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NATIONAL REMOTE SENSING CENTRE
Indian Space Research Organisation
NEWSLETTER
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inform inspire educate engage innovate
Volume 9 Issue 2

from the directors's desk

Greetings. I hope everyone is keeping themselves and their families safe during this pandemic. Like many organisations around the world, NRSC is also trying to balance institutional commitments while reducing the exposure of employees to the novel Corona virus. Despite the lock down, the centre could manage its core activity of data acquisition, processing and dissemination with minimum essential staff.

During the last six months, we acquired around 13000 satellite passes (99.92% efficiency) from which around two lakh data products were generated. The data reception antennae handled 2526, 2506 and 2810 passes (April-June) against 2543, 2675 and 2668 passes during the same months in 2019. Similarly, 113287 products (95064 in 2019) were generated during lockdown.

I am happy to share with you that we have successfully acquired Cartosat-3 data at AGEOS through in-house developed SPARK card & S/Ka-band hybrid antenna system. Several systems are in development stage for handling HRSAT, NISAR and NOVASAR satellite missions. We have successfully acquired RISAT 2B1 data from 89 orbits (all imaging modes) at IMGEOS. The 7.3 m tri-axis antenna systems has been established at Jodhpur.

The data dissemination from our data centre stood at 1 lakh IRS data products, 16000 sq km high resolution and 150 lakh sq km of non-IRS data. A rise in unique users on Bhuvan during the lock down period was observed.

I am happy to put on record that our VT-EQ aircraft has flown successfully for 72 hrs (Feb/March) completing the LiDAR surveys over Godavari River basin and the processing for 4802 sq km is initiated under NHP project. The processed data for 5032 sq km acquired by Airborne Laser Scanning system was handed over to INCOIS. We have created a 5.5 km spatial resolution near real-time actual Evapotranspiration dataset using NPPS, INSAT 3D and MET data.

The AMRUT project (GIS-based master plan development) is progressing well with completion of 99.5% satellite data procurement and 2D feature extraction for 240 out of 241 cities. The model Gram Panchayat spatial developmental plan is initiated for 32 gram panchayats. Around 1.5 crores assets are geotagged under MGNREGA phase 2 project. 96 lakhs houses are geotagged under Pradhan Mantri Awas Yojana in association with MOUHA. Around 8.93 lakh health establishments are geotagged under National Health Repository creation. Crop intensity maps (2019-20) have been derived at a circle level for Maharashtra.

121 flood products are disseminated to the disaster centres of West Bengal, Assam & Bihar states. NRSC is regularly monitoring the locust attack in Western and Central parts of India.

We have implemented an enhanced GEOS-Chem atmosphere transport model for simulation of Methane across the globe as a part of climate and atmosphere science program. One can now visualize the predicted CO_2 over Indian region and surrounding oceans at 0.250 grid scale.

NRSC has organised 9 outreach events under VSCP during Feb-Mar. (1 lakh participants) and is actively involved in ISRO Cyber Space Competitions-2020. The ISO 9001:2015 ISO QMS recertification audit of all campuses is completed and recommended for continuation of ISO certification for NRSC.

To effectively reduce the spread of COVID-19 in the campus, electronic means of communication is being preferred. The working environment is facilitated with thermal scanners, work from home, physical distancing, pedal operated sanitizers, VC meetings, enhanced capacity of transport services, sanitization programme, staggered timings, packed food, UV light file disinfectant chamber, in-house preparation of sanitizers (WHO standards) and weekly audit to ensure the adoption of COVID 19 prevention practices. NRSC promotes the use of Arogya Setu app.

NRSC shall move forward to live up to the expectation of the country in the era of liberalisation of space infrastructure for private industry.

Santanu Chowdhury, Director, NRSC

index

Director, NRSC inaugurating exhibition at GMRT, Pune on Feb. 28, 2020

1. Geospatial Technology based solution from Bhuvan to combat COVID-19

State and Central Government organisations are taking several measures to stop the spread of COVID-19 by actively delivering solutions for this problem. National Remote Sensing Centre (NRSC) has extended support to Government by providing Geospatial solutions on BHUVAN - Indian Geoplatform of ISRO. NRSC brought out various mobile applications and web based utilities aiding decision makers and citizens to fight against COVID-19 as given in table. *Figure 1.1 shows the COVID-19. dashboard and Figure 1.2 shows mobile Rythu bazar tracker.*

Sl. No.	Title	Description
1	COVID 19 Dashboard in Sync with Ministry of Health and Family Welfare	Providing daily state-wise growth, present day pan India scenario, state vs date and details of deceased in sync with Ministry of Health and Family Welfare on active, recovered and deceased cases as Time Series Visualisation, which is unique in nature https://bhuvan-app3.nrsc.gov.in/corona/ https://bhuvan-app3.nrsc.gov.in/corona/corona_dashboard/dashboard/dashboard.php?type=citizen
2	Citizen Reporting and Officer Reporting for Department of Health, Government of Telangana	Reporting the COVID symptoms from smartphones, which in turn enables Govt. officers to plan for survey and share the details through online tools. Administrators use the information on dashboard to monitor the status of pandemic with details. https://bhuvan-app3.nrsc.gov.in/corona/
3	Mobile Rythu Bazar Tracking for Department of Agriculture, Govt of Telangana	Provides real time coordinates of "Mobile Rythu Bazar" and enables estate officers of Agriculture Department to allocate vegetable transport vehicle and plan their routes efficiently with various in-built reporting tools. https://bhuvan-app3.nrsc.gov.in/track/smartrack/track.php
4	Home Quarantine Tracker - Narayanpet Dist, Dist Collectorate, Govt of Telangana	Helping in geotagging all the home quarantine cases and enabling in monitoring them from a simple-to-use dashboard and assist them for tele medicine, essential items distribution by SHG. https://bhuvan-app3.nrsc.gov.in/narayanpet/
5	Bihar Health Department : COVID-19 Containment strategy, Govt of Bihar	Geoportal for highlighting COVID-19 locations, Containment Zones, tertiary buffer zones for both urban and rural areas with Village boundaries and census data details on number of households, population details etc. for effective planning and monitoring of containment zones https://bhuvan-app3.nrsc.gov.in/biharcovid/
6	112+ India: CDAC	Providing Map-based services and custom bhuvan framework includes Bhuvan maps as Open Geospatial Consortium (OGC) services, JSON based bhuvan customised views for geolocation, visualisation and tracing https://apps.mgov.gov.in/descp.do?appid=1488&param=app
7	Monal 2020 from ECIL	Enables round-the-clock monitoring in case of home isolation of COVID-19 patients uses Bhuavn Services to geolocation of Patients, different zones (like Red/Orange/Green) of a specified area (like city/district/ State)
8	Annapurna Meal Centers, Greater Hyderabad Municipal Corporation, Govt of Telangana	Location, Proximity and easy navigation to Annapurna Meal Centres in Telangana for Greater Hyderabad Municipal Corporation https://bhuvan-app3.nrsc.gov.in/meal_center/index.php?state=TS
9	Amma Unavagam, Greater Chennai Corportaion, Govt of Tamil Nadu	Location, Proximity and easy navigation to Amma Unavagam in Tamil Nadu for Greater Chennai Corporation. https://bhuvan-app3.nrsc.gov.in/meal_center/index.php?state=TN

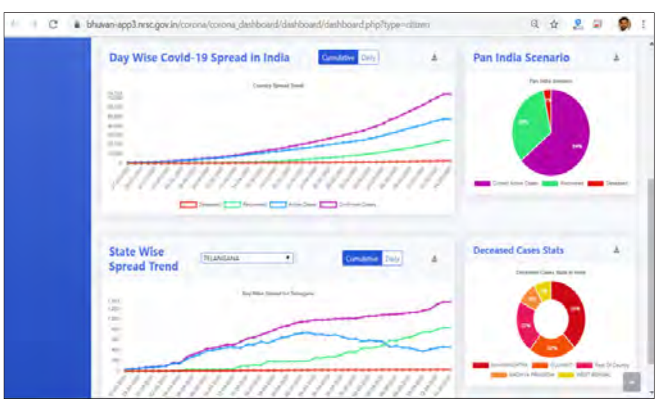


Fig. 1.1: COVID-19 Dashboard

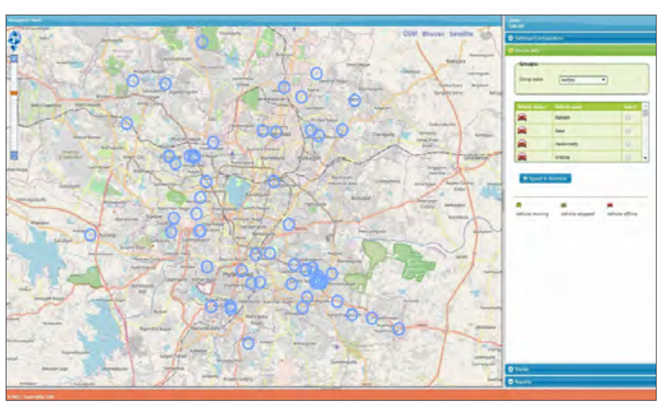


Fig. 1.2: Mobile Rythu Bazar – Tracker, Govt. of Telangana

COVID-19 Containment strategy - A case study for Bihar Health Department, Govt of Bihar

Bhuvan - Covid19 containment strategy (https://bhuvan-app3.nrsc.gov.in/biharcovid/index.php) is a Web GIS based application envisaged to provide geospatial support for Bihar Health Emergency Operation Centre to combat COVID 19. This is a unique tool deployed to help in mapping the Epicentre of the infections and to depict containment zones or hotspots for containment with tertiary buffer zones to manage the pandemic at field level (Figure 1.3). This is implemented as per Government stipulations to effectively fight, localise and contain the virus. Access for this application is provided only to Bihar State Department officials with authorized Logins.

Unique Features of the portal are:

- Completely Automated solution for uploading of Epicentres.
- Option for Officials to create all necessary data epicentre, Containment Zone (3km), Buffer Zone (5Km, 7Km) marking with Village details having no of households, population, etc.
- Facilitating visualization of more than 750 Epicentres (Urban and Rural) with selection of District and Patient.
- Visualization of Containment Zones (3Km) and Buffer Zones (5km, 7Km) along with Villages covered under these zones.
- Download of reports as Excel for each Epicentre with Villages covered, Number of Households, and Total Population.
- Customized print module enabling view of Epicentre, Villages, Buffer Zones with High Resolution Satellite image helping in planning activities.

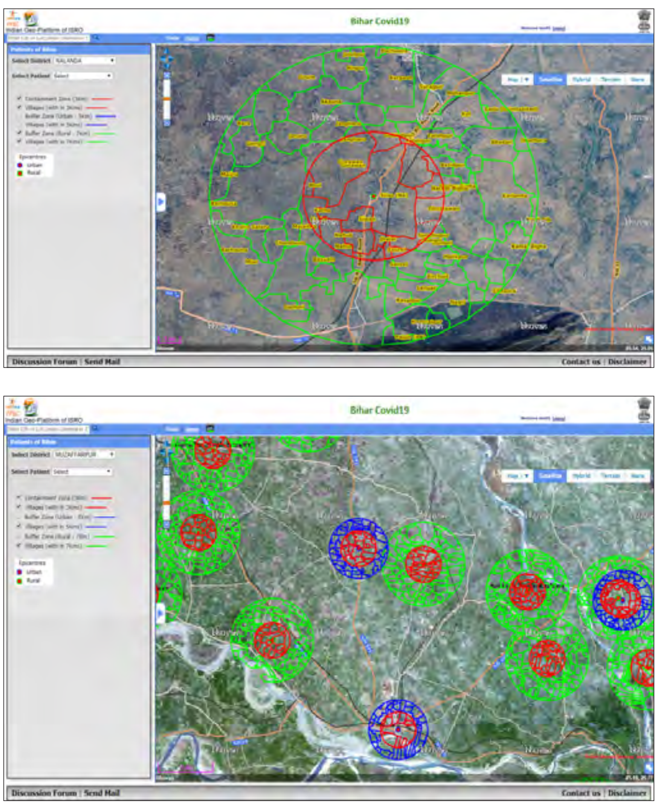


Fig. 1.3: Covid-19 containment strategy portal

2. BHOONIDHI: ISRO Open data access portal

Bhoonidhi - ISRO Open Data Access Portal facilitates the dissemination of coarse and medium resolution satellite data products in near real time to online users on web with user friendly searches (Figure 2.1). Data corresponding to India and surroundings from Indian Remote Sensing Satellite (IRS) and non-IRS sensors are made available to meet the growing need from large number of applications. Bhoonidhi was released during NRSC User Meet 2020. It's catalogue and browse features provide a quick insight into the huge data archive available at NRSC for users. It also serves as a regional data hub for the Sentinel satellites series and also disseminates Landsat-8 OLI data, which is acquired at Integrated Multi Mission Ground Segment for Earth Observation Satellites (IMGEOS)/NRSC Ground station (Figure 2.2).

To serve user needs while searching for satellite imagery, few more user specific search features were added in addition to the search features available at other contemporary data dissemination portals like Copernicus, Earth Explorer, etc. Search options like event based search, time series search, resolution based data search, etc. help users in quickly finding the correct satellite data that will serve their purpose (Figure 2.3). The portal also has many Area of Interest(AOI) options like point, location, polygon, map tools, etc., if user is interested in a particular area (Figure 2.4).

To ease the process of dissemination of the multiple data sets, the cart feature is also provided, which helps users to add diverse datasets on the fly to have an overview of the downloads. A bulk downloading utility is also provided to users, for downloading all the products of a search session as a batch job.

In order to automate the data downloading and search operations for users, a prototype version of Bhoonidhi API and python library is also released for selected users to search and download different datasets automatically.

With Honourable Finance Minister vowing for the liberalized satellite data policy, more satellites and sensor data are planned to be added in the portal, adding to the treasure of satellite data from ISRO. The portal can be accessed at https://bhoonidhi.nrsc.gov.in.

VSVP - A large gathering for Bus exhibition

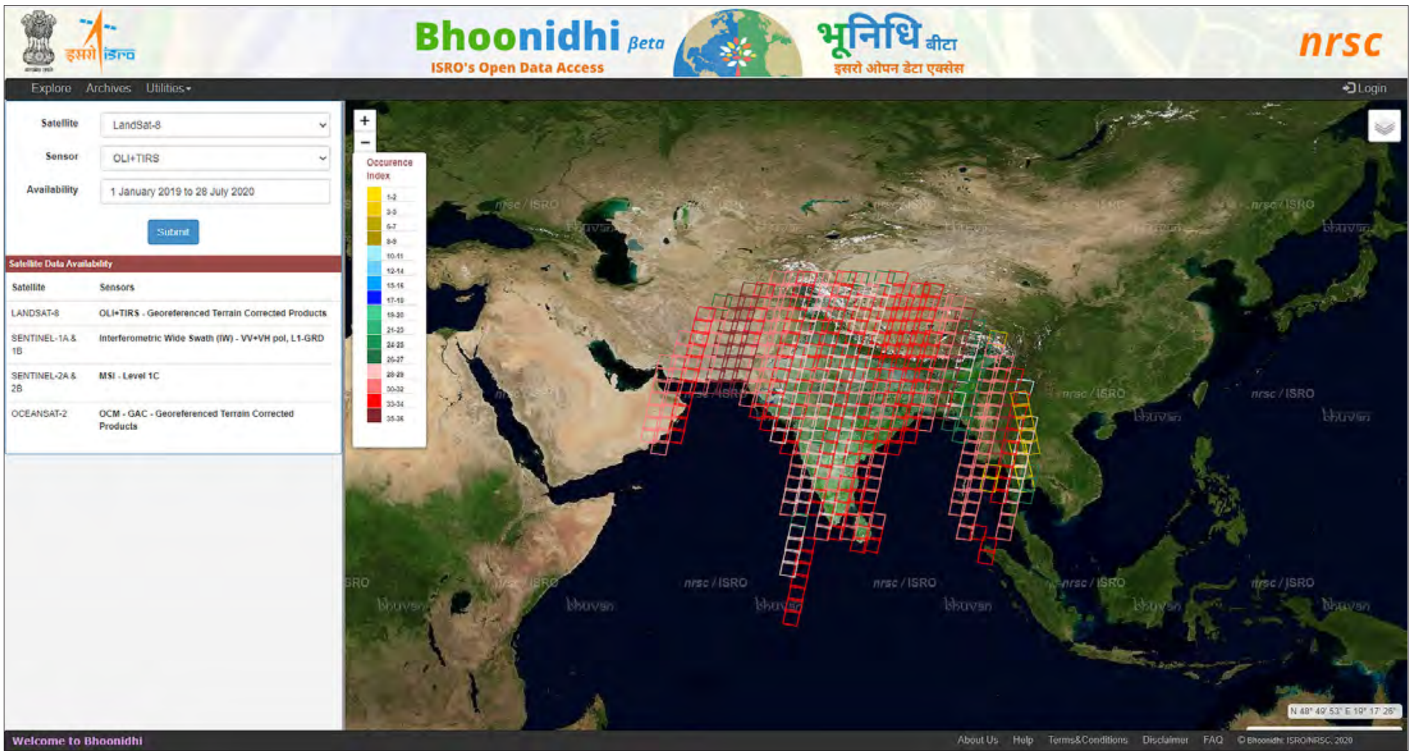


Fig 2.1: Landing page of Bhoonidhi

Satellite Data Availability	
SATELLITE	**SENSORS**
LANDSAT-8	OLI+TIRS || from 01-Jan-2019
SENTINEL-1A	IW : VV+VH (L1-GRD) ||from 01-Oct-2019
SENTINEL-1B	IW : VV+VH (L1-GRD) ||from 01-Oct-2019
SENTINEL-2A	MSI (L-1C) || from 01-Oct-2019
SENTINEL-2B	MSI (L-1C) || from 01-Oct-2019
OCCENSAT-2	OCM - GAC || from 01-Jan-2019

Fig. 2.2: Satellite data availability on portal

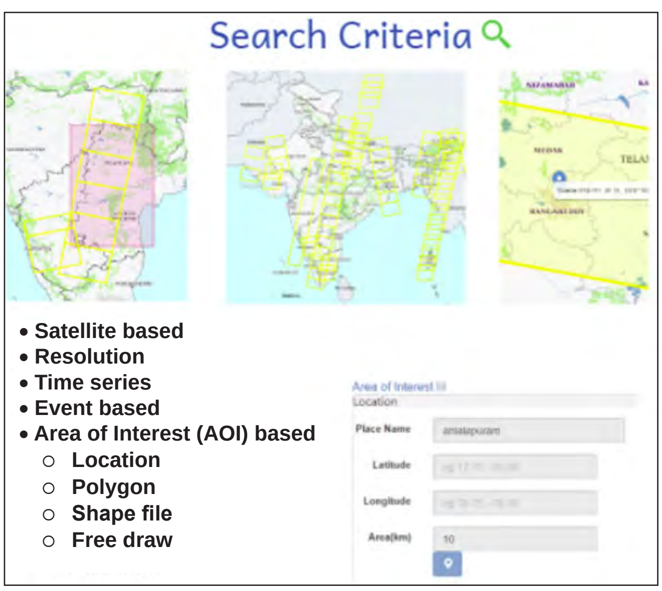


Fig. 2.3: Search criteria

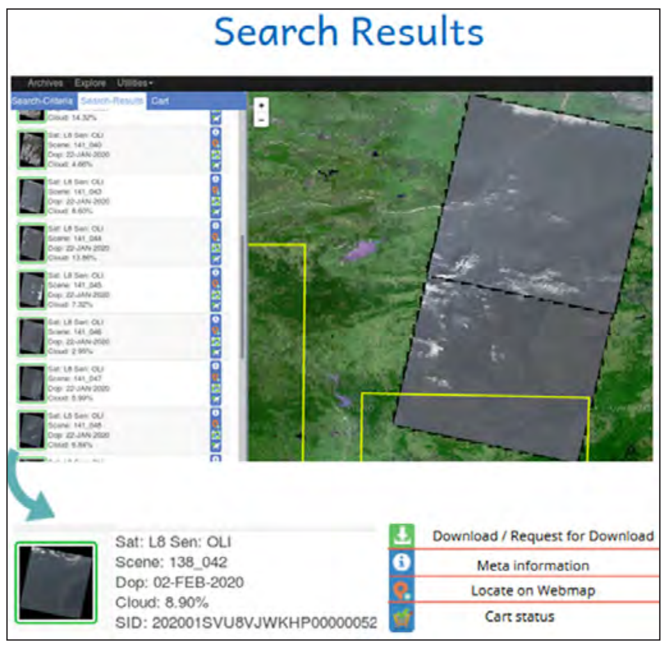


Fig. 2.4: Search results

3. Effect of Amphan tropical cyclone on locust swarm spread

The Desert locust (*Schistocerca gregaria*) is a sort of short-horned grasshopper that changes its behaviour and forms swarms of adults or band of hoppers thereby exhibiting gregarion nature. Serious infestation of locust swarms has severe consequences on food security and livelihoods. During the upsurge and plague, desert locusts can cause widespread damage to crops, as they are highly mobile and feed on large quantities of any kind of green vegetation that include crops, pasture and fodder. A typical swarm can be made up of 150 million locusts per km^2 and fly up to 150 km in one day in the direction of the prevailing wind. They eat large quantities of food and a very small, say, locust swarm of 1 km^2 can eat the same amount of food in a day as consumed by about 35,000 people.

Extended rainfall during the period 2018-2019 in the Horn of Africa and Southwest Asia led to locust upsurge during 2020. Favourable climatic conditions have aggravated breeding grounds in Arabian Peninsula and Indo-Pak border during the month of February. Also during the same time, the Hopper groups and bands have formed in Iran and some extent of Southwestern Pakistan. During the months of March and April 2020, migration of adult groups from these areas and small swarms from the breeding sites of Baluchistan, Indus valley, and Punjab in Pakistan have moved to the parts of Rajasthan and Gujarat.

By mid of May 2020, locust swarms with mature gregarious adult groups have infested in many parts of Rajasthan, Gujarat, Haryana and Punjab. Usually the temperature, soil conditions, wind trails and elevation derive the locust swarms and their movement in desert conditions.

During the period of May 16th and May 22nd, locust swarms have been seen in many parts of Madhya Pradesh, Maharashtra, Uttar Pradesh, Chhattisgarh and Telangana, which was very unusual. The reasons for the spread of locust swarms to these states have been investigated and attributed to the tropical cyclone Amphan that has occurred from 16th to 22nd May, 2020 in the Bay of Bengal.

The super cyclonic storm Amphan was originated from the remnant of a low pressure areas, which occurred near equatorial easterly wave over south Andaman Sea and adjoining Southeast Bay of Bengal (BoB) on 13th May. It concentrated into a depression over Southeast BoB in the early morning of 16th May and further intensified rapidly as deep depression, moved Northwestwards and intensified into cyclonic storm by the evening. By 17th May it has further intensified as a very severe cyclonic storm and as extreme severe cyclonic storm by the early hours of 18th May and continued till 20th May. During these five days, circular winds of speed around 80 kmph spanned in the states of Uttar Pradesh, Madhya Pradesh, Maharashtra, Telangana and towards Eastern coast. The wind speed and direction has been represented in the Figure 3.1. The outward cyclonic system has dragged further winds from the states of Punjab, Haryana, Rajasthan and Gujarat. These winds have created favourable conditions for existing locust swarms to fly towards states of Uttar Pradesh, Madhya Pradesh, Maharashtra, Chhattisgarh and Telangana.

RRSC-West and Locust Warning Organization (LWO) work together for locust studies. Point data representing the control operation and preventive measure in the locust affected areas have been shared by LWO (Figure 3.2). These points were geocoded and analysed by correlating with various environmental and climatic factors.

The outward cyclonic system of Amphan has influenced the fly direction of desert locust to the tune of approximately 1500 km distance and the dispersal of the locust swarms has spread to different states.

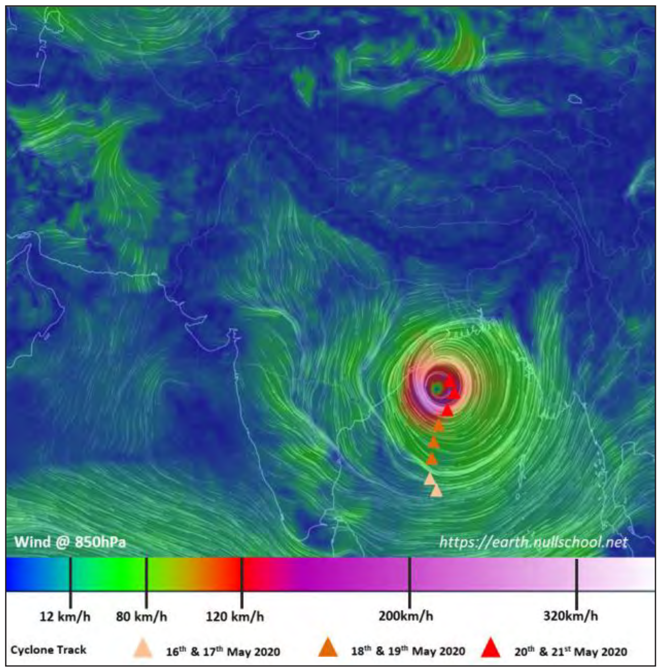


Fig. 3.1 Wind Speed and direction along with the track of Tropical Cyclone Amphan

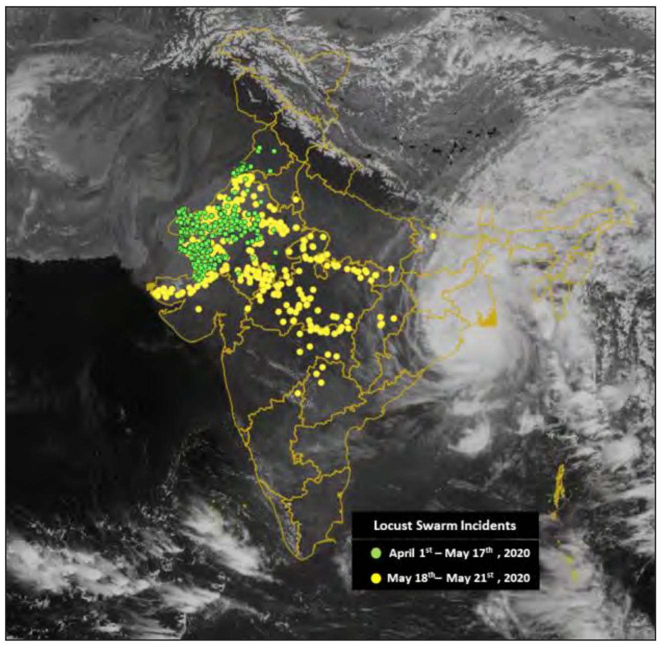


Fig. 3.2 INSAT 3D Visible band @ 1200 Hrs. on 20th May overlaid with the locust Swarms Incidents

4. Development of low lying flood vulnerable maps for urban disaster preparedness and response for Hyderabad city

Hyderabad city is witnessing urban flash floods almost every year. This is mainly due to urban development, encroachments and change in the rainfall pattern where occurrences of high intensity short duration rainfall is often witnessed. For the disaster preparedness and mitigation, it is important to know the vulnerable localities of the city to make strategic policies and land use planning towards making the city disaster risk resilient. In the present study, a terrain model Height Above Nearest Drainage (HAND) is used to identify the low lying flood vulnerable localities of Greater Hyderabad Municipal Corporation (GHMC), Hyderabad. On the request of GHMC, 30 circle-wise maps were provided to the control room of disaster management, Hyderabad before monsoon of 2019 for their preparedness.

Digital Elevation Model (DEM) of 10 meter spatial resolution derived from Cartosat satellite was used in the study. Vector data on administrative setup of zones, circles, roads, nalas, and water bodies were used, which were provided by GHMC. Further, Open Street Map (OSM) vector data such as point of interest, building footprints, settlements, and railways were also used.

The HAND model normalizes the topography in respect to the drainage network through two sets of procedures on a DEM. It runs a sequence of computations to create a hydrologically coherent DEM, define flow paths from the local drain direction grid (LDD) and resolves through depression breaching. A threshold value is found for the accumulated area that corresponds to the channel initiation and for the present study, a threshold of 7500 is best suited. From ground sources, the HAND classes 0-1 meter are found to be the best estimated class for water logged area within the study area.

After exporting the raster file from HAND model, vulnerable locality maps were composed using ArcGIS tool. In September 2019, Hyderabad city got inundated due to high intensity of rainfall. These maps were used by GHMC officials for taking necessary action and decision making on near real time basis. Figure 4.1 shows the methodology and Figure 4.2 shows the detailed view of vulnerable locality map for part of Qutubullapur circle. The study was highly appreciated by GHMC officials and suitable feedback was received.

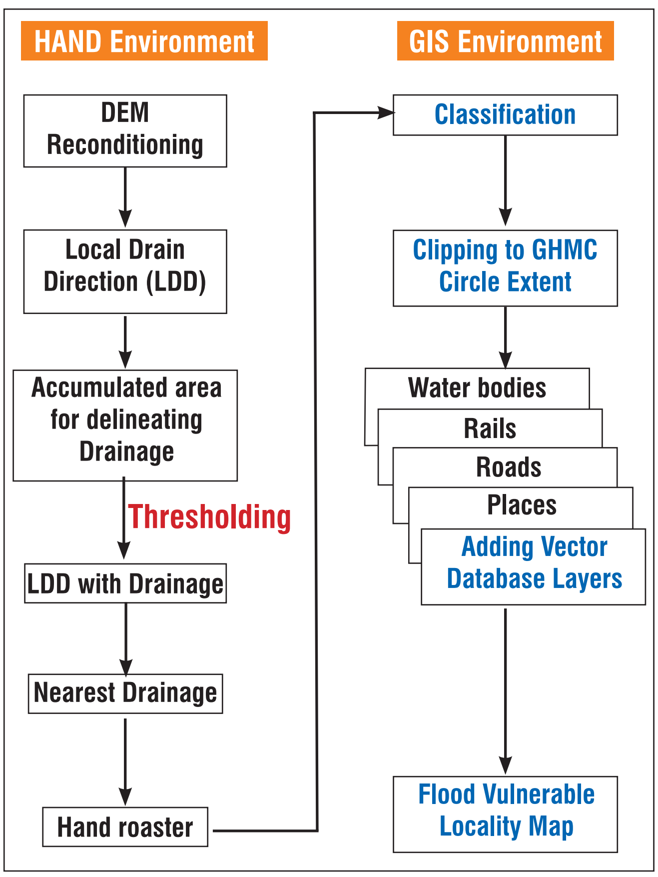


Fig. 4.1: Methodology

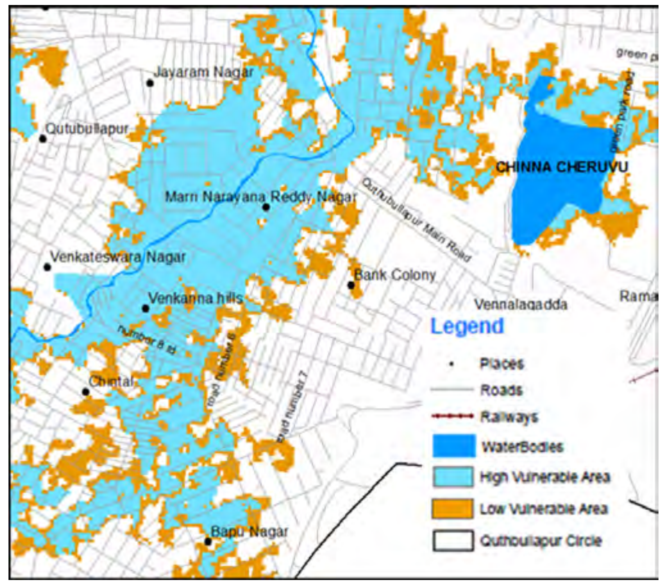


Fig. 4.2: Detailed map view of part of Qutubullapur circle

5. Bhuvan - Jaivoorja: Spatial information system of biomass potential from crop residues over India

India being mainly agrarian society, large quantities of crops is produced across the states and as a spin-off, significant amount of surplus crop residues are generated. These residues are often burned to clear the field on time to catch the next crop season. Instead, it should be diverted to produce energy, which is economically viable and environmentally sustainable. So, a meticulous plan is required to establish the biofuel/biomass plants to utilize it optimally. The most important information in this respect is to assess the kind of biomass available in and round the proposed plant along with its quantity. The spatial information system on biomass potential from crop residues would be an ideal tool to cater these requirements.

Considering the above mentioned issues, a hybrid methodology was adopted utilizing district level crop statistics and geospatial techniques to generate biomass potential from crop residues at 1 km grid level. District level crop production statistics were used to estimate district wise gross residue potential of the selected crops (rice, wheat, sugarcane and cotton) using respective residue production ratio. Further, crop maps were produced using multi-temporal satellite data and were further converted to crop fraction map at 1 km grid. MODIS Gross Primary Production (GPP) data product was then processed and used along with crop fractions to disaggregate district level gross biomass to 1 km grid level. These maps of gross biomass from crop residues were then converted to surplus biomass using district specific collectable coefficient. These were further converted to bioenergy potential from crop residues using the residue specific calorific values. Figure 5.1 shows the schematic representation of the methodology adopted to assess spatial variability of surplus bioenergy potential from crop residues.

These spatial maps of gross/surplus biomass from different crop residues along with relevant thematic and administrative layers were then used to develop a spatial information system (Bhuvan-Jaivoorja).

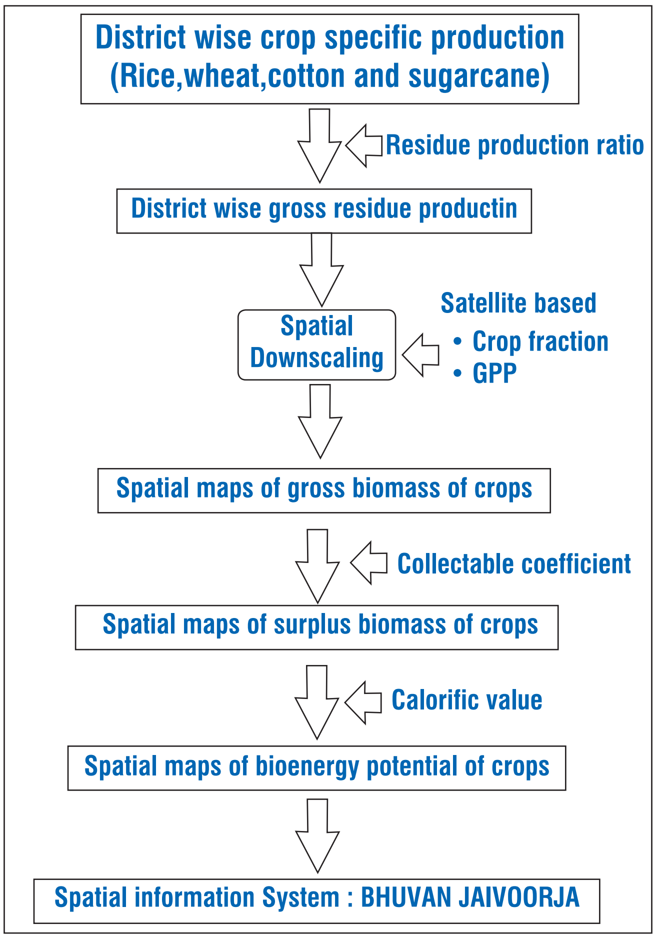


Fig. 5.1: Schematic representation of the methodology adopted to assess spatial variability of surplus bioenergy potential from crop residues.

Bhuvan Jaivoorja (https://bhuvan-app1.nrsc.gov.in/bioenergy/) allows visualization, annotation, delineation of the spatial maps of biomass potential of different crop residues over India. Spatial query module of it allows to draw a point of interest (proposed site of biofuel plant) over the map, delineate a fetch area of biomass collection and calculate amount and type of biomass available from it along with information related to land use and logistics (road network, railways, petrol pumps, etc). Thus, it facilitates planning/establishment of tailor made biofuel/biomass plants for better utilization of surplus biomass resources from crop residues. Bhuvan Jaivoorja homepage along with functionalities of portal are shown in Figures 5.2 and 5.3.

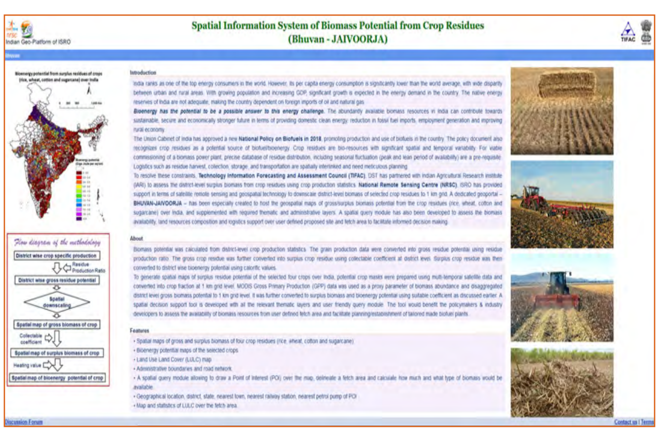


Fig. 5.2: Bhuvan Jaivoorja Homepage

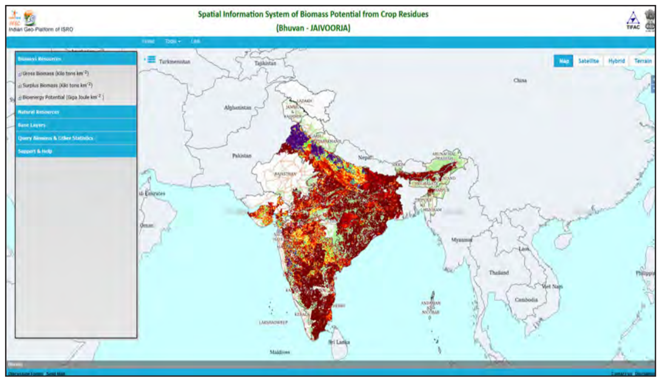


Fig. 5.3: Bhuvan Jaivoorja Geoportal

Spatial query module of Jaivoorja is shown in Figure 5.4.

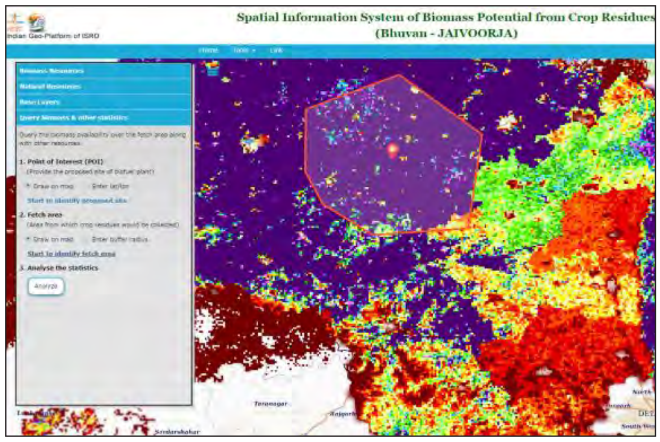


Fig. 5.4: Spatial query module of Bhuvan Jaivoorja.

6. Monitoring elephant movements & conflicts for conservation & conflict mitigation efforts

The elephant (*Elephas maximus*) population in Chhattisgarh has grown since the pachyderms started visiting the state's forests in the late '80s due to rampant deforestation in the neighbouring states. About 50% of the villages of Chhattisgarh state lie within 5 km radius of the forest, where the inhabitants are mainly tribal and economically backward whose livelihoods depend mainly on forests. As a result, sudden entry of herds of elephants to the village areas in search of food is becoming almost a regular matter. This has resulted in an increase of human-elephant conflict. At present, the state has over 247 elephants, which move around in 19 herds in nine districts. To address elephant conservation & human-elephant conflict proactively, different approaches need to be integrated. In this regard, geospatial technology plays a significant role in monitoring elephant corridors, analysing human-elephant conflict on a spatial basis for conservation and mitigation efforts.

To address the problem, five elephants (representing 5 different herds) have been collared by Wildlife Institute of India, Dehradun and Chhattisgarh Forest Department. These collars work on Iridium satellite technology as well as manual VHF tracking using a handheld antenna and receiver. RRSC-C/NRSC developed standalone customized software for monitoring these pachyderms, and record the conflicts on a daily basis. This software incorporates the facilities of raster as well as vector data display, map navigations and entry of current received position of the collared data (in terms of graticules, date, time & conflict). Collectively a database is maintained for all historic positions & conflicts recorded. In order to understand the habitat usage and other habitat requirements of the elephants, thematic database like land use / land cover, slope, settlements, roads & railway lines, waterholes & drainage (1:10K scale), along with the forest administrative boundaries were integrated in the software. This enables the input location data to be superimposed on the integrated maps, which gives thematic & administrative identities. This information is then utilized to know the present locations, calculate the paths, direction, daily activity levels, home ranges, corridors, analysis of diurnal & seasonal spatial variations in the behaviour of the elephants, to broadcast the presence of the elephants to the nearest settlements or vulnerable areas like railway crossings or roads.

Figure 6.1 shows the home range of one of the elephant herd in which one elephant named Dev is collared.A home range is the area in which an animal lives and moves on a periodic basis. The home range of Dev is almost stabilized and this has been derived from the Kernel Density Estimation (KDE) of the collared point data of Dev. A probability contours of occurence of Dev is also derived from the KDE. As seen from the Figure 6.1, a well differentiated corridor exists in agricultural land. Figure 6.2 depicts the trail path analysis of all the collared elephants on hourly basis, which shows that elephants are spending nearly 18 to 20 hours per day for feeding to meet their food demand. Path analysis shows that elephants are moving at an average speed of 394 meters per hour with a maximum speed of 726 meters and much of their activity is in between 16:00 to 06:00 hrs. Their activity level peaks at 04:00 hrs.in the morning and 16:30 hrs. in the evening. There is a dip in the movement pattern of the elephants with a very low-level of activity during 10:00 hrs. to 12:00 hrs. As per the activity level observed from Chhattisgarh, elephants sleep during 10:00 to 12:00 hrs. Figure 6.3 represents the hourly activity level of all the collared elephants in each land use / land cover class. It is observed that elephants prefer to stay in the forest during most of the day time, especially 03:00 to 16:00 hrs. and occasionally start to raid in agricultural land in between 18:00 to 01:00 hrs. Likewise, elephants sometimes break-in to the settlement area from 17:00 to 03:00 hrs. with a peak at 23:00 hrs. Elephants also need a lot of water and have to travel each day to get it if they stay in dry areas. As can be perceived from the Figure 6.3, elephants quench their thirst in the evening with a peak at around 17:00 hrs. The study also demarcated all the home ranges, sensitive corridors, where infrastructure can be deployed to ameliorate human-elephant conflict; analysis of diurnal & sessional spatial variations in the behaviour pattern of the collared elephants and hot spots of conflicts.

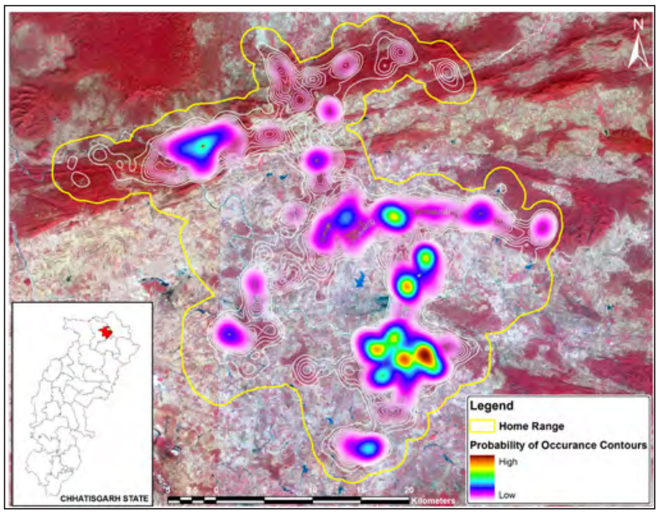


Fig. 6.1: Home range and probability contours of occurrence of the elephant Dev

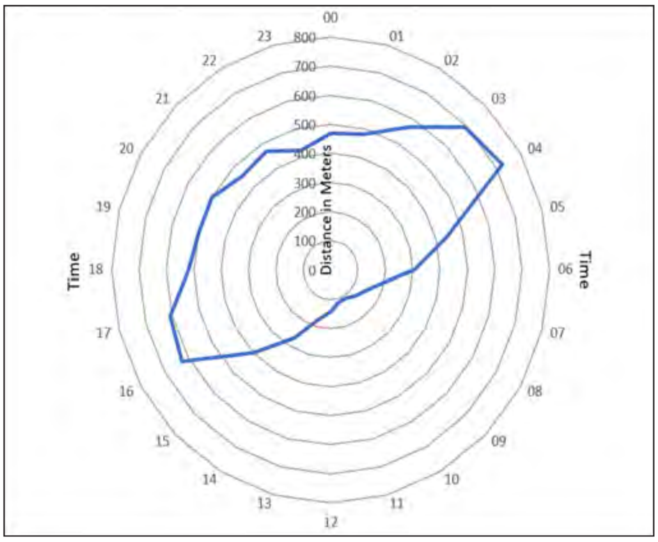


Fig. 6.2: Average of hourly activity level of all four collared elephants

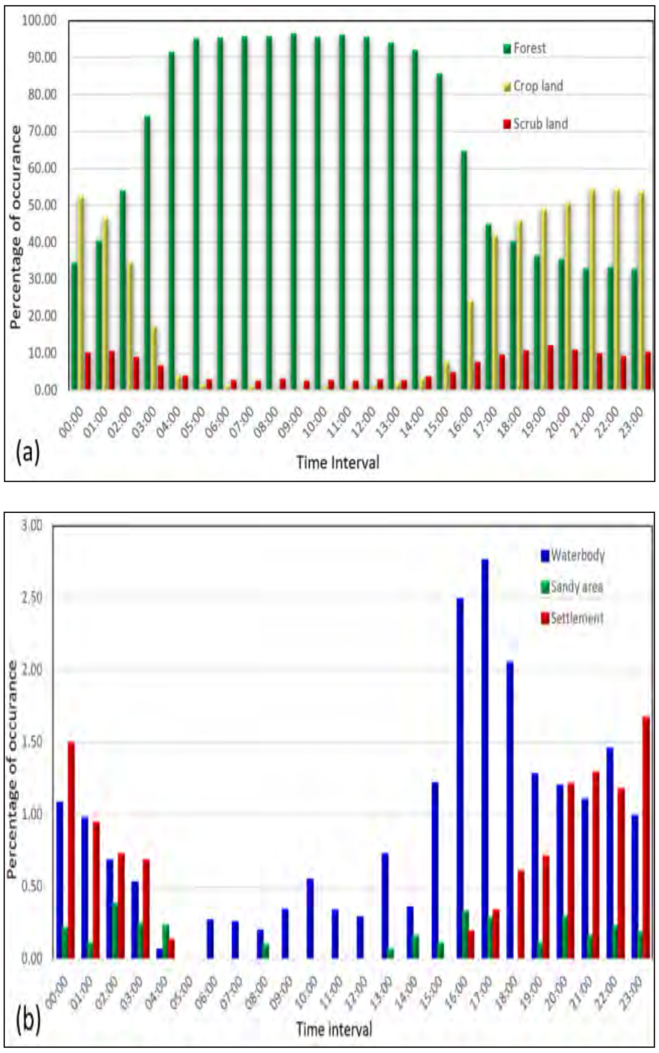


Fig. 6.3: Hourly occurrence of the elephants in different land use / land cover classes

7. National Health Resource Repository (NHRR)

National Health Resource Repository (NHRR) is a joint project of Central Bureau of Health Intelligence (CBHI), Directorate General of Health Services (DGHS), Ministry of Health & Family Welfare, New Delhi & National Remote Sensing Centre, Hyderabad. Understanding the need of timely and accurate health resources data from both public and private sector, CBHI in consultation with DGHS, conceptualized the framework of making a health resources repository, where both public and private sector data will reside.

NHRR project aims to create a web-based and geo-mapping enabled single platform of all the health resources (both government and private) which inter-alia includes, hospitals, diagnostic labs, doctors and pharmacies, etc. Further, this will also comprise of the data on health infrastructure, human resource and the availability of medical facilities in each health establishment in the country.

The objectives of NHRR project are as follows:

- To develop android based mobile (tablet) application for collection of health resources assets details.
- To develop an interface on Bhuvan platform to receive Mobile geo-tagged data, provide facility for moderation and display of assets.
- To link the healthcare resources assets data with administrative boundaries and natural resources data.
- To generate tools for data analytics and updation.
- To arrange capacity building activities for the Ministry officials for enabling data collection.

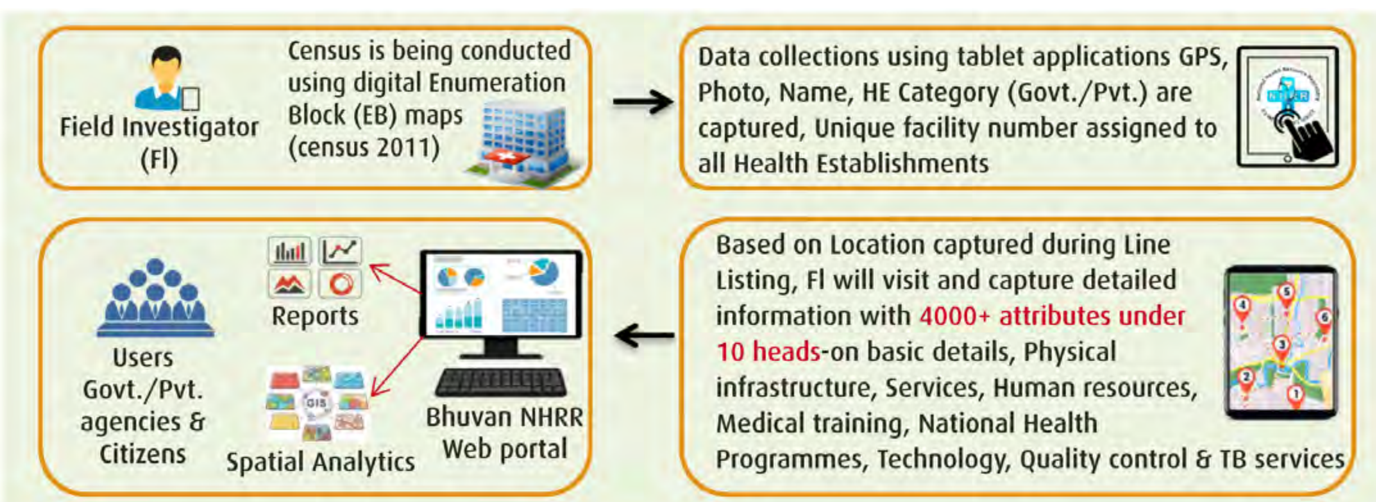
NRSC is facilitating the user for improved health care asset management, efficient health service delivery, evidence based planning & decision making, resource allocation, strengthen health information system and finally governance for good health & well-being in the country; and also supporting the recently announced: Ayushman Bharat - National health protection mission.

Under the collection of statistics act 2008, over 10 lakh hospitals, doctors, clinics, diagnostic labs, pharmacies and nursing homes would be enumerated under NHRR census capturing data on over 4000+attributes.

There are four technology application stages:

STAGE - 1	STAGE - 2	STAGE - 3	STAGE - 4
• Bhuvan NHRR Tablet Application	• Intermediary Web Application	• Bhuvan NHRR Web Portal	• Bhuvan NHRR Data Updation

NHRR Census methodology



The census of health resources assets is carried out in paperless mode using Bhuvan-NHRR android based mobile (tablet) application with 4000+ attributes.

Activities associated with data collection along with quality checks and data cleaning functionalities are monitored using Management Information System (MIS).

Bhuvan-NHRR Geo-web portal is developed as a single window solution for visualization, data analytics and generation of reports for making informed decisions, optimum utilization of health resources, and management of health resources so as to enhance health service delivery.

Nationwide data collection of health establishments is being done with the help of 12000+ field investigators and supervisors. Data of about 8,94,767 health establishments have been collected till July 2020.

8. Prioritisation of glacial lakes for Glacial Lake Outburst Flood (GLOF) risk assessment

Glacial lakes may at times release large quantities of glacier melt water from a moraine or ice-dam glacial lake due to natural dam failure resulting in catastrophic flooding downstream called GLOF. Many GLOF events occurred in the past in Indian Himalayas resulted in loss of lives and damage to settlements, transport network, hydro-power plants, etc. It is essential to have knowledge on location of glacial lakes, their susceptibility and the probable consequences of their breach. Due to their remote locations, rugged terrain conditions and high altitude, monitoring of these lakes is very difficult task by traditional surveys. Remote sensing technology is a useful tool for inventory and monitoring of glacial lakes and GLOF risk assessment.

NRSC has taken up GLOF risk assessment of glacial lakes in the Himalayan Region of Indian River Basins under National Hydrology Project (NHP), which is sponsored by Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation, Govt. of India. As a part of this activity, it is proposed to prepare an updated inventory of glacial lakes (>0.25 ha) and prioritization of glacial lakes for GLOF modelling and GLOF risk assessment based on glaciological, terrain and associated characteristics.

Case study - Indus River Basin

Resourcesat-2 (RS-2) Linear Imaging Self Scanner (LISS-IV) data covering the Indus river basin with geographical area of 3,42,738 km^2 is used for preparing inventory of glacial lakes (2016-2017) (Figure 8.1).

The water spread area of the lakes in false colour composite images ranges in appearance from light blue to dark blue (Figure 8.1). Apart from mapping physical boundary of lakes, 21 attributes are generated for each of the lake comprising its physical, administrative, hydrological & topographical characteristics. The glacial lakes in Indus basin are classified into 4 major categories and 10 sub types.

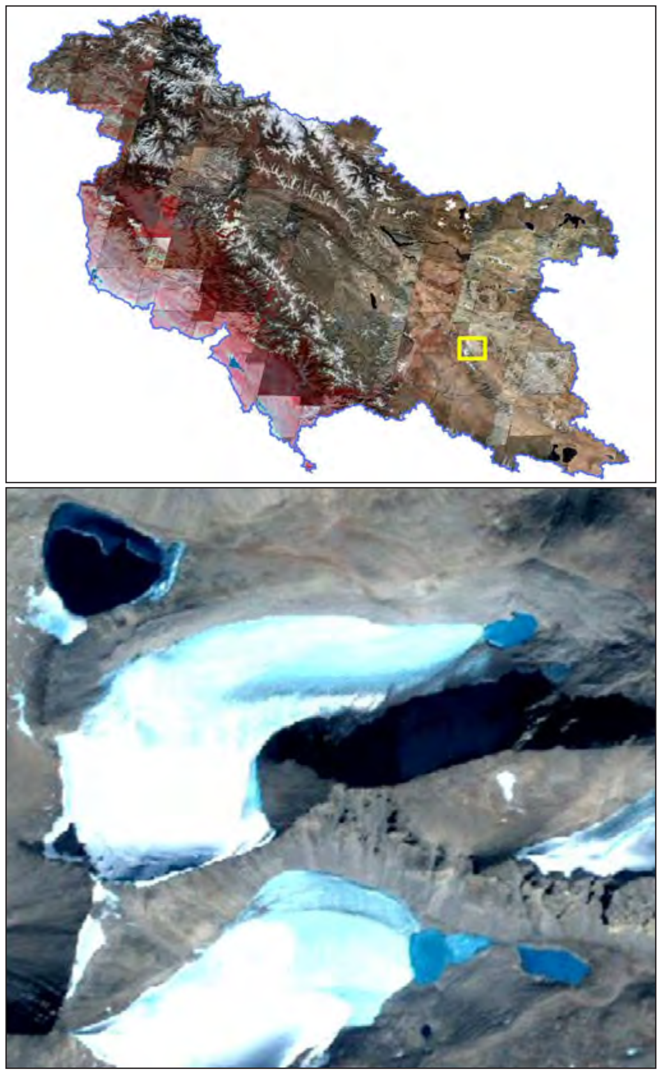


Fig. 8.1: Resourcesat-2 LISS-IV satellite image (top) and typical glacial lakes (bottom) in Indus basin

A total of 6,693 glacial lakes and water bodies are inventoried, out of which 5,335 are glacial lakes and 1,358 are water bodies (Figure 8.2). Maximum size of glacial lake in the basin is 262.56 ha. The total water spread area of all the lakes was 17,394 ha. Figure 8.2 also shows elevation & area-wise distribution of glacial lakes in the basin. Figure 8.3 shows distribution of 4 different types of glacial lakes in the Indus basin.

Preliminary screening of glacial lakes was carried out based on four parameter criteria comprising lake type, lake area, lake association with glacier and lake with settlements enroute river reach. The glacial lakes are screened in sequentially using the above criteria, i.e. type of lake (moraine, ice-dammed & cirque-erosion types are considered-2,612 lakes out of 5,335), area of lakes above 1 ha (1,049 out of 2,612 lakes), lakes associated with glacier (652 out of 1,049 lakes) and lakes with settlements enroute river reach (614 out of 652 lakes). Based on preliminary screening, 614 lakes out of 5,335 glacial lakes are considered for further prioritisation.

Prioritisation of Glacial Lakes: Satellite based four additional parameters namely distance & slope from lake to associated glacier snout and distance & slope from lake to nearest settlement are used in ranking of the glacial lakes along with two parameters used in preliminary screening (lake type and lake area).

Four different methods were attempted to rank the glacial lakes namely equal weight method, unequal weight method, analytical hierarchy process and qualitative analysis using six parameters mentioned above.

Five glacial lakes are selected based on unequal weighted method avoiding subjectivity in the ranking process. For the selected five glacial lakes, high resolution DEM will be procured and GLOF modelling will be carried out for different scenarios to simulate flood inundation maps along the river reach downstream of the lake. GLOF risk assessment will be carried out by integrating the simulated flood hazard maps and elements of vulnerability.

The information generated from this type of studies will be highly useful for Central / state disaster reduction planners, managers and decision managers to implement the disaster risk reduction measures in both short and long term.

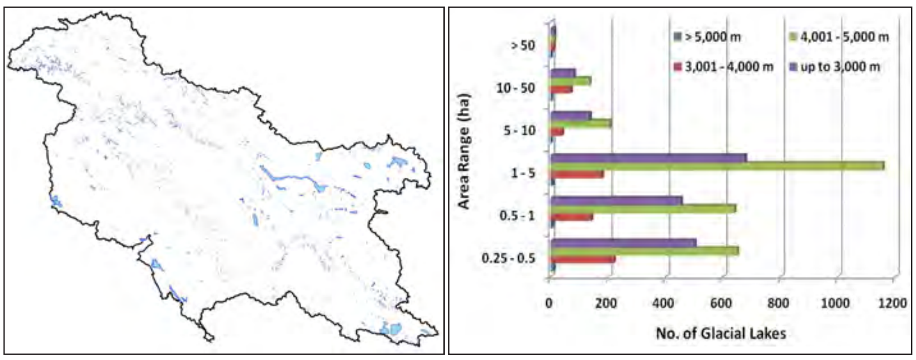


Fig. 8.2: Mapped glacial lakes (left) and elevation & area-wise distribution of glacial lakes (right) in Indus basin

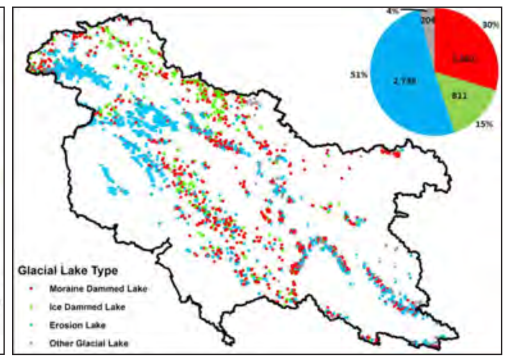


Fig. 8.3: Distribution of types of lakes in Indus basin

9. Biodiversity characterisation at community level in India using Earth observation data

India is one of the mega-biodiversity countries having high levels of endemism and high concentration of economically important species. In the context of national needs and technological advancements, the project on “Biodiversity characterisation at community level in India using Earth observation data” has been initiated as a joint effort of Department of Biotechnology and Department of Space, Government of India. The project is being coordinated by NRSC with participation of RRSC-C, IIRS, Kerala Forest Research Institute, French Institute of Pondicherry, Andhra University, and the M.S. University of Baroda in 9 regional landscapes across Western Ghats (6), Eastern Ghats (2) and Western Himalayas (1). Biodiversity is hierarchical and encompasses multiple levels of biological organization. There are three primary attributes of biodiversity - composition, structure, and function that incorporates elements of each attribute at four levels of organization: regional landscape, community-ecosystem, species-population, and genetic. This project is targeted in developing an Earth observation based strategy for monitoring biodiversity at the community level in India. The approach is to develop a description of vegetation composition, structure and function from remote sensing and field studies. Remote sensing data from a range of current Earth observation platforms is used to generate a set of multi-sensor and multi-temporal observations to identify those that are relevant to biodiversity assessment. It is aimed to assess decadal changes to the regional forest landscape, characterization of vegetation communities, identifying Earth observation variables that are relevant to monitoring biodiversity and generation of web-based data repository and information system in Bhuvan and its integration with IBIN and biodiversity information system.

The duration between two successive phenological events could be different from species to species. It would therefore be of interest to know this duration which may be termed as inter-phenophase duration. Since a given event itself will have a distribution, the median of one phenological event to another was considered to compute the inter-phenophase duration. A time series vegetation index data was used to generate 15 phenological metrics, which will support in discrimination of vegetation communities along with spectral data from very high spatial resolution data. To examine the seasonality and temporal signatures of vegetation community classes, Normalized Difference Vegetation Index (NDVI) values were extracted from Sentinel-2 data to produce the profiles of vegetation dynamics for 2018 in 9 regional landscapes. NDVI was calculated from red and near infrared bands. In this study, CropPhenology R software package was used to derive the 15 phenological metrics based on satellite-based NDVI measurements. The noise in NDVI time series data was removed by using the Savitzky-Golay filter. Leaf phenology curve for *Anogeissus latifolia*, a typical deciduous tree species is shown in Figure 9.1.

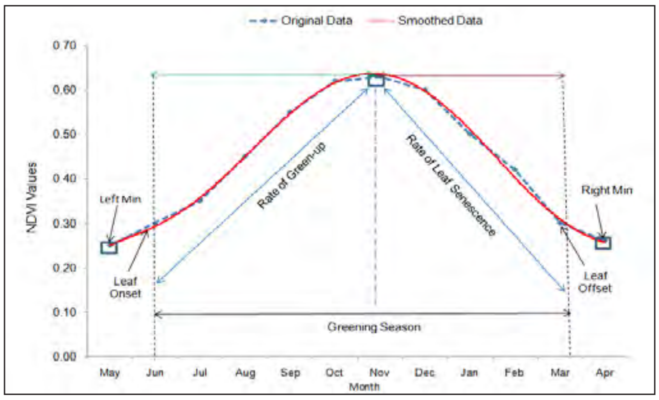


Fig. 9.1: Leaf phenology curve and associated phenometrics for Anogeissus latifolia community in Similipal, Odisha

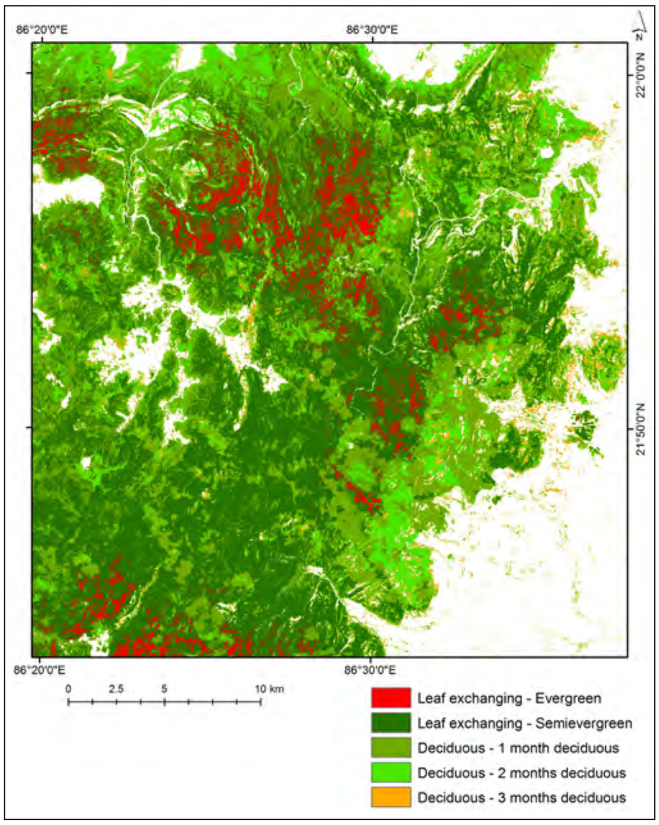


Fig. 9.2:Phenological vegetation types in Similipal regional landscape

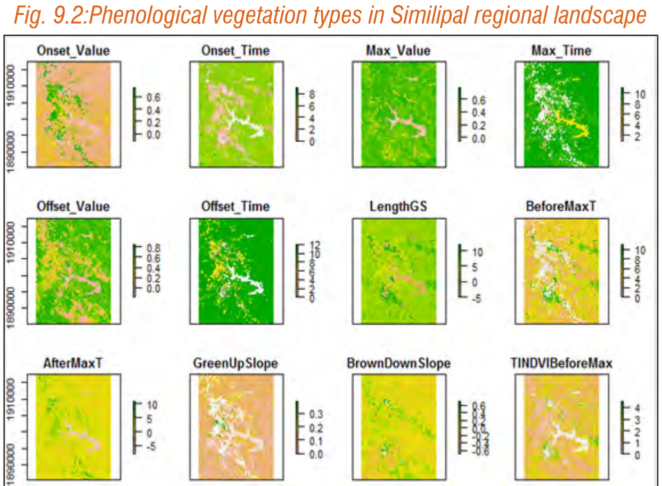


Fig. 9.3: Derived maps of phenological metrics in Chandoli landscape, Maharashtra

Phenological vegetation types of Similipal regional landscape is presented in Figure 9.2. Phenological metrics maps of Chandoli National Park, Maharashtra is shown in Figure 9.3.

10. Urban applications using very high resolution satellite data – AMRUT case study

India, being the second most populous country accounts for about 1.21 billion people (2011 Census) with about 31.16% of them living in 7935 towns and cities, which is expected to increase further in the coming years. This exerts a lot of pressure on land and other resources. Proper land management and provision of requisite infrastructure is essential for planned and sustainable development of a city/urban area.

Urban planners prepare master plan of a city/urban area indicating detailed land use allocation for future development of city / town (say over next 20 years or so) based on existing demography, land use, infrastructure and socio-economic conditions. Historically, these plans were prepared manually and with the advent of technology, both preparations of inputs as well as plan formulation are being attempted using state-of-art geospatial tools and technologies like remote sensing and GIS.

Large scale urban GIS database creation for master plan formulation for cities

Government of India launched Atal Mission for Rejuvenation & Urban Transformation (AMRUT) Mission with 'Formulation of GIS based master plan' as one of its important reforms targeting Class-I cities (Population greater than 1,00,000) considering the availability of master plans for less than 20% of cities. Town and Country Planning Organisation (TCPO) the Nodal Agency from Ministry of Housing and Urban Affairs (MoHUA) has envisaged a common basis for this purpose, wherein base map will be prepared on a scale of 1:4,000 using Very High Resolution Satellite (VHRS) data as per the requirement of state town planning departments and will comprise of uniform database schema and adhering to common design and standards across the country. Master plan will be prepared in GIS environment.

Technically, the process flow involved three distinct steps, viz., base map preparation from (Very High Resolution Satellite (VHRS) data (by NRSC), field verification and attribute data collection (by Urban Local Bodies [ULB]), and incorporation of the field information and finalization of GIS Database (by NRSC).

NRSC's contribution to AMRUT project comprises of geo-spatial database creation of 242 AMRUT cities from 21 states / Union Territories. This involves, evolving common design and standards and database schema for preparing the large scale urban geospatial databases. A dedicated facility was established for AMRUT geospatial database creation at Jeedimetla, Hyderabad where with the support of private geospatial industry supporting 2D feature extraction, around 300 personnel per day (working in 2 shifts) can work to reduce the turnaround time to less than three months per city. Methodologies were evolved and Standard Operating Procedures (SOP) were documented for both 2-D feature extraction from VHRS data and also for field verification and attribute data collection by ULB. NRSC trained concerned officials under this project.

AMRUT GIS Database Creation Facility

The pre-field Base map thus, generated can have up to 88 layers comprising of base details, viz., road, rail, bridges, flyovers and water bodies in addition to building footprints and urban land use. After rigorous quality checks of the data by both internal (by the industry) and external (by NRSC), PDFs (½ km X ½ km tiles) of the data are generated with unique numbers for field verification and attribute data collection. In addition to this, tile wise excel files for entire city are generated to record attributes, which otherwise would not be possible from satellite data and sent to ULBs.

As part of AMRUT cities' GIS database creation, ULBs are responsible for carrying out the ground truth and attribute data collection. The ULBs will examine the PDFs in the field for their feature correctness and consistency. ULBs shall also collect the attributes related to the line (road width, name, railway gauge, etc.) and polygon (use of the building, no. of floors, land use, etc.) features in the excel tables based on the unique IDs provided. This process will take about a month or two and the field data will be then sent to NRSC.

NRSC will update its pre-field base maps with the field derived information and finalize the content based on the unique IDs assigned to each geographic feature. The final database comprising of about 450 layers will be checked for both its content and topology and finalized. The final GIS database will then be handed over to the ULB for formulation of GIS based master plans. This step will take about a month's time. So far NRSC has handed over pre-field data to about 160 AMRUT cities and is on schedule to complete the task.

AMRUT Geospatial database prepared at 1:4,000 scale is of immense value to the urban planning community. Besides master plan formulation, this data is also useful in applications like monitoring land use change dynamics at regular intervals, identification of potential sites for rooftop solar energy harvesting, preservation and conservation of urban green areas, governance application like property taxation etc. The database can also be used as base for preparing sectoral plans and town planning schemes at larger scales.

AMRUT Process flow starting from VHRS data along with corresponding base map (given for field data collection) to the final GIS database (finalized after field data collection) leading to formulation of the GIS based master plan, for a part of Bhopal AMRUT city (Madhya Pradesh) are shown in Figure 10.1 for illustration purpose.

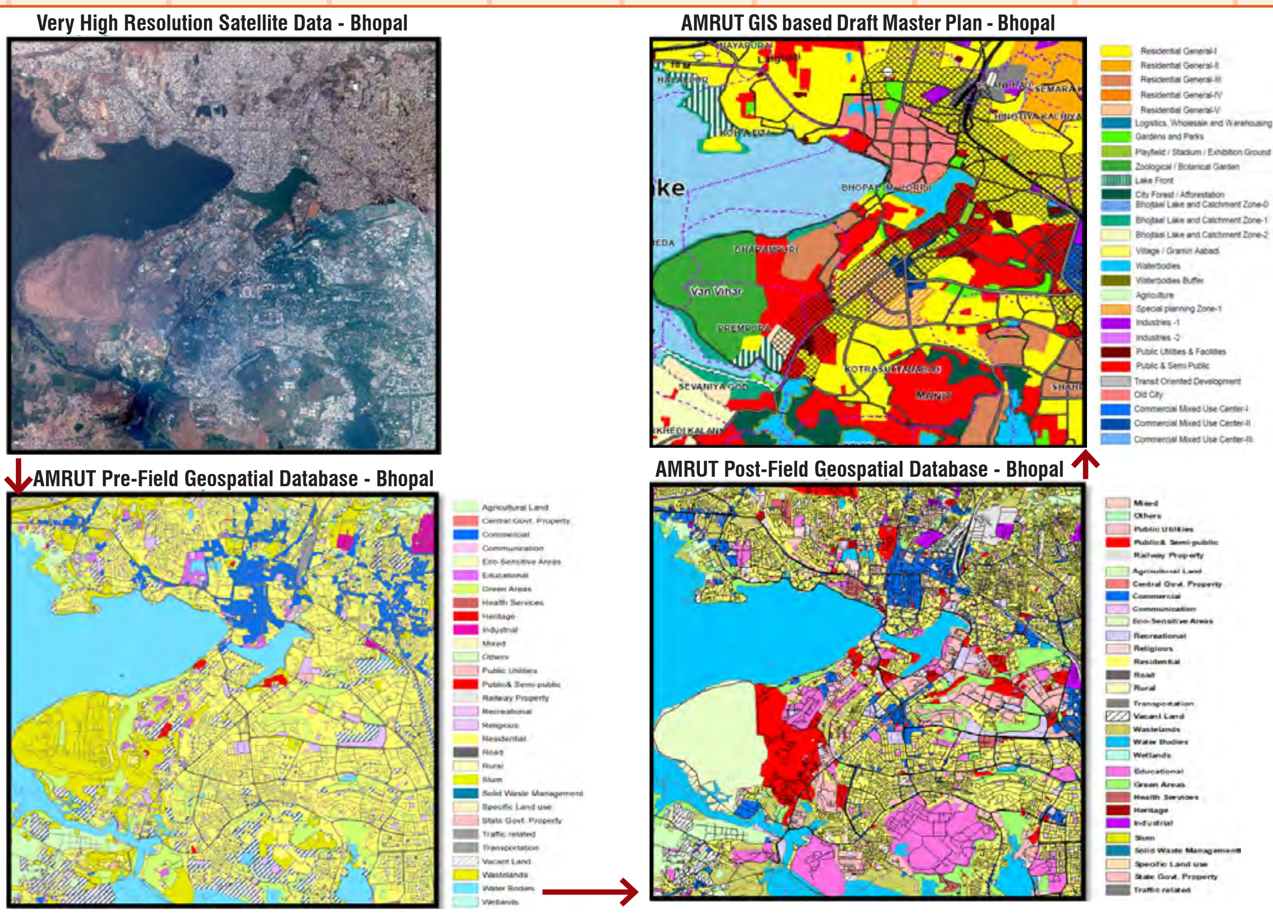


Fig. 10.1: Process flow of AMRUT GIS database creation

11. Assessment of spatial variation in soil carbon as a function of surface erosion processes in a semiarid region of India

Soil erosion disturbs topsoil and preferentially removes Soil Organic Carbon (SOC) from upslope sites, resulting in the mineralization, redistribution and burial of SOC in depositional environments. The information on the lateral movement of SOC during soil erosion can improve the understanding of global carbon budget. SOC loss from the ecosystem occurs mainly by water erosion, release of carbon into atmosphere and leaching. In order to estimate the SOC due to soil erosion, the Morgan-Morgan-Finney (MMF) model was selected, since it is a physically based-empirical model that needs less data than most of the other erosion predictive models. Besides, it is also amicable for geospatial processing as well as remote sensing based inputs. Soil loss prediction by MMF approach involve factor maps from kinetic energy of rainfall, topsoil rooting depth, percentage rainfall contributing to permanent interception and stream flow, crop cover management factor, ratio of actual to potential evapotranspiration, soil moisture storage capacity. These were used to generate output maps like volume of overland flow, rate of soil detachment by raindrop impact and transport capacity of overland flow. Annual soil loss estimation was done by comparing two maps of soil detachment rate and transport capacity and taking the minimum value from them.

Karnataka state with a total geographical area of 19.17 MHa forms the study area. It has a varied climatic conditions ranging from semi-arid in the central and eastern parts to humid in the Western Ghats. The soil varies with textures ranging from sands to clays. The soils are formed on varied lithologies dominantly on Granite-Gneisses. Physiography of the area can be categorized into coastal plains, undulating plains, pediments and hills. The Western ghat region receives rainfall more than 1200 mm while the northern Karnataka receives very low rainfall around 400 mm. Carto DEM, Climate Prediction Centre (CPC) 10 rainfall data, LULC classified map derived from AWiFS satellite data, Soil map at 1:50000 scale prepared by NRSC, ISRO and soil organic carbon map were used in the study.

MMF model is a physically based empirical model, which works by separating the process of soil erosion in the sediment phase and water phase. The water phase determines the runoff volume and the available energy of rainfall used to detach the soil particles. In the sediment phase of the model, the detachment of the soil particles is taken as a function of the soil erodibility, energy of rainfall and the interception of rainfall that is affected by vegetation. The rate of detachment of soil particles by rainfall and runoff is established together with the transport capacity of runoff in the revised MMF. The transport capacity is computed with the overland flow volume, slope and the crop cover management. In the revised MMF, changes are made in the simulation of soil detachability by rainfall that now considers leaf drainage and plant canopy height. The MMF model makes comparison of the rate of predicted splash detachment with the transport capacity of the runoff or the overland flow, and the lower value of the two methods is taken as the rate of soil erosion, determining which one of these two (detachment or transport) is the factor of limitation. The C factor is varying or can be adjusted according to the retention of crop residue and the tillage practices. Annual soil loss was calculated after the processing and estimation of required parameters. Areas affected with high erosion rates were observed in the higher elevated areas of the study area with high annual rainfall. A soil loss of more than 40 t/ha/year was observed in areas with loamy soil zones, steep slopes, high rainfall and sparse vegetation (Figure 11.1).

The highest soil loss greater than 80 t/ha/yr (very severe loss) is observed in 2% of study area. The erosion rate of 41-80 t/ha/yr (severe loss) is also observed in 13% of area followed by the

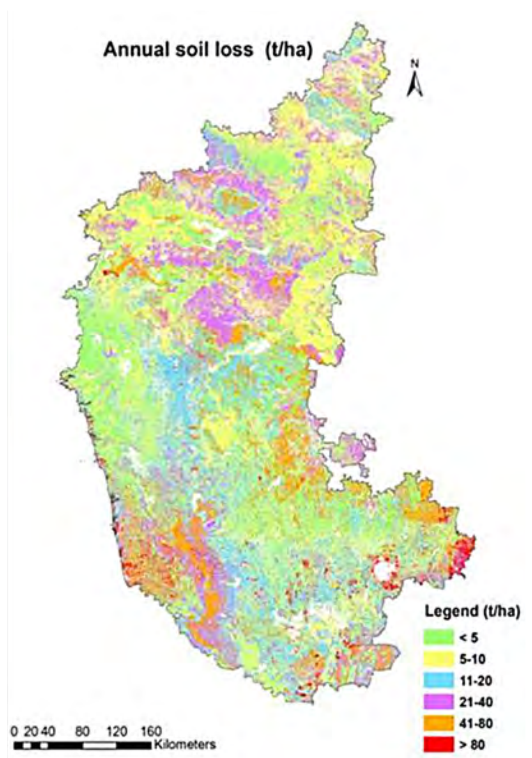


Fig.11.1: Annual soil loss in Karnataka

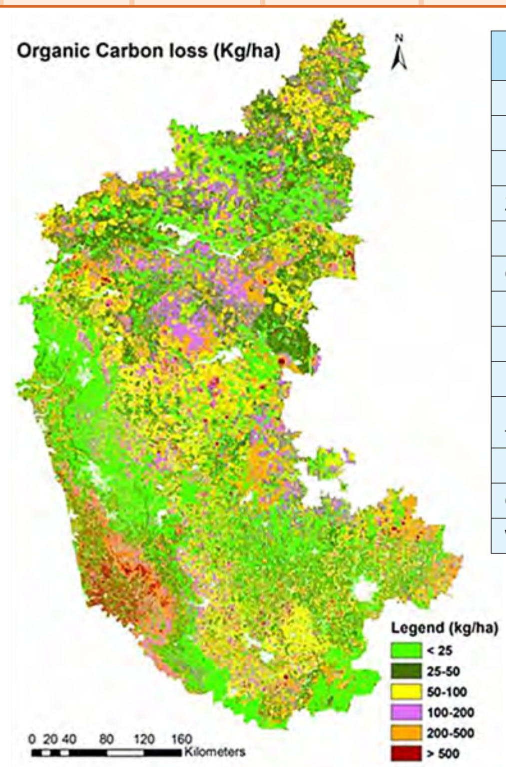


Fig. 11.2: Organic carbon loss in Karnataka

LULC Class name	Avg OC loss (kg/ha/year)
Built-up	1.9
Kharif crop	63.1
Rabi crop	73.9
Zaid crop	106
Double / triple crop	49
Current fallow	198
Plantation	129
Evergreen forest	90
Deciduous forest	142
Degraded / Scrub forest	176
Littoral swamp	6
Grassland	80
Wasteland	283

erosion rate of 21-40 t/ha/yr (15%) (Very high loss), 11-20 t/ha/yr (20%) (High loss) and 5-10 t/ha/yr (26%) (Moderate loss).

The average soil organic carbon loss was estimated considering the land use land cover and it is found that the SOC loss is maximum in waste lands followed by current fallow. The higher OC loss may be attributed to the high rainfall, soil texture (loamy), steep slopes and sparse vegetation (Figure 11.2).

12. Day ahead forecast of surface reaching solar radiation

National Thermal Power Centre (NTPC) Energy Technology Research Alliance (NETRA), a R&D Wing of NTPC, expressed interest to collaborate with NRSC in the areas of solar radiation and winds forecasting and accordingly, a joint project was taken up on "Application of Space Technology in Wind and Solar Energies: Forecasting the Surface reaching solar radiation and wind speed". Under this project, a methodology has been developed on day-ahead forecast of surface reaching solar radiation under all-sky conditions by incorporating near real time satellite data into Weather Research & Forecasting (WRF) -Solar model.

Steady increase in share of solar power in national power generation shows the importance of solar power forecast for stable grid operations. Solar power forecast mainly depends upon forecasting of surface reaching solar radiation at high temporal resolutions. On clear days, the solar radiation can be predicted with relative ease. Prediction of surface reaching solar radiation during partially cloudy and overcast conditions is a difficult task as this highly depends upon ability of the numerical weather prediction model in capturing the life cycle of a cloud. WRF-Solar is a numerical weather prediction model specifically designed for solar radiation studies, which allows aerosol-cloud-radiation interactions in a better manner. The basic WRF-Solar model can only read climatological aerosol parameters provided along with model. WRF-Solar model has been re-configured to read near real-time daily mean Aerosol Optical Depth (AOD) and angstrom exponent from MODIS Aqua and Terra and aerosol Single Scattering Albedo (SSA) data from Ozone Monitoring Instrument (OMI). The inbuilt United States Geological Survey (USGS) Land Use / Land Cover (LULC) data has been replaced with ISRO's AWiFS based LULC data over Indian region. WRF-Solar model is configured to cover entire Indian peninsula at 9 km spatial resolution. The initial and lateral boundary conditions are obtained from NCEP's Global Forecasting System's daily

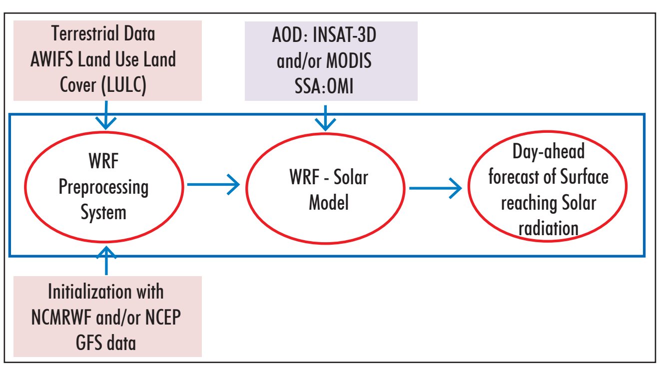


Fig. 12.1: Day-ahead forecast operational methodology

operational forecast data at 1°x1° spatial resolution; lateral boundary forcing is updated at every 6 hour intervals. Model is initialized at 00UTC for all experimental days and is run for 48 hours in order to provide a day-ahead forecast of surface reaching solar radiation at 15min interval. The operational forecast for next 24 hours is generated by 5:00 PM of current day. Day-ahead forecast operational methodology is shown in the Figure 12.1.

WRF-Solar forecasted surface reaching solar radiation is compared against ground based measured solar radiation data for all weather conditions (Figure 12.2).

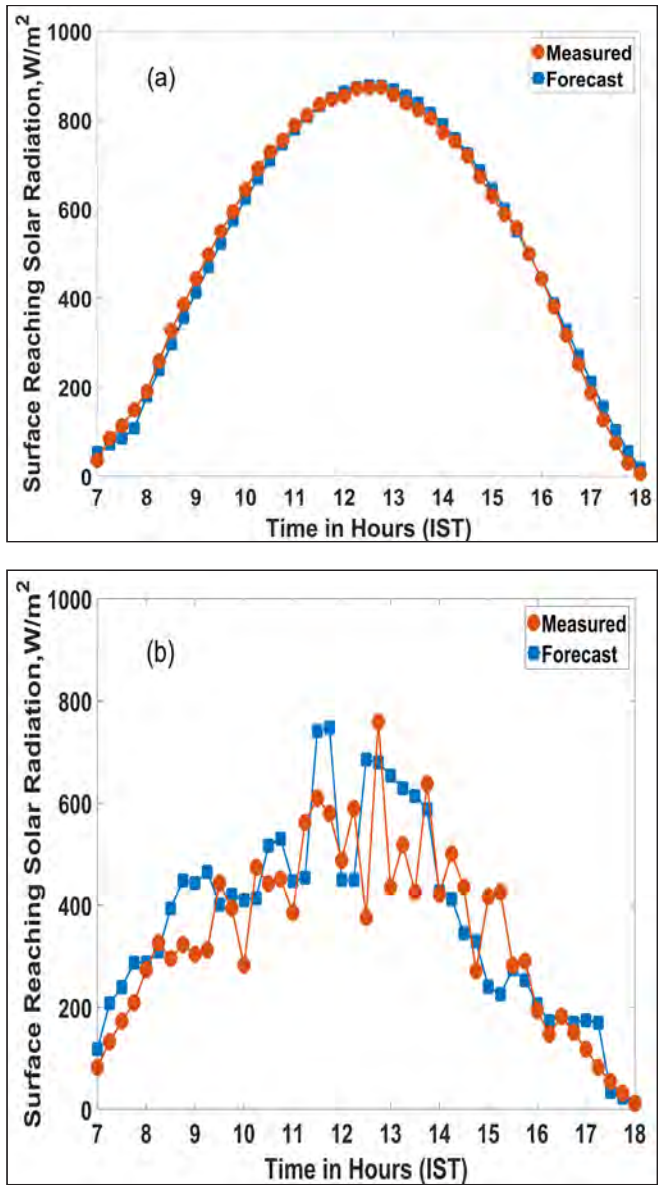


Fig. 12.2: Comparison of day-ahead forecast of surface reaching solar radiation against ground based measured radiation under (a) cloud-free day on January 03, 2019 and (b) Cloudy day on August 20, 2019 over Ananthapur

Analysis showed that the model is able to predict surface reaching solar radiation within a difference of 30-50 Wm-2 under cloud-free condition and within a difference of 50-250 Wm-2 under partial cloudy and overcast conditions. Also, an empirical methodology as a function of cloud type is generated to improve the model forecast for cloudy conditions.

13. Geospatial inventory of coffee plantations at national level (GeoCUP)

The traditional coffee growing regions in India are mainly confined to the Southern states (Karnataka, Kerala and Tamil Nadu). Coffee board has made concerted effort to promote its cultivation in the non-traditional regions(Andhra, Odisha and N-E states) which resulted in steady increase in coffee area. Coffee Board under Ministry of Commerce and Industry approached ISRO for collaboration in the field of geospatial technology to meet the operational and developmental requirements. A national level project namely "Geospatial inventory of coffee plantations at national level (GeoCUP)" was taken up by RRSC-South/ NRSC with the objectives a) Inventory of coffee plantations in traditional, non-traditional and N-E regions of the country and b) Site-suitability analysis in the selected districts of non-traditional regions.

High resolution Cartosat-1 (2.5m) and Resourcesat LISS-IV (5.0m) datasets corresponding to February-April months were utilized for mapping of coffee plantations. A combination of object-based classification and visual interpretation techniques were used for mapping of coffee plantations. The suitability analysis was carried using pedo-climatic and terrain parameters like elevation, slope, aspect, rainfall, temperature, soil depth along with LULC map at 1:50K to identify potential areas for cultivation of coffee plantations in the non-traditional regions.

Geospatial database on coffee plantations was generated at different administrative hierarchies. Spatial distribution of coffee plantations in the country derived using high resolution RS data is depicted in Figure 13.1. Intensive ground truth along with field experience of liaison officials of Coffee Board helped in mapping of coffee plantations.

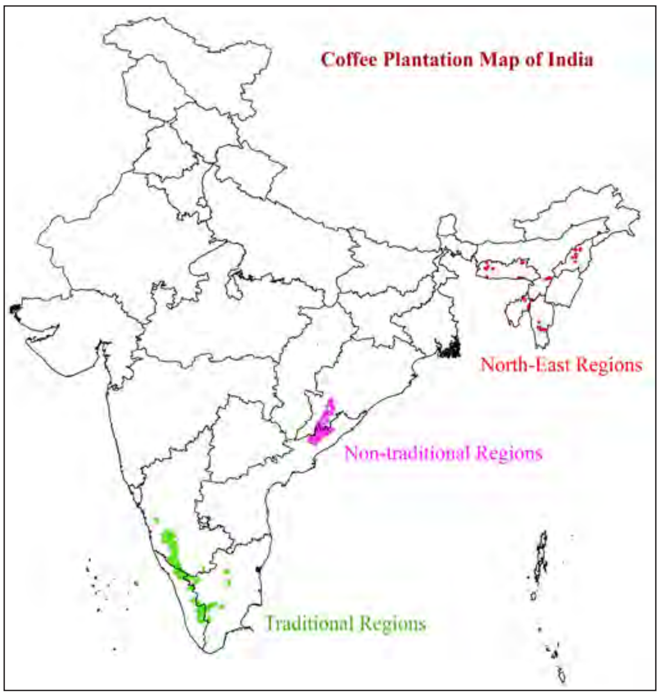


Fig. 13.1: National level coffee plantation map

The field verification of interpreted maps revealed that the overall mapping accuracy was better than 90%.This has been further independently validated for one study area (Madikeri taluk, Karnataka) using GPS enabled field data for 1076 locations indicating 94.1% accuracy. At national level, total area under coffee plantations was about 4.45 lakh ha in comparison to official estimate of 4.42 lakh ha showing relative deviation of 0.73 %.

The suitability analysis revealed that 1.20 lakh ha of potential lands are available in the 11 selected study districts for possible introduction of coffee plantations. Large contiguous tracts of coffee suitable areas are available in the hilly regions of Koraput, Malkangiri & Nabrangapur districts of Odisha and Hamirpur & Kangra Districts of Himachal Pradesh (Figure 13.2). Characterization of these lands could be taken up by the Coffee board for field level implementation.

The further work includes discrimination of coffee types, mapping of shade tree types & density, production estimation, forecasting of pest & diseases and impact of climate change on coffee production.

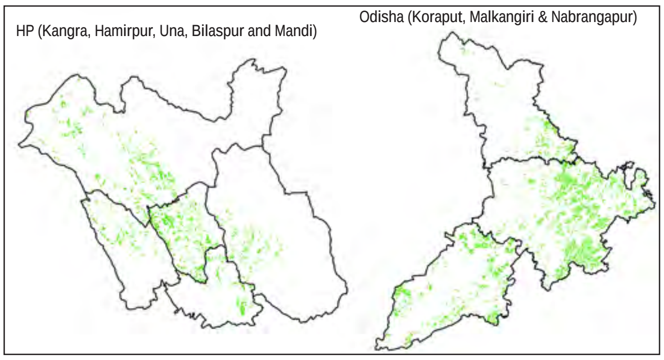


Fig. 13.2: Distribution of suitable areas for coffee cultivation in selected districts of Odisha and Himachal Pradesh

14. Modelled total alkalinity product for oceanographic application

Sea water Total Alkalinity (TA) is commonly defined as the excess base in the sea water and has gained importance due to events such as ocean acidification. Seawater TA acts as a buffer for any change in the ocean pH and is controlled by species composition of rivers, which is determined by weathering. The measurement of alkalinity is particularly useful because of its conservative nature with respect to water mixing. Change in alkalinity is also independent of temperature, pressure unlike pCO_2, pH and concentrations of individual chemical species.

Multiple studies have shown strong relationships between sea surface temperature, salinity and chlorophyll with TA suggesting the same can be exploited for observing basin scale changes. Decadal modelled TA products were generated for a period 2005 to 2018 to understand the long term changes in basin scale dynamics and same are being hosted on Bhuvan platform.

The basin scale difference of TA between Arabian Sea and Bay of Bengal is clearly evident in the processed data. On an average the northern Arabian Sea has the highest TA compared to similar latitudes in Bay of Bengal (Figure 14.1).

TA over the Bay of Bengal area ranged between 1900 to 2050 μmol kg-1. The lower values in Bay of Bengal are attributed to high riverine inputs which in general is low in TA. High surface TA in the Arabian Sea is presumably linked to Persian Gulf water, which comes from the north west boundary and spreads all over the basin. Here the TA ranged from 1900 to 2500 μmol kg-1 on an annual basis. These data sets are useful in understanding the changes in precipitation, evaporation and/or fresh water flow in any given region.

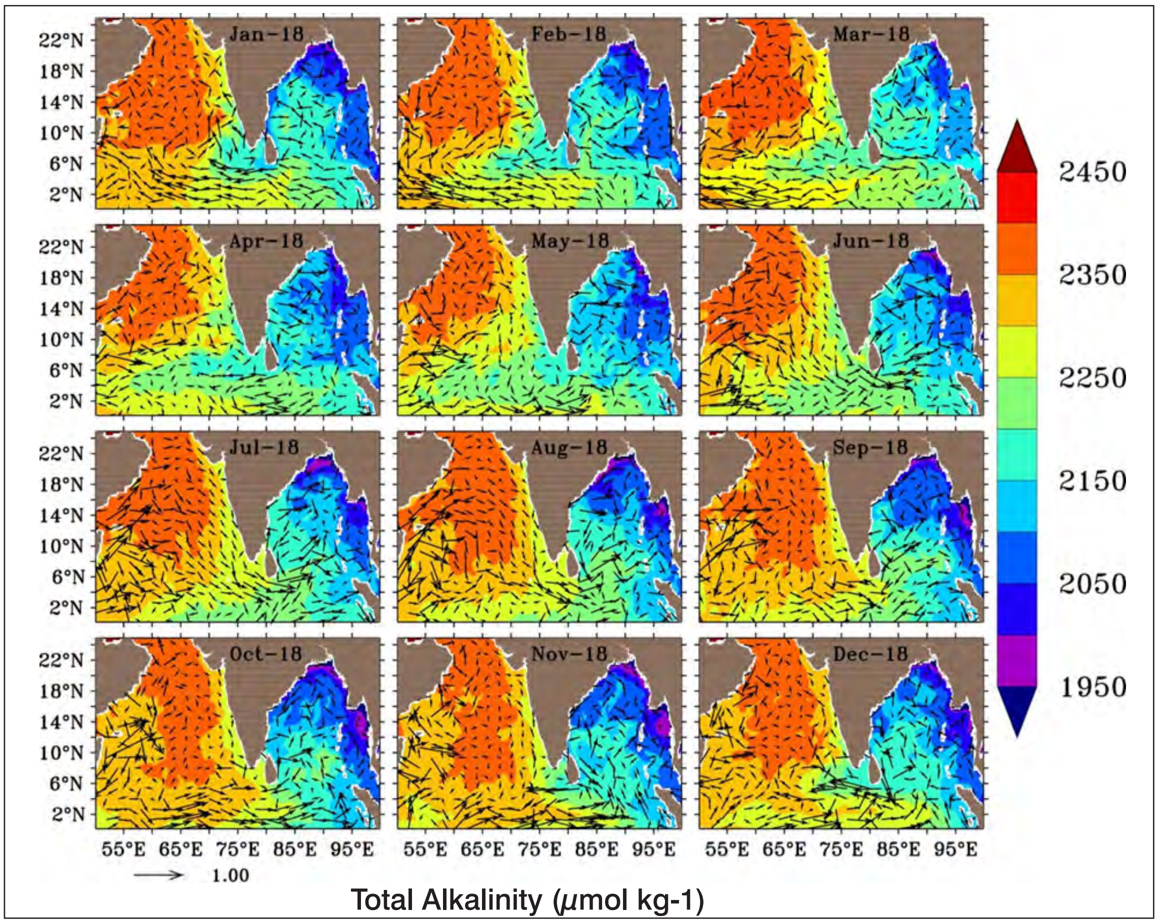


Fig. 14.1: Shows the seasonal changes in Model TA validated against word ocean data base for the year 2018. On an average the TA in Bay of Bengal is lower due to large river discharge

15. Development of full and hybrid polarimetric decomposition tool for multi-mission Synthetic Aperture Radar (SAR)

SAR polarimetry is a renowned tool for providing highly useful information about the region of interest in space-based remote sensing. In comparison to conventional single-channel SAR, multi-channel SAR systems like Full/Dual/Compact SAR polarimetry highly improve the quality of target identification and classification. Polarimetric SAR architecture involves using specific polarizations for transmission and reception of radar signals. The transmitted signal interacts with the target area and the received signal is analysed based on the target backscatter.

The elements of the scattering matrix are complex, and are obtained from the magnitudes and phases measured by the four channels of a fully polarimetric radar. As the horizontal and vertical components form a complete basis set to describe the electromagnetic wave, the properties of the target can be completely described by its Scattering Matrix (SM).

The target scattering matrix obtained from the Single Look Complex (SLC) SAR imagery is converted to coherency and covariance matrices. The three basic scattering mechanisms, namely single bounce, double bounce and volume scattering can be analysed from its derived scattering matrix/vector.

Polarimetric decomposition techniques are employed for classification studies and analysis. Different decomposition techniques use different polarimetric features that are derived from the scattering matrix and can be generally classified into two major types-Coherent and Incoherent decomposition techniques for Full-Quad Pol data. Coherent techniques are employed to study coherent targets or pure or point targets, where the incident and scattered waves are completely polarized waves. Some of the decompositions under this category are Pauli, Krogagaer and Cameron. The purpose of incoherent decomposition techniques is to characterize distributed targets. This is done by separating the coherency matrices used as target descriptors, into a combination of simpler matrices, which can be used for the physical interpretation of the target. Some of the famous decompositions encountered in this category are the Three Component Freeman Durden, Four Component Yamaguchi and General Four Component decomposition.

With compact polarimetry, or coherent dual-polarimetric SAR, only one polarization is transmitted, and two orthogonal polarizations are received. Compact polarimetric radars require that the relative phase between the two receive polarizations be retained. For hybrid pol data, target decomposition techniques are implemented by deriving the Stokes Vector and its Child parameters. C-Band SAR missions like Radarsat-2 operates in full-quad polarimetric mode while radar Imaging Satellite (RISAT -1) is designed to operate in hybrid polarimetric mode besides single and dual polarimetric modes. Upcoming SAR missions like NASA/ISRO SAR mission (NISAR)is designed to operate in L&S band with full, hybrid and dual polarimetric modes.

To perform polarimetric decomposition techniques, SARPOLTool (Beta) software module is developed in windows platform using Microsoft Visual Studio and dot net framework. It comprises of user interface and can perform polarimetric processing of full-quad and hybrid-pol data in addition to full-quad to pseudo-hybrid conversion. It can also handle Radarsat-2, RISAT-1 and Sentinel-1 datasets.

The salient features of the tool are:

- It is a GUI based-SAR polarimetric processing tool, which is capable of handling multi-SAR polarimetric data.
- Generation of polarimetric coherence and covariance matrices and Stokes matrices.
- Polarimetric speckle filtering using Boxcar and refined Lee algorithms.
- Implementation of polarimetric decomposition techniques for full-pol and hybrid - pol data.
- The output datasets are in TIFF format, which can be ingested easily for all practical applications.
- Static image display option
- Display of span image in the input channel.
- Display of RGB channel as well as surface, double and volume bounce channels in the output channels as selected by the user.

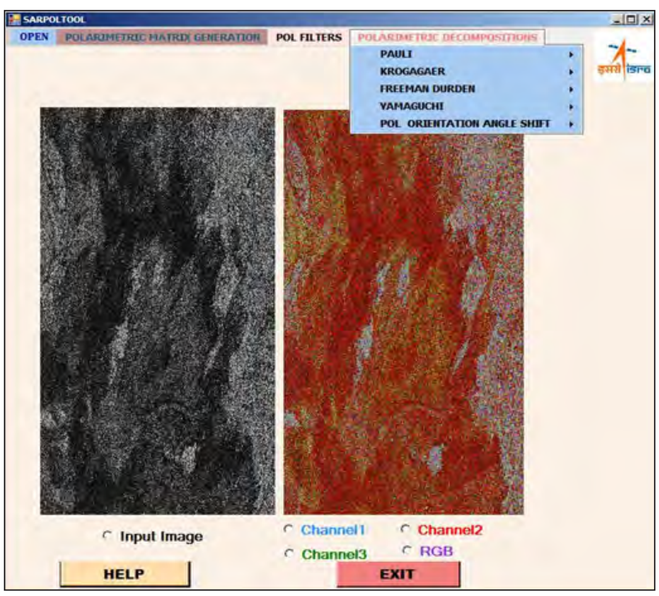


Fig. 15.1: SARPOL Tool-User Interface

Figure 15.1 shows front end view of the SARPOL Tool user interface. Full-pol decomposition outputs of IMGEOS site at Shadnagar with the deployed square trihedral corner reflectors are identified in their respective locations in the full-pol data as shown in Figure 15.2.

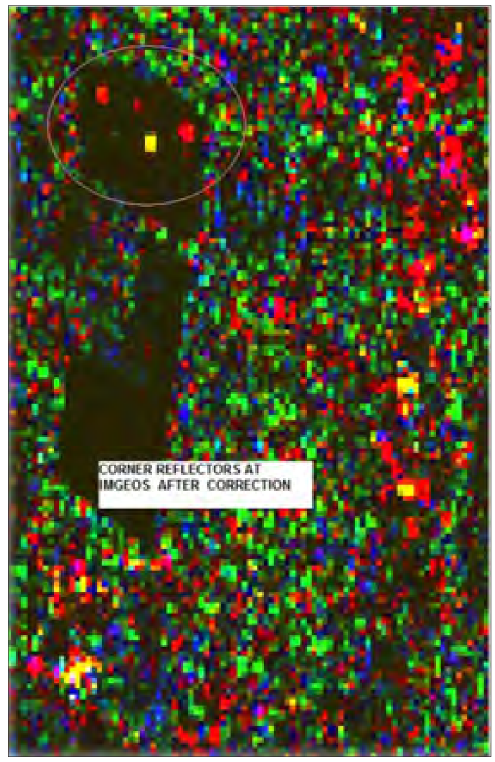


Fig. 15. 2: Corner Reflectors(red and yellow dots) in Full Quad RADARSAT-2-Freeman-Durden Decomposition (After Correction) over IMGEOS Cal_Val site

Freeman-Durden and Yamaguchi decompositions suffers from negative value powers in double bounce and surface bounce channels giving rise to misclassification.This can be corrected using appropriate algorithms for minimizing the volume over-estimation (Figure 15.2).

Figure 15.3 and Figure 15.4 represent the Freeman-Durden and Yamaguchi decomposition techniques applied on Radarsat-2 data acquired over Vancouver region. M-Delta polarimetric decomposed image for RISAT-1 c-FRS-1 hybrid pol data acquired over Sunderbans is depicted in Figure 15.5.

Terrain and land-use classification, ocean studies, oil-spill detection in the coastal regions, agricultural crop monitoring are some of the significant applications of polarimetric SAR. Many supervised and unsupervised classification methods are available to classify polarimetric SAR images based on the inherent characteristics of physical scattering mechanisms.

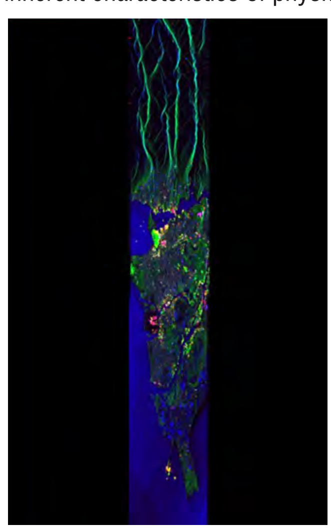


Fig. 15.3: Vancouver region-Freeman-Durden Decomposition-Radarsat-2 full quad

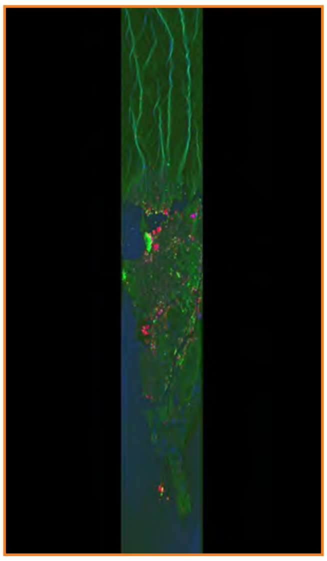


Fig. 15.4: Vancouver region Yamaguchi Decomposition- Radarsat-2 full quad

Fig. 15.5: Hybrid Pol m-delta decomposition of RISAT-1 cFRS-1 data (Sunderbans)

16. Monitoringsuspended sediment concentration in Hooghly estuary

Application of remote sensing for sedimentation studies has gained importance in coastal water quality studies. Region specific algorithms are essential to capture the variations induced by hydrographical and optical properties that are unique to the corresponding regions. Present study was carried out to calibrate a Total Suspended Matter (TSM) retrieval algorithm based on satellite reflectance from MODIS red band (645 nm) at 250m resolution for Hooghly estuarine region and validate it with in-situ observations. The Hooghly estuary and adjoining Indian part of Sundarbans is the region of our analysis. Hooghly estuary is a funnel shaped estuary and it is the first deltaic offshoot of the river Ganges (Figure 16.1).

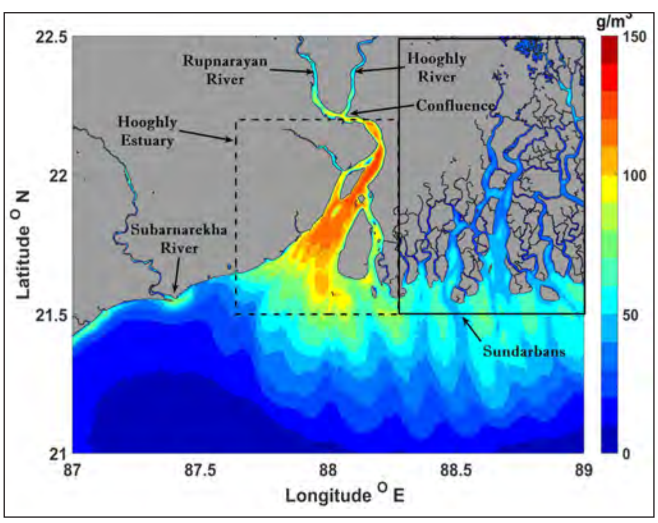


Fig. 16.1: Study region (Hooghly estuary) and the mean TSM for the period 2003 – 2018

The mean TSM concentration computed for the entire study period showed large variations in the Hooghly estuarine region, with the maximum values greater than 150 g/m³ in the lower parts of the estuary, decreasing further towards the upstream with values ranging from 40 to 100 g/m³. The Hooghly estuary is fed by 2 major river systems, namely the Hooghly/Ganges and the Roopnarayan. The abundance of TSM was observed to begin at the confluence of Roopnarayan and Hooghly rivers that increased further downstream. The influence of river discharge on TSM is also evident from the higher concentrations off the mouth of Subarnerekha river. The creeks inside the Sundarban mangrove region showed relatively less TSM concentration compared to the Hooghly river. Variations in the TSM distribution over Hooghly estuary could possibly be attributed to the discharge originating in the river, while it is absent in case of the creeks in the Sundarbans. Monthly climatological mean [2003 - 2018] TSM distribution in the study region computed from the daily datasets is shown in Figure 16.2.

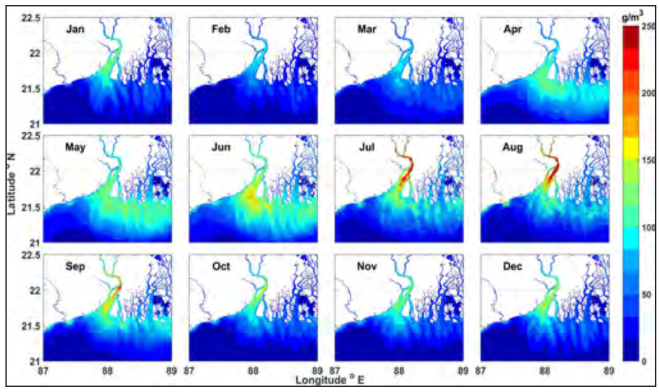


Fig. 16.2: Monthly mean computed from the long-term monthly data during 2003 – 2018

TSM concentration is found to be less than 50 g/m³ during February and March. Increase in the concentration is observed during the pre-monsoon season of April - May (100 - 130 g/m³), which further enhanced up to ~250 g/m³ during the SW monsoon season (June-September). This phenomenon could be attributed to the heavy river discharge during this period.

Gradual decrease in TSM in the estuarine region towards the end of monsoon season (September) signifies the role of rainfall and discharge (Figure 16.3) in the intra-seasonal variability.

Mean monthly TSM values in the annual cycle map are observed to be high during the SW monsoon months of June to September with a peak concentration value during July coinciding with the annual cycle of river discharge.

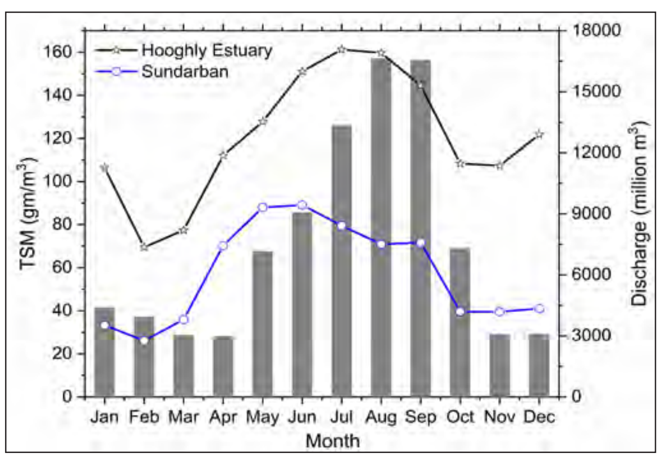


Fig 16.3: Annual cycle of TSM for the Hooghly Estuary & Sundarbans region. The mean annual discharge in the Hooghly estuary is shown as Bars

Effect of tides on sedimentation

The impact of tides on sedimentation is known but the actual offshore spread and quantity of sediments during different tide phases is determined in this study. The offshore spread of sediments is higher during ebb tide while it is lesser during flood tide. Yearly mean composite image is derived for TSM during ebb and flood tides for analysing effect of tides on TSM (Figure 16.4).

Hydrodynamic Model simulations

A hydrodynamic model (MIKE 21) is set up for the study region (Figure16.5) that is used to generate tides and currents in the Hooghly estuary. The tides generated using the model are validated using the data obtained from the existing tide gauges in the region (INCOIS)

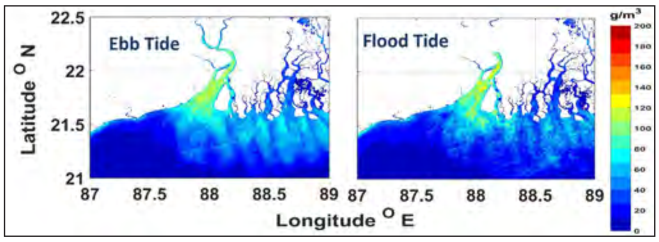


Fig. 16.4: Offshore spread of TSM during Ebb tide and Flood tide

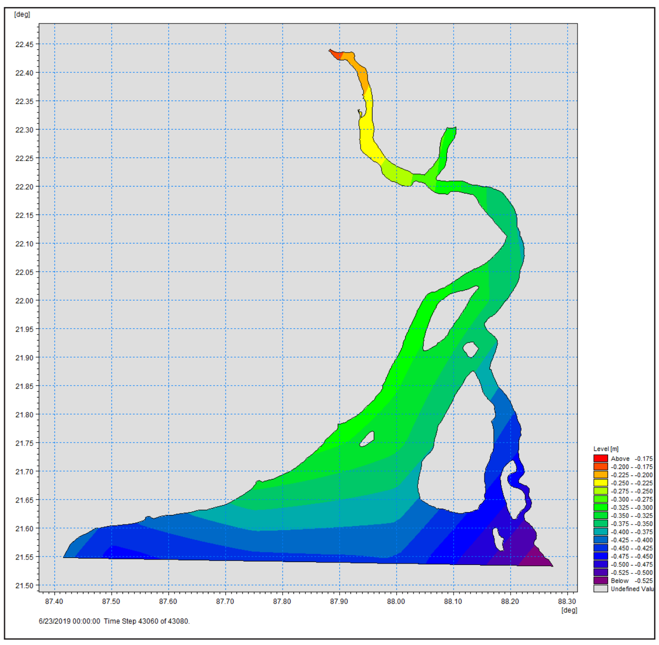


Fig. 16.5: Tides simulated using the Hydrodynamic model

17. Quality Management System of NRSC and sixth cycle ISO 9001:2015 recertification

Quality Management System (QMS) is a co-ordinated set of values and processes implemented by an organisation to ensure and demonstrate that it meets the standards demanded to satisfy the needs and expectations of its customers. A fully operational QMS helps the organisation to meet and demonstrate that it has met the desired goals.

NRSC had implemented ISO 9001:2000 based QMS in the year 2005 and got ISO certification. The scope of NRSC QMS has gradually increased from hardware processes initially to all activities of NRSC spread across 9 geographical locations in the country. NRSC had trained many batches of employees in ISO 9001:2015 Lead Auditor (LA) course and created a pool of internal auditors numbering more than 100 with at least two in each group, for implementation of QMS, supporting all QA activities of the group and monitoring through periodical internal audits. To automate QMS monitoring and towards improvement in operations, a QMS and Feedback Management System (FMS) dashboard were developed.

ISO 9001 certification of NRSC QMS had completed five cycles and has just completed re-certification audit of ISO 9001:2015 to enter into sixth cycle. Re-certification audit was conducted on 29th June and during 6th-10th July 2020, though the opening meeting was conducted on 4th June itself. Keeping in view of the prevailing pandemic Covid-19 situation, the recertification audit was carried out with utmost care by strictly adhering to the stipulated norms and precautions with minimum participants and the required physical distance. Audit was conducted in separate meeting halls with participation of minimum number of process owners. In view of the prevailing transportation restrictions, the audit of three Regional Centres (RC's) at Bengaluru, Nagpur and Jodhpur were conducted through video conferencing mode from RC-North, Delhi and audit of RC-East, Kolkata was done through video conferencing mode from NRSC, Hyderabad.

As the QMS was in place for 15 years, there were no major non-conformances observed in the re-certification audit. The closure meeting of re-certification audit was held on 10th July, 2020 and the certifying agency has recommended for continuity of the ISO 9001:2015 certification to NRSC.

Workshops / Events

NRSC User Interaction Meet - 2020 was organised during February 26 - 27 where 340 users participated apart from participants from ISRO centres. Dr. Ashok Dalwai, CEO, NRAA, MOA & FW was the chief guest. The meet had five technical sessions and one NDC interaction session. NRSC bi-annual Newsletter, P2P Volume:9, Issue:1 was released during this event.

P2P released in User Interaction Meet - 2020

Outreach Activities

NRSC has actively participated in Vikram Sarabhai Centenary Programme (VSCP) and organised programmes at 32 locations in different parts of the country. Around 2.8 lakh students were benefitted by the programme.

Exhibition bus at Mancheriyal

SISDP - Update Regional workshop at Delhi
(3rd – 4th March 2020)

SISDP - Update Regional workshop at Nagpur
(10th – 11th February 2020)

Bhuvan Jaivoorja was inaugurated on the occasion of '33rd TIFAC Foundation Day' by Dr. V K Saraswat, Chairman GC, TIFAC and Member NITI Aayog, Prof. Ashutosh Sharma, Secretary DST and Director, NRSC on 10th Feb. 2020

Glimpses of VSCP Pragramme

Publications

Total 36 papers which were published in peer reviewed journals during January to June 2020 are listed.

1. Anand, A., Krishnan, P., & Kiruba-Sankar, R. (2020). Feasibility of targeted fishing in mesoscale oceanic eddies: A study from commercial fishing grounds of Andaman and Nicobar Islands, India. International Journal of Remote Sensing, 41(14), 5011–5045. https://doi.org/10.1080/01431161.2020.1724347
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