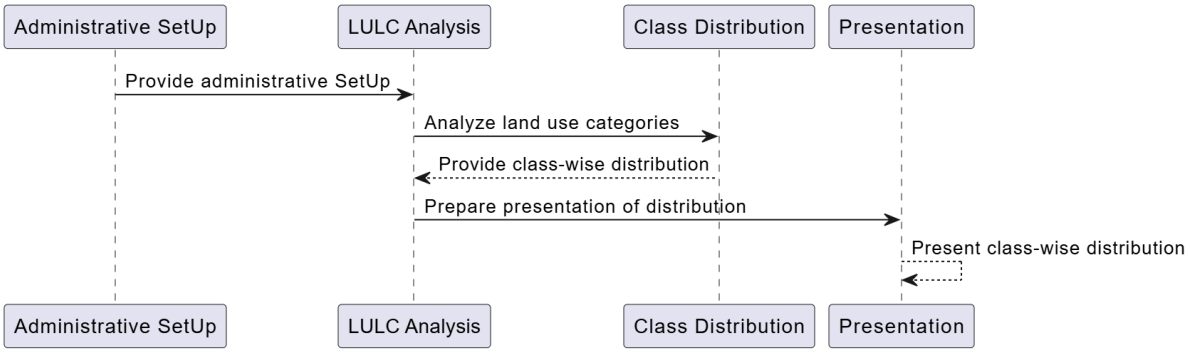


Figure-8 Sequence Diagram of class-wise graphical data presentation of Administrative Set-Up

It starts with administrative setup, followed by LULC analysis to identify land use categories. The class-wise distribution is then calculated and presented in a clear manner.

ii) Class wise distribution of Land use land cover area (Based upon Hydrological setup)

The Figure-9 outlines the process of hydrological analysis and LULC assessment.

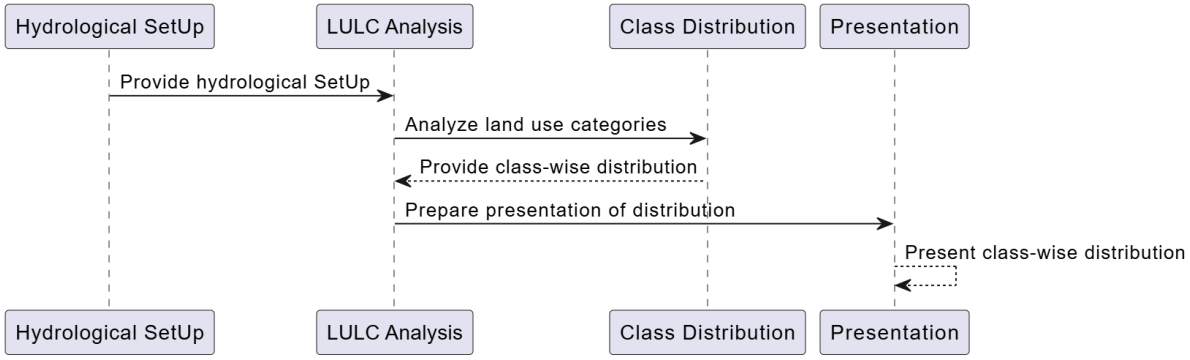


Figure-9 Sequence Diagram of class-wise graphical data presentation of Hydrological Set-Up

It starts with hydrological setup, followed by LULC analysis to identify land use categories. The class-wise distribution is then calculated and presented.

iii) Comparison between two consecutive year or decadal LULC cycle

The Figure-10 outlines the process of comparing LULC data from two different years.

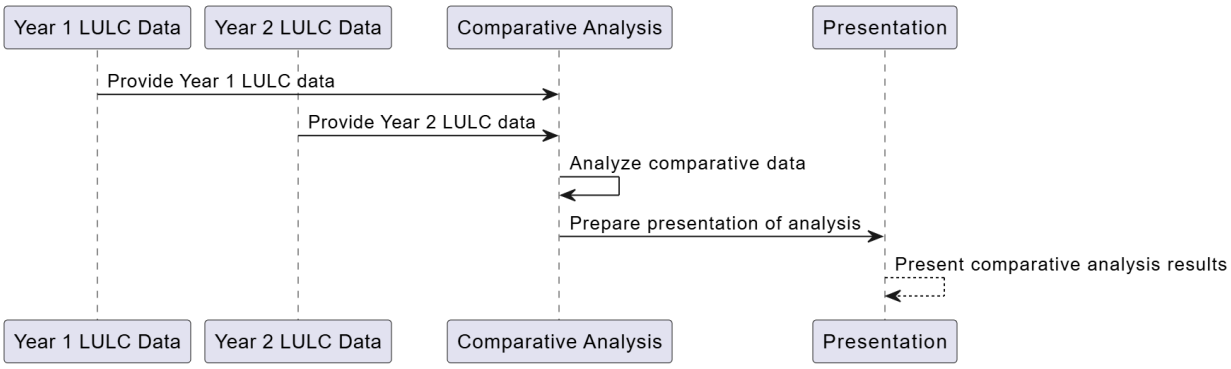


Figure-10 Sequence Diagram of Comparing two years with single class or all classes

It starts with providing LULC data for both years, followed by comparative analysis to identify changes. The results are then presented in statistical reports and represented in bar chart.

[6] Annexure-1: BSR of Land Use Land Cover from NWIC - Graph/Charts Section (a) Page2

3) **Output in tabular format**: —

State/District-wise, Basin/Sub Basin wise LULC status is provided in the form of tabular output and as per the time selection (yearly). The tabular output can be used to compare two LULC cycles and assess positive and negative changes over the time.

Figure-11 shows the process of comparing LULC data from two different years. It starts with providing LULC data for both years, followed by comparative analysis to identify changes.

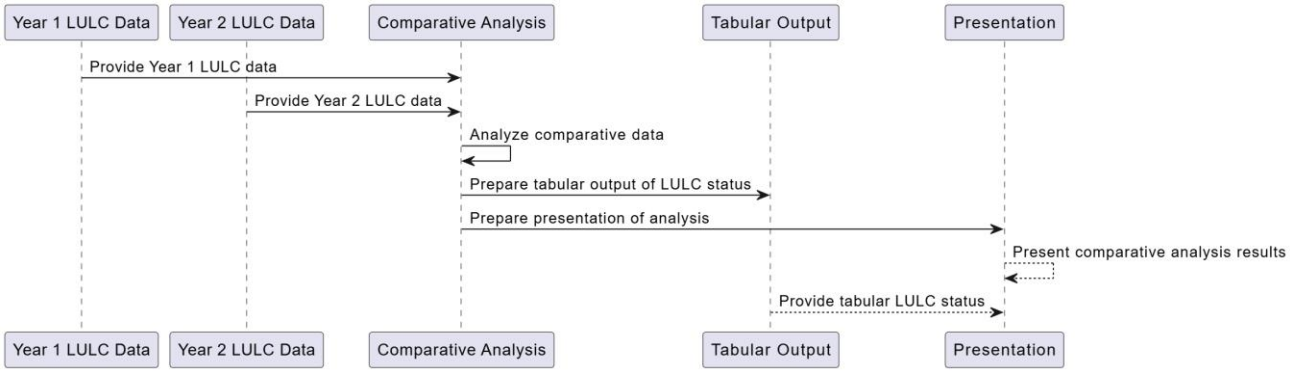


Figure-11 Sequence Flow of Comparative analysis of classes and between two years for change identification.

The comparison results are then represented in both tabular output and graphical chart.

4) **Pre-defined Text Report:**

The report may be generated at various levels such as country/state/district/basin/subbasin. If the user is interested in one region, then the detailed LULC Information and temporal yearly change may be provided with charts and relevant statistics. Comparative analysis for changes are included with facts and ground references in the report.

The sequence diagram Figure-12 starts with providing LULC data for both years, followed by comparative analysis to identify changes.

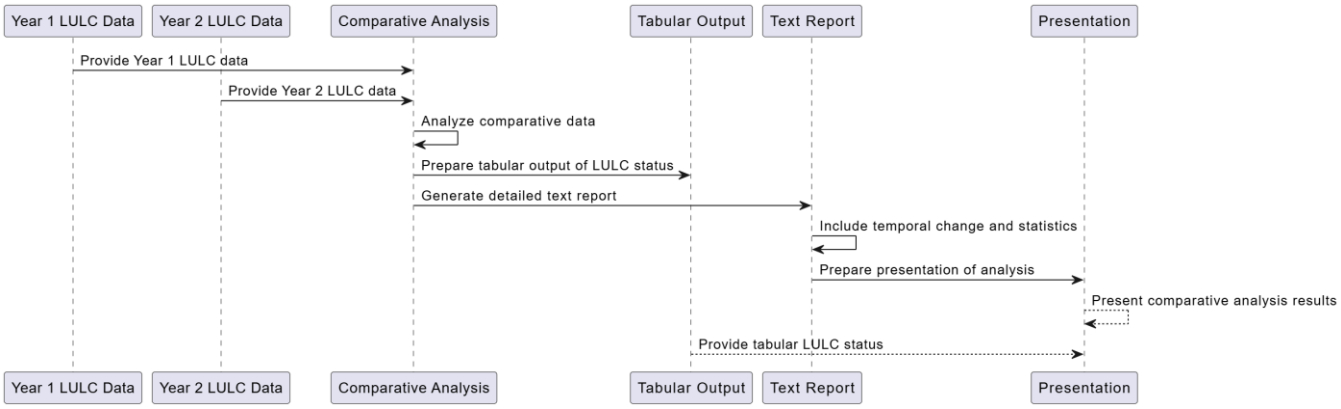


Figure-12 Sequence Flow of Pre-define Text Report Generate

The results are then presented in various formats, including tabular output, a detailed text report, and presentation.

Frequency: Satellite images shall be updated once in Five Years or earlier based on images provided by mapping agency (NRSC). Previous images and corresponding dataset shall be maintained in the system for temporal analysis.

5) **Value Adding Instrumental Tools, Layers and Other Features[7]:**

The system includes the component features like ThreeDTerrain, Navigations, Measure, Swipe Layers, Find Location, Buffer, Query Builder and Default Map. These components add value to the operations for LULC functions. The description of each component is mentioned in Table-1.

[7]Application URL:https://cache.ncog.gov.in/WARIMS

Table-1 Instrumental component features

Sr. No.	Name of the Instrumental DSS Components	Description
1	ThreeDTerrain	The ThreeDTerrain is essential for terrain-based calculations in infrastructure projects like rivers, forests, and dams. It includes map layer display feature to visualize terrain directly on map interface, aiding analysis and decision-making.
2	Navigations	This component allows user to navigate from State > District > Taluka/ Tehsil/ Block > Village and user can analyse the required details.
3	Measure	This component measure distances, areas, offsets, and feature locations on a map or scene. User can draw line to measure length, draw a polygon to measure area, or click an individual feature to get measure info.
4	Swipe Layers	It helps to overlap and compare the 2 layers which could be utilize for temporal analysis, change detection etc. Select two desired layers from layers panel, and then select one of the selected layer as left which will be static and other as right which will slide over the later.
5	Find Location	It assists in locating positions with latitude and longitude (Degree Decimal) or by using grid numbers. Additionally, clicking on the map automatically displays the corresponding latitude and longitude coordinates.
6	Buffer	This component allows user to perform the proximity analysis of the required area. By selecting the area of interest and inputting required range for analysis on the map, infrastructure/ assets within the context/ range area will be displayed.
7	Query Builder	Query Builder provides a GUI for creating query in a simplified way to help users filter records within a particular data layer as per their requirement. Using this DSS component, user can filter layer-wise features to provide certain conditions on the attributes.
8	Default Map	At any given point of time user can navigate to standard default view of map using single click of this button.

The value adding component features as shown in Table-1 supports to perform the functional tasks of different layers.

Moreover, LULC function includes layers and sub-layers to know the economic status and change analysis. Refer the Table-2 with the required selective options for each layer and sub-layers of LULC dynamics.

Table-2 Layers

Sr. No.	Name of the Layers	Sub-Layers
1	Administrative Boundary	• State • District • Sub-District • Village
2	Hydrological Boundary	• Basin • Sub-Basic • Water Shed • River • Major River • River Polygon

3	Base Map Gallery	• OpenStreet Map • High Resolution Map
4	Infrastructure	• Airports • Rail • Roads
5	Land Use - Land Cover	• Year (2005-2006) to Year (2022-2023)

The system also includes some important features as mentioned in Table-3 with Selective Set-Up with available statistical and graphical representation files formats.

Table-3 Other Features

Sr. No.	Features	Selective Set-Up
1	Unit Wise Selection	• Hydrological Set-Up (Select Basin) • Administrative Set-Up (Select State)
2	Pre-defined Text Report	• Hydrological Set-Up (Select Basin, Sub-Basin, Classes and Year) • Administrative Set-Up (Select State, District, Classes and Year)
3	Chart View	Land Use Land Cover Graphical Chart (Pie Chart and Bar Chart)
4	Statistics	Land Use Land Cover Tabular Data (Optional File Formats: CSV/Excel/PDF/DOC)

Based on this requirement design flow the technology specification and the system architecture are defined further.

2.3 Technologies Utilized and Supported

To develop the system as per the functional requirements, the scalable technology frameworks are utilized that can support even future needs. The technologies are enlisted in Table-4.

Table-4 Scalable Technologies and Framework (Utilized and Supported)

Geospatial :	Image Processing and Remote Sensing Techniques
Web Application :	Java SpringBoot 4.0, GeoWebCache, JQuery 3.7.4
Front-end :	OpenLayers 6, Thymeleaf 3.1.2, Bootstrap 5.3 (CSS & JS), HTML5
GIS Software :	QGIS 3.32 Lima
Cloud :	MeghRaj, NIC
Database :	PostgreSQL 9.4

The significance of the technologies as enlisted in Table-4 are described in the below Table-5

Table-5: Significance described for each technology as mentioned in Table-4

Sr. No.	Technology	Description about the technology significance
1.	Geospatial Technologies	Image Processing and Remote Sensing Techniques are utilized to prepare the satellite imagery data for the application in GIS Environment.
2.	Java Spring Framework : SpringBoot	SpringBoot is built on top of conventional spring framework, widely used to develop REST APIs, supports Auto-configuration, provides Apache Tomcat, optimize line of code, Spring Security provides features to create secure Java Enterprise Applications.
3.	GeoServer	GeoServer- GeoWebCache is a tiling server. It is Java web application used to cache map tiles coming from a variety of sources such as OGC Web Map Service (WMS).
4.	QGIS	Open Source GIS software QGIS functions, are utilized to analyze and edit spatial information and mapping services. In addition to compose and export graphical maps. It supports raster, vector, mesh, and point cloud layers. It used to enhance capabilities to effectively classify satellite images and monitor changes with temporal data.

5.	Thymeleaf	Thymeleaf is a modern server-side Java template engine which is used to emphasize the natural HTML templates that can be previewed in browser by double-clicking, to support independent work on UI templates without the need for a running server.
6.	Bootstrap	Bootstrap is open source front-end development framework used to enable responsive web development. The extensive customization options are utilized, to modify colors, typography, spacing, and other visual aspects of its components.
7.	OpenLayers	OpenLayers is an open source JavaScript framework utilized to render interactive maps from map tiles and vector data, to display and manipulate spatial data in web browser. It is used to display maps and perform operations such as data-driven visualization, geo-coding, routing, demographic analysis, and spatial analysis.
8.	PostgreSQL	PostgreSQL, an Open Source relational database system that is used to handle and analyse location data. The key features utilized are PostGIS Extension, Spatial Indexing, Real-Time Analysis, and Integration with Mapping Systems.
9.	MeghRaj, NIC	MeghRaj, NIC services are utilized in order to harness the benefits of Cloud Computing, Government of India. This ensures optimum utilization of infrastructure and speed up the development and deployment of e-Gov applications. For more detail, visit https://www.meity.gov.in/content/gi-cloud-meghraj

2.4 System Architecture

The architectures are designed for development of the functional needs by utilizing the technologies as mentioned in Table-7. The structure includes Data Architecture and GIS based System architecture for LULC. System architectures are kept scalable for future needs.

a) Data Management Architecture

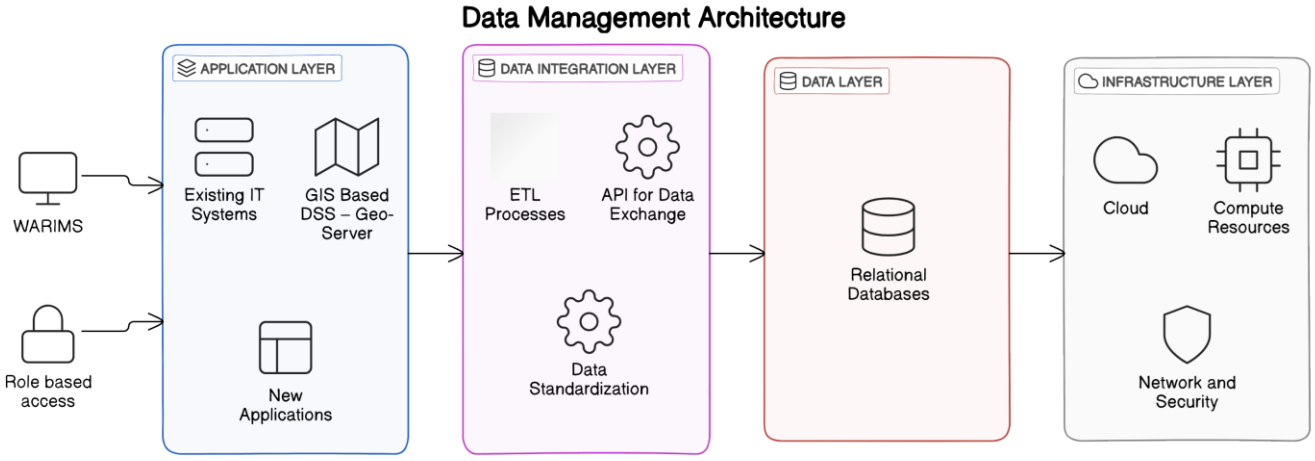


Figure-13 Data Architecture of the System[8]

The Figure-13 depicts data management architecture, outlining the key components involved in managing and processing the flow of data from various sources through different processing stages and storage mechanisms, ultimately supporting decision-making and analysis for LULC data.

Geospatial data management:

Geospatial techniques, including remote sensing and image processing within GIS environment, are utilized to prepare the data. This involves utilizing high-resolution satellite imagery, supplemented by minimal field checks.

The remote sensing and image processing techniques are applied to harness satellite imagery for land cover data and to carry out data pre-processing, respectively.

The processed data is utilized to create detailed land use maps for LULC mapping, illustrating different land cover types. Temporal analysis is conducted to track changes in land use over time using historical data.

[8] Proposed architecture is scalable to support future scope and needs, Refer Future Scope (Index Point-7, Page No-41)

Input Data Required

The input data required are various medium to high resolution satellite sensor images, legacy data and Survey of India (SoI) topo-sheets. Below are the parameters of the Geospatial time series data for change analysis in Land Use Land Cover:

Geospatial Time Series Data[9]:

a) Frequency: Yearly
   1. Monsoon Season — Kharif: August - October
   2. Post-Monsoon — Rabi: December - March
   3. Pre-Monsoon — Zaid: April — May

b) Resolution:[10]
   1. IRS R2 LISS III (23.5m) at 50k scale
   2. IRS P6 AWiFS (56m) at 250K scale
   3. ESA Sentinal-2 (10-15m)
   4. IRS R2 LISS IV (5.8 m) at 25k scale
   5. RISAT EO4 SAR FRS-2(3m), CRS (50m)

c) Extent of Coverage: Whole country (India)

Data Validation

Initial screening is required before integrating data received from various mapping agencies for its completeness and accuracy. Checking of figures/stats quoted in published reports with geographical raster/vector data layer provided/generated for particular mapping year. LULC classification and mapped area should also justify statistics, surveyed by department of Economics and Statistics.

b) GIS based Decision Support System Architecture

The GIS based system architecture includes different layers and sub-layers of this decision support system. As shown below the Table-6 includes the description about the Main Layers and Sub-Layers of the GIS based System Architecture as shown in Figure-14.

Table- 6 System Design Layers

Main Layers	Sub-Layers
A. User Access Layer	• User Interface (UI): Web Platform and Dashboards • Access Control: Role-based access for administrators, planners, decision-makers, scientists, and citizens. •

B. Application Layer	• GIS-based Decision Support Systems (DSS):
	  ○ Geo-Server: For GIS data serving and management.
	  ○ Map Services: Integration with map services for visualization.
	• Existing IT Systems Integration
	• New Applications Development

C. Data Integration Layer	• ETL: Extract, Transform, Load operations for data integration. • APIs: For data exchange between different systems and applications. • Data Standardization: Ensuring data consistency, quality.
D. Data Layer	• Database: ○ Relational Databases: For structured data.

[9] Annexure-1: BSR of Land Use Land Cover from NWIC: Input data required Page-3 (Standard Schedule)
[10] Refer Annexure-6 for Abbreviations

E. Infrastructure Layer	• Cloud Infrastructure:
	  ○ Cloud Platform: Infrastructure-as-a-Service (IaaS) and Platform-as-a-Service (PaaS) resources.
	  ○ Compute Resources: Virtual machines, GPUs for processing power.
	  ○ Storage Resources: High-capacity cloud storage for datasets.
	• Network Infrastructure: High-speed network for data transfer and accessibility.
	• Security Infrastructure: Firewalls, encryption, access controls for data security.

The below Figure-14 depicts the process flow of the main layers and sub-layers

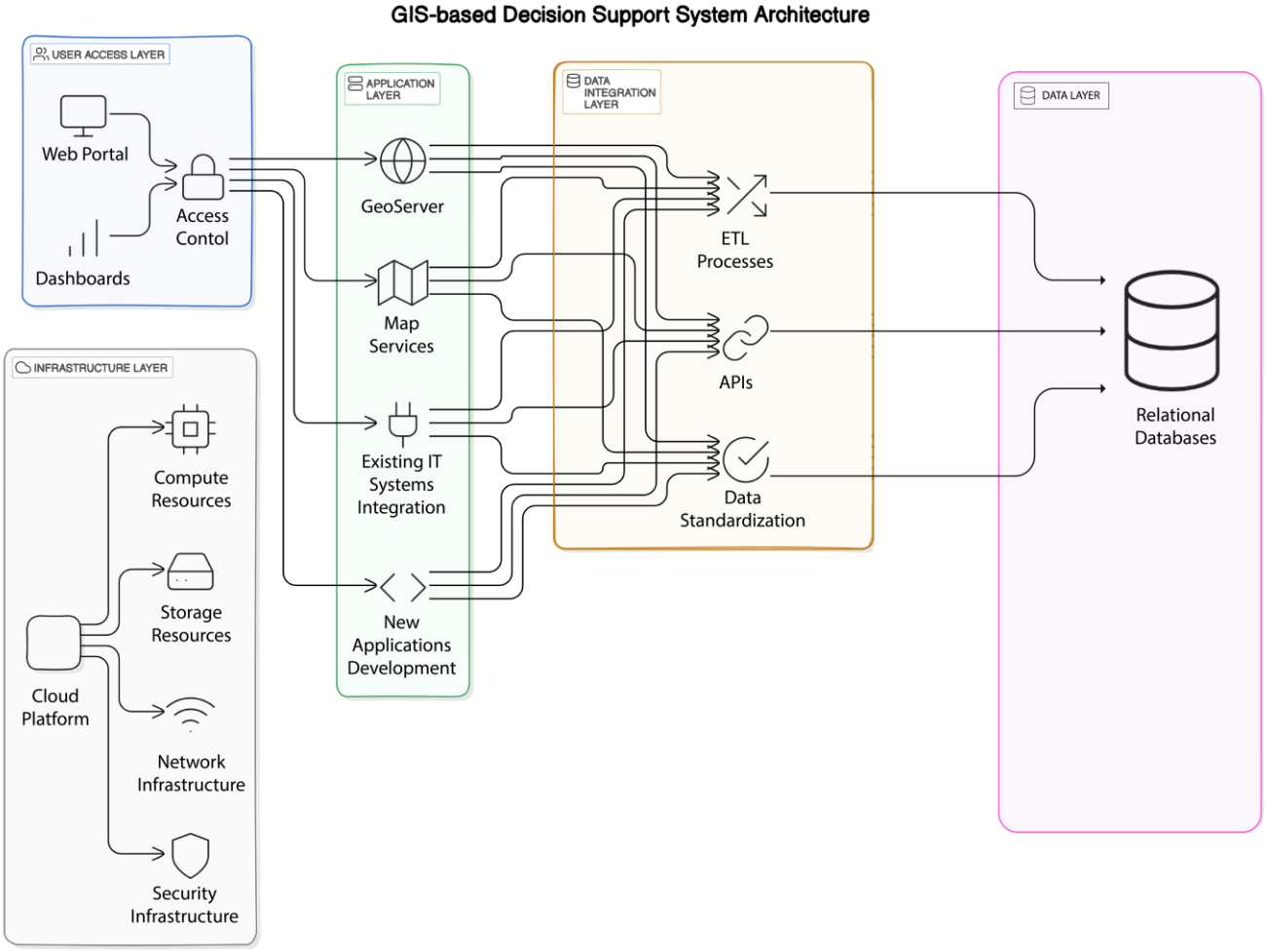


Figure-14 GIS based System Architecture[11]

The Figure-14 shows the system architecture of GIS-based Decision Support System (DSS).
It outlines the various components involved in collecting, processing, and analysing spatial data to support decision-making used for LULC dynamics.

Approach

National Remote Sensing Centre (NRSC) Land use division finalized a threefold classification system and adopted the same for Nationwide LULC analysis at various scale mapped every year. NWIC receives classified outputs on both 50k & 250K scale. To generate LULC using High resolution satellite data and QGIS, NRSC classification system can be adopted followed with intense ground checks. Both raster and vector-based mapping approach is considered to get most out of optical and microwave imageries.

[11] Proposed architecture is scalable to support future scope and needs, Refer Future Scope (Index Point-7, Page No-41)

2.5 Entity Relationship Diagram

The provided ER diagram in Figure – 15 illustrates a relationship between two major entities: lulc_subbasin and lulc_district of the LULC. It shows one-to-many relationship between two classes: **lulc_subbasin** and **lulc_district**.

Figure-15 ER Diagram for LULC data

Two Major Entities:

- **lulc_subbasin:** Represents a subbasin unit, associated with LULC data.
- **lulc_district:** Represents a district unit, associated with LULC data.

Unique Attribute: "uuid" attribute is unique identifier, and is present in both entities.

Overall, ER diagram shows the relationship between sub-basins and districts, for organizing and managing LULC data.

Data Attributes

a) **Geographical and Environmental Data Attributes:** The provided table in Figure-14 represents data attributes of geographical and environmental. It contains information about various spatial units and their attributes.

- **Entity:** The attributes represent "geographical_data".
- **Attributes:** The table includes attributes such as:

Identifiers:	OBJECTID, uuid, subbasin, sbcode, basin, bacode.
Temporal:	Year
Numerical:	built_up, kharif_crop, rabi_crop, zaid_crop, double_triple_crop, current_fallow, plantation, evergreen_forest, deciduous_forest, degraded_scrub_forest, littoral_swamp, grassland, shifting_cultivation, wasteland, rann, waterbodies_max, waterbodies_min, snow_cover, basin_f, subbasin_f.
Alias of the attributes	Object ID, UUID, Sub Basin, Sub Basin Code, Basin, Basin Code, Year Built Up, Kharif Crop, Rabi Crop, Zaid Crop, Double/Triple Crop, Current Fallow, Plantation, Evergreen Forest, Deciduous Forest, Degraded/Scrub Forest, Littoral Swamp, Grassland, Shifting_Cultivation, Wasteland, Rann, Maximum Area of Waterbodies, Minimum Area of Waterbodies, Snow Cover

b) **Land Use Land Cover Data Attributes:** The provided table in Figure-15 represents a data attributes of land use and land cover. It contains information about various spatial units and their attributes.

- **Entity**: The attributes represent data related to "land_use_cover".
- **Attributes**: The table includes attributes such as:

Identifiers:	uuid, district, dtcode, state, stcode.
Temporal:	Year
Numerical:	built_up, kharif_crop, rabi_crop, zaid_crop, double_triple_crop, current_fallow, plantation, evergreen_forest, deciduous_forest, degraded_scrub_forest, littoral_swamp, grassland, shifting_cultivation, wasteland, rann, waterbodies_max, waterbodies_min, snow_cover.
Textual:	statename_f, distname_f.
Alias of the attributes	Object ID, District, District LGD Code, State, State LGD Code, Year, Built Up, Kharif Crop, Rabi Crop, Zaid Crop, Double/Triple Crop, Current Fallow, Plantation, Evergreen Forest, Deciduous Forest, Degraded/Scrub Forest, Littoral Swamp, Grassland, Shifting_Cultivation, Wasteland, Rann, Maximum Area of Waterbodies, Minimum Area of Waterbodies, Snow Cover

geographical_data	
OBJECTID	string pk
uuid	string
subbasin	string
sbcode	string
basin	string
bacode	string
year	int
built_up	float
kharif_cro	float
rabi_crop	float
zaid_crop	float
double_tri	float
current_fa	float
plantation	float
evergreen_	float
deciduous_	float
degraded_s	float
littoral_s	float
grassland	float
shifting_c	float
wasteland	float
rann	float
waterbodie	float
waterbod_1	float
snow_cover	float
basin_f	float
subbasin_f	float

Figure-16 GIS & Environment Data Attribute

land_use_cover	
id	uuid pk
district	string
dtcode	string
state	string
stcode	string
year	int
built_up	float
kharif_cro	float
rabi_crop	float
zaid_crop	float
double_tri	float
current_fa	float
plantation	float
evergreen_	float
deciduous_	float
degraded_s	float
littoral_s	float
grassland	float
shifting_c	float
wasteland	float
rann	float
waterbodie	float
waterbod_1	float
snow_cover	float
statename_f	string
distname_f	string

Figure-17 LULC Data Attribute

The data-tables in the Figure-16 and Figure-17 stores data related to LULC, and other environmental factors for different spatial units (sub-basins, basins)/ (district, states).

2.6 Class Diagram

The class diagram as shown in the Figure-16 represents schema for a land use and land cover dataset. It consists of two main classes: **lulc_subbasin** and **lulc_district.**

a) lulc_subbasin class - Contains attributes for subbasin-level information, such as:

- subbasin_f (character varying): Subbasin name
- sbcode (character varying): Subbasin code
- basin_f (character varying): Basin name
- bacode (character varying): Basin code
- statename_f (character varying): State name
- stcode (character varying): State code

b) lulc_district class - Contains attributes for district-level information, such as:

- OBJECTID (double precision): Unique identifier
- year (double precision): Year
- built_up (double precision): Built-Up
- kharif_cro (double precision): Kharif Crops
- rabi_crop (double precision): Rabi Crops
- zaid_crop (double precision): Zaid Crops
- double tri (double precision): Double/Triple Crops
- current_fa (double precision): Current Fallow
- plantation (double precision): Plantations
- evergreen_ (double precision): Evergreen Forest
- deciduous (double precision): Deciduous Forest
- degraded_s (double precision): Degraded/Scrub Forest
- littoral s (double precision): Littoral Swamp
- grassland (double precision): Grassland
- shifting_c (double precision): Shifting Cultivation
- wasteland (double precision): Wasteland
- rann (double precision): Rann
- waterbodie (double precision): Maximum area of Water Bodies
- waterbod 1 (double precision): Minimum area of Water Bodies
- snow_cover (character varying): Snow Cover

In Figure-18[12], refer the Class Diagram for lulc_subbasin class and lulc_district class.

[12] Refer Figure-18 in Page-15

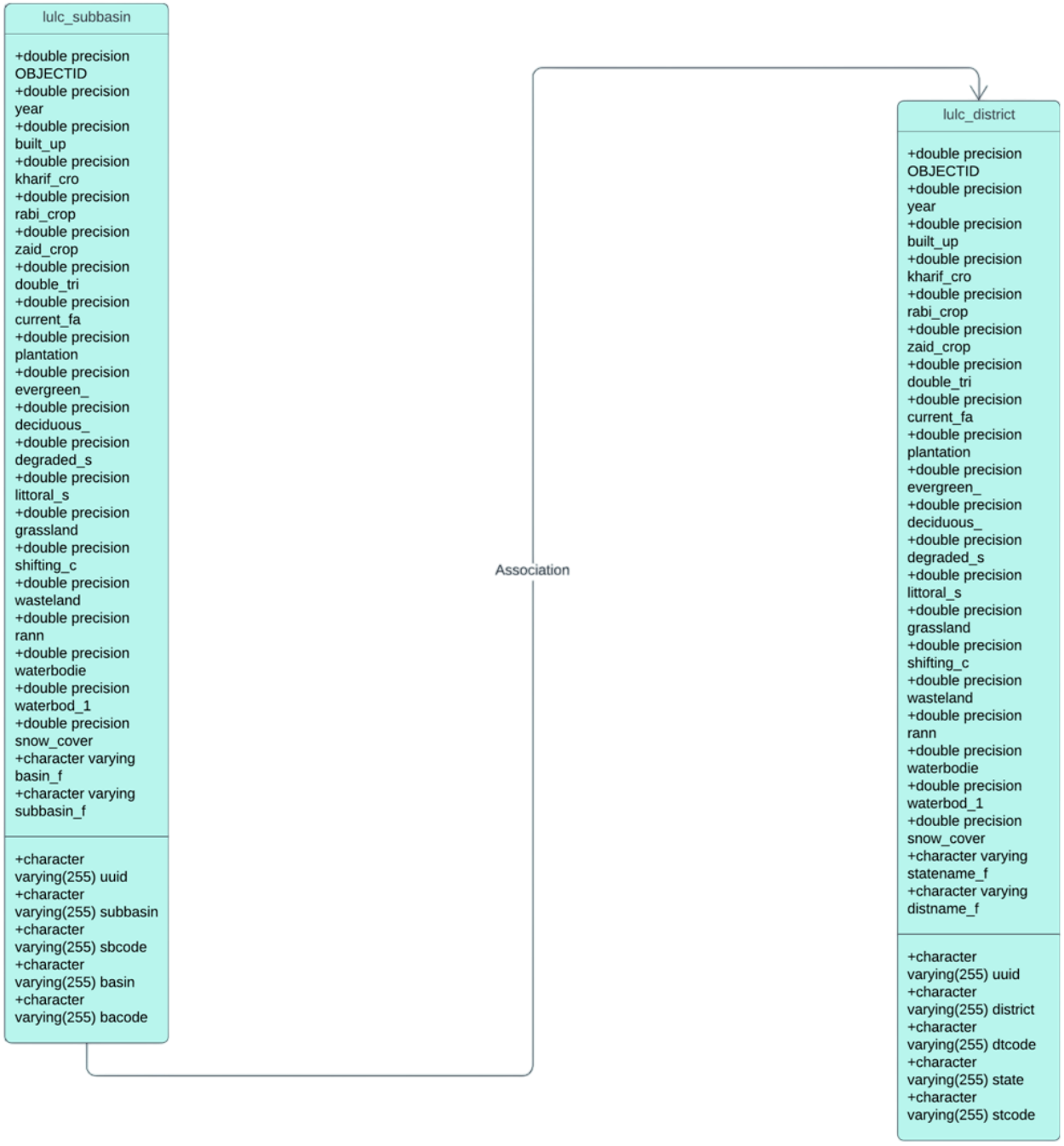


Figure-18 Class Diagram of classes: lulc_subbasin and lulc_district

lulc_subbasin class:	**lulc_district class**:
Has one-to-many relationship with the lulc_district class, where one subbasin can have multiple districts.	Has foreign key relationship with lulc_subbasin class, referencing subbasin attribute to establish connection between subbasin and district.

Overall, the class diagram in the Figure-18 provides suitable structure for storing and managing LULC data at both subbasin and district levels, to analyze and compare LULC changes over period of time.

2.7 Algorithm[13]

The major steps in LULC mapping are data preparation by selecting image, Interpretation to identify change area, ground truth and post classification correction, followed by generation of output.

The approach involves two methods for classification:

(i) Vector based on-screen visual interpretation of satellite images and
(ii) Raster-based image classification.

[13] Annexure-1: BSR of Land Use Land Cover from NWIC, Page-3

a) **On-screen visual interpretation** can be applied on to the terrain corrected Resourcesat-2 LISS III & LISS IV imagery. The methodology essentially is based on editing the previous year digitized layers for updating with reference to current year images. The output generally is good fit at 50k scale mapping for LISS-III and at 25k scale for LISS-IV image. This creates an advantage to assess changes over the period of time.

The methodology[14] for LULC mapping using IRS LISS III satellite data. It includes data acquisition, pre-processing, classification, ground truthing, quality evaluation &accuracy assessment, data integration and mapping &analysis.

b) **Classification System for LULC mapping:** IRS P6 AWiFS satellite data can be used for LULC mapping at 1:250K scale. Raster based digital image classification approach is successfully applied for country level mapping by NRSC/ISRO. For identification of agriculture, forest and water Normalised Difference Indices method are very popular and result oriented.

The flowchart[15] of raster based LULC classification depicts the classification methodology for land use/land cover mapping using multi-temporal AWiFS (Advanced Wide Field Sensor) and MODIS (Moderate Resolution Imaging Spectroradiometer) satellite data.

Overall, the approach helps to extract information from satellite imagery and produce LULC maps.

2.8 Process involved in data integration and development

The steps[16] for the process flow involved in data integration and development are designed in form of sequential diagram. The Figure-19 includes the sequence diagram about the flow of LULC data processing and analysis for further integration and development.

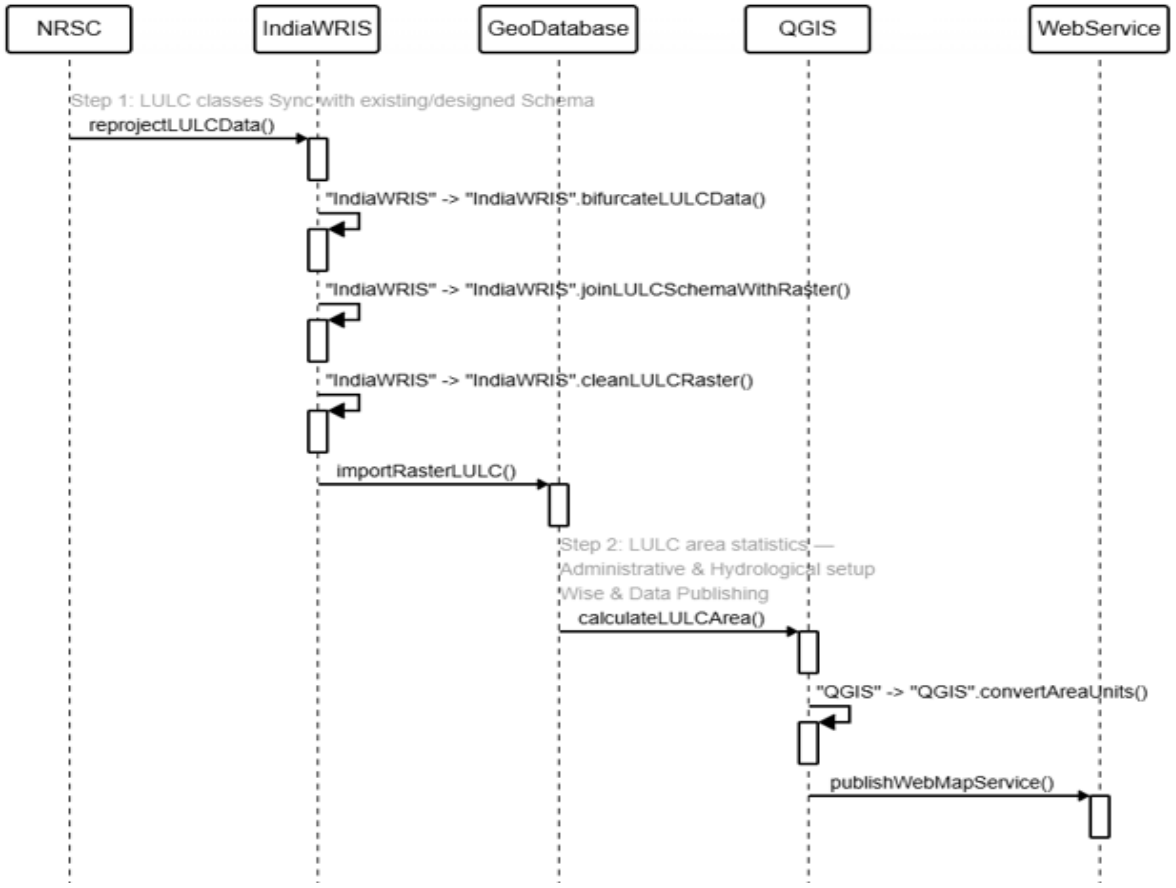


Figure-19 Sequence Diagram of Data Integration and Development

Overall, in Figure-19, the sequence diagram outlines the key steps involved in processing LULC data, from data preparation to analysis and visualization.

[14] Annexure-1: BSR of Land Use Land Cover from NWIC, Section: Algorithm/Tool (i) Methodology,Page-4
[15] Annexure-1: BSR of Land Use Land Cover from NWIC, Section: Algorithm/Tool (ii) Flowchart of raster based LULC classification methodology,Page-4
[16] Annexure-1: BSR of Land Use Land Cover from NWIC, Section Algorithm/Tool: Process involved in data integration & development (by NWIC), Page-5

2.9 Project Undertakings

Below in the Table-7 are the undertakings defined for the BISAG-N and NWIC, respectively.

Table- 7 Undertakings

BISAG-N	NWIC
• Design, Development and Deployment over cloud • Technical support • Providing of hosting servers and other software. • Standard Testing at PoC development level. • Operations and Maintenance (O&M) including Knowledge Transfer, Capacity Building & Training	• Overall project co-ordination, monitoring, guidance and support required for the project. • NWIC shall obtain and provide all the technical data, reports etc. required for the project. • NWIC shall appraise the project progress to the committee constituted to oversee WARIMS project implementation • Collaborate on requirement finalization and approval of designs and developments • User Acceptance Testing (UAT)

Accordingly, the further project plan and milestones are defined to develop the project requirements for the: Land Use Land Cover (LULC).

3. Project Plan

The project plan includes the milestone, phases, tasks, estimated and scheduled timeline, dependencies, risks and change management process for the system development.

3.1 Milestones

The milestones are planned for design, development, testing and deployment of the system.

- Milestone-1: Requirement Specification: Understanding and Analysis
- Milestone-2: System Design
- Milestone-3: System Development
- Milestone-4: System Quality Testing
- Milestone-5: User Acceptance Test (UAT).

Table-8 as shown below provides the details about the milestones, phases, estimated timeline and resource allocation for the system development of the -Land Use Land Cover.

Table –8: Project Milestones*

Milestones	System Development Phases	Total Effort (Estimated Work Days)	Team
1	Requirement: Understanding and Analysis & Review	5	Project Manager and Project Analyst
2	System Design	3	UI/UX Graphics and Web Designer
3	System Development	10	Software Developers
4	System Quality Testing	2	Software Quality Tester
5	User Acceptance Test (UAT)	5	NWIC

*Time may negligibly vary for specific tasks dependencies/risk/change where requirements may be critical. It is planned, monitored and reviewed by the project manager.

3.2 Phases and Tasks Detail

The required tasks are defined for each phase and the resources are assigned to accomplish those tasks as per project plan.Table-9 defines phases of each milestone. In same table, tasks of each phase are defined with details of resource allocation to accomplish that particular task of the phase. The project development phases and tasks are planned, monitored and reviewed by project manager and reported to project director.

Table-9: Project Development Phases and Tasks*

System Development Phases	Tasks Details	Assigned to
Requirement: Understanding and Analysis & Review	Requirement Understanding	Project Manager and Project Analyst
	Requirement Analysis	
	Data Availability	GIS Analyst
	Stakeholder Co-ordination	Project Analyst
System Design	Wireframe	Project Analyst / UI/UX Graphics Designer
	Approval from Stakeholder	NWIC
	Designing	Web Designer
	Review and Feedback	NWIC and MoJS Internal Agencies
System Development	Development and Deployment	Project Manager and Software Developers
System Quality Testing	Functional Testing	Project Analyst & Software Quality Tester
User Acceptance Test (UAT)	Feedback	NWIC, Domain Agency
	Go-Live	-

Whereas, Table-10 displays the number of personnel from BISAG-N assigned to accomplish the corresponding tasks of each phase and milestone.

Table-10: Project Development Resources

Sr. No.	Role	Number of Personnel
1	Project Director	1
2	Project Manager	1
3	Cloud Engineer	1
4	Software Developers	2
5	Software Quality Tester	1
6	Database Administrator	1
7	UI/UX Designer	1
8	Project Analyst / GIS Analyst	1
	Total	9

3.3 Project Schedule

The project plan for different phases and tasks of each milestone is executed and is defined with actual timeline in the project schedule.

Table-11 presents a summarized project schedule outlining the phases and tasks associated with the milestones necessary for the development of the Land Use Land Cover.

Table-11: Project Schedule

Task No.	Task Name	Start Date	End Date	Duration (Days)*
1	Requirement Specification Understanding	6-Oct-23	7-Oct-23	1
2	Requirement Specification Review and Analysis	6-Oct-23	7-Oct-23	1
3	Data Availability	6-Oct-23	7-Oct-23	1
4	Designing	7-Oct-23	9-Oct-23	2
5	Visualization on Map at country to State/District/Basin/Sub-Basin Level.	9-Oct-23	11-Oct-23	2
6	Filtering options for data (forest type wise) need to be provided. Category/class wise data visualization should be admin-wise (different states up to district) or hydrological boundary-wise (Basin up to sub basin).	11-Oct-23	17-Oct-23	6
7	Graphical data presentation should be both pie diagrams and Bar charts.	15-Oct-23	20-Oct-23	5
8	Class wise distribution of Area based upon Hydrological and Administrative	12-Oct-23	15-Oct-23	3
9	Comparison between two consecutive year with for all classes and also for single class.	15-Oct-23	22-Oct-23	7
10	Classes wise data mentioned in data panel. And Year wise data mentioned in the data panel.	11-Oct-23	17-Oct-23	6
11	Data Year drop down list available for user in the Data panel.	13-Oct-23	14-Oct-23	1
12	Comparison between two consecutive year with for all classes and also for single class.	15-Oct-23	22-Oct-23	7
13	Data Year drop down list available for user in the Data panel	25-Oct-23	26-Oct-23	1
14	Predefine Report Generate	1-Nov-23	5-Nov-23	4
15	In Comparison Added Swipe tool	10-Jan-24	13-Jan-24	3
	User Acceptance Testing (UAT)	(NWIC)		
	Go-Live	-	-	-

*The duration is estimated for each task based on its dependencies on other tasks and perform those tasks simultaneously to try and achieve the estimated timeline of the project.

Along with the project schedule, the Gantt chart is essential for several reasons like visual representation, task tracking, dependency management, resource planning & allocation and progress monitoring of the overall project management.

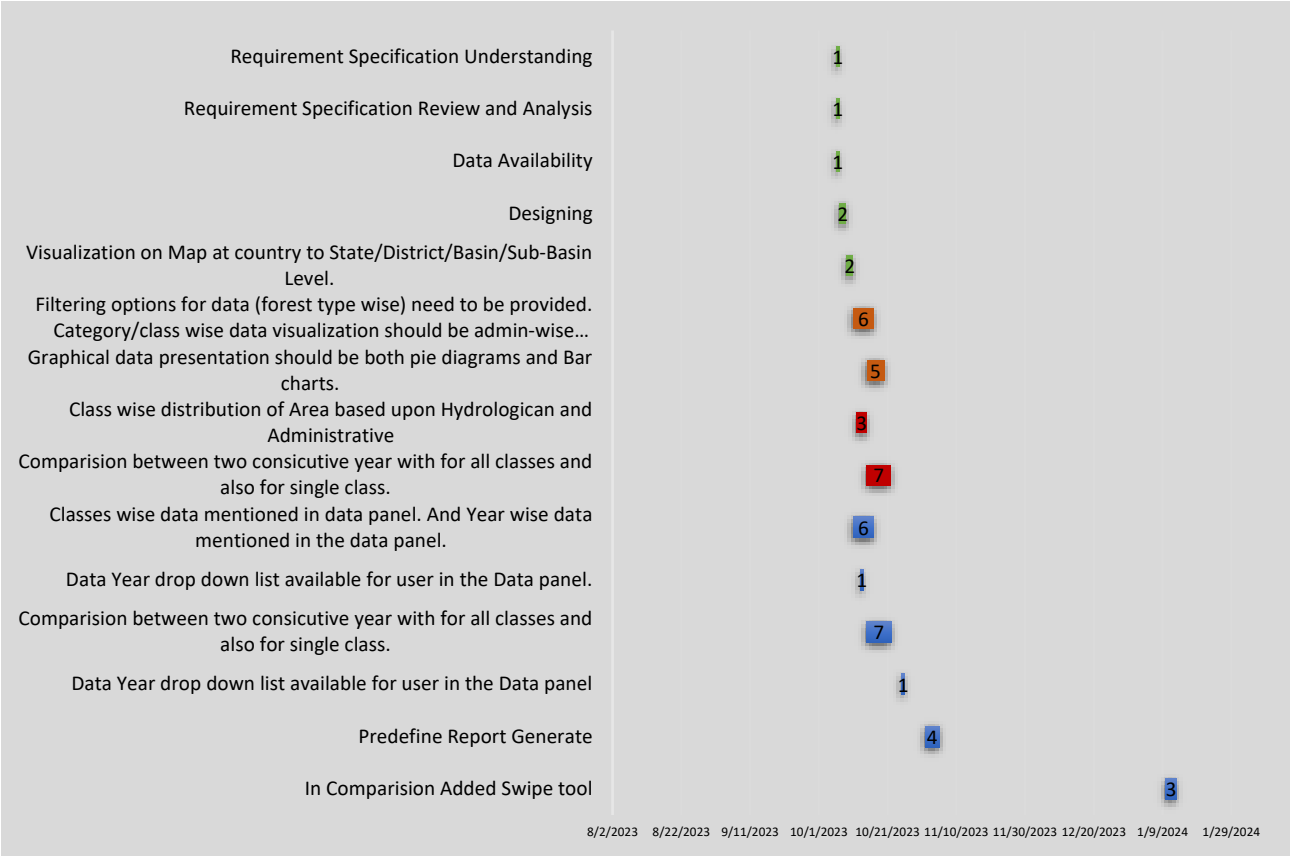


Figure-20 Gantt chart

Figure-20 demonstrates the Gant chart which is based on the project schedule.

The Gantt chart provides the information of tasks that are completed on specific timeline. The horizontal bar represents the duration of each task, which helps in identifying the dependencies and review the status of each task throughout the project development.

3.4 Dependencies, Risk and Change Management[17]

In project management, effectively managing risk, dependencies, and changes are crucial for success. Below are the key factors that are identified for Dependencies, Risk and Change Management within the project.

Understanding these interrelated elements enhances project resilience and facilitates smoother execution and delivery.

3.4.1 Dependencies:

Dependencies define the relationships between tasks, influencing their sequence and highlighting how delays can affect the overall timeline.

List of key Dependencies:

a) Non-availability of appropriate season data sometimes put constraints on the interpretation of the features owing to poor reflectance of data, cloud conditions/images and other phenological changes.
b) Incomplete or manipulated data (Interpretational errors).

[17] Annexure-1: BSR of Land Use Land Cover from NWIC

c) Registration errors when using old SOI toposheet for reference purpose. Unmatched GIS layer feature area with published statistics. Generally, raster and vector classification output doesn't match due to difference in mapping approach.

d) Software solutions and trainings are highly required in working with High Resolution Microwave Image.

3.4.2 Risk Management:

Risks are potential events that could negatively impact project goals, and early identification allows for the development of mitigation strategies. Performing risk management entails various risks and challenges.

At different stages of project, below are potential risks that were mitigated during project:

- The risk of requirements management of the project is mitigated by clear communication with stakeholders, coordinate data collection, document requirements, and verify understanding regularly.
- The risk of UI/UX design is mitigated by user-friendly design principles and tested usability.
- The robust data architecture systems with suitable validations are implemented to mitigate the risk of data quality management.
- The risk of coding standard and code audit are mitigated with code review and audit by qualified developers, prioritized critical issues, and allocate resources efficiently.
- The project code testing is done with standard testing practices and compared output.[18]
- The risk configuration issues are mitigated by using cloud setup of MeghRaj, by NIC.

3.4.3 Change Management

Changes that often arise from evolving requirements or unforeseen circumstances need to be managed carefully to maintain alignment with project objectives and stakeholder expectations.

Table-12 Change Management*

Change Log No.	Change Details	Updated Date	Status
1	Graph axis details and legends should be proper.	15/10/23	Completed
2	Percentage column should be added in the table.	20/01/24	Completed
3	Table column title should be reframe in proper format	19/01/24	Completed
4	Thousand separators should be placed in graph and table in all hierarchy.	19/01/24	Completed
5	Unit of Area should be shown in the data panel.	19/01/24	Completed
6	In swipe tool, year to be mentioned below the bar as well as vertical line should be placed on the map and latest year data should be on the top LULC (WRIS-MIS-07)	12/04/24	Completed

*Later to the development completion, and unless there are critical changes, any further queries will be handled through support.

Table-12 defines the status about each of the change performed during the project development after clear communication between the stakeholders.

[18] Refer Index Point 3.5 Software Testing, Page No.- 22.

3.5 Software Testing

The software testing is performed for thorough and comprehensive evaluation.
The project development is followed by testing checklist to ensure comprehensive evaluation.

Usually, there are many different tests in software development like Stored HTML, Malicious File Upload, Session Hijacking, OTP Bypass, SQL Error, Clear Text Credentials, Account Lockout Issue, Improper Error Handling, Concurrent Login, OTP & Form Bombarding, Outdated JQuery and Bootstrap, Improper Input Validation, Local IP Disclosure, CSP Header Missing, Auto Complete Enabled, Cookie w/o Same Site Attribute, and others. Table-13 enlists testing checklist of standard practice that were based on the requirement specification of LULC project development.

Table-13: Testing Checklist

Sr. No.	Testing Checklist	Preventive Measures within Development
1.	Stored HTML Injection	Have validated and sanitized user inputs, and have implemented proper encoding before rendering content.
2.	Session Hijacking	Have used HTTPS, enforced secure cookie attributes, and regenerated session IDs after login. Implemented session timeouts, monitor concurrent sessions, and notify users on log-out. Track IP addresses for anomalies and employ Cross-Site Request Forgery protection. IP addresses are encrypted.
3.	SQL Error	Used prepared statements, system will validate user inputs, implemented proper error handling, and leverage Object Relational Mapping frameworks like Hibernate.
4.	Improper Error Handling	Used centralized exception handling with @ControllerAdvice and log errors w/o exposing sensitive information. Provided user-friendly error messages and stack traces are hidden from end users.
5.	Outdated JQuery and Bootstrap	Regularly update to the latest version, use a package manager for dependency management. Monitor for security vulnerabilities with automated tools.
6.	Improper IP Validation	Used trusted libraries for strict validation of IPv4 and IPv6 formats and implemented whitelisting/blacklisting for IP addresses. Incorporated rate limiting to control requests and sanitize all user inputs. Done regular log access attempts and validated logic.
7.	Local IP Disclosure	It is ensured that error messages and logs do not expose internal IP addresses and configure firewalls to restrict external access. Environment variables are used to manage IP addresses and set server.address in application.properties to bind the server to a specific interface. Additionally, logging settings to avoid logging sensitive information and implement security headers to mitigate exposure risks is configured.

Whereas, the User Acceptance Testing will be performed by NWIC[19].

[19] Refer Index Point 2.9, Table-7 Undertakings, Page No.-17

4. User Manual[20]:

Refer this user manual detail to walk-through and understand the LULC.
The link of the Platform WARIMS (ncog.gov.in) is: *https://cache.ncog.gov.in/WARIMS/*

4.1 Dashboard Landing Page

The exhaustive Proof of Concept consists of multiple use cases and scenarios as per the finalized requirements by the core committee. In Figure-21, the dashboard of the landing page is as below:

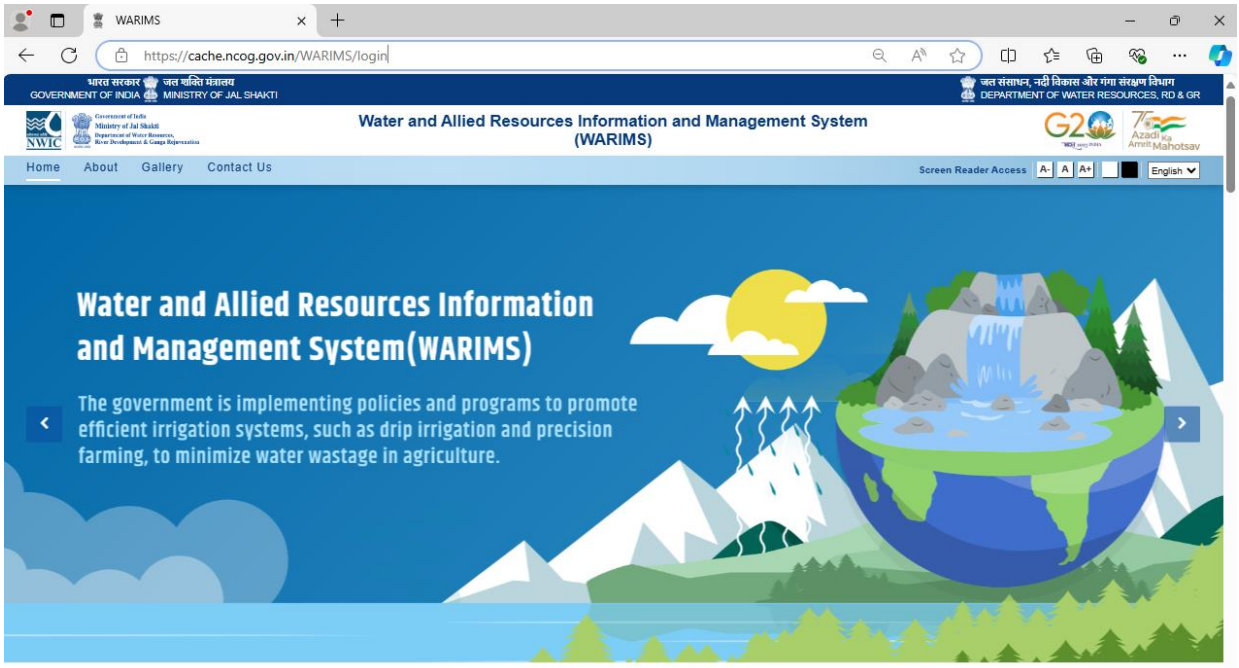


Figure-21 Dashboard Landing Page

Figure-22 shows the themes displayed in the dashboard of the landing page. User will select particular theme to access the Application and its Use Case.

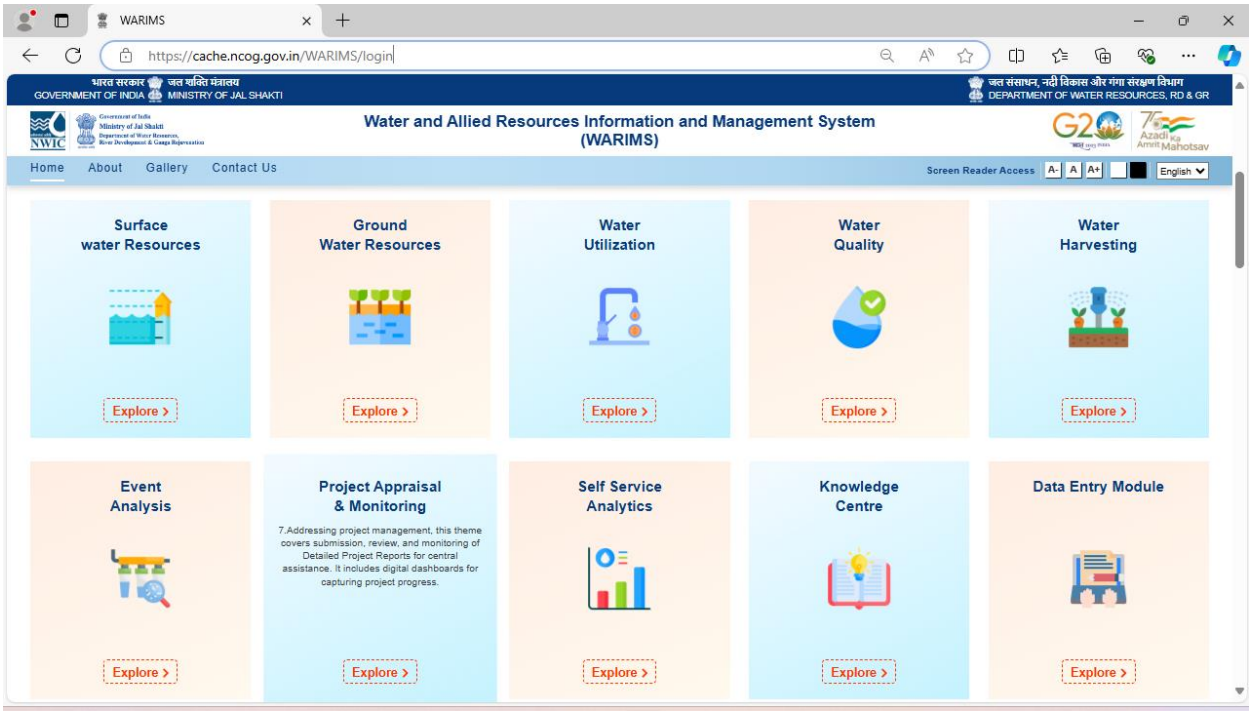


Figure-22 Themes on the Dashboard Landing Page

[20] Application URL: https://cache.ncog.gov.in/WARIMS

4.2 Access the Land Use Land Cover

As shown in Figure-23 follow the below steps to access the LULC in the WARIMS platform.

Steps:
Select → Surface Water Resources → Master Information System → Land Use Land Cover

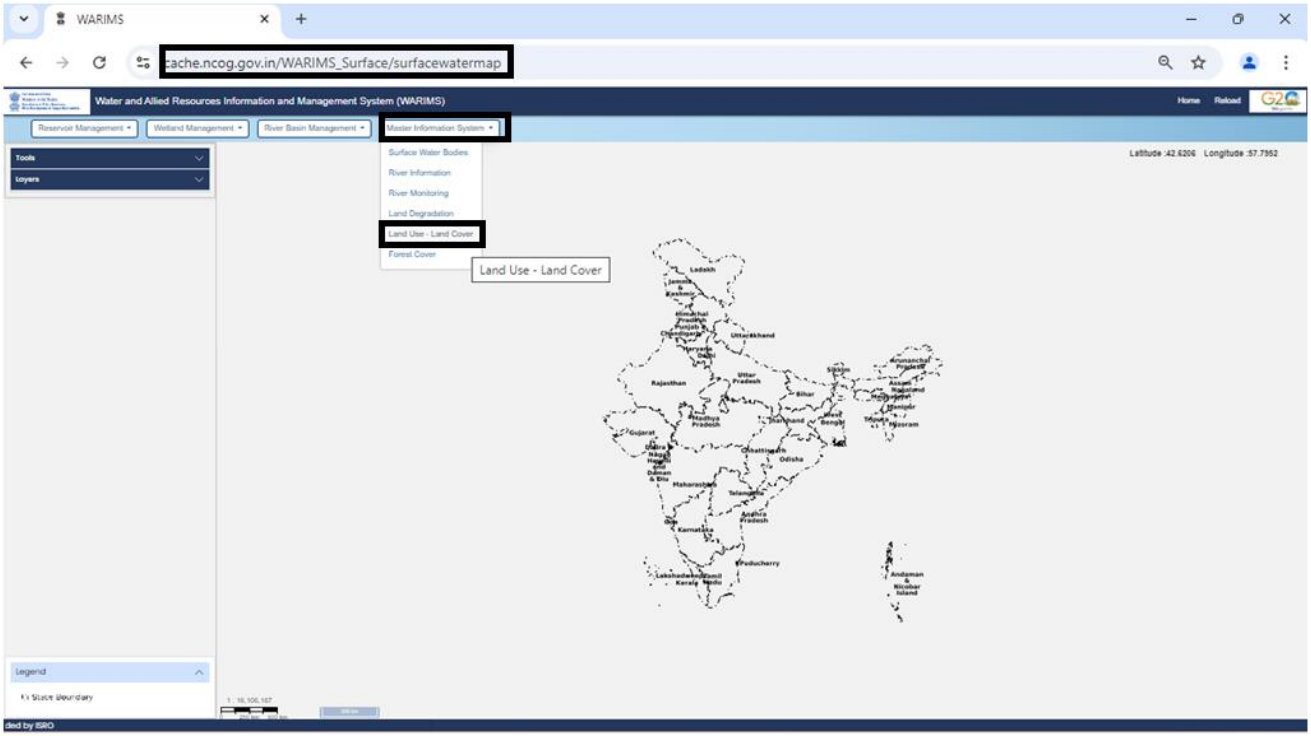


Figure-23 Access Land Use Land Cover (LULC)

Figure-24 shows the initial page of the: Land Use Land Cover (LULC)
of Application: WRIS – Land Resources, and Theme: Master Information System

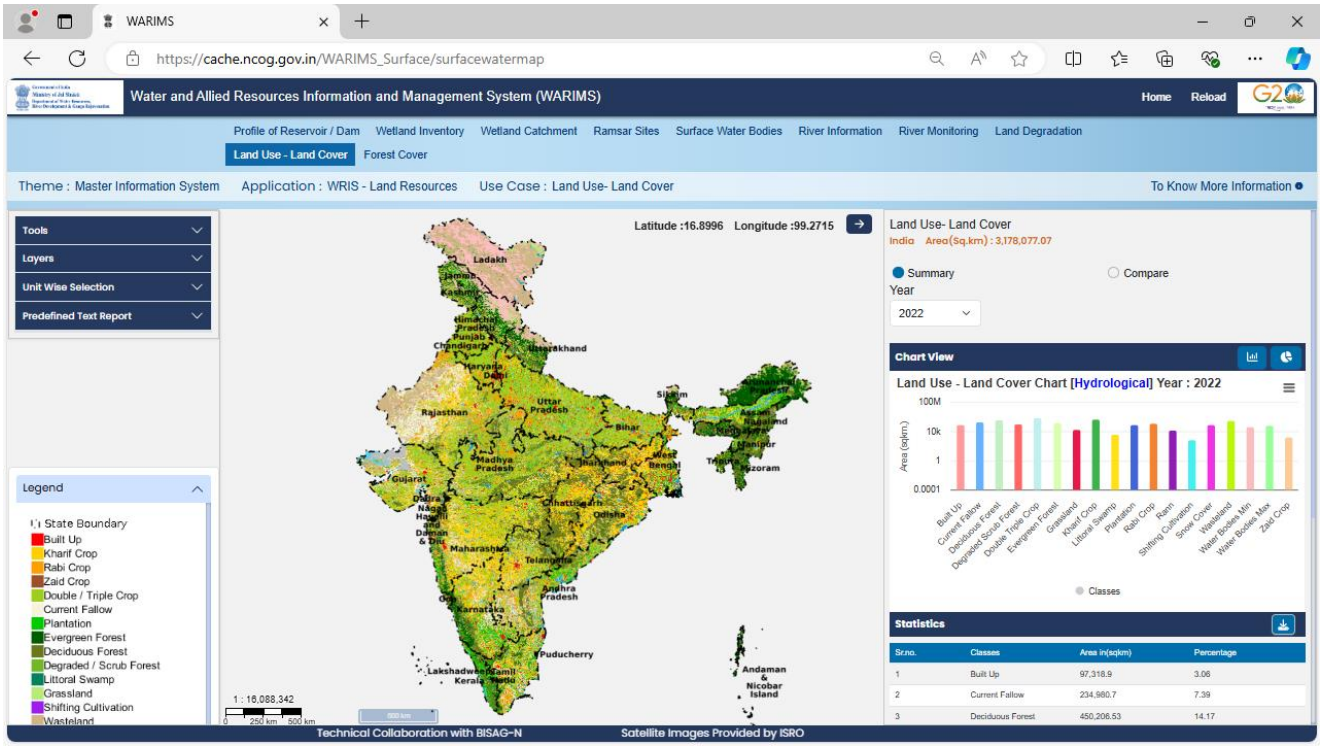


Figure-24 Home Page of the Land Use Land Cover (LULC)

4.3 Important Features

The Important features of the LULC include:

1. Tools
2. Layers
3. Unit Wise Selection
4. Predefined Text Report
5. Legend
6. Summary and Comparison (Year Wise) using Chart View (Bar Chart / Pie Chart) and
7. Statistics Report

Let us see the functionality of each of these features.

4.3.1 Feature Tools

The Figure-25 highlights the “Tools” options in the Left Side Vertical Menu.
The Tools includes the following features:

a) ThreeDTerrain b) Navigations c) Measure d) Swipe Layers	e) Find Location f) Buffer g) Query Builder h) Data Report from Query Builder i) Default Map

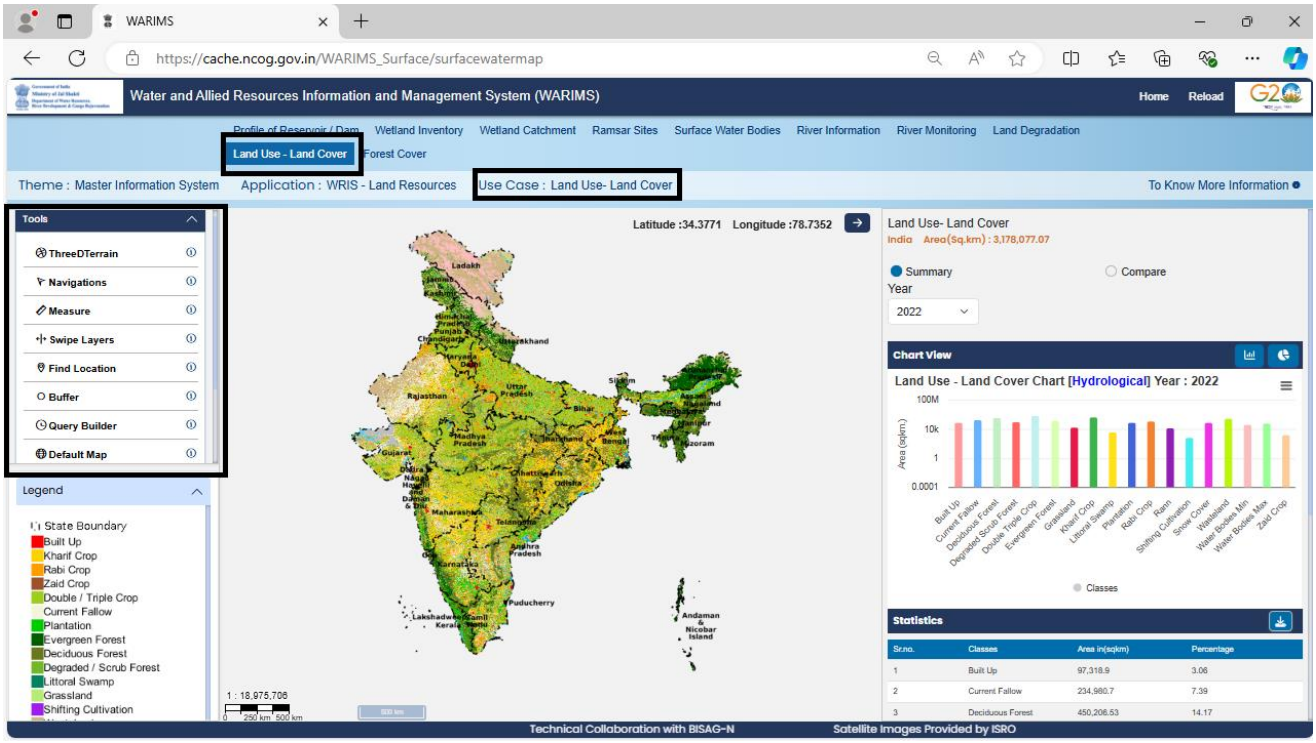


Figure-25 Component Features (Tools – Menu Introduction) of the (LULC)

Below is a brief introduction about the functionality of each feature of Tools:

a) ThreeDTerrain:

This component feature is essential for terrain-based calculations in infrastructure projects like rivers, forests, and dams. It includes a map layer display feature for visualizing terrain directly on a map interface, aiding analysis and decision-making.

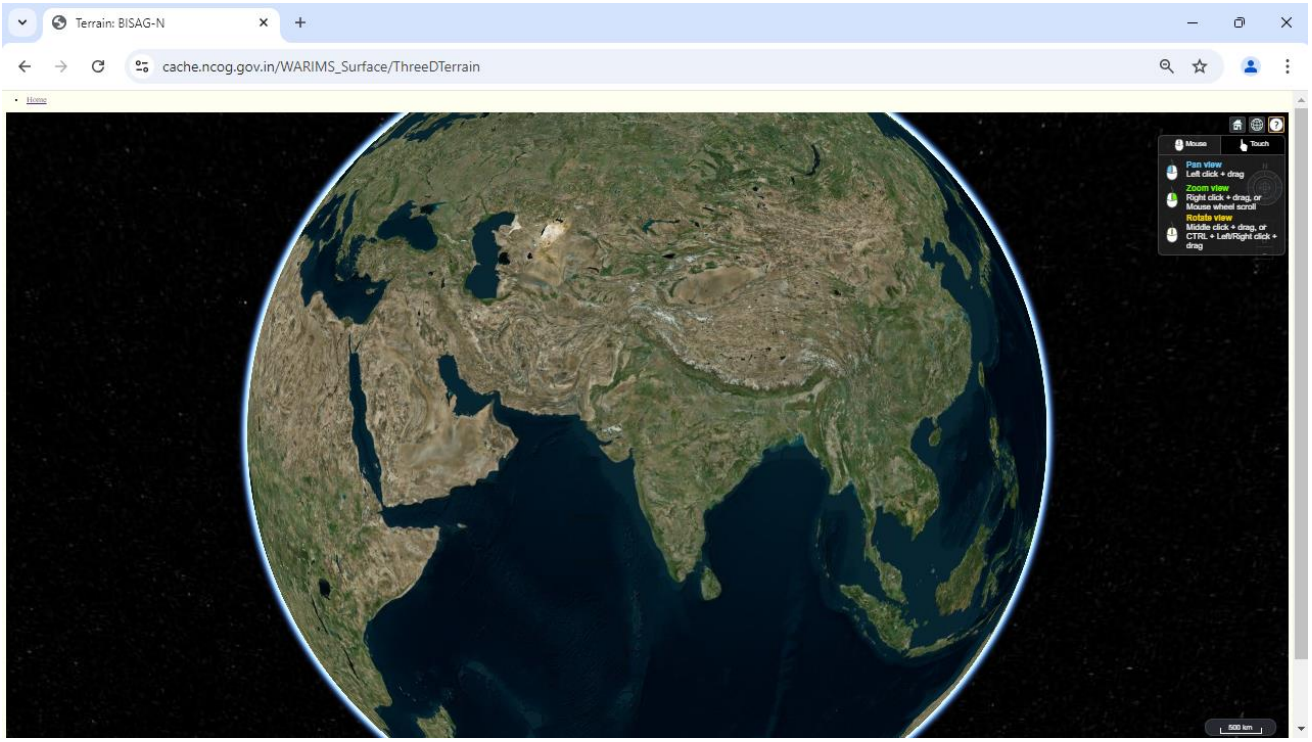


Figure-26 Component Features (ThreeDTerrain: 3D View) of the (LULC)

In Figure-26, the user can view the terrain in three dimensions with available features like pan view, rotate view and zoom view.

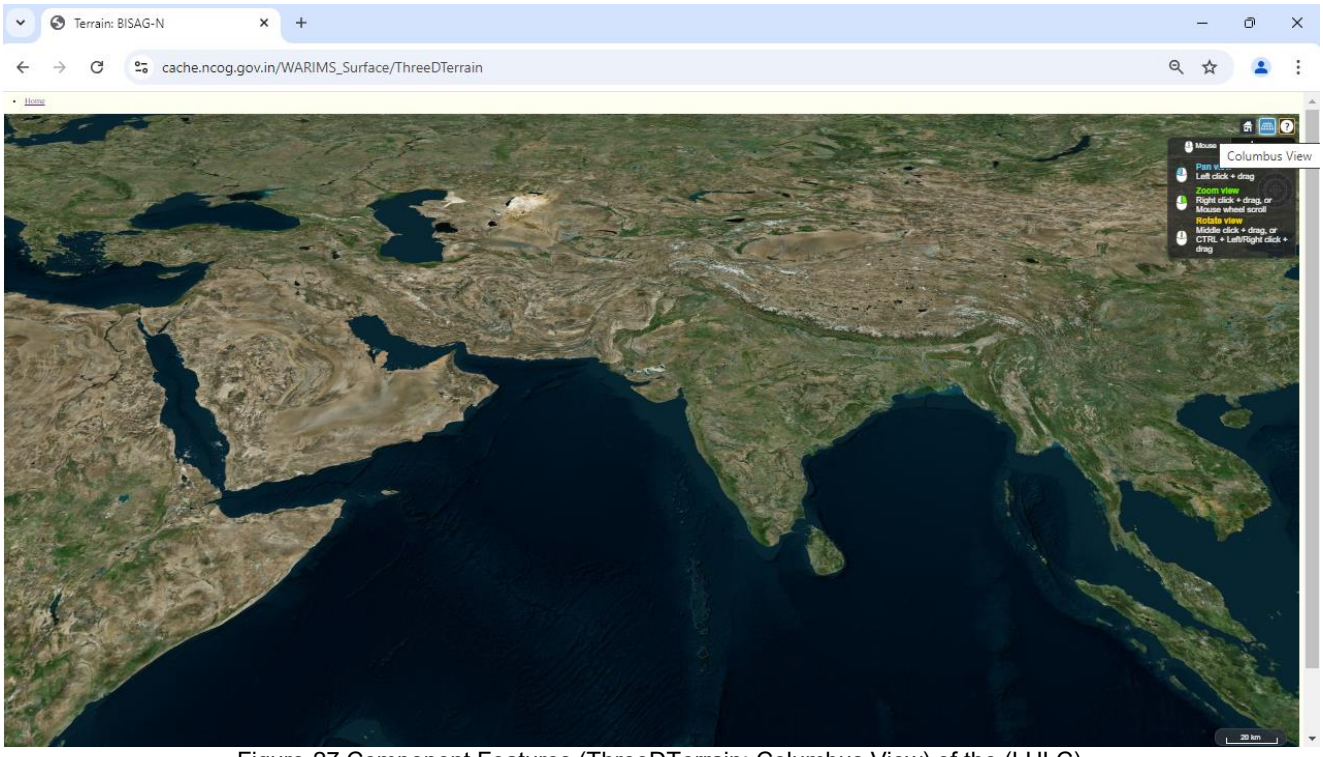


Figure-27 Component Features (ThreeDTerrain: Columbus View) of the (LULC)

Figure-27 shows the user can view the terrain in Columbus view. The user can view the terrain in Columbus view with available features like pan view, rotate view and zoom view.

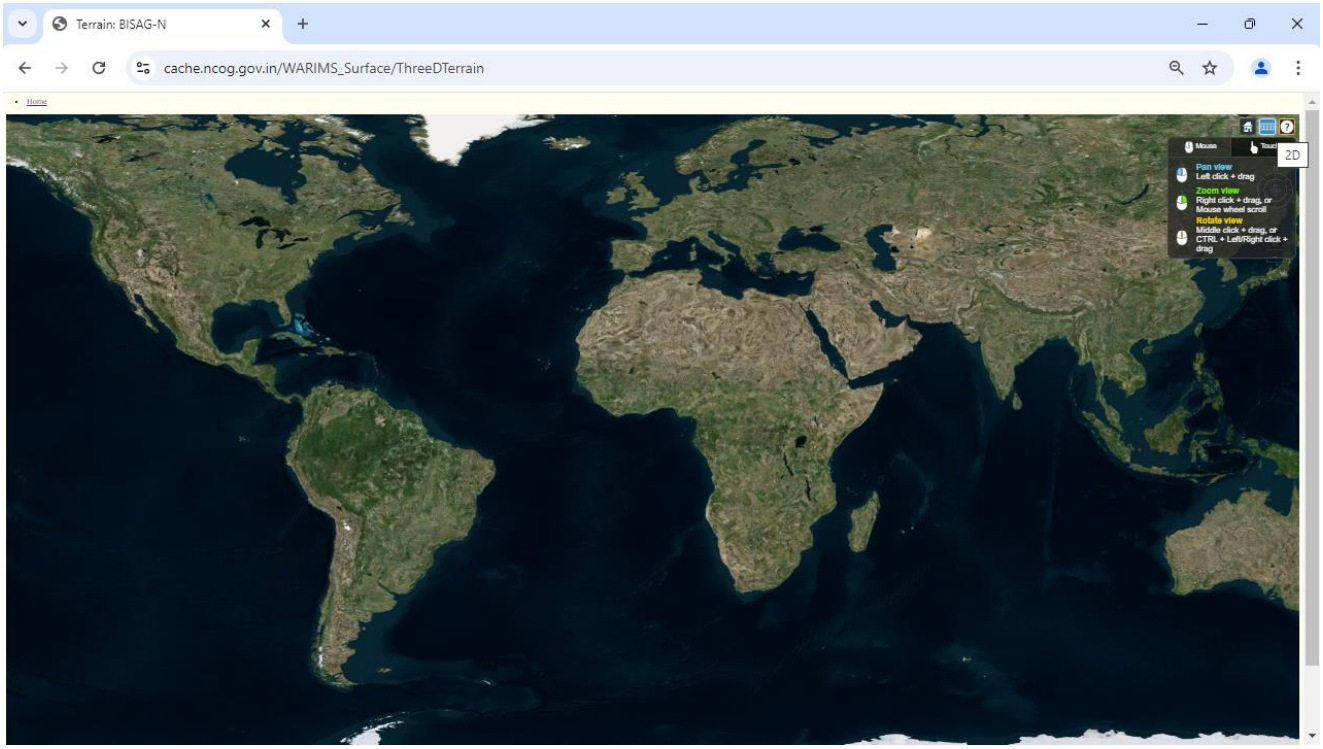


Figure-28 Component Features (ThreeDTerrain: 2D View) of the (LULC)

Figure-28 shows the user can view the Terrain in Two-Dimensional view. The user can view the terrain in two dimensions with available features like pan view, rotate view and zoom view.

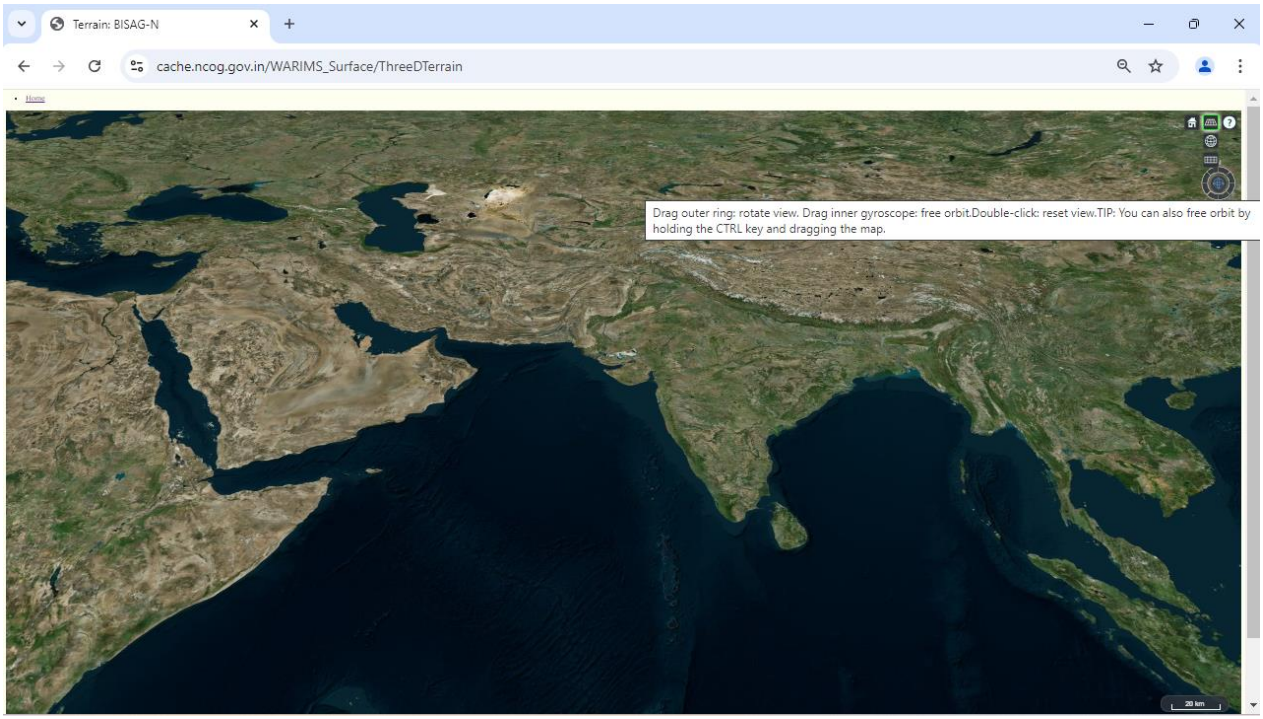


Figure-29 Component Features (ThreeDTerrain: Rotate View) of the (LULC)

Figure-29 shows the user can access the rotate view for each dimension like 2D, 3D and Columbus view. The user can drag outer ring: rotate view. Drag inner gyroscope. Free Orbit. Double-Click: reset view. TIP: user can also free orbit by holding the CTRL key and drag the map.

b) Navigations:

This tool as shown in Figure-30, allows user to navigate from State > District > Taluka/Tehsil/ Block > Village and user can analyse the required details.

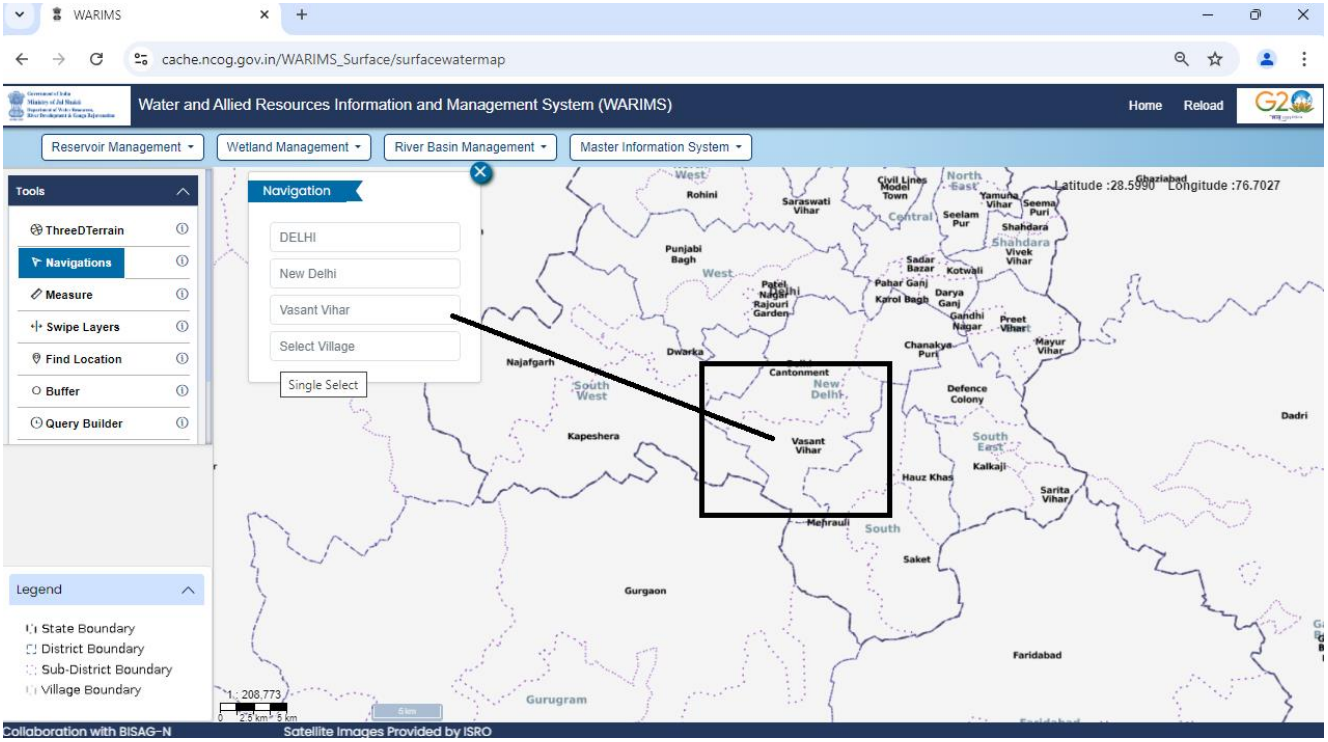


Figure-30 Component Features (Navigations) of the (LULC)

c) Measures:

The measure tool, measure distances, areas, offsets, and feature locations on a map or scene. User can draw line to measure length, draw polygon to measure area, or click an individual feature to get measurement information.

As in Figure-31 user may select Option-1:
Select Polygon → Measuring Unit (Square Meter/Square Kilometre/Acre/Hectare)

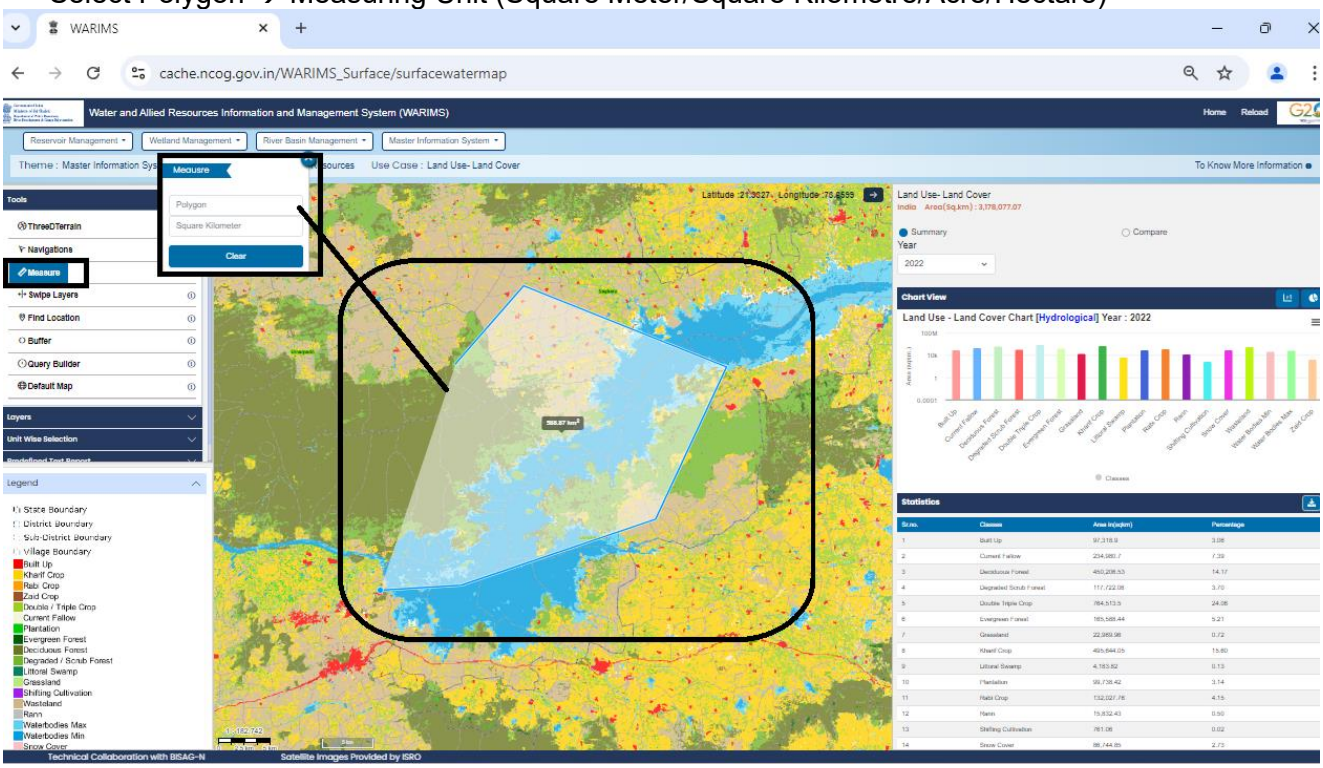


Figure-31 Component Features (Measures: Polygon) of the (LULC)

As in Figure-32 user may select Option-2:
Select Line → Measuring Unit (Meter/Kilometre/Feet)

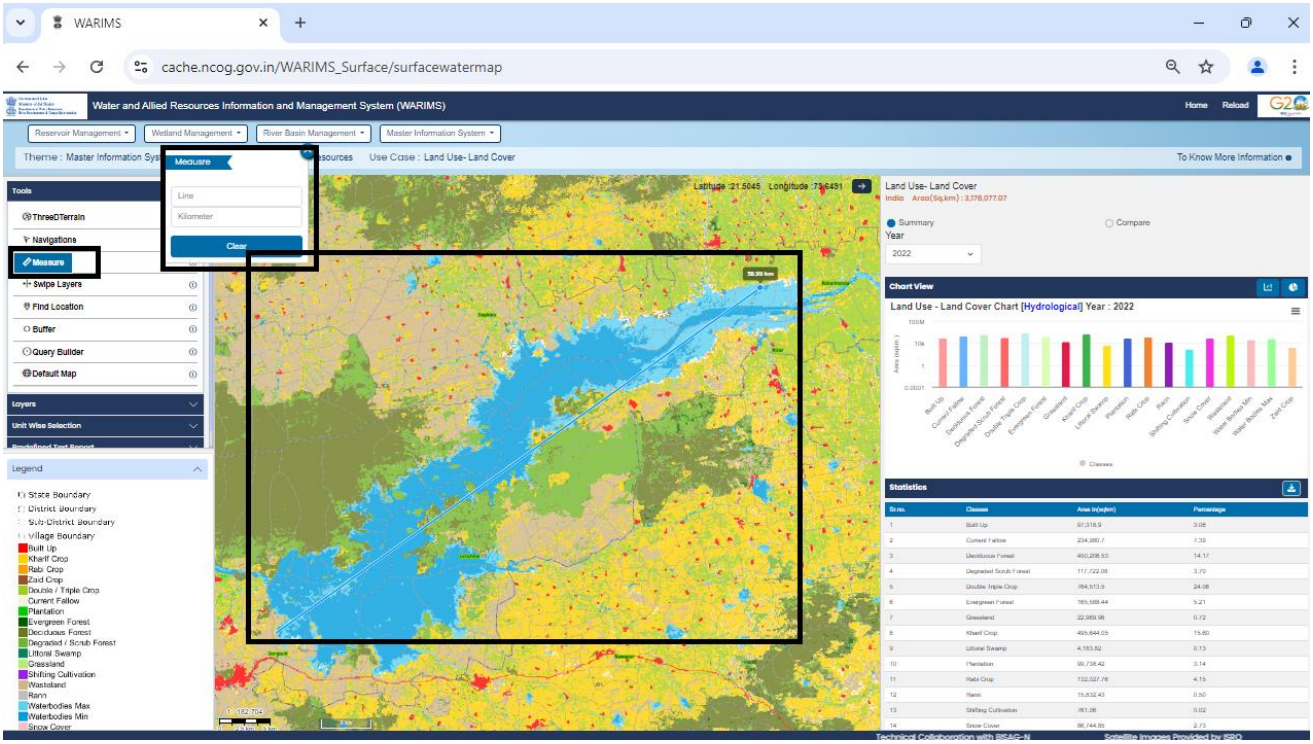


Figure-32 Component Features (Measures: Line) of the (LULC)

d) Swipe Layer:

As in Figure-33, this feature will help to overlap and compare the 2 layers which could be utilize for temporal analysis, change detection etc. Select 2 desired layers from layers panel, and then select one of the selected layers as left that be static and other as right that slide over.

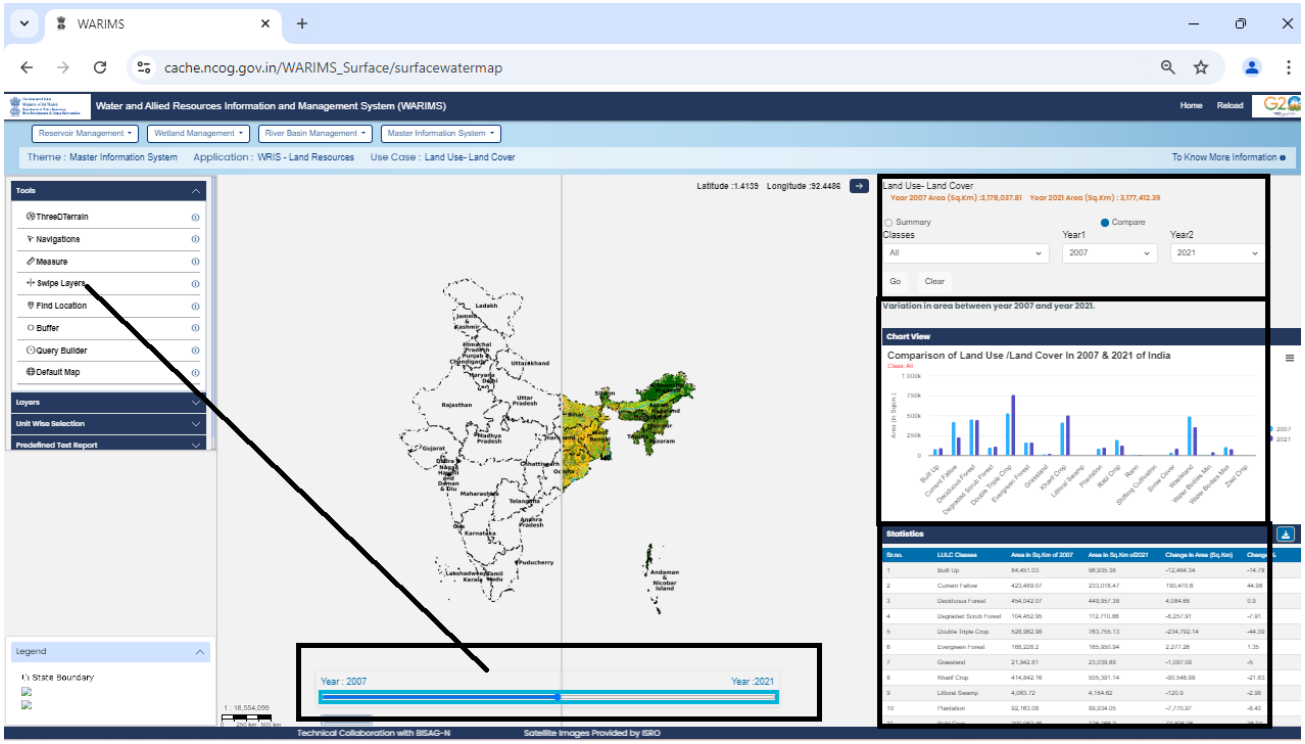


Figure-33 Component Features (Swipe Tool) of the (LULC)

e) Find Location:

As seen in Figure-34, this feature assists in locating positions with latitude and longitude (Degree Decimal) or by using grid numbers. Additionally, clicking on the map automatically displays the corresponding latitude and longitude coordinates.

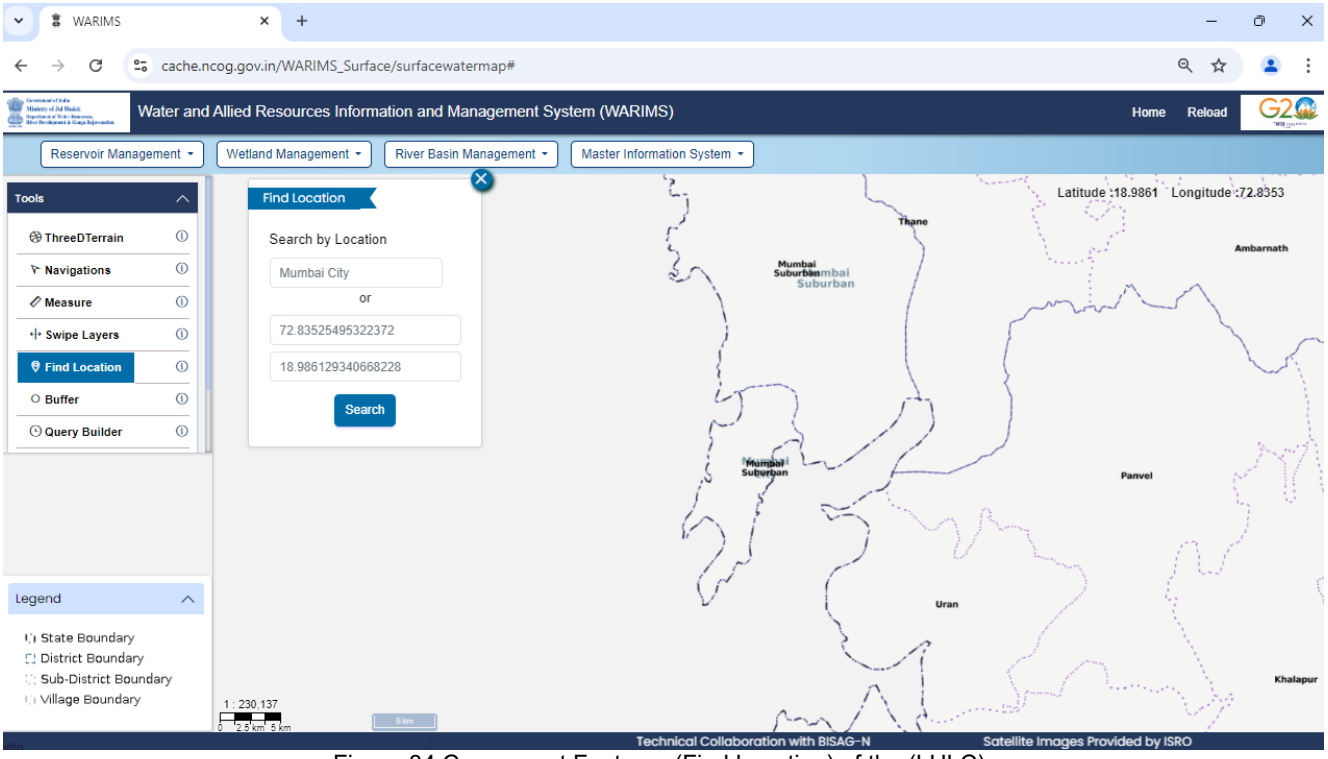


Figure-34 Component Features (Find Location) of the (LULC)

f) Buffer:

Figure-35 demonstrates this tool which allows user to perform the proximity analysis of the required area. By selecting the area of interest and inputting required range for analysis on the map, infrastructure/ assets within the context/ range area will be displayed.

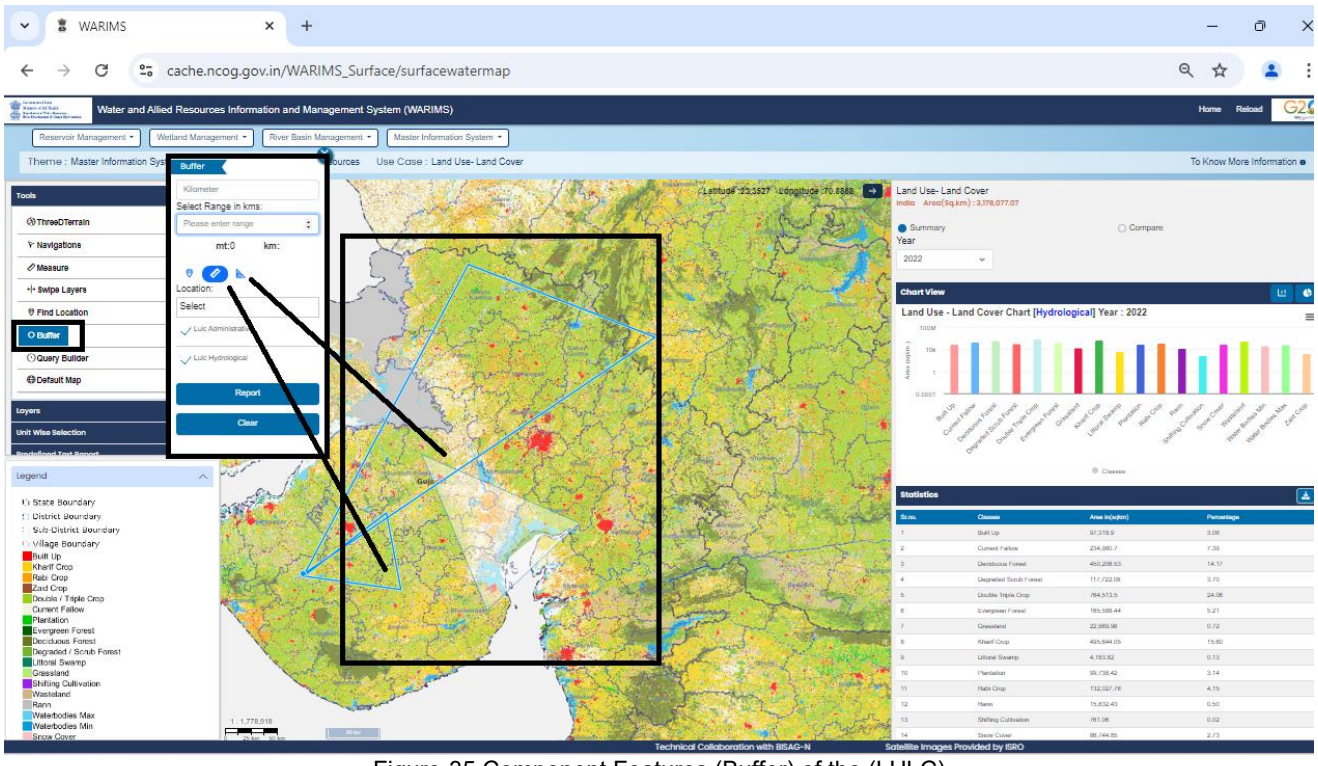


Figure-35 Component Features (Buffer) of the (LULC)

g) Query Builder:

Refer Figure-36 to see this component feature that provides a graphical user interface for creating query in a simplified way to help users filter records within a particular data layer as per their requirement. It is a tool through which user can filter layer-wise features providing certain conditions on the attributes.

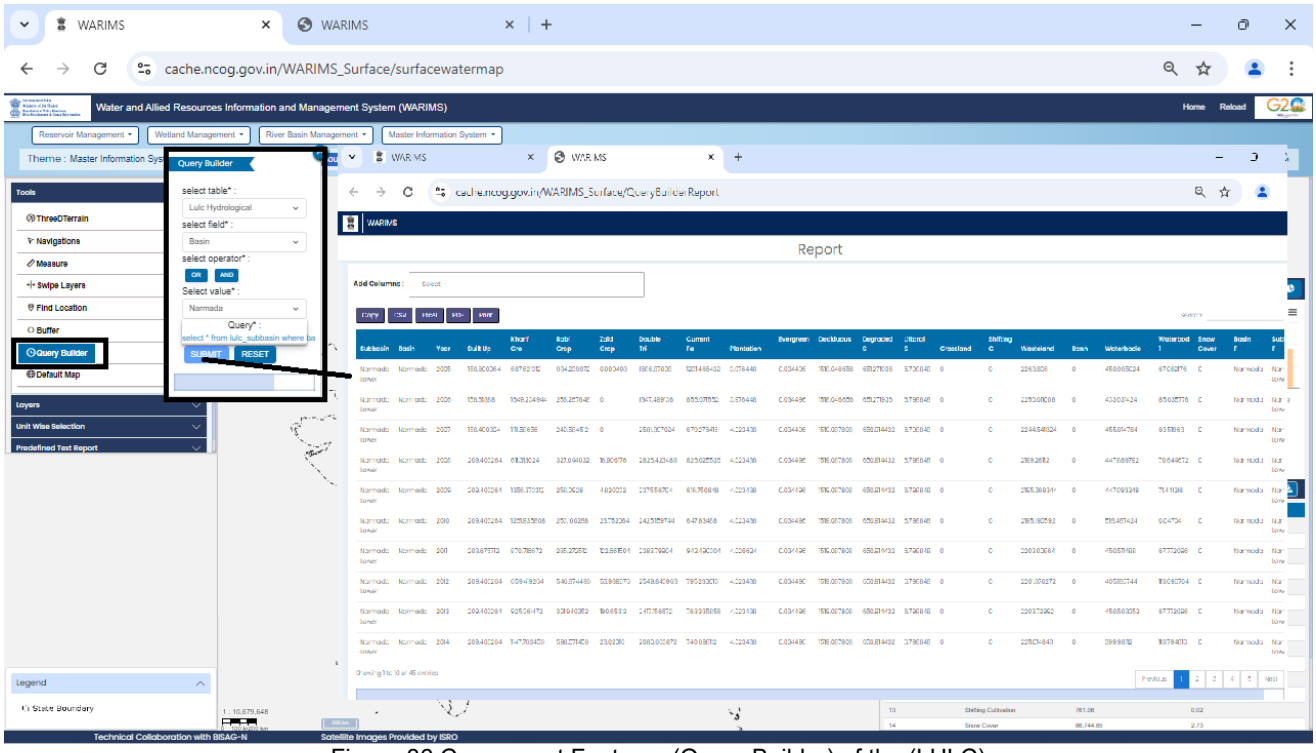


Figure-36 Component Features (Query Builder) of the (LULC)

h) Data Report from Query Builder:

Based on the inputs given in Query Builder, the data report will be generated that can be further downloaded into various file formats like CSV/Excel/PDF and also can be copied is available for print directly.

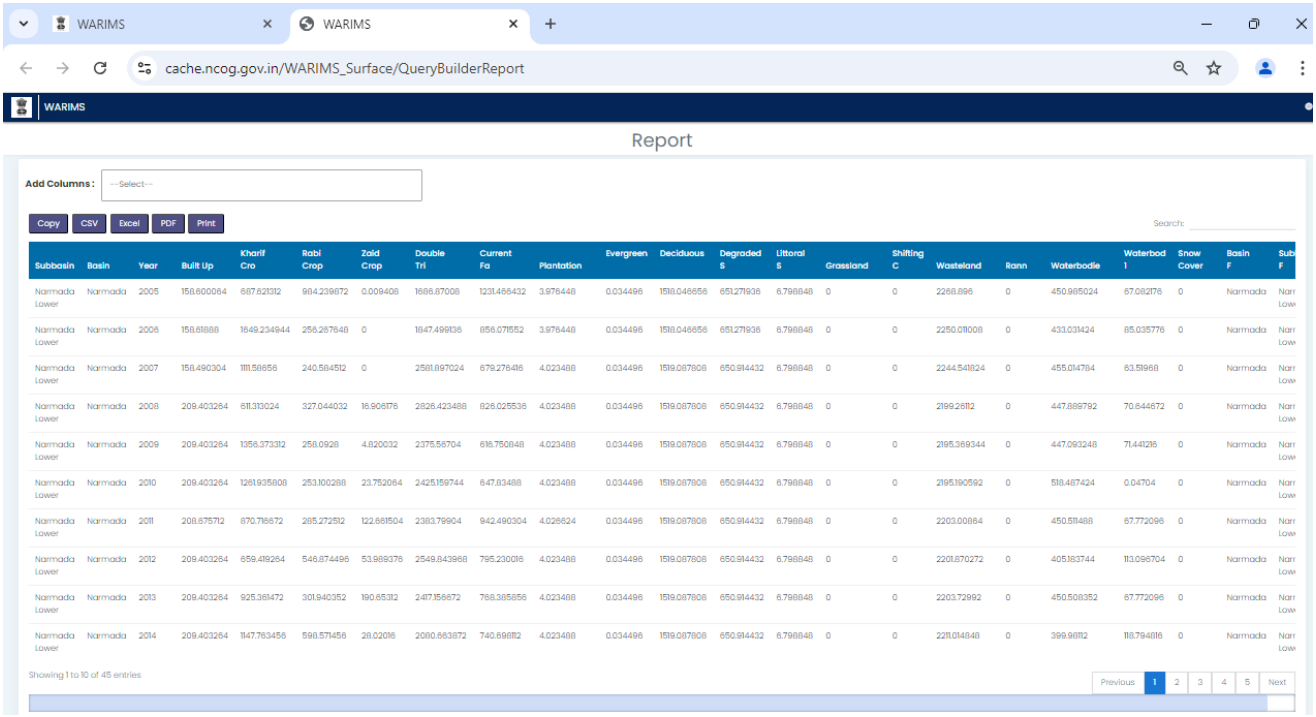


Figure-37 Component Features (Data Report from Query Builder) of the (LULC)

i) Default Map:

Figure-38 shows this option in which the user has the option to view the map as it was when a new instance was initiated. Thus, while working at any given points of time the user can go back to the standard default view of the map using single click of this button.

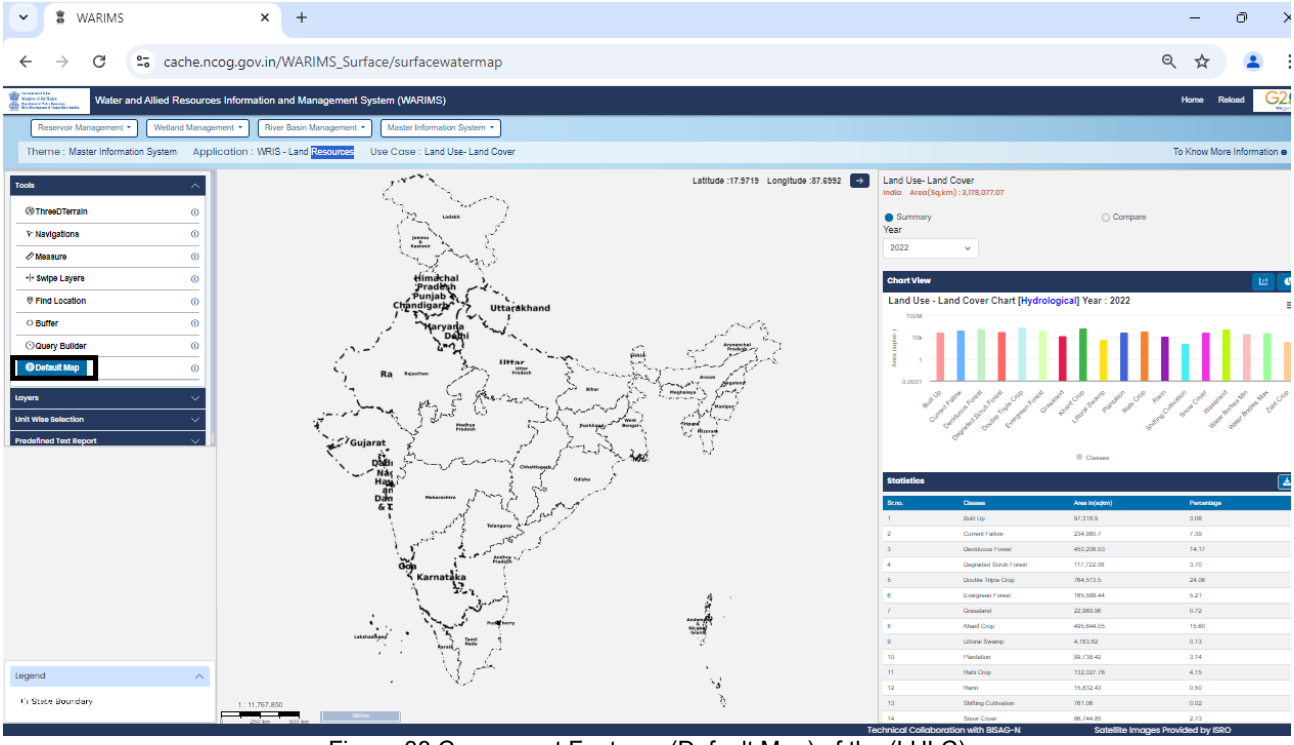


Figure-38 Component Features (Default Map) of the (LULC)

4.3.2 Layers

The Figure-39 highlights the “Layers” options in the Left Side Vertical Menu.
The following are the Layers:

a) Administrative Boundary b) Hydrological Boundary c) Base Map Gallery	d) Infrastructure e) Land Use – Land Cover

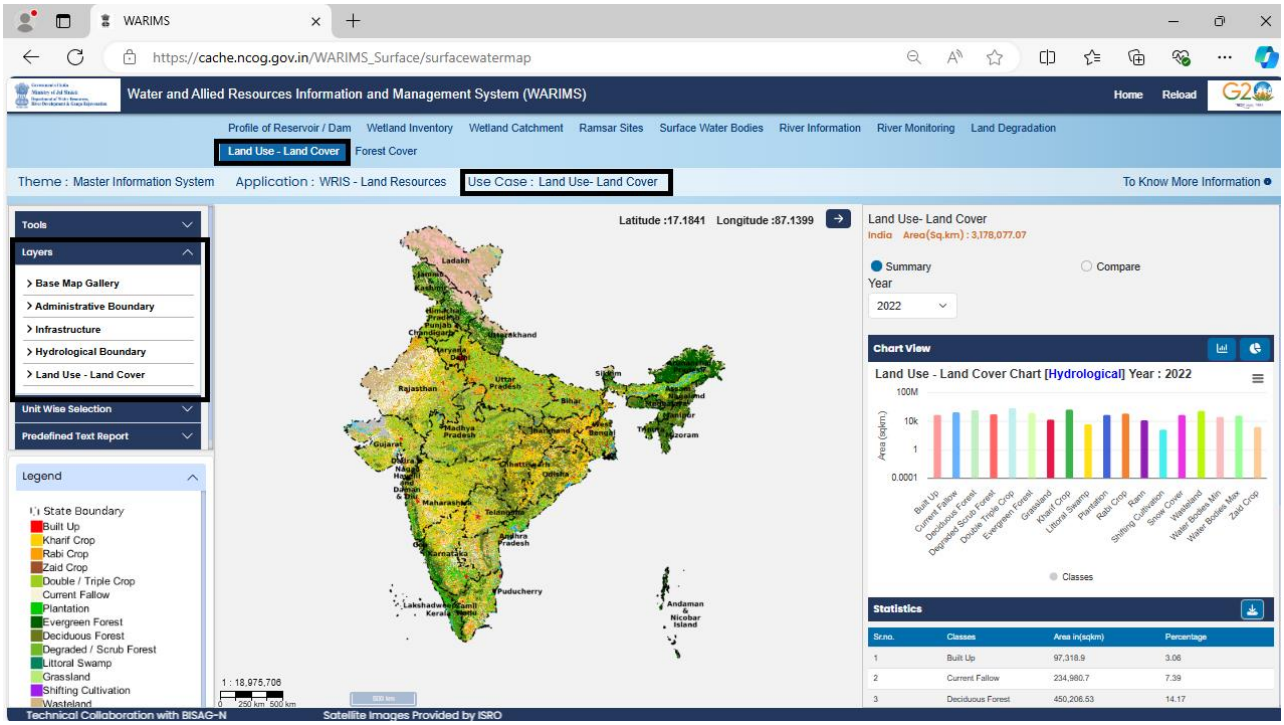


Figure-39 Component Features (Layers – Menu Introduction) of the Land Use Land Cover (LULC)

Find below the description and functionality of each “Layer”:

a) Features of LULC – “Administrative Boundary” within “Layers”:

As seen in Figure-40, the “Administrative Boundary” within the “Layers” has four options:

- State, District, Sub District and Village

User can access the Administrative Boundary of the Layers using above selective options.

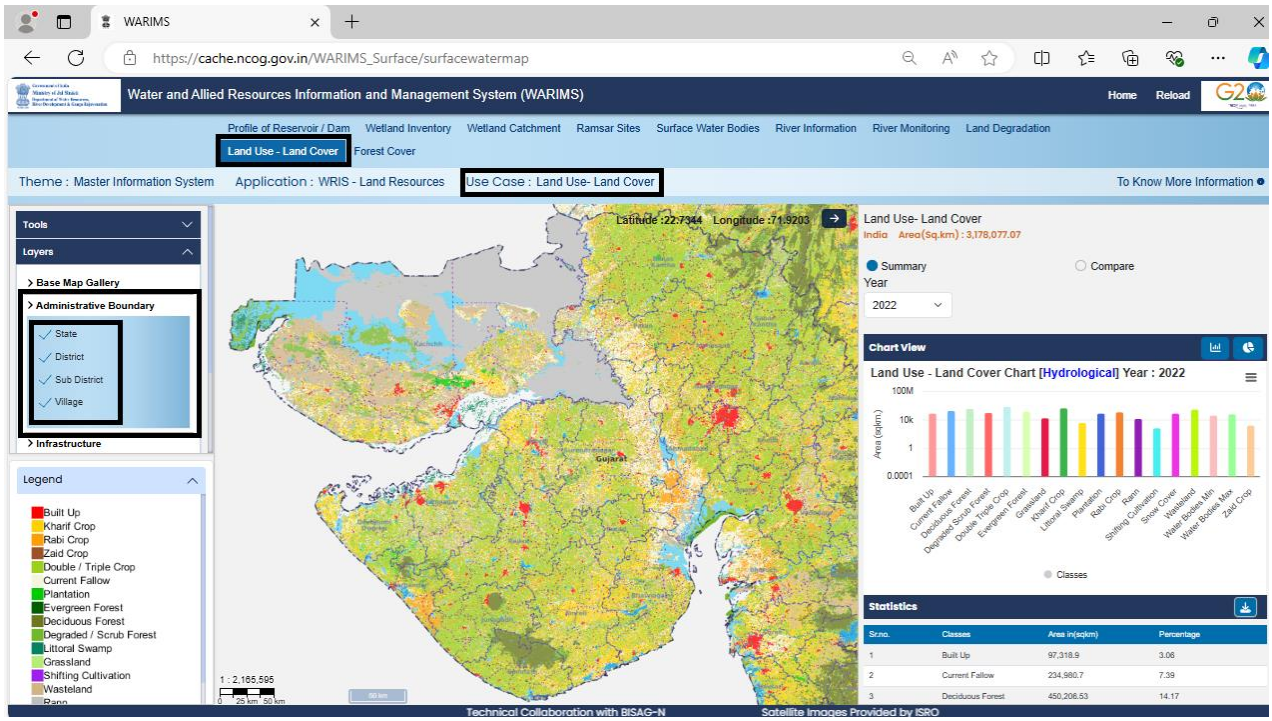


Figure-40 Component Features (Layers – Administrative Boundary) of the (LULC)

b) Features of LULC – “Hydrological Boundary” within “Layers”:

As seen in Figure-41, the “Hydrological Boundary” within the “Layers” has Six options:

- Basin, Sub Basin, WaterShed, River, Major River, River Polygon

User can access the Hydrological Boundary of the Layers using above selective options.

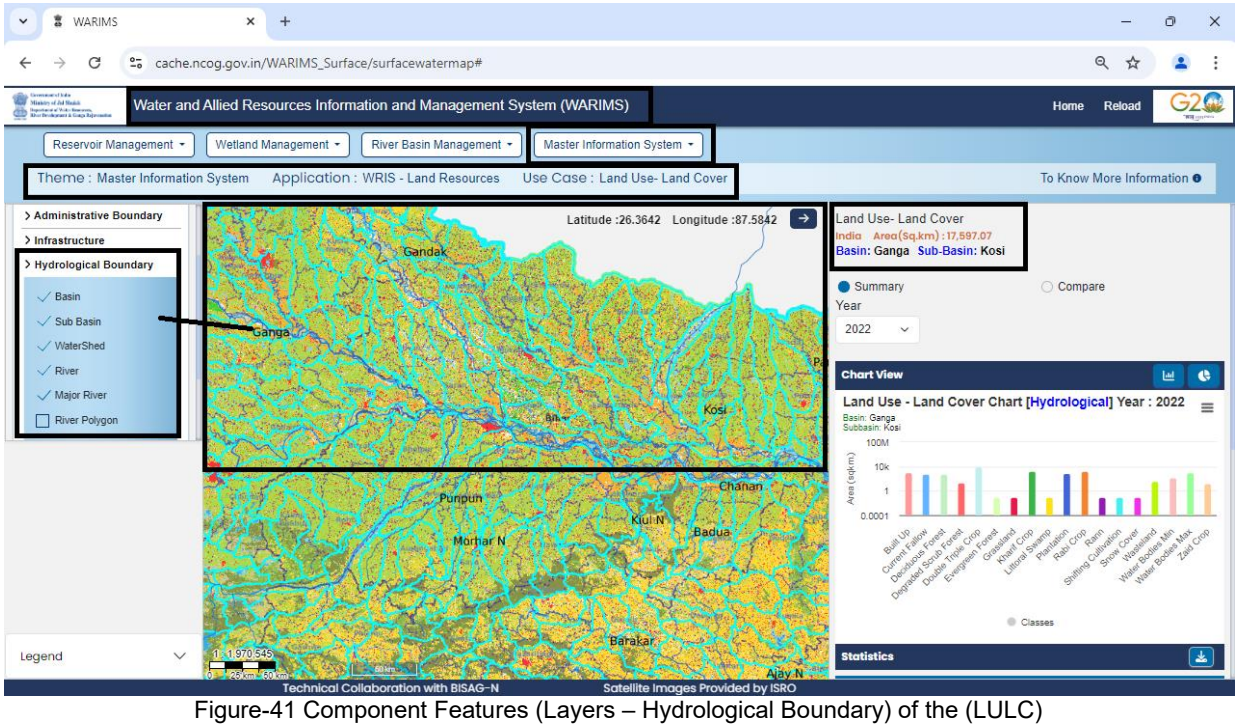


Figure-41 Component Features (Layers – Hydrological Boundary) of the (LULC)

c) Features of LULC – "Base Map Gallery" within "Layers":

The "Base Map Gallery" within the "Layers" offer below options:

i. High Resolution Images
ii. OpenStreet Map

As seen in Figure-42, the User can access the Layers using "High Resolution Image" options.

i) Goto: WARIMS→ LULC → Layers → Base Map Gallery → High Resolution Image

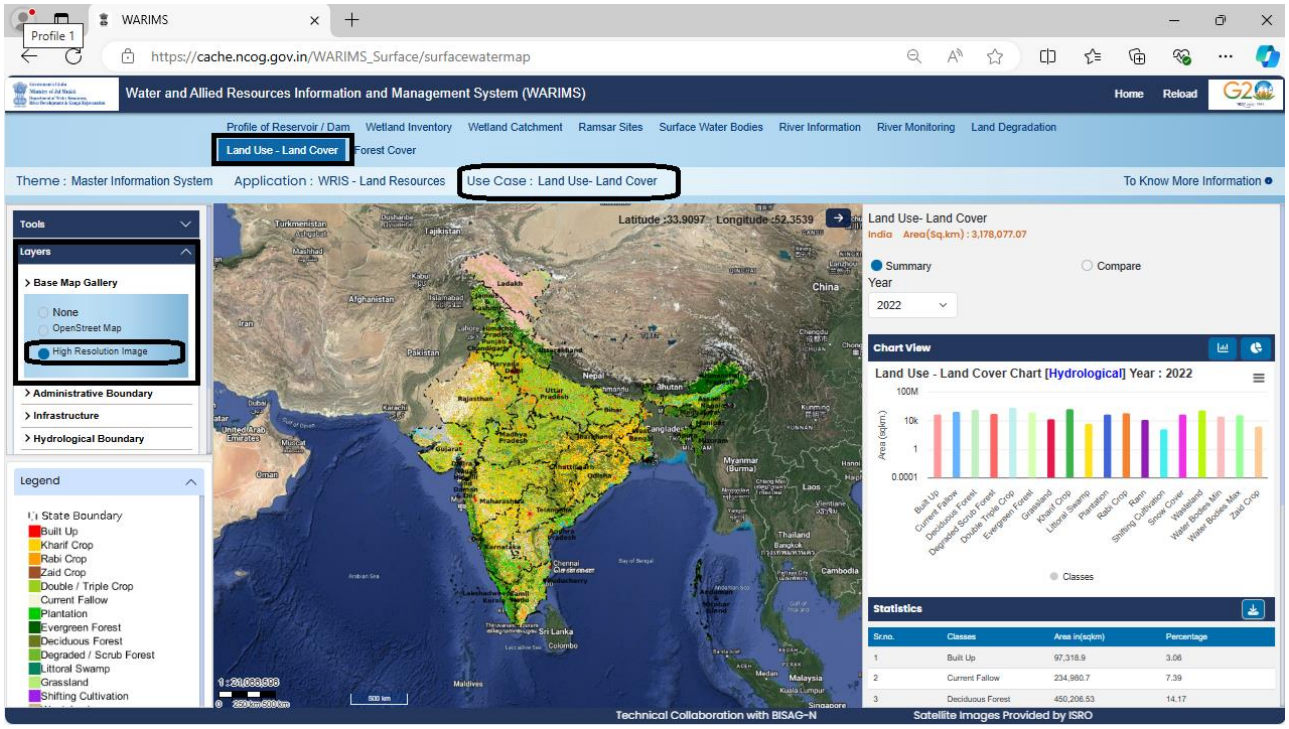


Figure-42 Component Features (Layers – Base Map Gallery with High Resolution Image) of the (LULC)

As seen in Figure-43, the User can access the Layers using "OpenStreet Map" options.

ii) Goto: WARIMS→ LULC → Layers → Base Map Gallery →OpenStreet Map

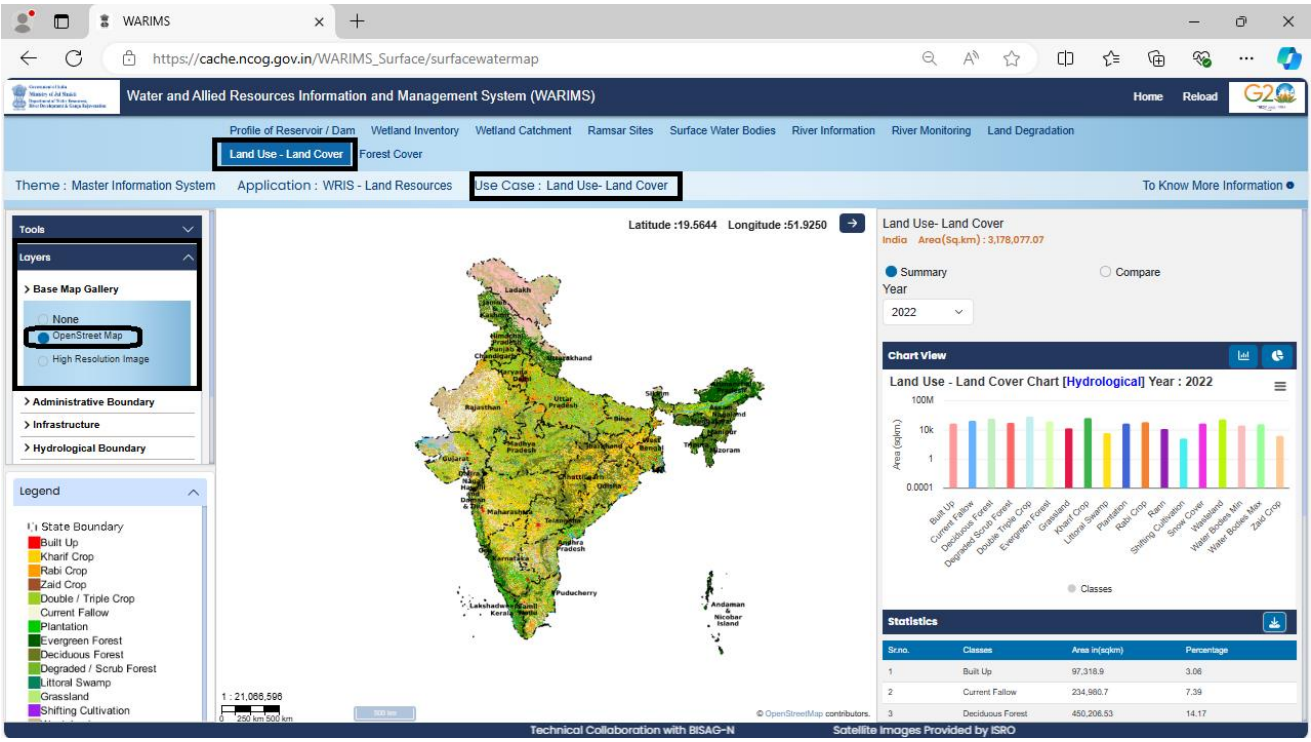


Figure-43 Component Features (Layers – Base Map Gallery with OpenStreet Map) of the (LULC)

d) Features of LULC – "Infrastructure" within "Layers":

The "Infrastructure" within the "Layers" has three options:

- Airports, Rail, Road

As in Figure-44, User can access the Infrastructure of the Layers using above selective options.

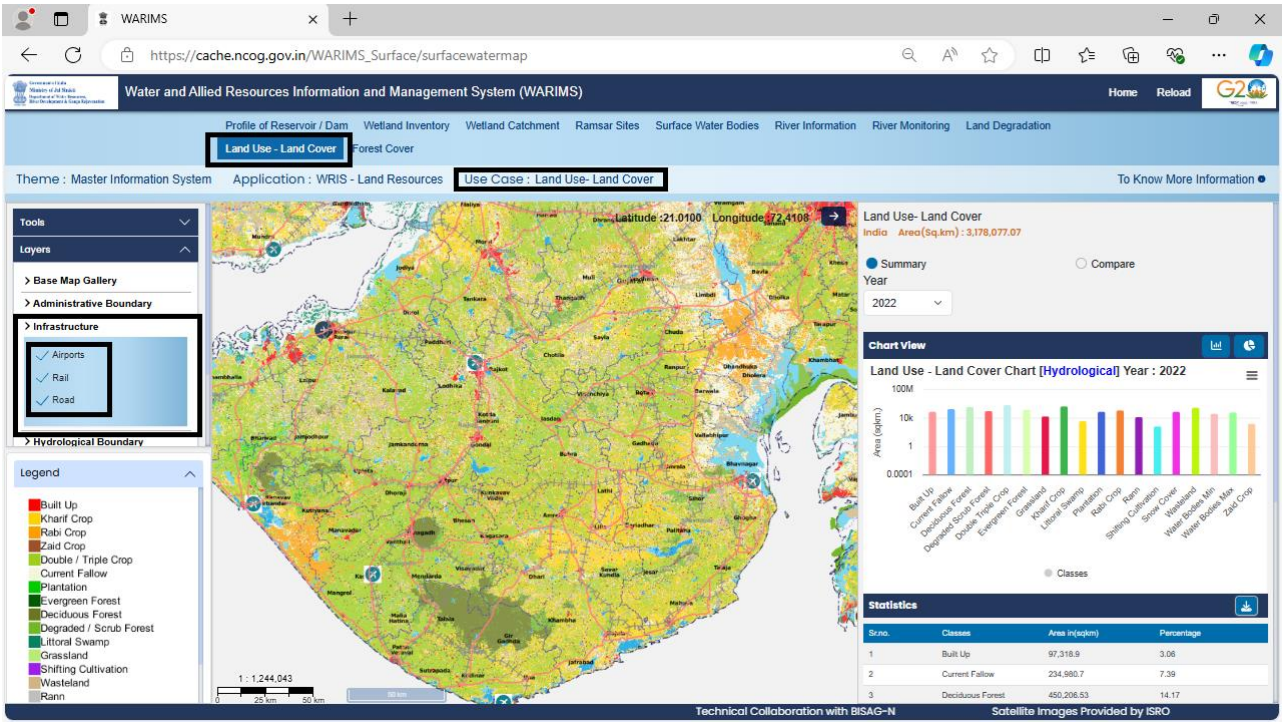


Figure-44 Component Features (Layers – Infrastructure) of the (LULC)

e) Features of LULC – "Land Use-Land Cover" within "Layers":

The "Land Use-Land Cover" within the "Layers" has Options from Year 2005-06 to 2022-23

As in Figure-45, User can access the LULC Layers using above selective Years.

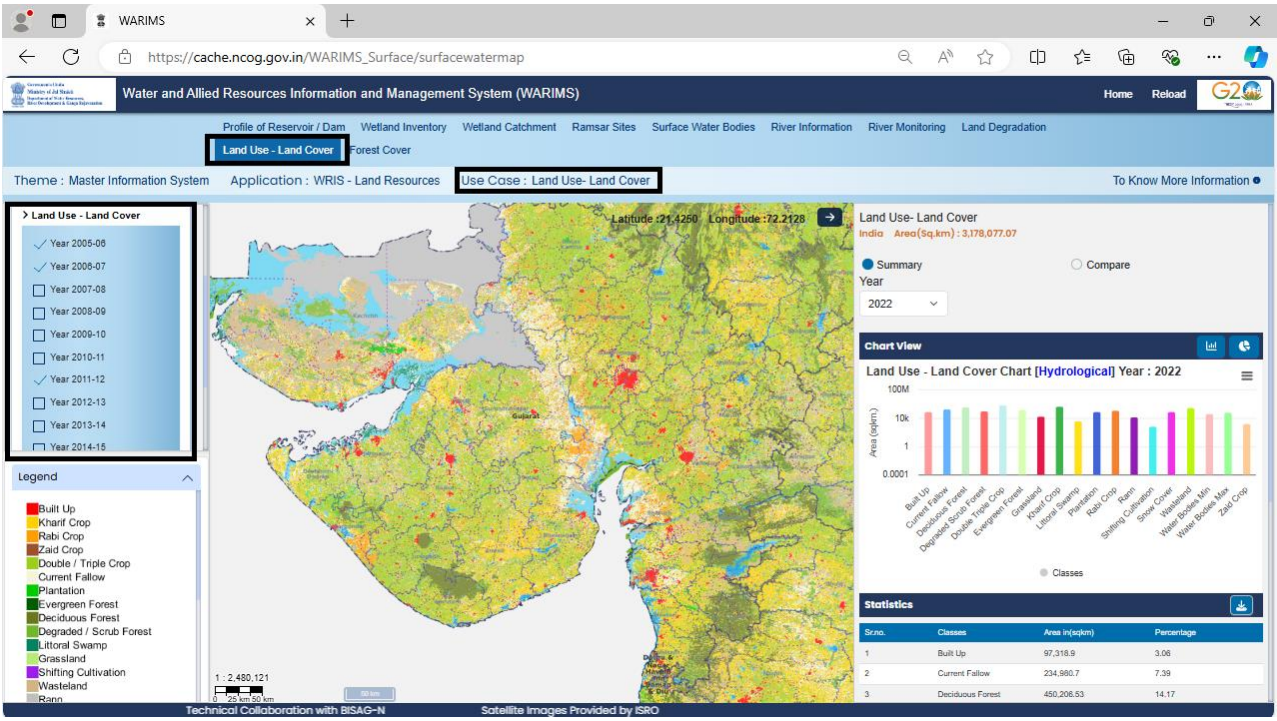


Figure-45 Component Features (Layers – Land Use-Land Cover) of the (LULC)

4.3.3 Unit Wise Selection

Unit Wise Selection offers two options, select either of any one option:

a) Hydrological
b) Political

a) As seen in Figure- 46 & 47, the user can access the Land Use-Land Cover: Hydrological (Unit Wise Selection)

Step to select Basin: Unit Wise Selection → Hydrological → Select →Basin

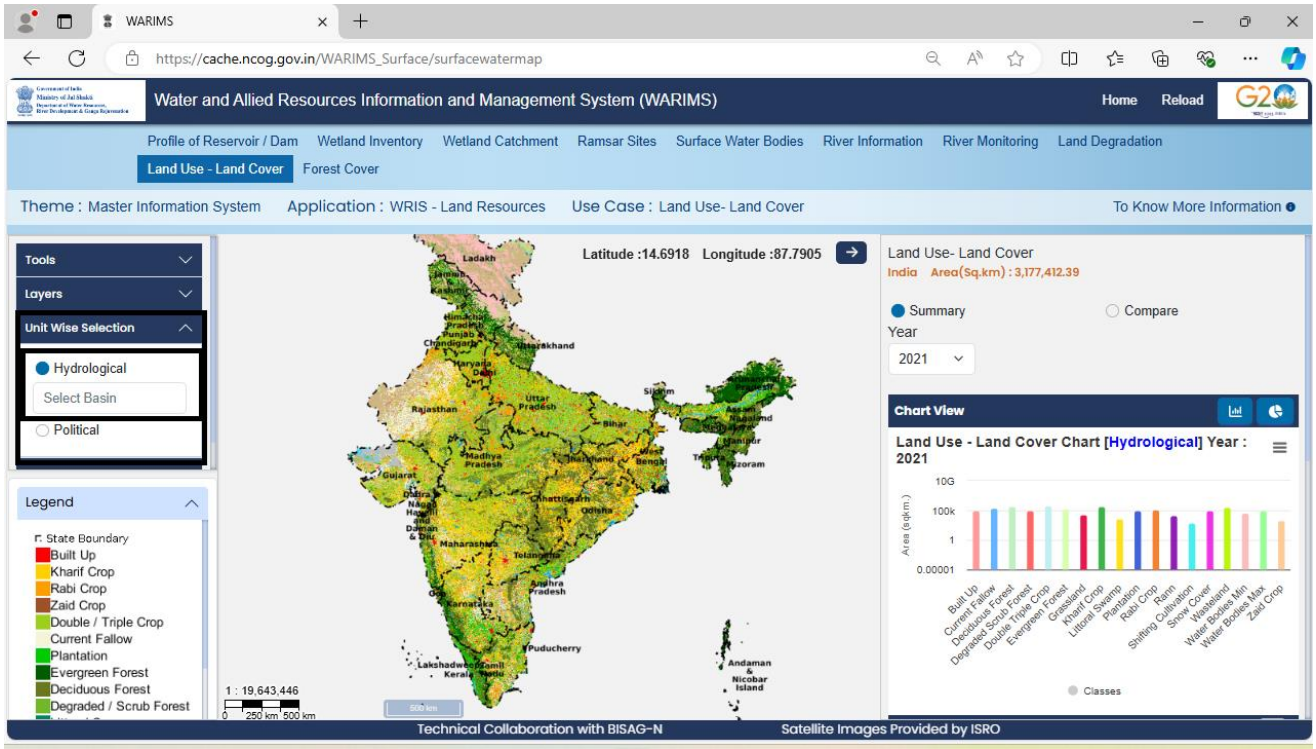


Figure-46 Component Features (Unit Wise Selection – Hydrological) of the (LULC)

Step to select Sub-Basin: Unit Wise Selection → Hydrological → Select →Basin →Sub-Basin

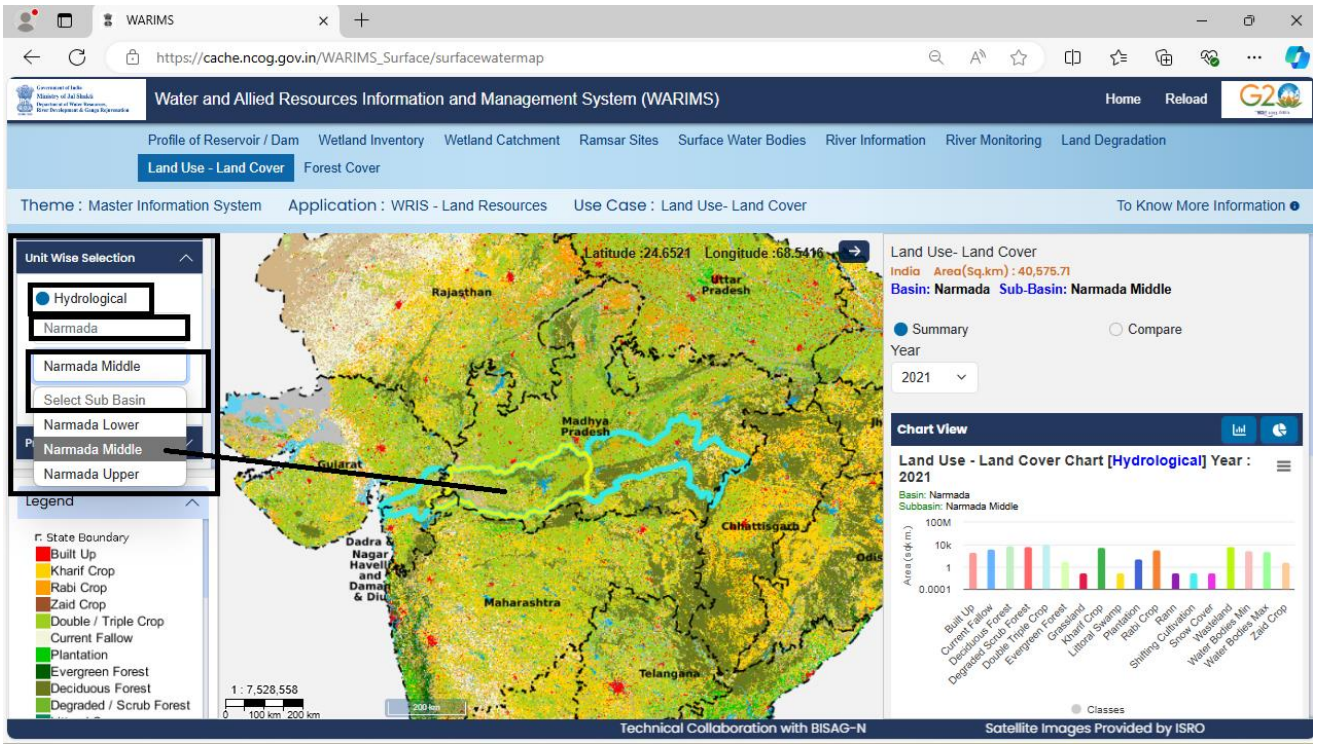


Figure-47 Component Features (Unit Wise Selection – Hydrological → Basin → Sub Basin) of the (LULC)

b) As seen in Figure-48, User can access the LULC: Political (Unit Wise Selection)
Steps: Unit Wise Selection → Political → Select →State →District

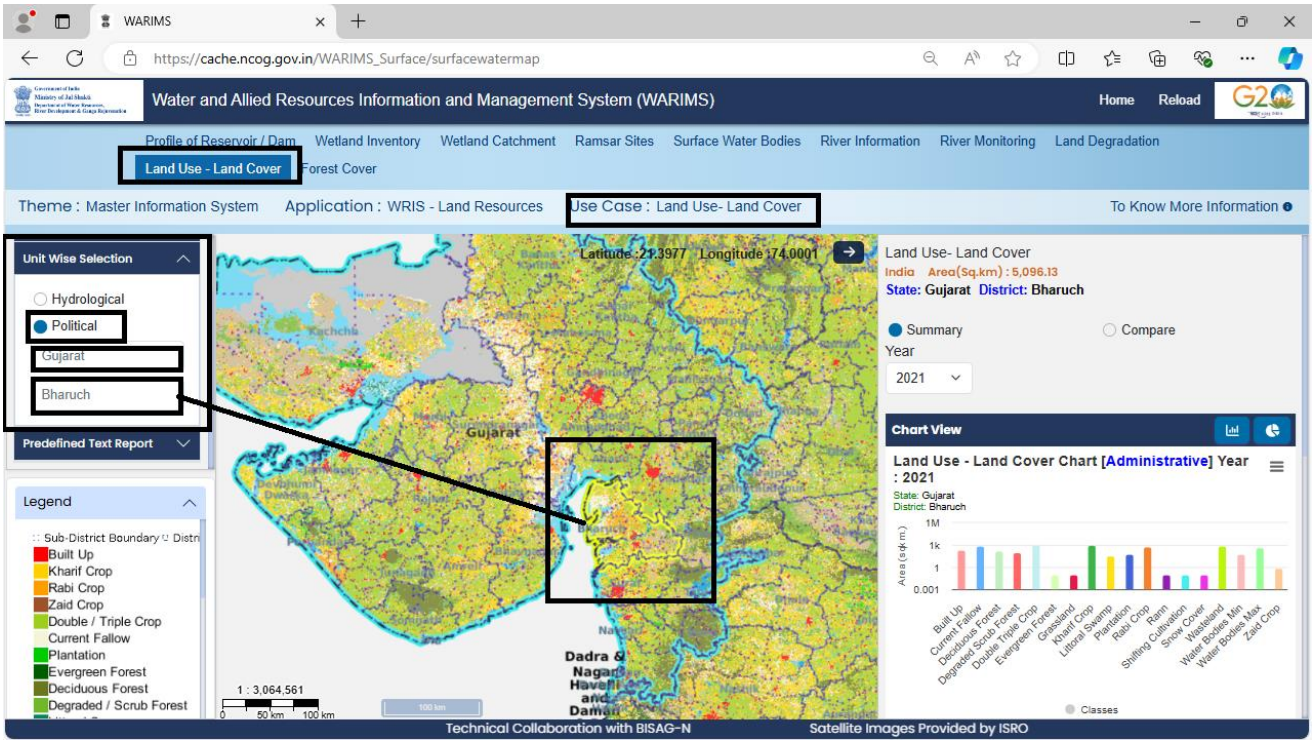


Figure-48 Component Features (Unit Wise Selection – Political → State → District) of the (LULC)

4.3.4 Predefined Text Report

The Predefined Text Report have two options, user may select either of any one option:
a) Hydrological and b) Political

a) As shown in Figure-49, User can access the LULC: Hydrological (Predefined Text Report)
Steps: Predefined Text Report → Hydrological → Basin →Sub-Basin→ Classes → Year
Then Click on the Button "Download Data" to receive the Predefined Text Report for the selected Hydrological Classes.

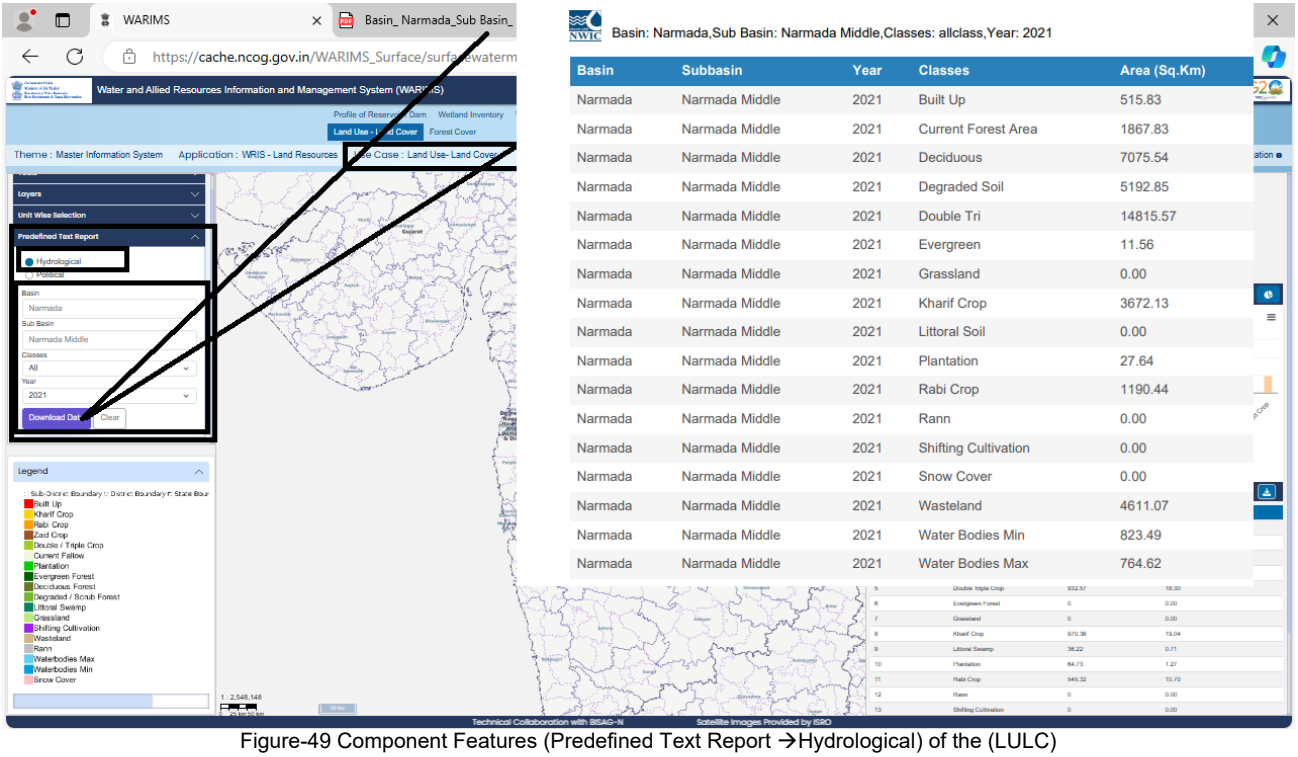
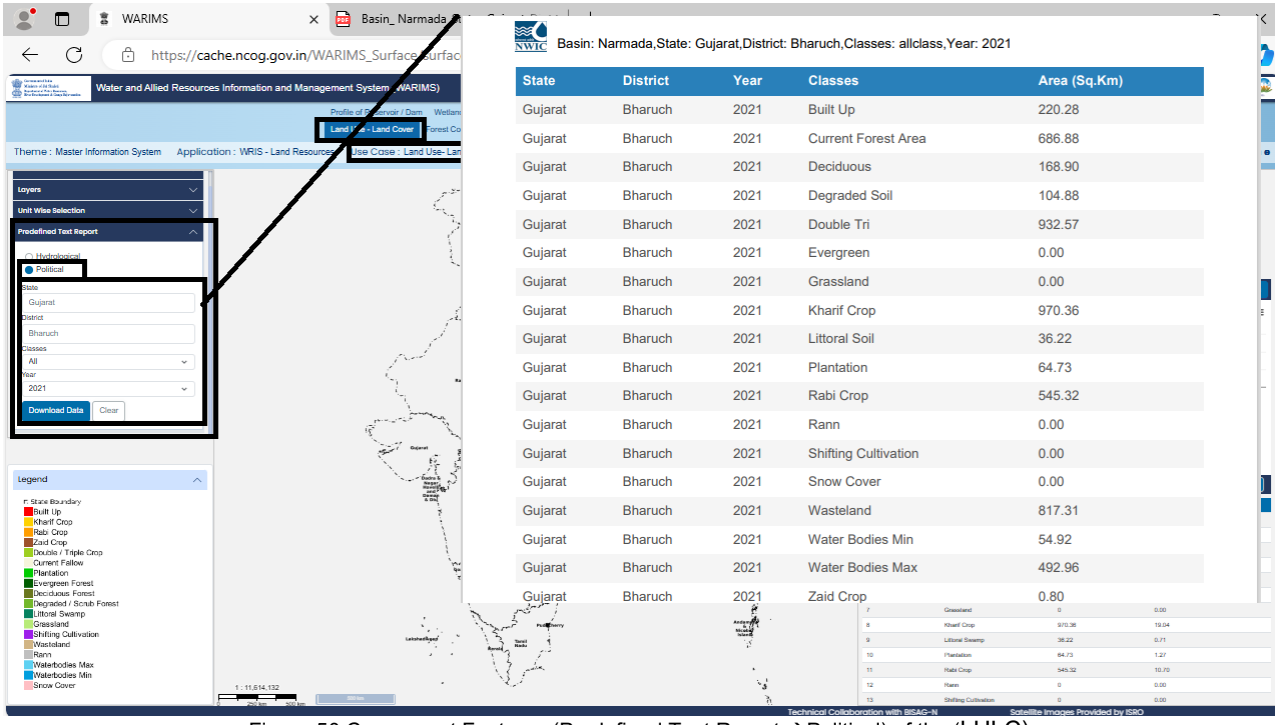


Figure-49 Component Features (Predefined Text Report →Hydrological) of the (LULC)

b) As seen in Figure-50, user can access the LULC: Political (Predefined Text Report)

Step: Predefined Text Report → Political →State →District → Classes → Year

Then Click on the Button “Download Data” to receive the Predefined Text Report for the selected Political Classes.



Basin: Narmada,State: Gujarat,District: Bharuch,Classes: allclass,Year: 2021

State	District	Year	Classes	Area (Sq.Km)
Gujarat	Bharuch	2021	Built Up	220.28
Gujarat	Bharuch	2021	Current Forest Area	686.88
Gujarat	Bharuch	2021	Deciduous	168.90
Gujarat	Bharuch	2021	Degraded Soil	104.88
Gujarat	Bharuch	2021	Double Tri	932.57
Gujarat	Bharuch	2021	Evergreen	0.00
Gujarat	Bharuch	2021	Grassland	0.00
Gujarat	Bharuch	2021	Kharif Crop	970.36
Gujarat	Bharuch	2021	Littoral Soil	36.22
Gujarat	Bharuch	2021	Plantation	64.73
Gujarat	Bharuch	2021	Rabi Crop	545.32
Gujarat	Bharuch	2021	Rann	0.00
Gujarat	Bharuch	2021	Shifting Cultivation	0.00
Gujarat	Bharuch	2021	Snow Cover	0.00
Gujarat	Bharuch	2021	Wasteland	817.31
Gujarat	Bharuch	2021	Water Bodies Min	54.92
Gujarat	Bharuch	2021	Water Bodies Max	492.96
Gujarat	Bharuch	2021	Zaid Crop	0.80

Figure-50 Component Features (Predefined Text Report →Political) of the (LULC)

4.3.5 Legend

Legend includes the different classes as below: (As shown in Figure-51)

1. Built-up	7. Evergreen Forest	13. Wasteland
2. Kharif Crop	8. Deciduous Forest	14. Rann
3. Rabi Crop	9. Degraded / Scrub Forest	15. Waterbodies Max
4. Zaid Crop	10. Littoral Swamp	16. Waterbodies Min
5. Double/Triple Crop	11. Grassland	17. Snow Cover
6. Plantation	12. Shifting Cultivation	18. Current Fallow

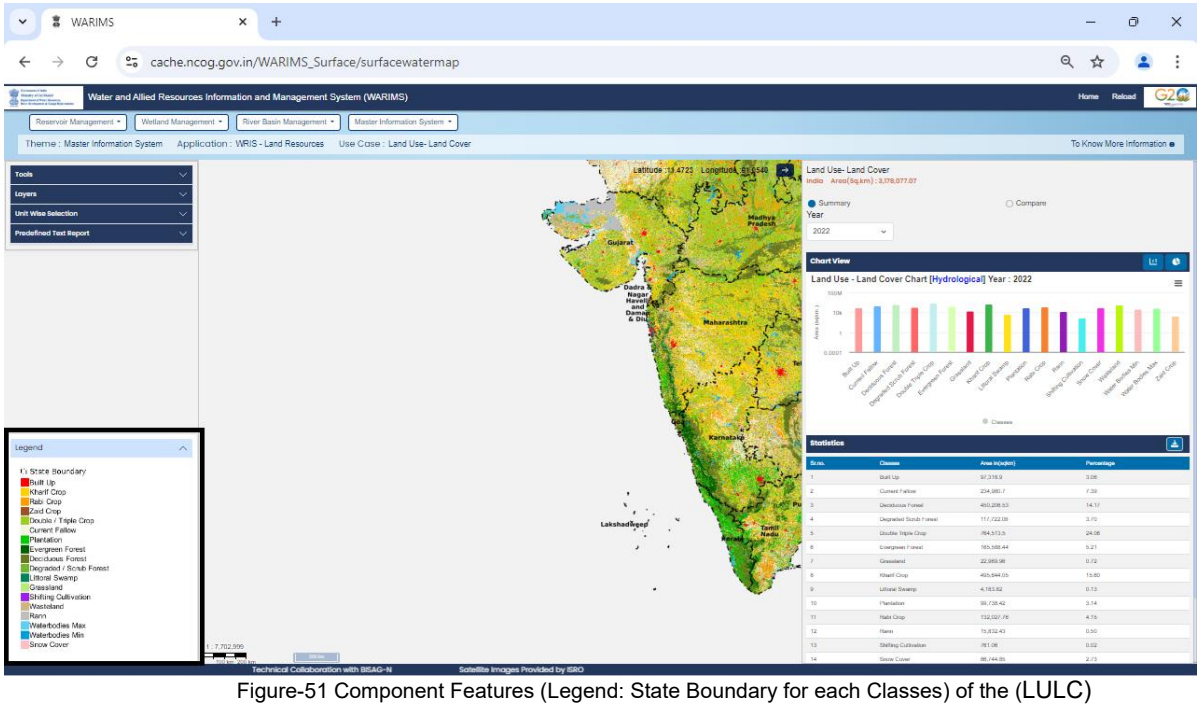


Figure-51 Component Features (Legend: State Boundary for each Classes) of the (LULC)

4.3.6 Reports

This feature offers Reports for the Summary and Comparison.

a) **Summary Report:** User can access the Land Use-Land Cover
As in Figure-52, Select the Year as an input for generating the summary report.

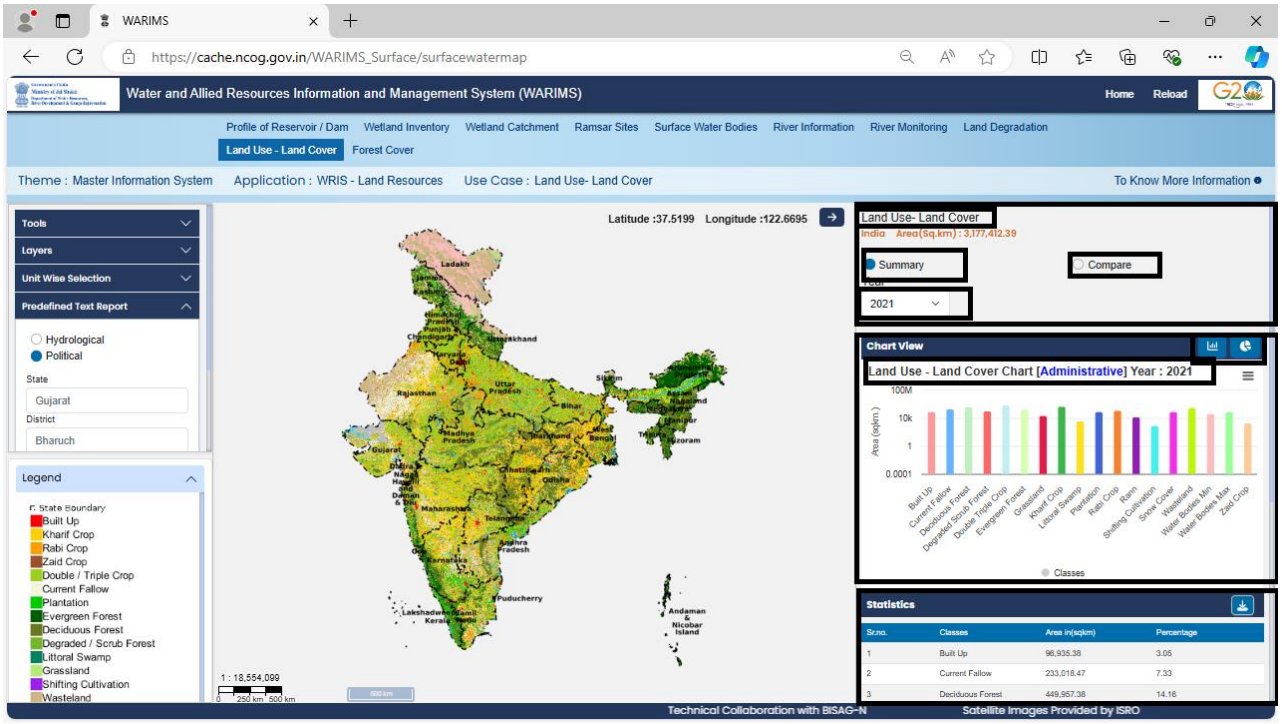


Figure-52 Component Features (Summary Report – Bar Chart + Statistics) of the (LULC)

Get the Summary Report into formats: (As in Figure-53)

- ChartView (Bar Chart/Pie Chart)
- Statistical Data (Downloadable)

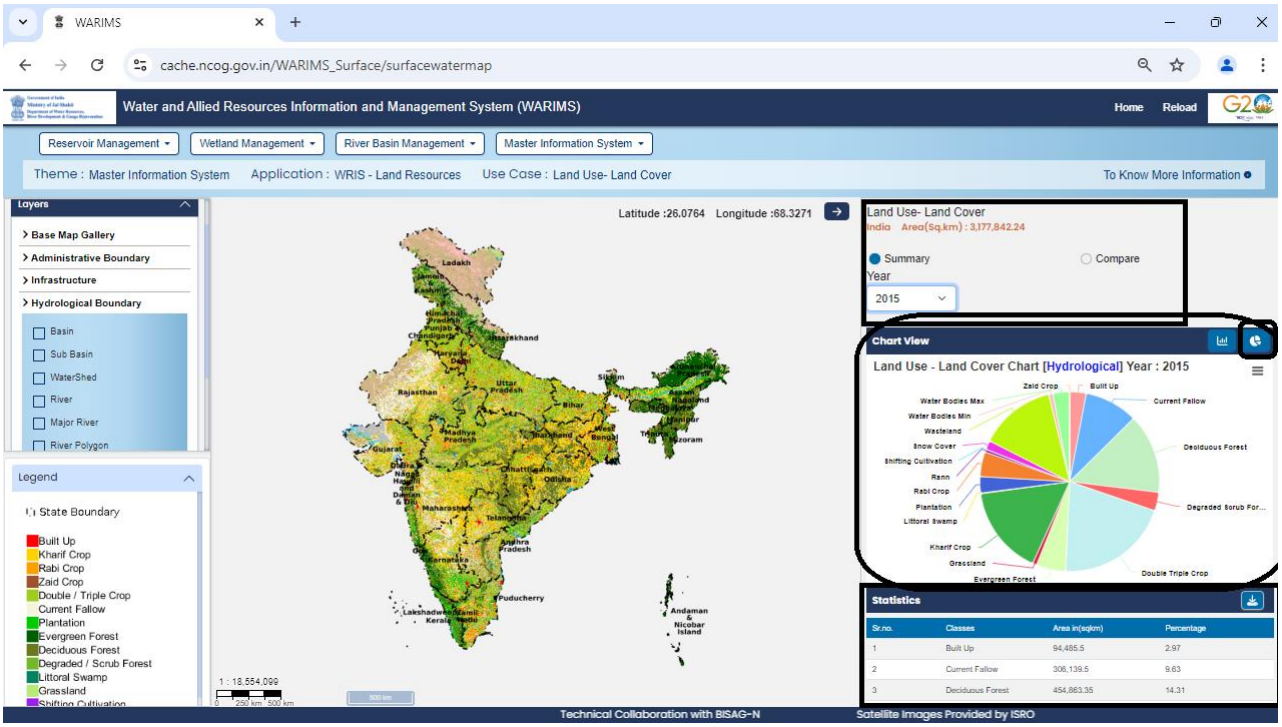


Figure-53 Component Features (Summary Report – Pie Chart + Statistics) of the (LULC)

b) Comparative Report: Get Comparative Report into formats:
As in Figure-54, Comparative Report with Bar Chart, Statistical Report and Swipe Layer Component for Spatial Temporal Analysis.

Step: Select Compare Button → Select the Class → Select Year1 and Year2 and Click "Go" Button

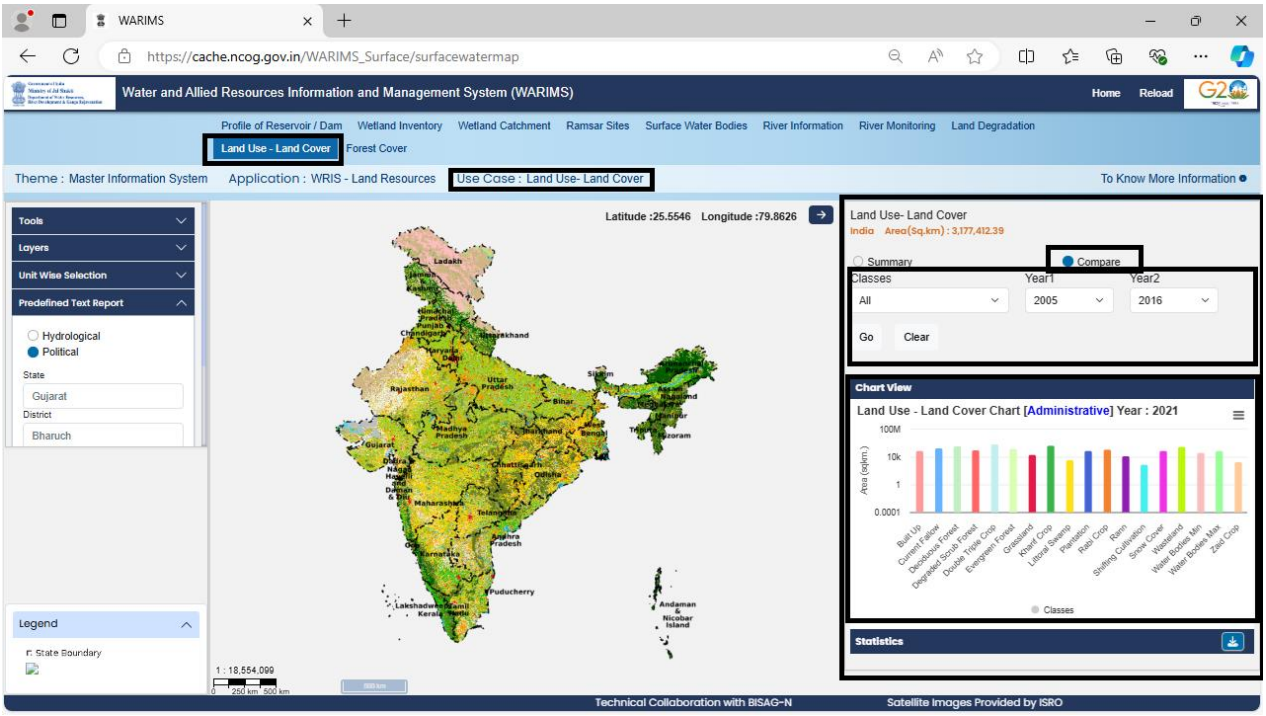


Figure-54 Component Features (Comparative Report – Bar Chart + Statistics) of the (LULC)

4.3.7 Statistics Report

The Summary and Comparison Reports are available in statistical form that can be useful for user to review and perform the analysis with statistical data. As in Figure-55, the statistical report can be available in downloadable format like: CSV/Excel/PDF/Doc.

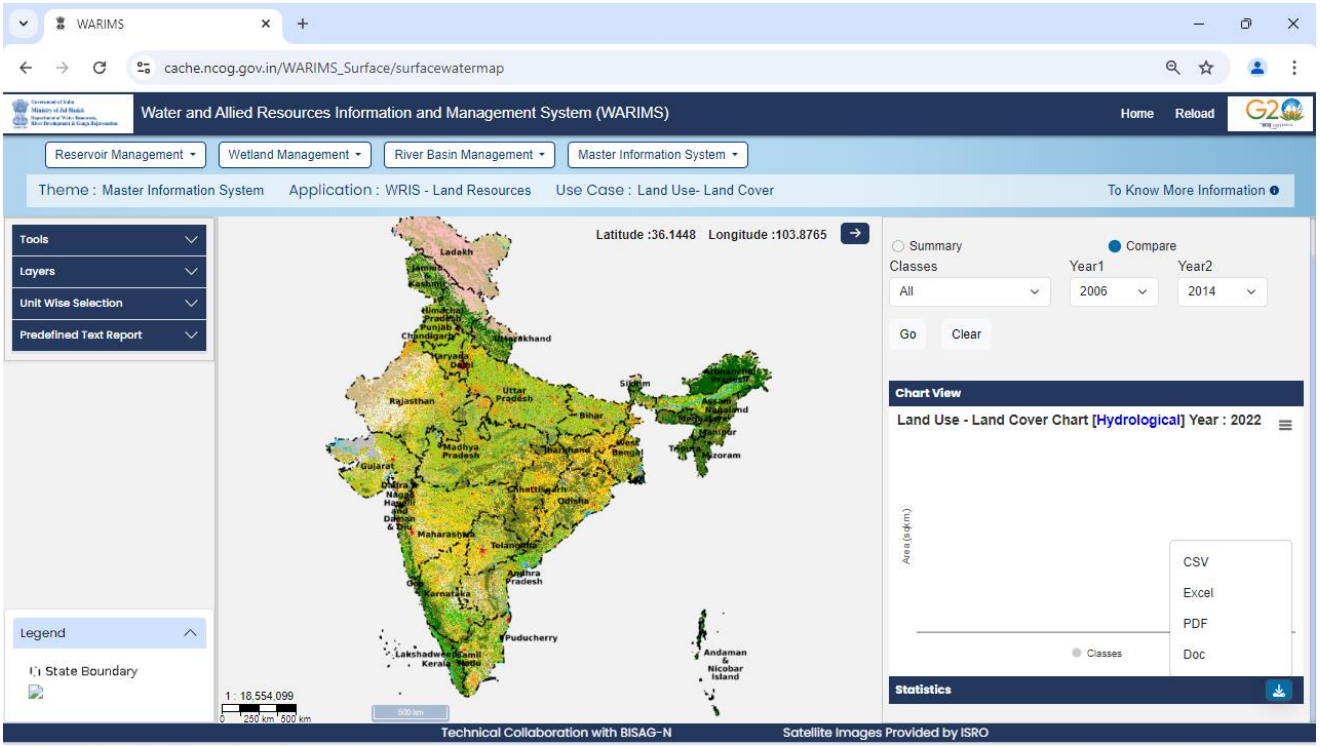


Figure-55 Component Features (Statistics Report) of the (LULC)

5. Conclusion

The system utilizes the methodology to create and update LULC maps and datasets, which are essential for various applications such as scientific research, industrial sitting, land improvement, watershed and coastal zone management, water resource management, and agricultural productivity improvement.

The system uses high-resolution satellite imagery from various sources, for mapping LULC at different scales. The process involves data preparation, interpretation, ground truthing, post-classification correction, and output generation using both vector-based on-screen visual interpretation and raster-based image classification methods.

The system emphasizes the importance of monitoring LULC changes for sustainable development and planning. It describes the generation of LULC maps at various administrative levels, from the country to the state/district/basin/sub-basin, and the provision of detailed LULC information and temporal changes through reports, graphs, charts, and statistics.

The system development has reviewed and implemented data integration, and other system related dependencies, risks, and testing. Changes in Land Use/Land Cover (LULC) are influenced by both human activities and natural forces. Effective monitoring of these changes is now available for the end-users like planners, policymakers, decision makers, administrators, academicians, farmers and public in general. The end-users can access this application to foster informed decisions for sustainable development. Finally, a comprehensive information system to track LULC over time is developed, that provides necessary insights to efficate planning for sustainable land management.

The web application provides all the necessary features in the menu options. The Application is accessible for the Classification of Land Use Land Cover for Various Classes of Hydrological and Political Features for Years. The Summary Report with Comparative statistics is available between two selected years. The statistical data report is available in printable formats.

In conclusion, the system provides comprehensive framework that is developed for LULC mapping system, which helps the user to understand land use patterns and their changes over time, ultimately supporting informed decision-making for sustainable land management and resource utilization.

6. Outcome

The project provides the stakeholders with temporal changes of LULC over Indian administrative and hydrological regions with maps, chart/graph and statistics based upon user specific query which enables informed decision-making for sustainable land management. Updated LULC information from various agencies on single frame helps identify environmental threats and optimize land use across sectors like agriculture and urban planning, supporting resource-efficient development efforts.

7. Future Scope

- System can be utilized for all the sectoral planning of land resources.
- The application can be made available in mobile application.
- The scalable system architecture allows the technologies, data framework, and testing strategies to adapt and support future governance needs.

8. Ideation

Innovative applications of Land Use and Land Cover (LULC) data can include creating:

- AI-powered monitoring systems for tracking land changes, developing sustainability dashboards for decision-making, leveraging citizen science platforms for local land observations.
- Additionally, automated environmental impact assessment tools and conservation planning resources can guide sustainable development by analysing potential impacts and enhancing biodiversity protection.

These innovations may enable practical, data-driven solutions for sustainable land resource management across various sectors.

9. Reference Material for Techno-functional Understanding

1 BSR for the Land Use Land Cover (From NWIC)[21]
2 ISRO/NRSC: NRSA/RSGIS-AA/NRC/NLULC- AWiFS/PROJREP/R01/JUN07,
3 NRSC (2014), Land Use / Land Cover database on 1:50,000 scale, Natural Resources Census Project, LUCMD, LRUMG, RSAA, National Remote Sensing Centre, ISRO, Hyderabad
4 Ranganath R. Navalgund, Remote sensing applications: An overview, Current Science, Vol. 93, No. 12, 25 December 2007
5 Manual - Preparation of Geo Spatial Layers using High Resolution (Cartosat-1 PAN -r LISS-IV Mx) Orthorectified Satellite Imagery, RS& GIS AA, NRSC, ISRO, March-2012

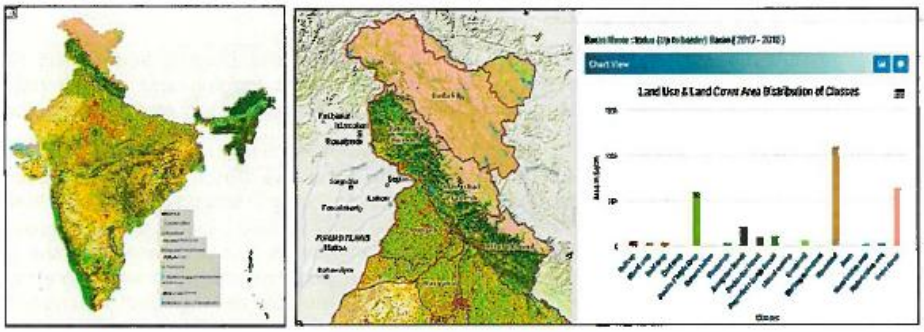
[21] Annexure-1: BSR of Land Use Land Cover from NWIC

Annexure – 1: BSR for the Land Use Land Cover (From NWIC)

Business Specific Requirements	
Theme	Master Information System
Application	WRIS-Land Resources
Use Case	Land Use – Land Cover
Use Case ID	WRIS-MIS-07
Other linked Use Case	Forest/Tree Cover (WRIS-MIS-05), Land Degradation (WRIS-MIS-06), Wasteland Study (09), Wetland Inventory (WM-UC-01), Water logging and salinity (IM-UC-11), Crop Yield Estimation (CWM-UC-11), Land resources-allied themes and also usefull as important model parameter
Description	Land Cover is defined as observed physical features on the Earth's Surface. When an economic function is added to it, it becomes Land Use. (FAO, 2005) Land use is a very human-centric term. This is mainly the focus on the activity that is being practiced on a piece of land. Changes in LULC do not always have to be driven by humans; the land can also undergo changes through the forces of nature. Therefore, it is necessary to timely monitor the changes in land use/land cover pattern for a particular area or the whole. The detection of such changes gives planners and policy makers answers to some important questions which is essential for sustainable development. Information on land use/land cover and the changes over a period of time attain prominence because of its primary requirement in all the planning activities.
Used by	Planners, Decision makers, administrators, academicians, farmers, and the public in general
Priority	**High Priority:** Land use serves as base for many applications and also as a model parameter required in many thematic studies. Land use land cover mapping addressing Kharif, Rabi and Zaid crops, greening of wastelands, seasonality of wastelands, surface water bodies, forest vegetation and other high temporal land use practices using satellite remote sensing data can provide a reliable database. The LULC maps and database should be used at broad level for the following purposes: • Scientific research involving carbon cycle, hydrologic cycle, energy budget studies, weather/climate prediction; • Siting of industries, SEZs etc.; • Land improvement programmes; • Watershed management; • Coastal zone management; • Water resource management • Agricultural productivity improvement etc.
Phase	**Phase-1** Subsumed
Business Problem	**Issue:** Land resource related queries such as, what type of land is more severely under threat, where do forests need protection, which direction is an urban Centre growing, and is that posing any dangers to the natural environment, how is the changing land use affecting the atmosphere and nearby water resources, where do we have the best opportunity to exploit land as a natural resource, and so on are always asked and requires timely updated spatial database to answer and assess the situation. **Approach:** NRSC Land use division finalised a threefold classification system and adopted the same for Nationwide LULC analysis at various scale mapped every year. NWIC receives classified outputs on both 50k & 250K scale. To generate LULC using High resolution satellite data and Google earth engine, NRSC classification system can be adopted followed with intense ground checks. Both raster and vector based mapping approach is considered to get most out of optical and microwave imageries.
Output	Land use land cover on desired scale/resolution
Outcome	LULC classified data on 50k (vector) & 250K (raster) scale. Temporal changes of LULC over Indian administrative and hydrological regions with maps, chart/graph and statistics and also based upon user specific query. Updated LULC information from various agencies within single frame

Annexure-1 (Page-1/6)

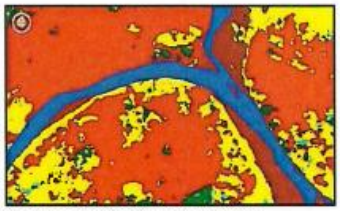
Visualization	1. **Map –** LULC map at country to State/district/Basin/Sub-Basin level from IRS LISS-III (23.5m) data on 1:50K scale and from IRS P6 AWiFS (56m) data on 1:250K scale (NRSC)

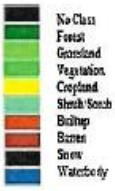


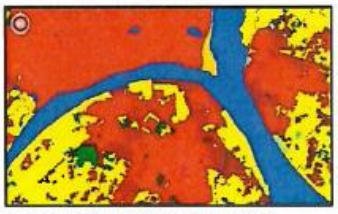
High Resolution LULC Map: LULC data can also be prepared for the area of interest using high resolution satellite images (*IRS-L4, RISAT SAR, Sentinal-2 etc.*) with required ground checks and disseminated with finer details and standard symbology

ERS Copernicus Sentinal-2 Image (10m)

IRS R2 LISS-IV Image (5.8m)



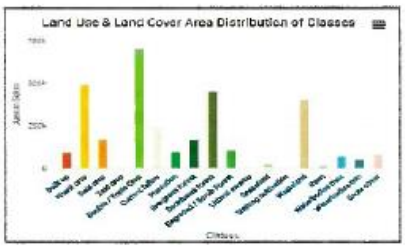


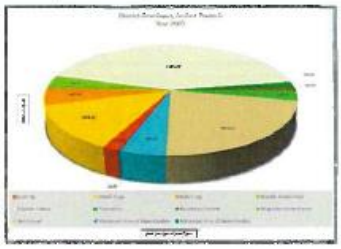


Sentinal-2 Image(10m) Classified LULC

LISS-IV Image (5.8m) Classified LULC

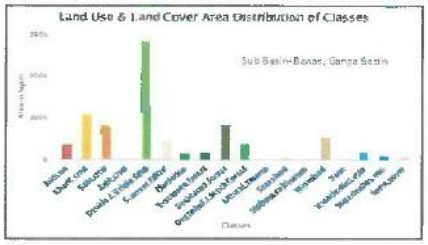
2. **Graph / Charts:** Various **Pie/Bar** charts can be drawn based upon administrative/hydrological setup indicating Land use land cover classes
   (a) Class wise distribution of Land use land cover area (Based upon administrative setup)

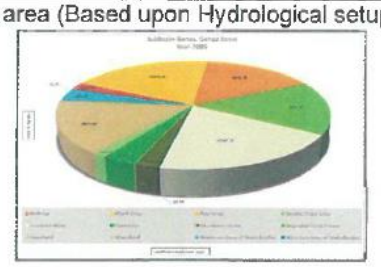




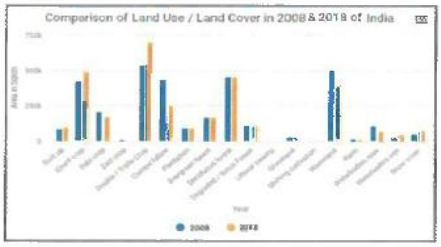
Annexure-1 (Page-2/6)

(b) Class wise distribution of Land use land cover area (Based upon Hydrological setup)





(c) Comparison between two consecutive year or decadal LULC cycle



LULC Classes	Area in Sqkm of 2008	Area in Sqkm of 2018
Built up	84406.46	99678.94
Kharif crop	414613.00	409509.39
Rabi crop	200062.61	169900.77
Zaid crop	7988.24	8594.86
Double / Triple Crop	538998.03	608009.89

3. **Output in tabular format:** – State/District-wise, Basin/Sub Basin wise Land use land cover status can be provided in the form of table and as per the time selection (yearly). Comparison between two LULC cycle can also be provided to assess positive and negative changes over the period of time.

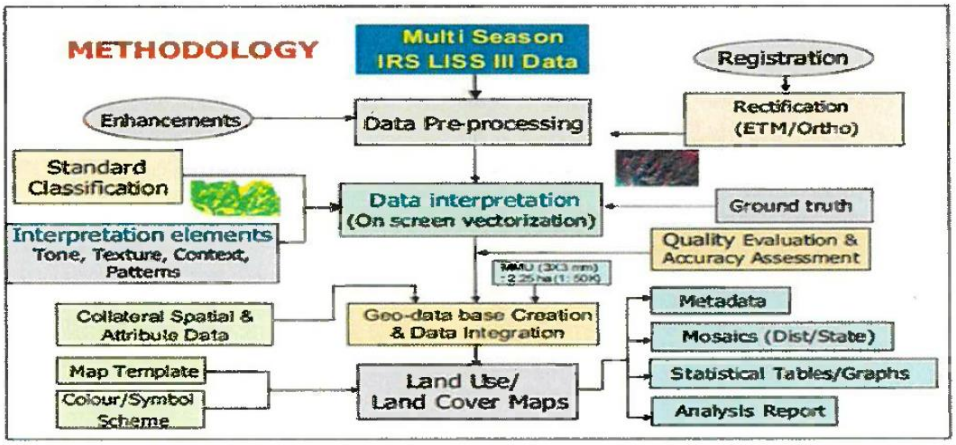
S.No	Classes	Area Sq. Km
1	Built up	8477.468
2	Kharif crop	5102.304
3	Rabi crop	5007.584
4	Zaid crop	366.658
5	Double / Triple Crop	60826.903
6	Current fallow	9035.140
7	Plantation	3396.768
8	Evergreen forest	21522.462
9	Deciduous forest	9845.986
10	Degraded / Scrub Forest	11150.982
11	Grassland	6671.953
12	Wasteland	109916.107
13	Waterbodies	5204.085
14	Snow cover	65419.638

S.No	Category	2007-2008	2017-2018	Change	Percent
1	Built up	4732.268	8477.468	3745.200	36.98
2	Kharif crop	4608.048	5102.304	494.259	10.73
3	Rabi crop	3433.095	5007.584	1574.488	45.86
4	Zaid crop	87.385	366.658	279.273	319.59
5	Double / Triple Crop	57496.634	60826.903	3330.269	5.79
6	Current fallow	8041.278	9035.140	5004.138	-42.74
7	Plantation	3381.336	3396.768	15.432	0.46
8	Evergreen forest	21518.962	21522.462	3.500	0.02
9	Deciduous forest	9853.638	9845.986	-7.652	-0.08
10	Degraded / Scrub Forest	11150.274	11150.989	0.715	0.01
11	Littoral swamp	0.003	0.003	0.000	0.00
12	Grassland	6214.436	6671.953	457.517	7.36
13	Wasteland	152529.947	109916.107	42613.840	-27.94
14	Waterbodies	5200.209	5204.985	4.776	0.09
15	Snow cover	25712.868	65419.638	39706.770	154.48

4. **Predefined Text Report:** The report may be generated at various level such as country/ state/district/basin/sub basin. If the user is interested in one region, then the detailed LULC information and temporal change (year) may be provided with graph/charts and relevant statistics. Comparative analysis for changes may be included with facts and ground references in the report.

Frequency	Once in five years, updated as provided by concerned mapping agency (NRSC)
Measures of Success (KPIs)	To generate spatial and change database on land use/land cover. Major change areas will be specifically identified. This will enable planners and administrators to initiate the appropriate measure for preventing / arresting the degradation and development of natural resources.
Input Data Required	Various medium to high resolution satellite sensor images, legacy data and SOI toposheets
	Geospatial Time Series Data: •**Frequency:** Yearly 1. Monsoon Season – Kharif: August - October 2. Post-Monsoon – Rabi: December - March 3. Pre-Monsoon – Zaid: April – May •**Resolution:** 1. IRS R2 LISS III (23.5m) at 50k scale 2. IRS P6 AWiFS (56m) at 250K scale 3. ESA Sentinal-2 (10-15m) 4. IRS R2 LISS IV (5.8 m) at 25k scale 5. RISAT EO4 SAR FRS-2(3m), CRS (50m) •**Extent of Coverage:** Whole country
Process	
Algorithm/Tool	The major steps involved in Land use land cover mapping are data preparation by selection of image, interpretation to identify change area, ground truthing and post classification correction, followed by generation of output. The approach involves two methods for classification (i) Vector based on-screen visual interpretation of satellite images and (ii) raster-based image classification.

(i) On-screen visual interpretation can be applied on to the terrain corrected Resourcesat-2 LISS III & LISS IV imagery. The methodology essentially is based on editing the previous year digitized layers for updation with reference to current year images. The output generally is good fit at 50k scale mapping for LISS-III and at 25k scale for LISS-IV image. This creates an advantage to asse ss changes over the period of time.



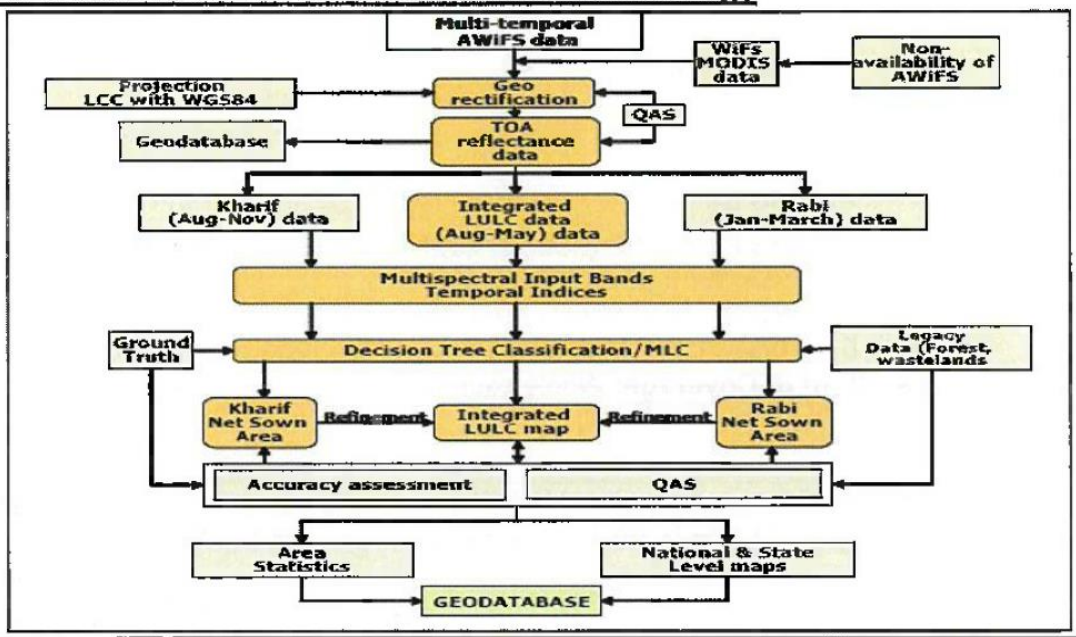
LULC classification scheme and brief description of classes are as given hereunder:

Sl.	Description-1	Description-2	Classes from NRC LULC50K Mapping Project
1	Builtup	Urban	Residential, Mixed builtup, Public / Semi Public, Communication, Public utilities / facility, Commercial, Transportation, Reclaimed land, Vegetated Area, Recreational, Industrial, Industrial / Mine dump, Ash / Cooling pond
		Rural	Rural
		Mining	Mine / Quarry, Abandoned Mine PIt, Land fill area
2	Agriculture	Crop land	Kharif, Rabi, Zaid, Two cropped, More than two cropped
		Plantation	Plantation - Agricultural, Horticultural, Agro Horticultural
		Fallow	Current and Long Fallow
		Current Shifting cultivation	Current Shifting cultivation
3	Forest	Evergreen / Semi evergreen	Dense / Closed and Open category of Evergreen / Semi evergreen
		Deciduous	Dense / Closed and Open category of Deciduous and Tree Clad Area
		Forest Plantation	Forest Plantation
		Scrub Forest	Scrub Forest, Forest Blank, Current & Abandoned Shifting Cultivation
		Swamp / Mangroves	Dense / Closed & Open Mangrove
4	Grass/ Grazing	Grass/ Grazing	Grassland: Alpine / Sub-Alpine, Temperate / Sub Tropical, Tropical / Desertic
5	Barren/uncultivable Wastelands	Salt Affected Land	Slight, Moderate & Strong Salt Affected Land
		Gullied / Ravinous Land	Gullied, Shallow ravine & Deep ravine area
		Scrub land	Dense / Closed and Open category of scrub land
		Sandy area	Desertic, Coastal, Riverine sandy area
		Barren rocky	Barren rocky
		Rann	Rann
6	Wetlands / Water Bodies	Inland Wetland	Inland Natural and Inland Manmade wetland
		Coastal Wetland	Coastal Natural and Coastal Manmade wetland
		River / Stream / canals	Perennial & Dry River/stream and line & unlined canal/drain
		Water bodies	Perennial, Dry, Kharif, Rabi &Zaid extent of lake/pond and reservoir and tanks
7	Snow and Glacier		Seasonal and Permanent snow

(ii) **Classification System for LULC mapping**

IRS P6 AWiFS satellite data can be used for LULC mapping at 1:250K scale. Raster based digital image classification approach is successfully applied for country level mapping by NRSC/ISRO. For identification of agriculture, forest and water Normalised Difference Indices method are very popular and result oriented.

Flow chart of raster based LULC classification methodology



	Process involved in data integration & development:(by NWIC) **Step 1:** LULC classes Sync with existing/designed Schema 1. Reprojection of classified LULC raster data received from NRSC into India WRIS Projection (LCC) 2. LULC is then bifurcated as per classification Schema based on threefold classification system (Attribute table) 3. Joining LULC Schema table with LULC Raster file based on primary key (LULC web code) 4. Cleaning LULC Raster by removing null values and extra unwanted fields 5. Import Raster LULC in new Geodatabase and create area field to calculate the area (in Sq.km) of Raster LULC **Step 2:** LULC area statistics – Administrative & Hydrological setup Wise & Data Publishing 1. Calculate LULC class area for all Districts/Sub Basin using Tabulate Area tool in ArcGIS (Table) 2. Calculate area Sq. m to Sq.km in newly created blank Master Table for LULC classes 3. Publish web map service and appropriate data table for final GUI development **Note*** Other agencies are working in line with NRSC but with limited ground truthing and varying mapping scale. NRSC is also mapping LULC under SIS-DP project through visual interpretation on IRS LISS-IV Pan & Carto merge data to produce output at 1:10k scale
Data Validations	Initial screening is required before integrating data received from various mapping agencies for its completeness and accuracy. Checking of figures/stats quoted in published reports with geographical raster/vector data layer provided/generated for particular mapping year. LULC classification and mapped area should also justify statistics, surveyed by department of Economics and Statistics
Software Requirement (specific if any)	ARC GIS/PRO, ERDAS Imagine, Hydro tools, QGIS
Dependencies & Risks	Non-availability of appropriate season data sometimes put constraints on the interpretation of the features owing to poor reflectance of data, cloud conditions/images and other phenological changes. Incomplete or manipulated data (Interpretational errors). Registration errors when using old SOI toposheet for reference purpose. Unmatched GIS layer feature area with published statistics. Generally raster and vector classification output dosen't match due to difference in mapping approach. Software solutions and trainings are highly required in working with High Resolution Microwave Image.
User Acceptance Testing (UAT) By	NWIC
Development Responsibility	NWIC
Reference material	1. ISRO/NRSC: NRSA/RSGIS-AA/NRC/NLULC- AWiFS/PROJREP/R01/JUN07, 2. NRSC (2014), Land Use / Land Cover database on 1:50,000 scale, Natural Resources Census Project, LUCMD, LRUMG, RSAA, National Remote Sensing Centre, ISRO, Hyderabad 3. Ranganath R. Navalgund, Remote sensing applications: An overview, Current Science, Vol. 93, No. 12, 25 December 2007 4. Manual - Preparation of Geo Spatial Layers using High Resolution (Cartosat-1 PAN + LISS-IV Mx) Orthorectified Satellite Imagery,RS & GIS AA, NRSC, ISRO, March-2012

For any communication/clarification on the BSR, the following Officer may be contacted.		
Nodal Officer Name & Designation:	Dr. Rakesh Singh, Deputy Director	**Signature :** 16/3/23
Organization:	National Water Informatics Centre	
Contact No.: **Email id:**	9006150281 dd-services-nwic@gov.in	
BSR prepared by Subject Matter Expert (SME), Name & Designation:	Dr. Dharmesh Singh Hydrologist	**Signature :** 16/03/23
Organization:	NWIC	
Contact No.: **Email id:**	8447025987 hydrologist.nwic@gmail.com	

This is to certify that the above BSR has been vetted and found satisfactory.

Details of Domain Organization SPOC and SME for Verification and Approval of above BSR

16/3/23 **(Signature of SPOC)** **SPOC Name:** Dr. Rakesh Singh **SPOC Designation:** Deputy Director **Organization:** NWIC	16.3.23 **(Signature of SME)** **SME Name:** Sh. Karthic S.R. **SME Designation:** Deputy Director **Organization:** NWIC

Annexure – 2: Project Blueprint Synopsis[22]

Project	Land Use- Land Cover (LULC) (WRIS-MIS-07)
Application	WRIS-Land Resources
Theme	Management Information System (MIS)
Platform	The Water and Allied Resources Information and Management System (WARIMS)
Initiative For	Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti (MoJS)
Developed By	Bhaskaracharya National Institute for Space Applications and Geo-informatics (BISAG-N), Ministry of Electronics and Information Technology, Government of India.

Specification Outline

Land Cover is defined as observed physical features on earth's surface. When an economic function is added, it becomes Land Use. Timely monitor the changes are necessary in LULC pattern for a particular region. Change detection helps audience' answers to important questions which is essential for sustainable development. Change detection information of LULC over a period of time is primary requirement in all planning activities.

End Users

Planners, Decision makers, Administrators, Academicians, Farmers, and the Public.

Governance Need

Land resource queries require updated spatial information for tracking land use changes and urban growth impacts, enabling informed decision-making on environmental management. This information helps to protect natural environments and optimize land as natural resource.

Scope

LULC serves as a model parameter required in many thematic studies. LULC mapping address Kharif/ Rabi / Zaid crops, green/season wastelands, surface water bodies, forest vegetation and other high temporal LULC practices using satellite remote sensing data.

Success Criteria

To generate spatial change data on LULC. To enable end users initiate the appropriate measure to prevent / review degradation / development of natural resources.

Technologies Utilized and Supported

Geospatial :	Image Processing and Remote Sensing Techniques
Web Application :	Java SpringBoot 4.0, GeoWebCache, JQuery 3.7.4
Front-end :	OpenLayers 6, Thymeleaf 3.1.2, Bootstrap 5.3 (CSS & JS), HTML5
GIS Software :	QGIS 3.32 Lima
Cloud :	MeghRaj, NIC
Database :	PostgreSQL 9.4

Schedule*

Milestones	Phases	Work Days	Team
1	Requirement: Understanding and Analysis & Review	5	Project Manager, Project Analyst
2	System Design	3	UI/UX Graphics & Web Designer
3	System Development	10	Software Developers
4	System Quality Testing	2	Software Quality Tester
5	User Acceptance Test (UAT)	5	NWIC

*Overall project activities is planned, monitored and reviewed by project manager and reported to project director.

[22] Annexure-1: BSR of Land Use Land Cover from NWIC

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Annexure-6: Abbreviations

Abbreviations	Full Name
API	Application Programming Interface
AWiFS	Advanced Wide Field Sensor)
BSR	Business Specification Requirement
CRS	Common Reference System
DSS	Decision Support Systems
EO	Earth Observation
ESA	European Space Agency
ETL	Extract, Transform, Load
FPGA	Field-Programmable Gate Array
FRS	Forest Resources Survey
GIS	Geographic Information System
IaaS	Infrastructure-as-a-Service
India-WRIS	India Water Resources Information System
IRS	Indian Remote Sensing Satellite
ISO	International Organization for Standardization
IT	Information Technology
IWRM	Integrated Water Resources Management
KPI	Key Performance Indicator
LGD	Local Government Directory, Government of India
LISS	Linear Imaging Self-Scanning Sensor
LULC	Land Use Land Cover
MoJS	Ministry of Jal Shakti
MODIS	Moderate Resolution Imaging Spectroradiometer
NRSC	National Remote Sensing Centre
NWIC	National Water Informatics Centre
OGC	Open Geospatial Consortium
O&M	Operations and Maintenance
PaaS	Platform-as-a-Service
QA	Quality Assurance
R2	Resourcesat-2
R&D	Research and Development
RISAT	Radar Imaging Satellite
SAR	Synthetic Aperture Radar
SoI	Survey of India
SQL	Structured Query Language
TBD	To Be Determined
UAT	User Acceptance Testing
UAV	Unmanned Aerial Vehicle
UI	User Interface
UX	User Experience
WIMS	Water Information Management System