Geospatial Technology: Journey from Data to Intelligence

ISRS and ISG National Symposium

Abstracts

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Abstracts

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Natural Resources Monitoring and Accounting

Development of a Smart phone based Soil Quality parameters estimation Application (SSQ-App) at farmer's field level based on Quantitative Colour Measurement

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Soil quality which indicates the ability of a soil to effectively perform its various designated functions is known to be highly influenced by various inherent as well as anthropogenic factors. Due to the complex nature of soil quality, its measurement mainly relies on use of various indicators, which are primarily the different quantifiable soil properties. Among the various indicators, soil organic carbon, nitrogen as well as clay content are known to influence numerous soil physical, chemical as well as biological processes thus playing a prominent role in determining soil quality. Soil colour is an important soil physical property which is influenced by different soil quality parameters through their spectral response in the visible range of the electromagnetic spectrum. Hence, soil colour has long been used as a tool for identification of soil as well as determining various soil characteristics in qualitative manner. However, no such attempts have been made in India to predict different soil quality parameters using soil colour measurements. The present study was carried out for development of prediction models for soil quality parameters(Soil C, N, Clay) based on quantified colour measurement and development of a mobile based application for real time monitoring of soil nutrients at farmers field level particularly for the Himalayan region of Uttarakhand. Nearly 2500 surface soil samples from different land use types and belonging to different textural classes, were pre-processed and subdivided into two parts. One part was used for estimation of various soil quality parameters including soil organic carbon (SOC), nitrogen (N), clay content (%) as well as different nutrients using standard laboratory analytical procedures and other part used for quantitative measurement of soil colour using mobile based NixProTM colour sensor. The colour sensor measured colour of each soil sample in eight different quantitative color space models of which five color spaces (namely LAB, LCH, XYZ, RGB, CMYK) were further selected and used for model development. The soil property and corresponding colour databases thus generated were further used for the development of prediction models. The soil Database was then segregated based on broad textural groups â€“ fine, medium and coarse and development of colour based soil quality prediction models for each of the textural groups was attempted. Multiple linear regression modelling approach was adopted for identification of soil quality sensitive color spaces as well as development of prediction models. Among the 05 different color spaces compared, LAB color space was found to be the most suitable for prediction of soil properties. Using the identified color spaces, predictive models were developed. Prediction of soil organic carbon and total Nitrogen in medium and fine textured soils could be done with considerable accuracies as revealed by the results. The developed models predicted organic carbon, nitrogen and clay content with adj R2 values of 0.73, 0.67, and 0.58 respectively, in medium texture group while lower adj R2 values of 0.40 (SOC) and 0.58 (nitrogen) were observed in case of fine texture group. The prediction ability of models developed for coarse textured soils were found to be very low. Further attempts to predict available phosphorus and potassium content yielded no significant relationship with any of the colour spaces. The soil

quality parameter predictions models were further used for development of mobile based application (Mobile App) which could be adopted by the farming community at field level to monitor soil quality based on the soil color. The mobile app operates based on the photograph of soil samples by converting the RGB values into LAB colour space and further employing the developed prediction equations depending on the broad textural group to which the soil belongs. A prototype of the application has been developed and is in further improvement phase to enhance its efficiency for accurate prediction of SOC as well as Nitrogen content in the soils. The application could be a very helpful tool for the farming community by enabling them with a less expensive tool for estimating quality parameters of their soils with considerable accuracies

Endmember Variability Based Spectral-Spatial Weighted Sparse Unmixing for Abundance Estimation of Red and Black Soil over Sparsely Vegetated Areas Using AVIRIS-NG Image

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Modern spaceborne or airborne hyperspectral sensors have proven essential in agriculture systems due to their high spectral-spatial sensitivity in the visible-near-infrared and short-wave infrared (VNIR/SWIR) regions of the electromagnetic spectrum. The mapping of bare soil types using hyperspectral imagery (HSI) is crucial compared to traditional pixel-based classification methods due to the spectral mixing between the significant agricultural features such as vegetation, soil, and crop residue. Most spectral unmixing methods focus on analysing the HSI by considering endmembers as independent entities and fail to produce accurate results. However, in agricultural fields, the endmembers are spatially and temporally varied. Moreover, incorporating spectral variability within the endmember class generates ill-posed inverse unmixing problems. In this context, sparse unmixing methods have been practical to incorporate spectral variability by introducing spectral-spatial weighting factors in the sparse regression process, which enhance the sparsity in the abundance estimation and produce more stable results. In this study, an endmember variability-based spectral-spatial weighted sparse regression model (SSWU-SV) is developed for hyperspectral unmixing analysis, which is demonstrated using AVIRIS-NG imagery in the agriculture field over Berambadi Catchment, Karnataka region. Spectral variability within the endmember class, such as red/black soil, crop residue, vegetation, etc., was incorporated for estimating the fractional abundance of red and black soil over sparsely vegetated areas. The proposed methodology produces promising results as compared to the traditional least square-based methods (fully constrained least square method). Accuracy assessments were carried out using spectral angle distance (SAD) and root-mean-square error (RMSE). Extracted endmember bundles for each class and corresponding estimated abundance maps using FCLS and SSWU-SV are depicted in Figure 1(a), Figure 1 (b) (1st row), and Figure 1(b) (2nd row), respectively. Accuracy assessment of FCLS and SSWU-SV using RMSE and SAD is displayed in Figure 2 (1st row) and Figure 2 (2nd row).

Improving the classification accuracy of coastal mangroves using sentinel 2 data fused with google earth images

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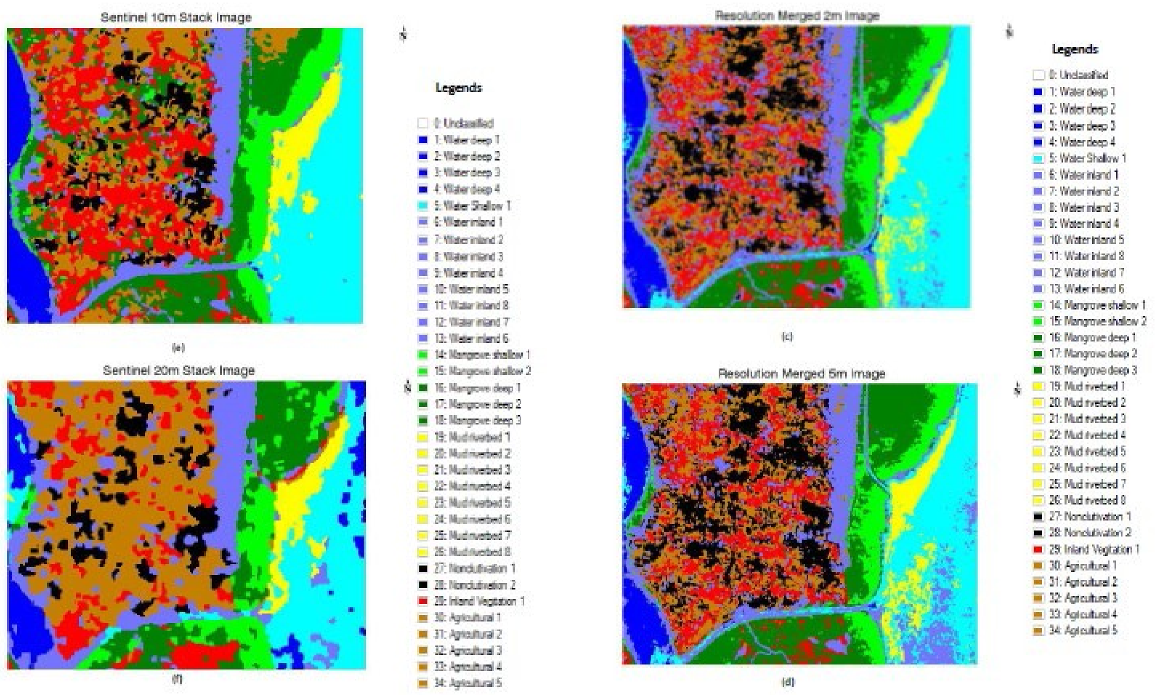
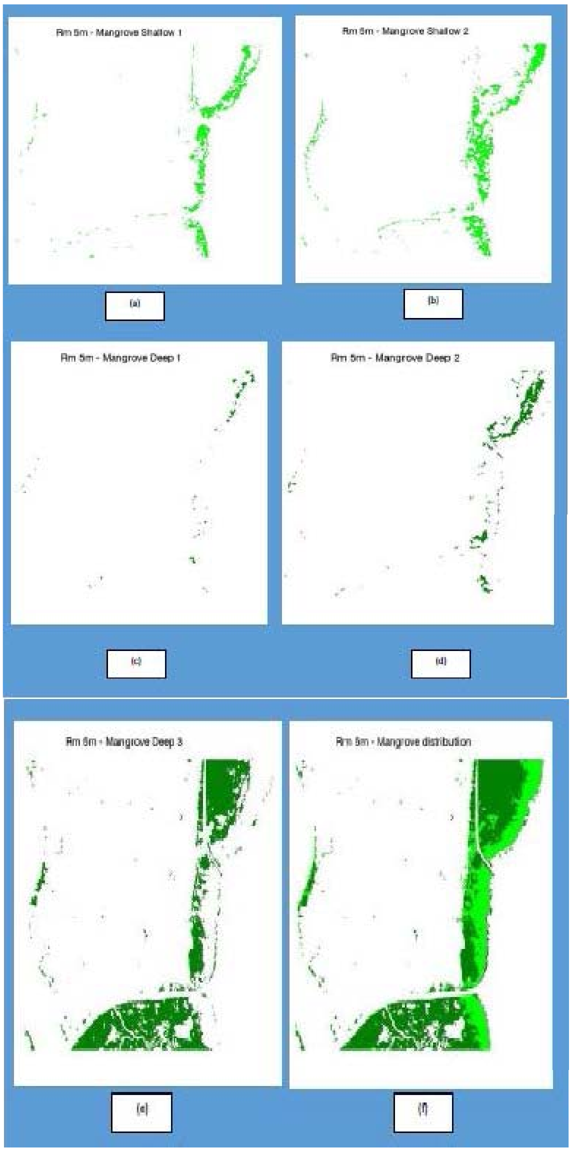
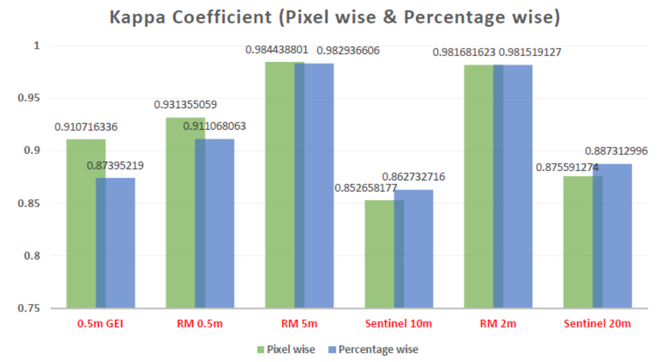
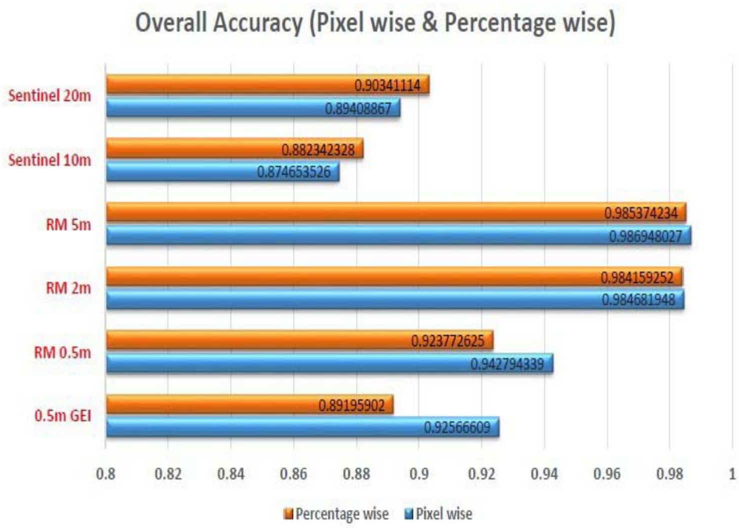
More than 50% of the world's mangroves have been destroyed and in the past two decades, 35% of the damage was caused by coastal cultivation and development. In this study, we are experimenting with whether **Resolution Merging or Pan Sharpening** Technique in QGIS can improve the classification accuracy of coastal mangroves rather than using Sentinel bands alone. By downloading high-resolution Google earth Images for the study region of "**L-block**" Island In the Sundarbans region, Indian Territory at resolutions **5m,2m**, **and 0.5m** and merging with Sentinel 2A bands of 10m resolution with the band no **2,3,4,8 and 3,4,8,11,12** band of 20m Resolution and doing a side by side comparison, the Overall accuracy of RM 2m and Rm 5m are showing improved maximum likelihood classification accuracy as about **25%** with respect to Sentinel bands alone with resolutions 10m and 20m. The Kappa coefficient values also saying the same. By generating Confusion Matrix and Accuracy assessments The Mangrove vegetation classification and able to Idendify **5 of Mangrove species** in the given region based of their Spectral characteristcs. The final Over all Accuracy Pixel wise shows about more than **9%** improvement in Percentage wise and **6%** in terms of pixel wise. 'Resolution merged 2m and 5m is giving better spatial distribution information about coastal mangrove vegetation. Thanks to the presence of the bands SWIR (Short wave infra-red) 1 and 2 coupled with these images.




Rm 5m - Mangrove Shallow 1
Rm 5m - Mangrove Shallow 2
(a)
(b)
Rm 5m - Mangrove Deep 1
Rm 5m - Mangrove Deep 2
(c)
(d)
Rm 5m - Mangrove Deep 3
Rm 5m - Mangrove distribution
(e)
(f)


Kappa Coefficient (Pixel wise & Percentage wise)
1
0.95
0.9
0.85
0.8
0.75
0.910716336
0.87395219
0.931355059
0.911068063
0.984438801
0.982936606
0.852658177
0.862732716
0.981681623
0.981519127
0.875591274
0.887312996
0.5m GEI
RM 0.5m
RM 5m
Sentinel 10m
RM 2m
Sentinel 20m
Pixel wise
Percentage wise


Overall Accuracy (Pixel wise & Percentage wise)
Sentinel 20m
0.90341114
0.89408867
Sentinel 10m
0.882342328
0.874653526
RM 5m
0.985374234
0.986948027
RM 2m
0.984159252
0.984681948
RM 0.5m
0.923772625
0.942794339
0.5m GEI
0.89195902
0.92566609
0.8
0.82
0.84
0.86
0.88
0.9
0.92
0.94
0.96
0.98
1
Percentage wise
Pixel wise

Indexed based approach for Monitoring and Burn Severity Analysis of Forest Fire in Charda Forest Block of Bahraich Forest Division, Uttar Pradesh

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Forest fire plays a major role in the degradation of the forest area and extremely difficult to control. It affects the essential factors such as climate, water cycle, the habitat of thousands of life forms and the whole environmental ecosystem. In Uttar Pradesh forest fire are mostly incited by human activities, such as land clearing and extreme drought. The number of incidences of forest fires is increasing day by day and more area is burned every year due to forest fire. The burned area mapping is essential for the forest officials to plan for mitigation measures and restoration activities after the fire season. Accurate mapping of fire burn severity is essential to support fire management activities such as strategic planning, mitigation measures and vegetation monitoring.

Satellite remote sensing and GIS technology has become a primary data source for forest fire monitoring, mapping, fire danger rating prediction and fire ecology research. This technology for this purpose provides great convenience in the detection of the fire areas and the severity of the fire affected area.

Charda Forest Block of Bahraich Forest Division has been selected for the study of forest fire because of its diversity in forest types. During ground verification it was found that human interference like poaching, carelessly throwing of cigarettes and bidi stubs, match sticks by grazers/ travelers are the main reasons of forest fire in Bahraich Forest Division. Information provided by Forest Department, U.P., poaching is main cause of forest fire in Charda forest block. The poachers use forest fires for terrorizing wild animals and hunting.

For identification of forest fire affected areas in fire alert location has been downloaded from the forest fire portal http://fsi.nic.in/index.php of Forest Survey of India, Dehradun in year 2021. Latest Sentinel satellite images pre and post fire has been selected for analysis because of its 5th day revisit period. Mapping extent of forest fire affected area and burn severity analysis forest fire has been done through NBR and dNBR indices supported by field survey.

There are 64 total fire points were found out of which 09 were large and 55 were small fire was observed in Charda Forest Block in year 2021. On the basis of large fire points, mapping and assessment of forest fire through pre & post fire satellite images fire affected area was estimated 1497.68 ha in Charda Forest Block of Bahraich Forest Division. In major part of Charda forest block, Moderate low severity is noticed, which covers about 718.896 ha area besides that Moderate-high severity and Low severity also observed and covers 462.211ha and 293.822ha area respectively. Low post fire regrowth also observed which covers about 22.64ha area in Charda forest block.

The forest type and forest density wise mapping was also done in fire affected areas and it was observed that mainly sal with teak forest was affected by fire which covers 603.268 ha area of forest block besides that sal, teak&teak dominated, jamun dominated and miscellaneous forest was also affected by fire which covers 332.42 ha, 405.207 ha, 0 .65 ha and 88.13 ha area respectively. Other landuse classes also classified as Grassland, scrub and forest blank which covers area 55.56 ha, 5.56 ha, 6.17 ha respectively.

The results of this study showed that, remotely sensed data is an important tool to identify and map the fire affected areas in forest. Integrated usage of remotely sensed data, GIS and GPS data along with other ground truth information provide valuable information about spatial distribution and areal extent of the fire damages.

Prediction of spatial soil carbon loss influenced by surface erosion processes using geo-spatial modeling: A case study from Karnataka, India

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The lateral transport of Soil Organic Carbon (SOC) must be determined to understand the C loss from the various ecosystems. Hence, the present study has been formulated to spatially predict the SOC loss due to soil erosion using physically based-empirical Morgan–Morgan– Finney (MMF) model in Karnataka, India. The spatial distribution of various environmental factors such as slope, rainfall, vegetation, soil texture, and land use and cover were derived using multi-temporal satellite images with adequate ground truth. These outputs along with ancillary datasets were used to calculate soil erosion rate of the study area. A number of inputs on soil carbon density, 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 were also computed. These inputs were used to generate volume of overland flow, rate of soil carbon detachment by raindrop impact and transport capacity of overland flow for MMF modeling to estimate the annual soil carbon loss over the study area. Results show that areas affected with high erosion rates were mostly observed in the higher elevated areas of the study sites having high annual rainfall. The highest soil loss of greater than 80 t ha^{-1} year^{-1} (very severe) was observed in 2% of the study area. The erosion rate of 41–80 t ha^{-1} year^{-1} (severe) was observed in 13% of area followed by the erosion rate of 21–40 t ha^{-1} year^{-1} (15%) (very high loss), 11– 20 t ha^{-1} year^{-1} (20%) (high loss) and 5–10 t ha^{-1} year^{-1} (26%) (moderate loss). It was observed that the SOC loss was maximum in waste lands (283 kg ha^{-1} year^{-1}) followed by current fallow (193kg ha^{-1} year^{-1}). The higher SOC loss may be attributed to the high rainfall, high soil erodibility, steep slopes and poor surface cover protection in such areas. The findings of the current study are useful to understand the C loss from the various land use land covers and formulation of suitable management practices to protect the C loss from soils.

Alteration mineral mapping using AVIRIS-NG hyperspectral data in the gold bearing Gadag Schist belt, Karnataka, India

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Hyperspectral data has always served as an efficient tool for delineating characteristic minerals associated with a mineral/ore deposit. The spectral/radiometric quality of hyperspectral data is finer than ever in the Airborne Visible Infrared Imaging Spectrometer-Next Generation (AVIRIS-NG). High spatial resolution (5 m) AVIRIS-NG data with 5 nm spectral bandwidth allows mapping surficial presence of minerals at a great detail. This prospect has been tested in this study to map the potential zones of gold mineralization. The Gadag schist belt in Karnataka, India has been reported as auriferous in nature with ancient gold mining remnants visible in the area. Gold mineralization in the area occurs in the quartz veins which are found along faults, shear zones showing presence of extensive hydrothermal alteration. In this study, (Visible Near Infrared) VNIR and (Short Wave Infrared) SWIR bands of AVIRIS-NG data have been utilized to delineate different lithologies and alteration mineral zones present, acting as a proxy for gold mineralization. Sensor error correction was performed on L2 AVIRIS-NG data and pure endmembers were further derived. Extracted endmembers of the characteristic minerals of Phyllic to Argillic alteration zones were compared against established spectra of minerals and soils from the United States Geological Survey (USGS) and Johns Hopkins University (JHU). Alteration mineral endmembers showing high scores in comparison with the USGS/JHU spectral libraries have been selected. These endmembers have been used to demarcate the alteration zones using Spectral Angle Mapper (SAM) classification technique. Band Ratios (BR)/ Indices along with different combinations of such were also generated, to map and co-relate the potential sites of alteration or characteristic minerals. The obtained results were observed to be very promising and were consistent with the existing literature and geological map prepared by the Geological Survey of India.

Assessment of River Water Dynamics and Optically Active Water Quality Parameters over Punjab, India using Google Earth Engine Approach

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River water bodies in Punjab region have been impacted extensively by natural changes and human influences which affects biological diversity and human wellbeing. Remote sensing approach along with high end computational resources offers multiple observations for mapping and monitoring river water dynamics and water quality parameters with high spatial and temporal resolutions. This study used freely available high resolution multispectral datasets for mapping and monitoring river water dynamics and optically active water quality parameters viz. chlorophyll-a concentration and total suspended matters in Satluj and Beas River over Punjab region. Landsat multispectral imagery from Google Earth Engine (GEE) database has been used to derive the river water dynamics like river water occurrence, river water occurrence change intensity, river water recurrence, river water seasonality and transition in river water class during period from 1984 to 2019 while sentinel-2 imagery has been used to derive optical active water quality parameters during period from 2018 to 2022. A pixel based classification system has been utilized to extract the water and non-water pixels and semi-analytical inversion model is used to retrieve the optically water quality parameters. The highest peak of surface water area has been observed in year 1998 and deficit peak has been observed in year 2019. The images of derived chlorophyll concentrations and total suspended matter have been found ranging from 0 to 36 mg/m^3 and 0 to 153 mg/m^3. The spatial and temporal variations of water quality parameters are associated with climatic variables, rainfall and high runoff over study area and the surrounding reasons. The rainfall in the Punjab state and surrounding areas is strongly occur during the monsoon season (June to September) that delivers higher loads of suspended materials and dissolved solids into the river and these materials consequently decrease the light penetration in the river water. Water quality parameters monitoring is an important indicator to measure the productivity and eutrophication of the river water system. The decay pattern of river water and water quality changes from the newest generation of high resolution earth observation satellites can provide timely inputs and will be beneficial for the policy makers and management of water resources.

LSMS and OBIA Techniques are used for Automatic Detection of the Built-up Area

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The present study was carried out for automatic detection of built-up area using high resolution Sentinel-2 multispectral data in Faridabad city. Hierarchical decision rules including spectral, geometric and spatial characteristics to be used for object-based Image analysis (OBIA) of high-resolution satellite data with the integration of different thematic layers to automate urban mapping procedure in Orfeo ToolBox (OTB) which is free and open source. Segmentation and classification algorithms were used for the OBIA process. For the process of image segmentation Large-Scale Mean-Shift (LSMS) algorithm and for the process of classification support vector machines (SVM) algorithm were used. The total built-up area of Faridabad city obtained by the analysis of the Sentinel-2 data using OBIA classification was 54230 ha. It includes residential, institutional, commercial, industrial, utility & services, recreational, airport and restricted area. The overall accuracy was found to be 86.71%. Therefore, this kind of study would be time and cost-effective methods for urban planners and decision makers.

Bamboo Mapping in part of North East India using Random forest in Google Earth Engine

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Bamboo, known to be a multipurpose crop in the tropics, is an important non-wood forest product. It provides diverse ecosystem services. Bamboo forests are ecologically important for their role in carbon sequestration, soil erosion control, water conservation, and land rehabilitation. In this study, the spatial distribution of bamboo was mapped in part of northeast India using a random forest classifier in the Google Earth Engine (GEE) platform. For the present study, Sentinel-2 data of January, April, and November 2021 were used. Ten spectral bands of Sentinel-2 data and three spectral indices, viz. normalized difference vegetation index, normalized difference water index, and enhanced vegetation index were generated for different months. Apart from these spectral variables, the Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM), aspect, and slope were also used. A combination of spectral variables of different months, along with the integration of topographic variables, was attempted. The overall accuracy of the map was found to be 91.8%. The short-wave infra-red (SWIR) band was found to be the most important variable for distinguishing the bamboo forest from non-bamboo vegetation. The dominance of bamboo observed in the hilly areas may be primarily due to the shifting cultivation, also known as the slash and burn, practiced by the local tribes. Over time, the shifting cultivation patches which are left fallow are primarily occupied by bamboo. The mapping of the spatial distribution of bamboo can act as the baseline information for environmental protection and sustainable resource management. The generation of maps may also constitute an initial step in specifying national, regional, and global forest bamboo resources more productively. The use of the GEE platform offers a great opportunity to access a vast array of freely available data through Google's cloud computing resources for big data analysts.

An Integrated Geospatial Modelling Approach to Assess and Predict Growth Pattern and Loss of Agriculture Land In The Industrial Town of Mandideep, Madhya Pradesh

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Developing countries like India needs Industrial growth as it unleashes dynamic and competitive economic performance which generates income and employment, facilitates international trade and increases resource efficiency, and is thus a major driver of poverty alleviation and shared prosperity. At the same time this Industrial growth brought rapid urbanization. It leads to changes in farming, soaring population growth, and an ever-increasing demand for workers. This creates stress on infrastructure as well as increased outgrowths and rapid change in Land use Land cover. Change of land use land cover (LULC) has been known globally as an essential driver of environmental change. Thus, predicting future industrial growth in the most rapidly growing regions of India becomes a significant endeavour. A third of the planetâ€™s land is severely degraded and fertile soil is being lost at the rate of 24bn tonnes a year, according to The Global Land Outlook (Convention to Combat Desertification, 2017). The most comprehensive study of its type, it maps the interlinked impacts of urbanisation, climate change, erosion and forest loss. Mandideep is a town in Goharganj sub-district of Bhopal district in the state of Madhya Pradesh. Mandideep is 23 km from the state capital Bhopal and is basically an Industrial township which came into existence in late 1970s. Agriculture was the primary source of livelihood before industrialization. Currently there are a total of 650 industrial units in the town. This gradual increase in industrial units from 1970 has resulted in increased length of road network, more housing units, commercial centres and related amenities and infrastructure because of that the land use has changed immensely. Though Mandideep is the leading industrial town in central India, environmental damage could worsen in the future. So, it is crucial to monitor the growth of this area and land use/land cover change. In this research, techniques have been selected to investigate and observed the temporal changes in the land use of Mandideep industrial town through unsupervised Maximum likelihood classification by Landsat 7 & 8 datasets. The population of the Mandideep area has increased 23% in the past decade, so to effectively compare the after-effects of Industrialization, the images dated January 2021, January 2016, January 2011, January 2006 and January 2001 were produced through USGS Earth explorer which was used for further analysis. The maximum likelihood classification of the images has been used to inspect urban sprawling. In the last 10 decades, the built-up has grown from 2.5 sq. km to almost 49 sq. km. Agriculture land has been reduced from 175 sq. km to 168.62 sq. km. Although the agriculture land decreased by only 2% between year 2001 to 2021. But in absolute numbers the area has reduced by approximately 7.5 Sq. Kms which also amounts to around 2500 tons of wheat produce per annum in Madhya Pradesh. Classified satellite images show that this growth is beyond the Mandideep town boundary and in a scattered manner which has leaded sprawling around the town. The industrialization has impacted the town so much that the built up area has phenomenally increased by more than 2000%. Vegetation areas referring to trees and shrubs with large foliage have reduced drastically from 37.7 sq. km. to 10.13 sq. km which is by 73%. Hills have also reduced by almost 26%. Road widening to satisfy the demand of the

growing Industrialization is the main reason for vegetation and hilly area reduction. Water bodies in the town have also been reduced by 2.9 to 2.3 sq. km. An overall reduction of 21% has been observed. Furthermore, these reductions predominantly observed in the waterbodies within the municipal boundary. By analysing the LULC change trends of the past 10 years prediction of the future LULC is carried out using Pearsonâ€™s correlation and Cellular Automata (CA)-Markov chain model approach for the year 2025. The predicted LULC of 2025 shows the same trend. According to the prediction built up will grow up to 66% of total area of the town and only 3% agriculture land and green cover will remain. Waterbodies will shrink up to 0.6%. This analysis provides the conclusion that in 20 years, the natural features of the study area have drastically changed due to human intervention and if same trends continuous precious fertile land will encroached by hard surfaces like concrete. This may cause adverse environmental effects like draught, waterlogging, pollution. Agricultural land not only provides the largest share of food supplies but also ensures an essential number of ecosystem services. This analysis will help town planners, policy makers to evaluate existing vulnerabilities and prioritize a sustainable solution.

High-resolution remote sensing for precise biomass estimation of Himalayan forests

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Conventional field-based methods of biomass estimations are tedious, time-consuming, and not so accurate. The tree height and girth measurements are basic inputs for such biomass estimations. The field-based sampling protocols provide tree height and girth on quadrant basis and thus doesn't depict real ground conditions. Secondly, the allometric equations used to estimate the biomass of tree species, using the above tree parameters, are also generalized and derived for some different locations. These factors lead to an approximate biomass values and that too not for each tree rather for a group of trees falling in the quadrants. These biomasses form the base for carbon estimations of trees/forests in India. Ultimately, the reported carbon sequestrations are not so accurate and are not the actual representation of real-time ground situations. In this backdrop, we are using modern drone-based multispectral remote sensing and terrestrial LiDAR remote sensing for biomass estimation of sub-tropical forests of the northwestern Himalayas. The drone-based data acquired for the study area has helped us in the preparation of forest-type maps at 1:500 scales. Also, we could retrieve tree- level height and girth values using LiDAR point cloud data. Based on this information, we have prepared allometric equations specific to the tree species of our study area. The modern remote sensing technique thus provided tree-level biomass and carbon values at 70-80% accuracy. The technique is also rapid as compared to the conventional methods as for the quadrant-based method it took two and a half hours for measuring tree attributes for single quadrants, while the LiDAR method provided tree parameter values just in ten-fifteen minutes.

Modelling the Spatio-Temporal Pattern of Thermal Zones and Their Correlation with Satellite-Derived Land Use Indices for The Past Three Decades In Salem, Tamil Nadu

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A rapid increase in India's population has led to replacing natural vegetation with impermeable man-made structures, resulting in local thermal zones, which can cause fatal damage to society. This study examines the effect of land use changes on the thermal nature of Salem, Tamil Nadu, over the last three decades by analyzing the spatiotemporal pattern of Urban Heat Island (UHI), Urban Hot Spots (UHS), and Urban Thermal Field Variance Index (UTFVI). The land surface temperature (LST) and subsequent UHI and UHS models were derived using thermal bands. However, the classification algorithm may introduce errors and bias. The following land use indices are used to address the issues Normalized differential vegetation index (NDVI), Normalized differential built-up index (NDBI), Normalized differential barren index (NDBaI), and Modified Normalized Difference Water Index (MNDWI). Pearson's correlation and scatterplots are used to investigate the relationships between LST and land use indices. The results have shown that UHS has steadily increased, creating a need to tackle the increasing thermal zones to provide a sustainable habitat. The correlation study reveals that the intensifying temperature scenario is partly caused by the overexploitation of water and vegetation resources due to urbanization. The geographic understanding the current state of UHI in this city, urban planners can provide eco-friendly planning for developing a smart city, mitigate the UHI effect, and create thermal comfort zones.

Assessment of Net Primary Productivity of Alpine Pasture using CASA Model in a part of Western Himalaya

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Himalayan alpine ecosystem forms one of the highest, unique and geographically vast alpine pastures of the world. It provides invaluable biomass resources especially forage for the domestic livestock during summer monsoon, thereby, supporting rural livelihoods of a large number of agro-pastoral communities in India. Natural and biotic disturbances like climate warming, excessive livestock grazing, developmental projects, and tourism are greatly affecting the structural and functional attributes of Himalayan alpine pastures. The consequence of these activities on the productivity of Himalayan alpine pastures is to be understood and managed. However, the Indian Himalayan Region lacks baseline information regarding the productivity of alpine pastures. To address this situation, Carnegie-Ames- Stanford-Approach (CASA) model was tested in Google Earth Engine (GEE) for estimating the spatio-temporal variations in net primary productivity (NPP) of three major alpine vegetation classes (*Danthonia* grasslands, *Kobresia* sedges, and mixed herbaceous meadows) in Manali Valley of Kullu Forest Division, Himachal Pradesh, India. The CASA model requires five main inputs viz, monthly total solar radiation required for estimating PAR; remote sensing data like NDVI, land cover types for estimating fractional PAR; monthly average temperature for determining temperature stress coefficients (T_1 and T_2), monthly total precipitation for determining moisture stress coefficient (W); and maximum light use efficiency (E_{max}) estimated from crop harvest. PAR, T_1 and T_2 were derived from ERA-5 datasets, while FPAR and W was estimated using the MODIS datasets (MOD15A2H.006 and MOD09A1.006). Emax was derived from the literature and was determined to be 0.608 gC MJ^{-1}. The alpine pasture NPP was calculated for 20 years (2001-2020) specifically for the growth period due to the region's short growing season for plants, lasting from early May to late September. Overall, the NPP ranged from 0.77 to 58.04 gC m^{-2} yr^{-1}. Mixed herbaceous meadows recorded highest average annual NPP (20.49 gC $m^{-2}yr^{-1}$), followed by *Danthonia* grasslands (18.45 gC $m^{-2}yr^{-1}$) and *Kobresia* sedge meadows (12.75 gC $m^{-2}yr^{-1}$). *Danthonia* grasslands showed constantly higher difference in NPP of protected and disturbed sites, while, *Kobresia* showed lesser difference. The differences in NPP of mixed herbaceous meadows varied among protected and disturbed sites. The study also strengthens the fact that alpine pasture productivity is a function of species composition, climatic factors, and biotic pressure. The simulated NPP of alpine pastures showed promising results and forms the base for understanding the change in productivity pattern of different vegetation types of alpine pastures with respect to increasing biotic pressure.

Association between Vegetation Optical Depth and AMSR2 Microwave Channels over biomes of the Indian Region

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Satellite-based observations are invaluable for providing extended and frequent observations of vegetation. However, remote sensing of vegetated surfaces predominantly indicates top-of-canopy conditions in the widely used visible and near-infrared spectral bands. This is due to the limitation on penetration capacity associated with the wavelengths inherent to these spectral bands. Microwave remote sensing on the other hand is able to penetrate vegetation and the underlying surface also by virtue of employing longer wavelengths. Additionally, radiation emissions from the surface are attenuated by the moisture present in the vegetation canopy overlying the surface, prior to its measurement by space-based radiometers. The Vegetation Optical Depth (VOD) is a parameter which quantifies the vegetation-induced attenuation of the microwave radiation. It depends on various factors such as the density, type and water content of vegetation and the wavelength of the sensor. VOD has great potential for continuously monitoring spatialâ€“temporal variations in ecosystem as it is sensitive to vegetation water content and remains unaffected by cloud or high sun zenith angles. In the present study, we examine VOD retrieved at multiple microwave frequencies acquired by the Advanced Microwave Scanning Radiometer 2 (AMSR2) satellite over the Indian subcontinent. The Land Parameter Retrieval algorithm employed for the retrieval includes an analytical solution for VOD using the Microwave Polarization Difference Index. This approach retrieves VOD and soil moisture simultaneously under the assumption of a globally constant single scattering albedo and further assumes that soil and canopy temperature are similar. Since this assumption generally does not hold for daytime observations and so only observations from the descending mode were used for this analysis. In general, shorter wavelengths experience higher attenuation by vegetation than longer ones. As a consequence, VOD estimates from long wavelengths are generally more sensitive to deeper vegetation layers (e.g. stem biomass) while VOD estimates from short wavelengths are more sensitive to leaf moisture content. The present study used C, X, and Ku bands of AMSR2 to estimate VOD values for one year data. We have observed the association of increase in VOD values with increasing frequency is dominant over various plantation/vegetation cover types. Our analysis provides new insights about the relationship between frequency and VOD over Indian region.

Estimation of Actual Evapotranspiration using Remote Sensing based on Dual Crop-Coefficient Soil Water Balance Approach

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Evapotranspiration is one of the major processes within terrestrial hydrological cycle. The loss of water from soil and vegetation links hydrological cycle with carbon and energy cycle of earth system. Despite being the prominent process after precipitation for flux of water from earth surface to atmosphere, its measurement remains challenging and sparse in nature. Satellite remote sensing has enabled estimation of evapotranspiration using principles of surface energy and water balance. Most of the existing remote sensing based methods require cloud-free data over an area for estimation of evapotranspiration on a given day. This study proposes a method for estimation of evapotranspiration using passive microwave derived soil moisture from SMAP and bio-physical parameters like LAI and vegetation fraction. This method uses the dual crop-coefficient based soil water balance approach with satellite remote sensing inputs. The actual evapotranspiration is estimated by adjusting the reference evapotranspiration using dual coefficients based approach where transpiration and soil evaporation are characterized separately. Basal crop coefficient, which is derived using leaf area index (LAI) and vegetation fraction, is used to characterize the surface characteristics of the crops. Soil water stress coefficient determines the rate of transpiration based on the water availability in crop root zone. SMAP level-4 root zone soil moisture product is used to compare water availability in the crop root zone with soilâ€™s water holding capacity. Rate of soil evaporation is determined based on the available water in top soil layer which is characterized using SMAP level-3 soil moisture product. A three - day composited actual evapotranspiration product is derived for the cropped area with in Indian region and is validated with evapotranspiration measurements of eddy-covariance flux towers.

ShrinkIng Urban Greenery Spaces within the Catchment of Upper Bagjola Canal, West Bengal- A Case Study Using Geospatial Technology Applications

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With the change of time the land which is a natural resource has undergone a huge modification. The land which is a fixed natural resource is modified with a spike in sedentary population resulting to forested land are being converted to agricultural land so that food may be provided to the mass and with escalation of population pressure for residential areas these agricultural lands have been converted to built up areas leaving behind little green space. This phenomena is not different for North Dum Dum Municipality, a part of Kolkata Metropolitan Area and very near to Kolkata Megacity. The Bagjola Basin derives its name from bag/bagdi backward community whose main occupation used to be fishing and cultivation. Jola/Jala is a part of gangetic fluvio –deltaic moribund area which is dominated by wetland Hooghly River on west and Bidyadhari river on east. It was navigable and was used as waterways for trade and commerce even prior to colonial rule (1747) and during British Rule used to be a two way flowing canal receiving water from Bhagirathi-Hooghly as it gets bifurcated from Bhagirathi- Hooghly becoming a distributary channel at Arihadah, Dakshineshswar Kamarhati Municipality, coordinates 88 .3666^0 E,22.6470^0 N and ends at V.I.P Road crossing where from it is known as lower Bagjola Basin and meets Bhagirathi-Hooghly again at Kulti Gung . The water of this canal is useful for irrigation. The history of this canal speaks about colonial rule since the period of Battle of Plessey. It was an important water way for East India company. The ruins of **Clive House,** which previously used to be cotton gowdown**,** is the witness . Bagjola River/Canal has a flow direction of NNW to SSE.Basin covers municipalities like Panihati, Kamarhati, Baranagar, Dum Dum (DDM) , North Dum Dum (NDDM), South Dum Dum (SDDM) and few areas of Kolkata Municipal Corporation. The former name of South Dum Dum Municipality used to be Bagjola Municipality which proves the importance of this canal. The study area, North Dum Dum Municipality, has witnessed an increase in population resulting to the reduction of green space, which has been analysed by supervised classification method done in Erdas Imagine 2014 for the years 1990, 2006 and 2017 . There has been significant reduction of agricultural areas, waterbodies for providing room for residential and commercial areas. ArcGis 10.5 and QGIS 3.14 versions have been used for digitization purpose. There has been vertical expansion for accommodating rising population with less infrastructural development for the drainage facilities. Waterlogging is a major problem here as Bagjola which is a spill over channel is now clogged with waste deposits and huge siltation leaving no room for extra water retention within the canal. Immediate attention is needed to solve this water logging problem as this is giving rise to a number of diseases like dengue, malaria, gastric, fever, skin allergies. When this waste water dries up leaving a stinky smell all over resulting to respiratory ailments as well. This urban sprawl is growing with no municipal infrastructure to support its growth.

Long term monitoring of urban conditions over Navi Mumbai from thermal infrared remote sensing

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Urbanization in India has been rapid and challenging in terms of providing adequate quality of life. One of the most known consequences of urbanization is the alteration to the local thermal conditions. The aim of this study is to understand the urban growth and changes in the thermal regime of Navi Mumbai in Maharashtra, a city rich in biodiversity. Data from Landsat satellites have been used from 1990 to 2020 towards this exercise. First, the regions that underwent a transformation from natural land cover state to urban (i.e. impervious state) were identified from the Land Surface Temperature (LST) anomalies. Secondly, the surface Urban Heat Island Intensity (SUHII) was also estimated at multiple time intervals. The changes in the LST anomalies and SUHII were then related to changes in vegetation, population and built-up area to identify the major influencing factors of LST.

The northern part of the city became progressively warmer with time, whereas the western and southern boundaries of the city were relatively cooler. Though the southern part of the city became urbanized with high-rise buildings, it did not experience increased LST anomaly due to the presence of mangrove vegetation and coastal areas nearby. Further, the wind pattern might also help this part of the city to be relatively cooler. It was observed that there is a proliferation of informal settlement clusters near the vicinity of the industrial corridor existing within the city. These informal urban settlements non-uniformly distributed across the city experienced increased heat ingress. It was inferred that with time, population density had increased while the open and vegetated spaces shrunk contributing to the increased surface temperature in these poorly planned settlements.

Based on the results, we are now drawing out measures based on green infrastructure in developing resilient infrastructure for reducing the impact of heat ingress in such informal settlements. The findings have the potential to become a part of the climate action plan for local-level policy building in Indian cities.

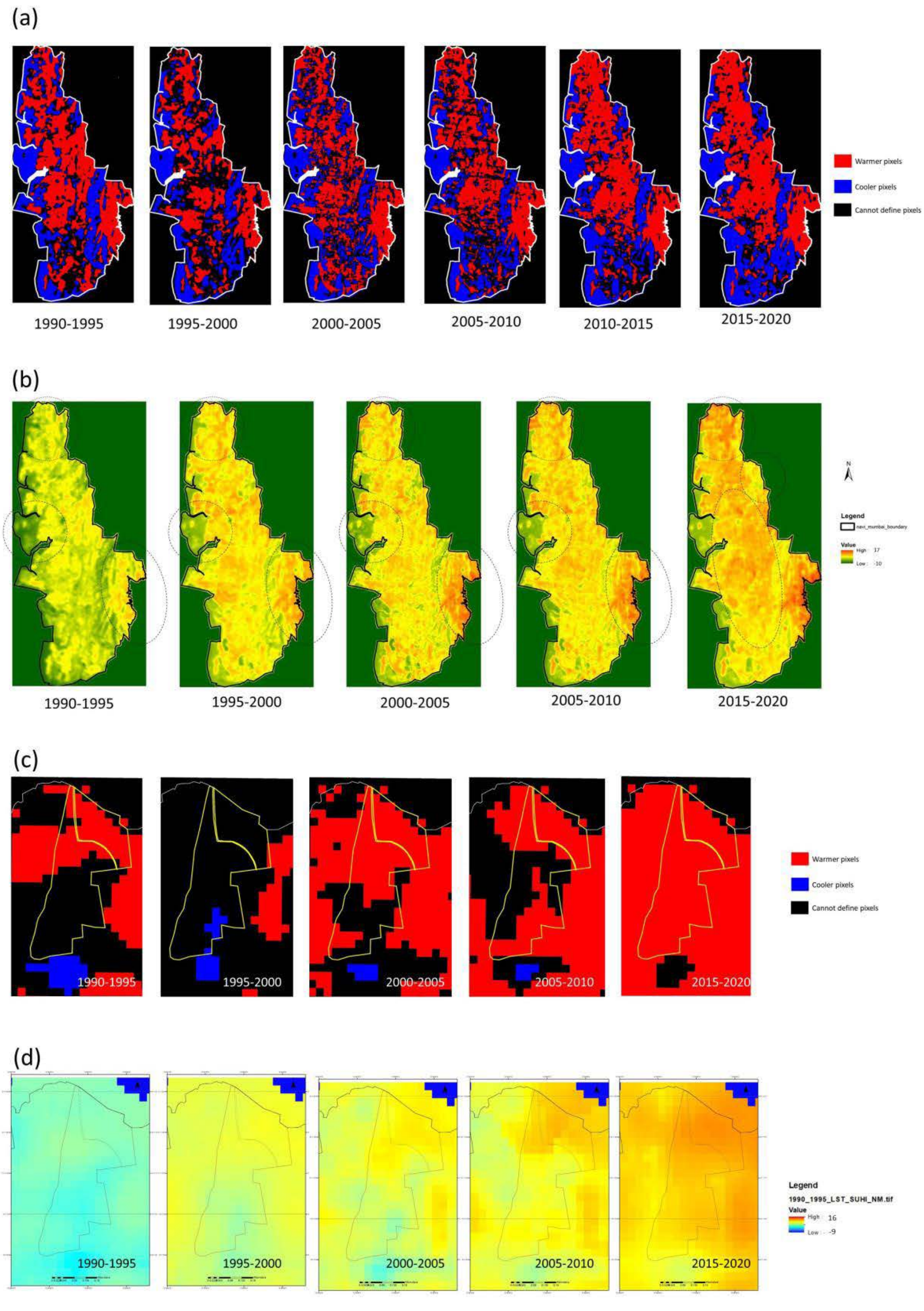

Figure 1 (a) Spatial Anomaly Change over Navi Mumbai. (b)Surface Urban Heat Island Intensity over Navi Mumbai. (c) Spatial Anomaly Change over a slum settlement located on the northern region of Navi Mumbai. (d) Surface Urban Heat Island Intensity trend over a slum settlement located on the northern region of Navi Mumbai

Spatio-temporal analysis of groundwater levels in the Tons river basin, India

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In different parts of the world, groundwater resources are often overexploited due to increasing water demand. India is the largest user of groundwater in the world. It uses an estimated 230 km^3 of groundwater per year. More than 60% of irrigated agriculture and 85% of drinking water supplies depend on groundwater. If current trends continue, in 20 years, about 60% of all India's aquifers will be in critical condition. Groundwater monitoring is fundamental to understanding system dynamics, trends in storage, and the long-term sustainability of an aquifer. Depth to groundwater level data is the key source of information used to understand the response. The present study focuses on long-term trend estimation and spatiotemporal variations of Depth to Groundwater Level (DGWL) changes using a geospatial approach and analysing the groundwater fluctuations using the standardised depth to water level index (SDWLI) method over the Tons river basin. Spatiotemporal analysis of the groundwater level of the basin helps to understand the spatial variation of changes in the groundwater level over 24 years (1996-2019). Inverse Distance Weighting (IDW) spatial interpolation was used to prepare spatial maps for pre-monsoon and post- monsoon seasons for each year. These maps can give us a basic idea about the location of the over- exploitation of groundwater. The trend in DGWL using non-parametric tests like Innovative trend Analysis (ITA), Mann-Kendall (MK), and Sen's slope (SS) and parametric methods like Standardised Depth to Water Level Index (SDWLI) was also analysed. The wells were divided into four clusters based on the annual fluctuation rate using the Hierarchical Cluster Analysis (HCA) method. A representative well from each cluster was then selected, and graphical ITA plots of both seasons were plotted for visual interpretation of the trend. Using this method, more than 58% of wells exhibited an increasing trend in DGWL for the pre and post-monsoon season. Mann- Kendall test was also performed to the MK test, and the SS test was used to evaluate the magnitude and significance of trends obtained from the ITA method. More than 26% of wells showed an increasing trend in both seasons. SDWLI plots were also plotted for the representative wells from each cluster. Three methods gave comprehensive and similar indications about increasing DGWL in the basin. It was observed that most of the central part of the basin faced a high rate of groundwater depletion. Land use land cover change analysis shows that the total built-up area doubled from 46 km^2 in 2000 to 102 km^2 in 2020. Forest cover also decreased by about 440 km^2. Deforestation leads to a decrease in the water-holding capacity of the soil. Hence, the movement of water from the soil surface into the ground is reduced. This results in a decrease in the groundwater level. Also, a decreasing trend was observed in the rainfall for the basin. Unevenly distributed rainfall, less recharge, and over-exploitation of groundwater for irrigation drinking and industrial demand in this region cause a sharp decline in groundwater levels. Artificial recharge to groundwater is one of the most efficient, scientifically proven, and cost-effective technologies to mitigate the problems of over-exploitation of groundwater resources; hence, we have also identified a few

locations for constructing various groundwater recharge structures such as Percolation tanks, Nala bunds and check dams. This study will assist decision-makers in identifying the reasons for groundwater depletion and prepare a roadmap to manage groundwater efficiently at the local level.

Fore-warning of forest fires using static and dynamic factors

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Forest fires are one of the important natural threats to forest ecosystems. Forest fires occurring in Indian forests have mostly anthropogenic origin. Forest fires causes loss of standing biomass, poses threat to wildlife and biodiversity. In India, majority of the peninsular India, North India and Northeast India are areas that are repeatedly affected by forest fire. Wide number of studies estimate the damages caused by the fire, but there are limited studies that can give fore-warning before the event. This study focuses on providing early warning and developing a spatial map of possible areas for forest fire. The model is based on static (anthropogenic – namely roads and settlements) and dynamic factors (weather data including daily temperature and rainfall). In India, forest fire occurs typically during January to May, with peak during March to May. For characterising fire occurrences, MODIS daily fire product data for past years was used. It was found that most of the fire points occurred in 3 km and 5 km distance to road and settlements. Apart from this, fire hot-spots were evaluated indicating the pixels having repeated events of forest fires each year. Short term weather forecast from WRF (Weather Research and Forecasting model) model was considered for future 72 hours (3 days). Based on data of daily temperature and rainfall data, a drought factor was computed. Fire index from static factors, hot-spots and dynamic factors were combined for deriving Forest fire danger index (FFDI); more the value indicates higher likelihood of the pixel to catch fire.

The index was validated using actual events occurred by taking case study of random 23 days data. The predictions were made and actual events were overlaid on this map. It was found that majority of the events occurred in high risk and moderate risk areas.

Automatic Land Water transition zone detection from satellite images using Python

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Water detection by index computation and thresholding is a widely used technique in remote sensing. Most of the work involves single threshold to determine water and non-water substance. A novel approach is taken in the work to apply specific range of values of mNDWI to identify land-water boundary/transition region along with land and water region separately for the satellite images of optical sensors using Python platform. This enables to identify land, water and land water transition region with the same indexing scheme and for images of various geographical locations. This scheme is very useful to estimate land water transition region which aids to monitor erosion/growth of coastal region, island, water bodies etc. in a very convenient way. Also as entire processing is carried out in python, each step of processing is completely transparent and flexible enabling user for appropriate tuning if required. The scheme may be extended to use for other indices also in order to enhance detection capability of various features in target scene.

Satellite-based assessment of paddy stubble burnt area progression in Punjab

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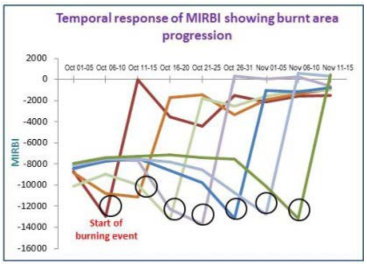
The post-harvest burning of crop residues in the *kharif* season in northern Indian states is a serious challenge – both in terms of the pollution being caused as well as the resulting photochemical smog in the neighboring areas. As per latest estimates, the area under paddy crop in Punjab in current kharif season (2022-23) is expected to be higher than previous years, while stubble generated will touch 19.99 MT. This also translates to increased quantum of paddy stubble that may go up in smoke production. Various measures by government for crop residue management viz. bio-decomposition, stubble collection and pelletisation, etc. have been addressing the issue but to a very limited extent. Need of the hour is the availability of a spatial information of stubble burnt area and its dynamics for monitoring, assessing and planning preventive measures. Moreover, the surplus biomass in the form of stubble can be gainfully used as input to biofuel plants.

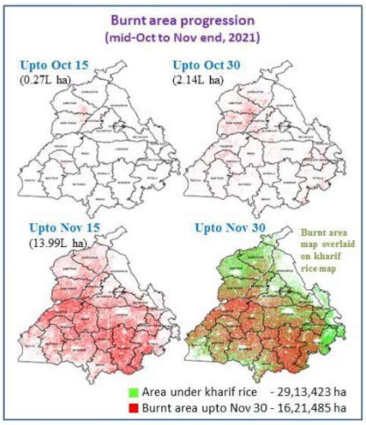
Burnt area assessment is fairly well understood and quantified using standard methods from optical remote sensing datasets covering Short Wave Infrared (SWIR) and Near Infrared (NIR) regions. However, the requirement is of daily/real time assessment of the area burnt and its progression. Near real time satellite based detection of active fire locations is being done from MODIS and Suomi-NPP VIIRS, and is available on ISRO's geo-portal *Bhuvan*. These observations are only indicative of stubble burning fires, and do not quantify the actual burnt area. Moreover, these coarse spatial resolutions of the fire events (375 m and lower) are not indicative of the field-level progression of stubble fires.

The present study has been taken up in Punjab state for 2021-22 *kharif* season, with four major objectives – (a) Mapping of area under *kharif* rice using temporal SAR data, (b) Relative evaluation of various satellite-based indices for estimation of stubble burnt area; (c) Field-level quantification of the actual burnt areas and its weekly/fortnightly progression using the identified index, and (d) Quantification of the, the amount of biomass burnt.

The state of Punjab contributes about 60% of the wheat and 40% of the rice to the central pool. The cropping intensity is high at 190%. Paddy is the dominating *kharif* crop, occupying about 89% of the *kharif* cropped area. The total area under rice crop in Punjab for 2021 *kharif* season was mapped using 12-day interval Sentinel-1 VH datasets of 10 m resolution. The period May 15 to September 15 covers the full *kharif* rice season in the state - from field preparation and transplantation to senescence and harvesting. The unique temporal backscatter response of the rice crop was used to delineate the *kharif* rice pixels using decision rule based classification. A total of 29.13 Lakh ha was estimated to be under *kharif* rice crop.

There are several indices that have been used to map the agricultural burnt areas. Most of them employ a combination of NIR and SWIR bands. While NIR indicates plant vigor, the SWIR band is moisture-sensitive. The multispectral Sentinel-2A/2B data offers 5-day interval data with 10m/20m spatial resolution, along with Red, NIR and two SWIR bands. A combination of these bands works well for mapping and monitoring the progression of post-harvest stubble burning at field level. Temporal images from October 01 to November 30, 2021 cover most of the post-harvest stubble burning events in Punjab. In this study, the temporal progression of burnt areas was compared for five different burn indices - Normalized Difference Moisture Index (NDMI), Normalized Burn Ratio (NBR), Normalized Difference Vegetation Index (NDVI), Burn Area Index (BAI) and Mid Infrared Burn Index (MIRBI). Of these, the MIRBI (SWIR1 – 1610 nm, SWIR2 – 2190 nm) demonstrated maximum sensitivity in detecting the occurrence of burning event as well as in capturing the burnt area when compared to other indices. Of the 29.13 Lakh ha *kharif* rice area, about 16.21 Lakh ha of stubble was burnt in the fields, amounting to 56% of the total rice area in Punjab (till Nov 30, 2021). In Firozpur, Sangrur and Barnala districts, over 75% of rice stubble area had been burnt.





District-level pre-harvest production estimates have been used to assess the total biomass potential at district level. This has been further down-regulated to assess the surplus biomass potential using collectable coefficient. The district level biomass potential has been disaggregated to 1 km grid using crop fraction and GPP/NDVI. Surplus crop factor has been intersected with burnt area to assess the biomass burnt.

In conclusion, the MIRBI index with two SWIR bands has demonstrated maximum sensitivity for detecting and capturing burnt area signature from rice residue burning. The methodology can be automated and operationalised for timely, regular and continuous monitoring of the burnt area progression. The quantification of surplus biomass will aid in appropriate decision making towards bioenergy solutions. Further, the spatial map of amount of biomass burnt can be used to assess the amount of Green House Gases (GHG) and particulate matter emission using bottom-up approach.

Assessment of Long Term Coastline Monitoring from Satellite Imageries using Geospatial Techniques from Panavila to Pullaviala, Kerala, India – A Case Study

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The shoreline is affected due to natural phenomenon like Rainfall (floods), Earthquakes, cyclones (Tunami), landslides, coastal erosion and also due to anthropogenic activities like deforestation, sand mining, cultivation of crops, construction of infrastructures, urbanization etc. Continuous monitoring of these changes is necessary in order to maintain the stability of coastal area and to plan for new developments and implementation of coastal protection works. The stability of the shoreline can be monitored using digital remote sensing satellite data. The remote sensing satellites has a advantage that it can map regions which are inaccessible or poorly accessible and provide temporal data. This temporal (Multi-date) digital satellite imageries is used to assess the dynamic changes in the shorelines, by delineation of water and land boundary using digital image processing software.

Shoreline change studies using geospatial techniques helps to identify areas prone to erosion and accretion, vulnerable hazard areas zoning etc. so that causes can be studied and remedial measures can be taken for deriving the benefits of the coastal areas and for sustainability of coastal areas and protection of the coastal environment, safe and productive navigation and future developments plans etc.

This Paper Assesses the shoreline changes from Panavila to Pullaviala, Kerala, for the period of 1973 to 2021 using Geospatial techniques, and estimates erosion and accretion in a cost effective manner. For this study the Landsat satellite data has been used due to satellite availability from 1972 along with Survey of India Toposheets. To cover entire time period nine satellite image have been used, which includes from Landsat 1 MSS to Landsat 8 OLI/TIRS.

There are numerous techniques by which shoreline can be extracted from satellite images in the case of Landsat such as Supervised classification, unsupervised classification, thresholding, and band rationing are the most popular methods, for the current study thresholding and digitizing method is used for delineation of land and water. This process is carried out for all the satellite imageries to extract the shoreline. All the shorelines are superimposed to find the changes and estimate the erosion and accretion from Panavila to Pullaviala, Kerala, for the period of 1973 to 2021.

Time series mapping of water quality parameters of Chembarambakkam lake using sentinel 2 data

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Water quality monitoring is the systematic collection and evaluation of data about the chemical, physical, and biological quality of the water bodies, and assesses how external changes, both natural and anthropogenic, affect that quality. The concentration of these characteristics determines whether the water quality is suitable for drinking, invertebrates to conduct life processes, industrial use, or even the natural formations that occur in the environment. In-situ measurement offers high accuracy, but it is a labor-intensive and time-consuming process, and hence it is not feasible to provide a simultaneous water quality database on a regional scale where Remote sensing techniques make it possible to monitor and identify large-scale regions and water bodies that suffer from qualitative problems in a more effective and efficient manner. Remote sensing satellites measure the amount of solar radiation that is reflected by surface water. The reflectance of water is influenced by the concentration and nature of water quality parameters, and the parameters which have an effect on the optical properties of water bodies can be identified through Remote sensing data. For monitoring the quality of water in inland waters, multispectral remote sensing provides an efficient, accurate, and high spatial and temporal resolution method. Knowing their composition is crucial because their ecological function in water bodies depends on whether they are mostly organic or inorganic compounds.

In this study, an attempt has been made to study the changes in the Chembarambakkam lake water quality located in Chennai, Tamil Nadu, India. The changes in water quality parameters such as Chlorophyll, Turbidity, Total suspended solids, and dissolved oxygen have been studied and mapped over a time period of January 2021 to December 2021 solely using the Sentinel-2 remote sensing data, in the absence of ground observations. The spatial distribution map for each parameter was generated using ArcGIS software. The comparison studies made between the pre-monsoon and post-monsoon of the study area are listed and tabulated, it is observed that the spatial distribution of water quality parameters varies by 29% from Pre-monsoon to post-monsoon.

Assessing intra-annual and seasonal vegetation trends in Alaknanda River basin, Uttarakhand: An outcome of 40 years of Earth Observation time series data

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Azim Premji University

Mountain forests are important natural capital stock providing ecosystem services to the local communities and helping sustain their livelihood. Forest resources play a crucial role in local communities as it helps in uplifting poverty, economic growth, and food security. Climate change primarily impacts these natural resources leading to degradation, affecting the livelihood of the local communities. The Indian Himalayan region (IHR) is no exception to the impact of climate change being observed globally. The anthropogenic disturbances further compound the degradation. Recent studies suggest that the IHR has experienced significant changes, such as a reduction in the extent of glaciers, changes in forest cover and ecosystem characteristics, etc. These, in turn, affect forest dynamics, species distribution and diversity, ecosystem production, and associated services, which impact livelihood. In the present study, the Alaknanda River basin has been chosen as the study area as it represents the Himalayan Mountain system characterised by unstable geological structure, the linkages in ecological and societal systems, and lack of economic activities leading to dependence on forest for livelihood and anthropogenic disturbance in the basin. These transformations can be quantified by studying long-term trends in vegetation characteristics using Earth observation time series and its linkage with land use land cover dynamics. In this study, Seasonal Trend Analysis (STA) was conducted on published AVHRR-MODIS NDVI combined monthly time series data (1982-2021) and long-term change in the spatial pattern of inter-annual and intra-annual signals was assessed. In STA, the first step is decomposing each yearâ€™s data using harmonic analysis. The second step is to investigate trends in harmonic parameters representing intra and inter-annual changes in vegetation using non-parametric Mann Kendall and Theil Sen Slope. The first two harmonics were considered for the trend analysis. The harmonic 0, i.e., amplitude 0, represents the interannual variation in greenness. The harmonic one, i.e., amplitude one and phase 1, represents peak annual greenness and the timing of maximum greenness. The trend analyses on these harmonic parameters indicate if the change over the years is significant and at what rate the change is occurring. The result suggests a substantial change in greenness over the years, mainly in the forested area. Approximately 40% of the vegetated area is going through a significant difference ($p < 0.05$) in mean annual greenness, out of which a significant increasing trend is observed in 23% of the site. Approximately 50% of the significant increasing trend in mean yearly greenness has occurred in the elevation range 656-1968m, i.e., the area falling under subtropical and sub-temperate regions and covered with oak and pine forest. However, the decline in mean annual greenness has been observed in rhododendron and fir forest. The magnitude of yearly greenness peak (amplitude 1) has also increased significantly ($p < 0.05$) in approximately 56% (48% increase and 8% decline) of the area. Most of the changes are observed to have occurred in the low and medium elevation (i.e., sub-tropical, sub-temperate and temperate) regions having an elevation between 656-1968m and are dominated by pine and oak forest. The increase in peak annual

greenness has also been observed in the cropland area, suggesting a change in the cropping pattern. However, the declining trend in yearly greenness peak has been observed in fir forests at higher elevations (i.e., 2624-3936m). The study indicates that the study area has faced significant changes in the timing of peak annual greenness over last 40 years. A significant change in green-up time has been observed in 78% of the vegetated area, with almost 76% of the area showing early green-up. Most of these areas are in middle and higher elevations (i.e., 1312-3936m) i.e., sub-temperate, temperate and alpine regions and have oak, deodar and pine as dominant forest types. At higher elevations, significant early green-up has been observed in the alpine pasture as well. These observed long-term changes in the last 40 years can be attributed to human intervention, in addition, to changes in climatic parameters. Keywords: Alaknanda River Basin, AVHRR NDVI, MODIS NDVI, Seasonal Trend analysis, Mann-Kendall Trend Analysis

Decadal change in Vegetation Condition in Marathwada, Maharashtra -A Geospatial Approach

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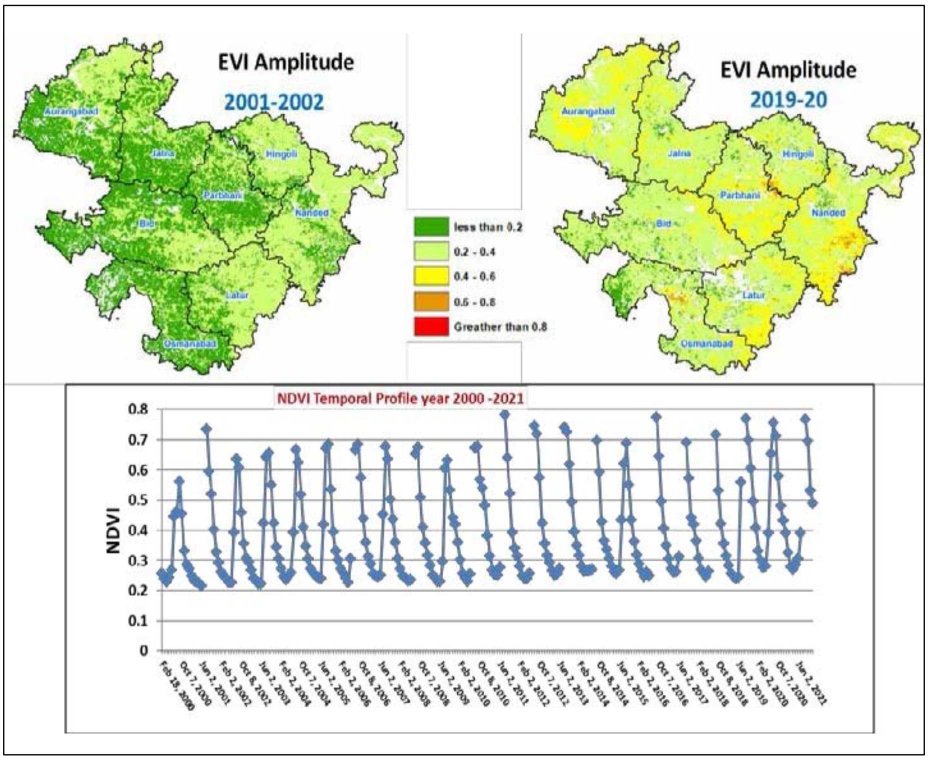
Marathwada region of Maharashtra is one of the most chronically drought affected region of India. This region has witnessed sequential drought events between the years 2012 to 2016 with severe impact on natural resources and socio-economic structure. Satellite remote sensing enabled techniques could go a long way to assess the temporal and spatial variability of natural resources with acceptable accuracy. With newer developments in sensor technology, computational infrastructure and free and open source data and algorithm, the long term change detection in agriculture condition of any geographical region is now quite feasible. The present study attempts to analyse the long term change in vegetation condition that is expressed through spectral vegetation indices like NDVI (Normalised Difference Vegetation Index), EVI (Enhanced Vegetation Index), SAVI (Soil Adjusted Vegetation Index) etc derived derived from the Moderate Resolution Imaging Spectro radiometer (MODIS). At the same time The change is start of the season(SOS) and End of the season(EOS) were computed using time series analysis of NDVI and EVI for 2001 onwards and any significant change is recorded. The region of significant change with respect to vegetation indices or phenology are identified and further correlated with environmental drivers like temperature, rainfall etc. The findings of this study will help in identifying the cause and effect relation between the vegetation condition and environmental variables. The Fig 1. Depicts change in EVI amplitude over the years along with the temporal variation in NDVI.



Use of earth observation satellites for routine monitoring of Indian mangroves; a comparative study carried out in Kerala and Andhra Pradesh, India.

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Indian mangroves cover 4975 sq km, offering significant protection to the country's coastline. Due to the extensive distribution of mangroves along the Indian coastline, doing a single field study to monitor mangroves yields misleading results. Periodic mangrove monitoring is necessary for evaluating the dynamic changes to mangroves and could be accomplished with the support of earth observation satellites. Mapping mangroves in the coastal regions of Kerala and Andhra Pradesh was done using Sentinel-2A, 2B multispectral images. A standard methodology was established based on the verification of several classification algorithms carried out in these states. Among the three different classification algorithms tested, *viz.,* K- Nearest Neighbor (KNN), Maximum Likelihood (MLC), and Random Forest (RF) classifications, RF classification was proven to be the best. In Andhra Pradesh and Kerala, the RF classification accuracy was 0.86 and 0.8 respectively. Forty-one patches of mangroves were identified and mapped in Andhra Pradesh and 59 patches of mangroves in Kerala using the classification. In contrast to Kerala, which has sparse and discontinuous mangrove patches, Andhra Pradesh has extensive patches in the Krishna-Godavari River delta, especially in the East Godavari and Krishna districts. Kerala had dense mangrove patches in the Kannur and Ernakulam districts. Mangroves covered 33.84 sq km in Kerala, compared to 409.86 sq km in Andhra Pradesh. According to the land use classifications, Andhra Pradesh's aquaculture and agricultural operations have impacted the state's mangroves. In contrast, destruction of mangroves are primarily a result of infrastructure development activities in Kerala. However, mangroves in certain regions in these states are improving as a result of the restoration efforts, and such measures are advocated to protect mangroves across the nation. This approach could be used to map mangroves throughout the country's entire coastal region and could be used as a baseline data for the periodic reviews of changes in mangrove cover in future using Sentinel satellite images. Artificial intelligence-based machine learning algorithms can be used to streamline the classification techniques used.

Rainfall induced landslides and their impact on large wood budget in a mountainous stream

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Each year, flooding in India from extreme rains results in a loss of around $3 billion, which constitutes about 10% of global economic losses. The Himalayan rivers get flooded every year because of unusual rainfall and melting of snow mountains. Most of these rivers pass along the deep valleys with dense forest at both sides. Large trees from these forests and their broken parts also flow along with the high speed flood water. Floods can turn out to be more disastrous with additive factors like associated large woods travelling along with. These floating woods can be highly destructive because they make the peaceful waters capable of overtopping their banks and destruction of nearby structures. Thus it is of supreme importance to quantify the potential wood volume that may be recruited to the channel. Kameng river, a tributary of the mighty Brahmaputra, has been selected to be worked upon for this research work. The upper part of the river passes through valleys with mountains having very steep slope. Moreover, rainfall amount in this reason also considerably high which triggers shallow landslides. Thus the recruitment of woods into river channel is mainly due to the landslides. For better accuracy of wood volume quantification, we have identified the areas susceptible to rainfall induced landslides. The predictors of rainfall induced shallow landslides includes three broadly classified factors like topographical, environmental and hydrological factors. The topographical factors are mostly extracted from the DEM using GIS interface. Similarly the environmental factors include landuse landcover of the area and the hydrological factors include the rainfall intensity and distance of the point from the river. Initially, various data sources were used and introduced in ArcGIS including satellite images, time series observations, spatial data, and geological and topographic maps. In order to identify the landslide hazard area, a multi-parametric dataset containing satellite data and other conventional data including maps were considered for the demarcation of potential wood debris flow zone. Weights were assigned to different classes in each theme based on their relative importance towards sliding of earth and tree by applying the overlay analysis. Then, the susceptible zones were delineated by overlaying all the thematic layers of the weighted overlay method using the spatial analysis tool. Area of different susceptible zones are calculated separately and are overlaid with the value of tree density and canopy density to estimate the total potential volume of the wood recruitment. However, the probability of recruitment was decided based on the distance of the tree from river, height of the tree, slope and degree of landslide susceptibility of the area. Hence the actual volume to be recruited was found out by analysing the probability factor with the potential volume of wood recruitment. Approximation of wood debris in a mountainous reach can be helpful in damage assessment which will lead to flood risk mitigation.

The digital cadastral information and RS satellite data in natural resource monitoring and accounting - Geospatial Technology, Journey from data to intelligence

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The digital cadastral information and Remote sensing satellite data in natural resource monitoring and accounting - Geospatial Technology, Journey from data to intelligence. Dr. S. Jane Mithra 1*, Manu V.2, A.Nizamudeen3 1. Scientist, Kerala State Remote Sensing & Environment Centre, Thiruvananthapuram, 695033. 2. Project Scientist, Kerala State Remote Sensing & Environment Centre, Thiruvananthapuram 3. Director, Kerala State Remote Sensing & Environment Centre, Thiruvananthapuram *Corresponding author: jane_mithra@yahoo.com The Geospatial technology becomes very important to decision-makers across a wide range of disciplines and the importance of the spatial dimension in assessing, monitoring and modeling for sustainable management of natural resources is well recognized all over the world. The basic pre -requisite for application of Geospatial technology is the spatial data of various thematic information in analytical units of natural, administrative and revenue in different scales at national, state, district, taluk, block, village cadastral, survey plots and Field Measurement Book (FMB) for sub-plot level for effective planning and management. Satellite Remote sensing is a powerful tool for generating large amounts of spatial and temporal data related to nature and its resources in a relatively short time. This paper describes the journey from digital village cadastral data generation of state of Kerala to the success applications in various fields. cadastral data on 1:5,000 scale was collected from Department of Survey and Land Records, Government of Kerala which is vectorized and generated seamless digital data for entire state under the ISRO sponsored Space based Information Support for Decentralised Planning Project (SISDP) during the period 2010-2016. The ortho-rectified data from RRSC has been used as base map for geo-referencing the state-wide cadastral data with high level accuracy. The large-scale cadastral information is the basis recording and disseminating information about ownership, value and use of land and its associated resources. It is proved that this digital cadastral data in conjunction with remote sensing satellite data using new methodologies are facilitating and supporting the decision making. Presently this digital data is being used for various applications in the state in different sectors including wide range of public service. The application of satellite remote sensing data at cadastral level in resource information and decision support has become very popular through this. The major application sectors, departments and purposes are described here. The utilisation of cadastral survey plots wise information in temporal change of land use / land cover in Paddy and Wetlands is a major application area. 500 agriculture data bank reports were validated at cadastral level and more than 30,000 technical reports were generated using FMB information under this work for the Department of Agriculture Development & Farmerâ€™s Welfare. The survey plots wise information was gathered for the Semi-high Speed Silver Line project for land acquisition along the proposed alignment of 530 Km from Thiruvananthapuram to Kasaragod for Kerala Rail Development Corporation Ltd. Similarly plot wise cadastral information at 60 M buffer zone along the Inland water ways from Thiruvananthapuram to Ernakulam were prepared for Kerala Waterways and Infrastructure Ltd. The wetland boundaries were demarked with survey plots wise information for State Wetland Authority of Kerala (SWAK). The recommendation of Dr. Kasthurirangan Committee on Ecologically Sensitive Area (ESA) of 123 villages in Western Ghats were demarcated using the same cadastral information for Department of Environment & Climate Change. Based on the direction of the Honorable Supreme court Order, One Kilometres buffer zone (ESZ) with landuse /land cover and subsisting structures around the boundaries of protected National Parks & Wildlife Sanctuaries were demarcated at cadastral level for Department of Forest and Wildlife. The use of cadastral data and geospatial information in other areas are disputes of constructions in protected / restricted areas, legal/court cases, land boundary disputes for Home and Vigilance department, web applications and mobile applications. Disputes in mining and encroachment in quarry land, etc. All these applications and utilization of the digital cadastral and geospatial information was enabled the centre to extend its service to the public as well as to gather huge revenue to the Centre and state. The future scope of the digital cadastral data usage under Geospatial Technology is envisaged in field of land revenue taxation, spatial activities of local body, resurvey process, land registration with mutation and transactions. The challenge in handling cadastral data is real time updation since the mutation of land parcel is a dynamic process. This can be overcome by the intelligence use of integrated Geospatial technology in coming days. Key words: Geospatial Technology, data to intelligence- The digital cadastral and RS data, natural resource monitoring and accounting.

Biophysical Parameter Retrieval from temporal Sentinel images and Inter comparison with MODIS and PROBA products

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A vital requirement in agriculture, forestry, environmental assessment, and biodiversity management is timely information on the status of vegetation. Continuous Spatial LAI (Leaf area index) information is an essential variable to monitor crop ecosystem and modelling water, carbon and energy fluxes between land and atmosphere. Remotely sensed LAI helps to study the spatial and temporal variability of crop health status due to biotic and abiotic stresses and other input deficiencies like nutrients.

Sentinel application platform (SNAP) is provided with Sentinel level 2 prototype processor (SL2P) for the retrivel of vegetation biophysical parameters such as leaf area index (LAI). Previous studies of SL2P LAI retrievals were conducted at uniform agriculture areas but not in in heterogeneous agricultural areas, So, the present study biophysical parameter retrieval from temporal sentinel images and Inter comparison with MODIS and PROBA products was conducted for rice and maize crop at Karimnagar district, Telangana. Sentinel 2 sensors has high spatial (10–60 m) and temporal (≤5 days) resolutions with thirteen visible near-infrared and shortwave-infrared bands bands (including three red-edgebands) and especially narrow bands in red and red edge region help to retrieve better LAI maps and also well-suited to vegetation monitoring. SL2p processors from SNAP (Sentinel application platform) the algorithm enables users to generate so-called 'L2B' products from atmospherically corrected L2A MSI data. L2P adopts artificial neural networks (ANNs) that are trained with RTM simulations from the coupled Leaf Optical Properties Spectra (PROS-PECT) and Scattering by Arbitrarily Inclined Leaves (4SAIL) models. The algorithm provides retrievals and predicted uncertainties of leaf area index (LAI), FAPAR (Fraction of absorbed photo synthetically active radiation), FVC (Fraction of vegetation cover), Cab (Chlorophyll content in the leaf), CWC (Canaopy water content) from sentinel 2 data.

The LAI maps of Rice and Maize crops derived from Sentinel 2 image at Karimnagar district, Telangana (Fig.1) shows that higher LAI was observed at 1st fortnight of October and gradually decreased by December. This shows that decrease in LAI with end of season from peak LAI. The study compares the sentinel 2 retrieved LAI, crop specific (GT LAI) derived from traditional methods from the field (*In-situ*) and remotely sensed coarse spatial resolution instruments like MODIS and PROBA-V LAI products for correlation studies.

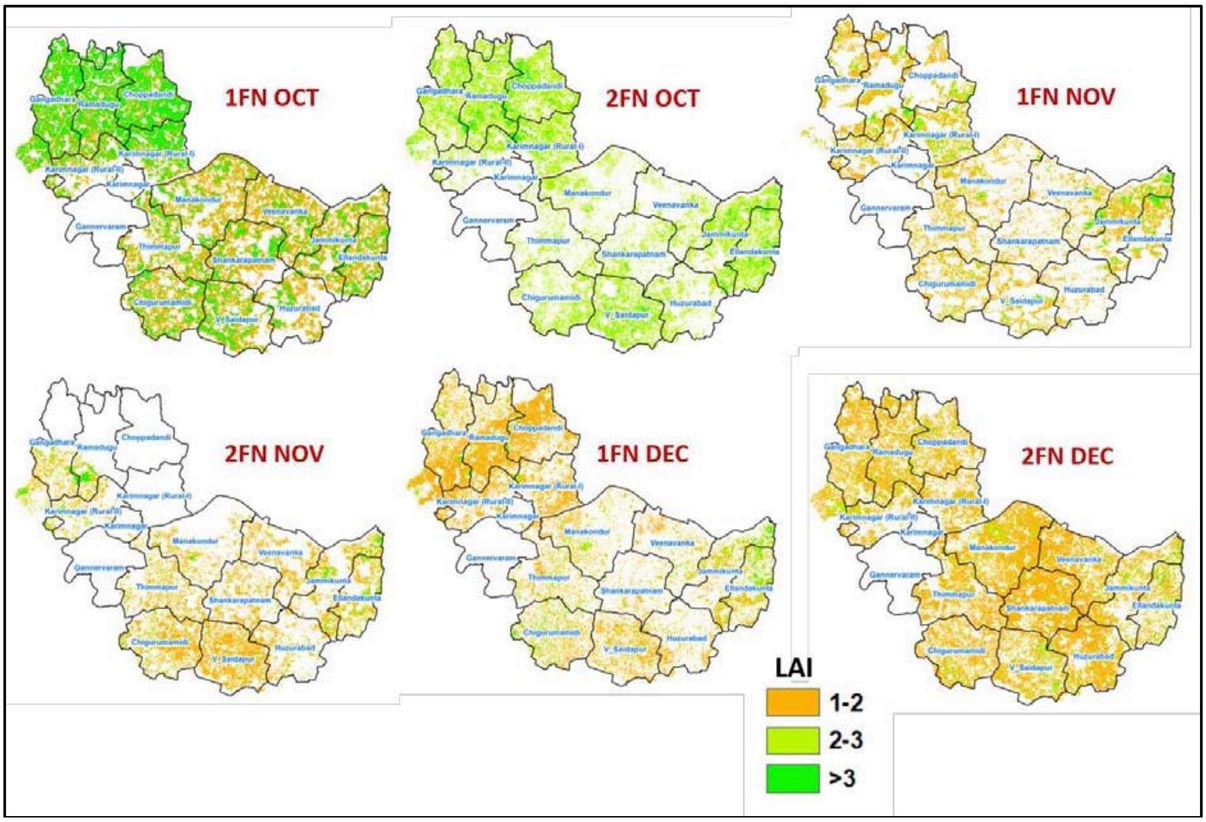

Fig.1. LAI maps of Rice and Maize crops derived from Sentinel 2 image at Karimnagar district, Telangana.

Mapping the changing green cover of Ahmedabad city during 2003-21 using remotely sensed NDVI data and Statistical Analysis

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With the onset of urbanization and industrialization, there is a continuous decrease in the green cover (that includes the forest cover and the urban green spaces) which is adversely affecting the environment having implications on human health and functioning. Thus there is a need to assess the changing green cover of the cities and then undertake the urban greening measures. It is with this background, the present study of analyzing the changing green cover of Ahmedabad city of Gujarat, which is the 7th largest metropolis of India covering a geographical area of approximately 464 sq km, was undertaken. In this study Moderate-Resolution Imaging Spectroradiometer (MODIS) Terra Normalized Difference Vegetation Index (NDVI) datasets were downloaded and processed for the city of Ahmedabad for a period of 19 years (2003-2021) from NASAâ€™s EARTHDATA web portal (EARTHDATA, 2020). The green cover of Ahmedabad city had a declining trend in the vegetation density during 2003-18 and the cityâ€™s annually averaged NDVI dipped to 0.265 in the year 2018, lowest of the entire study period (2003-21). In the year 2019, Ahmedabad Municipal Corporation planned a major Urban Greening initiative under the name Mission Million Trees where in 10,87,000 saplings were planted across the city. The statistically analysis in terms of the Mann-Kendall Trend test for all the data points across the city for the two time periods (considering the Mission Million Tree activity in the year 2019) i.e. 2003-2018 and 2003-2021 revealed that, after the year 2019, around 45.3% area of the city registered an increase in the vegetation densification, however 28% area of the city which is mainly the eastern part of the city that includes the industrial belt having the locations like Nikol and Odhav continue to witness a decreasing trend in the NDVI inspite a major urban green initiative like Mission Million Trees and the Green Belt norms which are to be followed by the industries. The present study puts forward comprehensively the various aspects of Urban Vegetation which is a very important aspect of the environment and also brings out the effectiveness of the urban greening initiatives especially the Mission Million Trees. The study will be of great help to the Ahmedabad Municipal Corporation to further initiative the urban greening measures such that the entire city witnesses an improvement in the green cover which will have far reaching impacts on the overall human health and environment.

Decision Support Systems for e-Governance

Flood Risk Mapping using Multi-criteria Analysis: A case study on the Gandak River Basin

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Climate change has increased populations' susceptibility to flooding worldwide. An international river basin, with the rivers source at the Tibetan plateau, the Gandak River Basin (GRB) has a distinct geography that includes glaciers, snowfields, and steep terrain in Nepal and Tibet (autonomous region of China), whereas the downstream portion creates a riverine flatland in India. Due to the complicated character of the alpine habitat, understanding the hydrological reactions and high precipitation occurrences of GRB is difficult. In the previous 20 years, the Gandak watershed has seen catastrophic extreme precipitation leading to flood occurrences in several districts spanning both Nepal and India (Chaubey et al. 2021). Considering the recent increase in flood occurrences in the Gandak river basin, reliable flood risk probability evaluation is a crucial aspect of mitigation and adaptation.

The studies suggested that the combination of Geographical Information System and Multi- Criteria Analysis enables integrating the elements of vulnerability, risk and hazard analysis, which includes the environmental, social and economic aspect. Hazard analysis and vulnerability analysis leading to flood risk zonation (Risk analysis) of a river basin is one of the most significant non-structural strategies for supporting optimal floodplain control and development. The technique used- Analytical Hierarchical Process is a basic and easy-to- implement weighing approach, however it relies on expert opinions and judgements at the first phases for allocating weights to different parameters, which may cause error. The varied years of data taken for a few criteria can also be seen as a limitation.

The purpose of this work is to perform flood risk mapping of the Gandak river basin using the multi-criteria Analysis- Analytical Hierarchical Process (MCA-AHP) amalgamated into GIS. This study attempts to address the gap left by the lack of an existing risk map for the whole Gandak river basin. Weighted analysis of multisource data such as Decadal average precipitation, DEM, Slope, NDVI, Drainage Density, Soil Type, LULC, GDP per capita, Population Density and Road Density have contributed in flood risk analysis for this study. The methodology followed was:

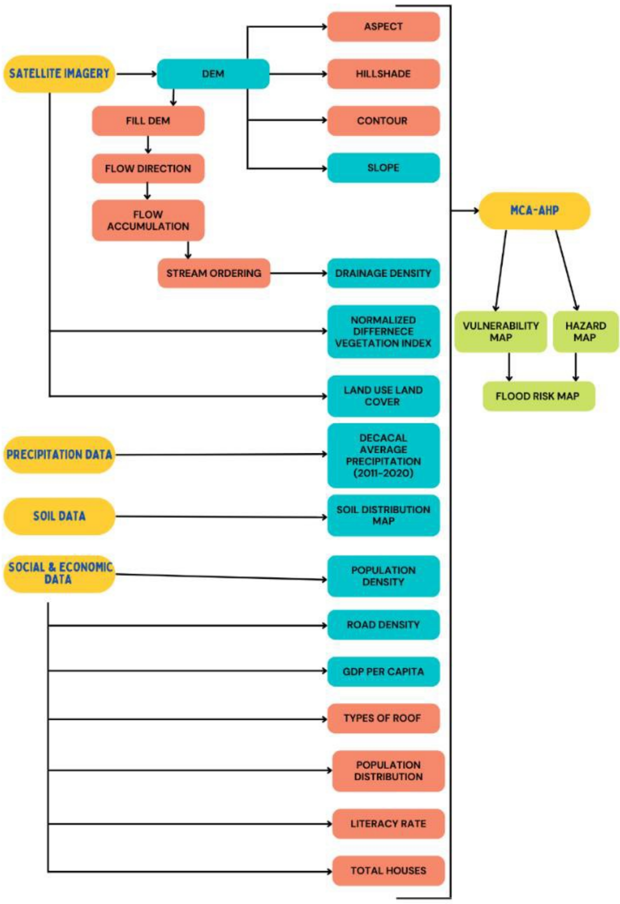

Fig. 1: MCA-AHP methodology framework

The flood risk map might be a useful starting point. The results for the study reveal that in hazard and vulnerability criterion, LULC and population density, play the most vital role in causing floods. The total area of the watershed is 42562 km2. Out of this the low-risk area is about 68.18%, moderate- risk area is 25.45% and high-risk area is 6.37%. The highest risk area is mostly concentrated in the plainer regions of the basin. Flooding of the Gandak River is exacerbated by the shift in slope from mountainous to plain.

GIS as core component for integration and development of citizen web Portal for Moradabad Smart City

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L&T smart world and communication

The primary objective of Moradabad under its smart city mission is to enhance the safety, security and improve efficiency of municipal services and other government departments to promote a better quality of life for residents. To achieve these objectives, Moradabad smart city administration desires to foster the development of a robust ICT infrastructure that supports digital applications and ensures seamless steady state operations, city management, surveillance, emergency response mechanisms and real time tracking of services and vital city metrics throughout the city and in government departments. GIS is platform for Smart City - Geographic Information System (GIS) is core to any Smart City development as it provides a robust and effective integration environment to bind location Features to multiple information systems to gather, view and analyze their physical attributes and parameters for efficient decision support. The Smart City model uses robust GIS for building urban resilience. The GIS framework seamlessly integrates with other technologies supporting visualization and analysis in real time. This becomes the mainstay of â€˜smartâ€™ management providing resource optimization, open and participatory governance, and efficient monitoring and management of city infrastructure. GIS is deployed at every stage of planning and development of a Smart City. The underlying framework is served by ICT (Information and Communications Technologies), while the focus is on the â€˜spatialâ€™. GIS â€“ ICT is underlying scalable framework, with seamless flow of data / information, connecting departments and stakeholders. It integrates not only every stakeholder but also every aspect of smart city processes â€“ starting from conceptualization, planning, and development to maintenance. GIS acts here as centralized Geo spatial information system that provides geo spatial information to each module & system for business function execution. This 2-way information exchange would help Moradabad administration to manage & control their day-to-day operations. GIS helps in data driven decision making which makes possible real time management and decision making in the ecosystem. Scope of the Moradabad Smart city for GIS includes implementation of Enterprise GIS, web GIS application and dashboards along with GIS integration with Smart city applications and city based mobile application. GIS integration has carried out with required existing applications and ICCC through OGC map service and REST API flow. Development of enterprise web GIS portal is carried out using COTS enterprise GIS platform. Web portal provides facility for viewing, querying, analysing and utilizing the geographic Information to fulfil the needs of department. Citizen Panel present over the web portal provides visualization of basemap, legends, layers, querying of layers, identification of details of the selected object or location.

Multi-Criteria Decision Analysis (MCDA) Based Evaluation of Forest Fire Risk Zones in Pilibhit District using Satellite Remote Sensing and Analytical Hierarchy Process (AHP) Techniques.

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A forest fire can be a real ecological disaster, regardless of whether it is caused by natural forces or human activity. It is impossible to control nature, but it is possible to map forest fire risk zones and thereby minimise the frequency of fire, avert damage, etc. Forest fire risk zones are locations where a fire is likely to start, and from where it can easily spread to other areas. Anticipation of factors influencing the occurrence of fire and understanding the dynamic behaviour of fire are critical aspects of fire management. A precise evaluation of forest fire problems and decisions on solution methods can only be satisfactorily made when a fire risk zone map is available.

Satellite data plays a vital role in identifying and mapping forest fires and in recording the frequency at which different vegetation types/zones are affected. A geographic information system (GIS) can be used effectively to combine and integrate different forest-fire-causing factors for demarcating the forest fire risk zone map.

This study is an attempt to suggest an appropriate methodology for forest fire risk zone mapping. Forest fire alert location has been downloaded from Forest Survey of India, Dehradun through forest fire portal (http://fsi.nic.in/index.php) i.e. MODIS and SNPP/ VIIRS data for analysis of forest fire extent in year 2021.

Forest fire risk mapping is based on eight causative factors i.e. Forest type, Forest Density, Bare Soil Index (BSI), Population Density, Settlements, Roads, Slope and Aspect. Metrological datasets viz. temperature and rainfall were used to monitor the vulnerability of forest fire prone months as well as wet and dry months.

AHP method has been used as a decision added method that generate relative ratio scales of paired comparison matrix of different thematic layers at each level of hierarchy. A pair-wise comparison matrix was made to compare all factors against each other based on their importance (equal, moderate, strong, very strong, and extremely strong).

Forest fire risk index (FFRI) was generated by using AHP method to evaluate the criteria relative importance weightage and weighted overlay technique. The FFRI layer has been classified into five classes such as very high, high, moderate, low and very low. The FFRI method is employed to prepare the forest fire risk zone map. Based on the analysis forest fire risk zone map divided into three zones in study area i.e. high, moderate and low 'forest fire risk' zones which are 34.15%, 51.57% and 14.28% of total area respectively.

Forest fire risk zone map has been validated during ground truth survey for accuracy assessment and GPS points have been collected for correlation with fire locations of study area downloaded from forest fire portal http://fsi.nic.in/index.php and converted into GIS environment were overlaid over the generated forest fire risk map in ArcGIS.

The study shows that the present methodology based on RS and GIS techniques is reliable. The prepared forest fire risk zone map can helpful for the forest managers and disaster management agencies to identify fire risk zones easily and take preventive measures, reduce damage of natural resources, loss of life and property.

Mapping of storm water harvesting potential within parks and open spaces using gis

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Floods have become common in urban areas. It can be noted that they are mainly caused by disturbance to natural water cycle. The impact of rapid urbanisation, climate change and deteriorating and outdated infrastructure are aggravating current water challenges of flooding. Water scarcity has further led to high rethinking of sustainable stormwater management system which poses high rehabilitation cost which can even overwhelm the capacities of the urban local bodies.

By implementing storm water harvesting the problem of flooding can be addressed. Storm water harvesting in public parks and open spaces provide a unique opportunity to utilize the excess run-off for groundwater recharge, at the same time providing space and time for flood waters in case of moderate and extreme runoff during peak day.

In cities we have large area planned for public parks and open spaces which provide opportunity to harvest harvest stormwater. This potential can be achieved by allocating only 20-30% of area of these parks and open spaces or 2% of total urbanisable landuse. This can help in reducing stormwater runoff and thus managing of stormwater within local area.

Rainfall can be converted to manageable resource by contributing 20-30% of open public space for harvesting infrastructure. The following has been accessed using Geographic Information System (GIS) in local area of panipat. The result map shows the maximum storm water potential that can be achieved within local area with providing various stormwater harvesting technique in different hierarchy for Public parks and open spaces.

A GIS-Based Ecotourism Site Suitability Assessment of Scotland, United Kingdom

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An important aspect of tourism that has attracted a lot of attention recently is ecotourism. It is well known that the travel and tourism sector, and ecotourism, in particular, contribute significantly to sustainable development. In this regard, Scotland, a country that is a part of the United Kingdom, is one of the top tourist destinations for people interested in the outdoors. The Atlantic Ocean borders mainland Scotland to the north and west, the North Sea to the northeast, and the Irish Sea to the south. Mainland Scotland makes up the northern part of the island of Great Britain. Its southeast border with England is 96 miles (154 km) long. It also includes over 790 islands, most of which are in the Hebridean and Northern Isles archipelagos.

This study's primary goal was to evaluate and depict the possibilities for the growth of sustainable ecotourism. GIS- Multi-Criteria Decision Analysis (GIS-MCDA) methodologies were used to design the research approach, using 21 geographical indicators. For this, regions with the potential to draw tourists were selected, and GIS analysis was used to assess the practical elements for increasing and lowering tourism development efforts.
The findings of this study suggest that the southern region of Scotland might be developed as a centre for nature tourism in the southwest of the nation since it has the potential to include some areas that are not well known to travelers and even to tourism planners. In this context, the outcomes may also be crucial for local stakeholders, organizations, and stakeholders in the tourism industry for various applications, including the investment in and development of infrastructure and amenities for the tourism industry in high-potential locations. The study promotes future research on the selection of valuable criteria and the use of effective methods for the assessment and mapping of tourist sustainability. It can be seen as a step forward in tourism research.

Role of IT in SMART CITY Development

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A Smart City is one that is able to link physical capital with social one, and to develop better services and infrastructures. It is able to bring together information technology, and political vision, into a coherent program of urban and service improvements. Smart City is a city well performing in six characteristics: - Smart Economy - Smart Mobility – Smart Environment - Smart People - Smart Living - Smart Governance. Cities now a day face complex challenges to meet objectives regarding social-economic development & quality of life. The concept of “smart cities” is a response to these challenges. This paper explores “smart cities” as the city which will embrace new technologies, focussing on smart innovation, to create a city i.e. competitive, open, interconnected and intelligent.

Urban Area Mapping for Rescue Operations during Disaster by using Satellite Data

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With the advancement in geospatial technology, application-specific monitoring is now possible in the near real-time like agriculture, urban planning etc. But there are certain areas where there is a need for real-time monitoring that can be done with the help of UAVs but its limitation is short flying time and small coverage areas. In the scenarios where real time monitoring is must such as border surveillance, disaster mitigation etc, the UAVs may takes time to cover the area and process the result. During the disaster, the primary focus of the government is to carry out rescue operations by evacuating people from high-risk areas to safer places. Prior information on locality during a disaster may be helpful for the rescue team. The challenge here is to correctly segregate and map urban areas. Therefore, the objective of this proposal is to map the urban areas that can help concerned authorities to formulate a strategic plan to tackle different disaster events. Thus, the motivation of this proposal is to locate and map the urban area, which can help the decision-makers to take timely action to save human lives, and optimize the financial burden and resources. This work will provide an opportunity for disaster management authorities to mitigate the effect of natural disasters to a larger extent. The decision-makers can issue directions to local bodies under their jurisdiction, within the time frame without wasting efforts. This will help to share vital information and build smooth mutual coordination among various concerned departments. For this purpose, satellite data will be used to classify the urban area and meteorological data will be used to validate those urban areas.

This work will provide an opportunity for disaster management authorities to mitigate the effect of natural disasters to a larger extent. The decision-makers can issue directions to local bodies under their jurisdiction, within the time frame without wasting efforts. This will help to share vital information and build smooth mutual coordination among various concerned departments.

Smartcity Planning Using Geoinformatics for UNESCO World Heritage Site Badami of Bagalkot District

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India is one of the biggest countries and is 7th largest nation in the world; also India is 2nd country in population next to China. The Towns are like trees, both of them grow under natural limits. These limits affect in the formulation of a cityâ€™s master plan.Our government had planned to upgrade selected 100 cities under Smart City scheme and 12 cities under HRIDAY scheme. In olden days, it has been observed that, the historical development of towns is usually around major water sources; the modern development is as per a master plan. One of the objectives of any master plan is to guide town development by studying the natural properties of the town border and to determine a suitable direction of town growth. It should include general information for understanding the effective factors on the townâ€™s formation. Cities in the technologically advanced world are as per the master plans. Then by these plans city is grown and control network and enhance the distribution of amenities like water, power and health care, to all habitants. The objective of this study is to propose a smart city plan for the historical Badami town. An accurate land use/land cover map is prepared for appropriate allocation of land resources of the Badami Town and its surroundings, to suggest short-term and long-term measures for future growth and web information. Smart city has different sectors, among those sectors the Concept of Sustainable planning is adopted in this project. It also takes into consideration the prepared department master plan to smart layout for transportation and infrastructure. A GIS driven analysis of factors such as urban planning, which in turn creates various types of geo-referenced data, was carried out to create, store, edit, visualise, analysis, and to present the data needed for carrying out the allocation of land for meeting various needs of the smart city.After the implementation of the Smart concepts desirable results have obtained and these outputs have the potential to fulfil the need of all the inhabitants without causing any pollution. The outputs of this project would help in sustainable planning for innovative Smart layout and implementation of master plan for future growth of Badami Smart City.

Innovative Geospatial Technology in Urban Mapping and City Planning: Government Initiatives

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The innovative geospatial technologies are used as scientific tools for mapping of urban areas and city planning for preparation of Master Plans of the towns and cities in the perspective of 20 to 25 years. Such technologies enhance view of geospatial data and their utilization in collection and processing of data. The Govt. of India has taken various initiatives to promote geospatial technologies in urban mapping and city planning.

i. Urban Mapping

During Eight Five Year Plan (1992-97), a project on “Urban Mapping” as a pilot scheme was undertaken for preparation of large-scale urban maps using aerial photography for 53 towns at 1:2500 scale. The works of Aerial Photography and Mapping of all 53 towns was completed by then the NRSA Hyderabad in December 2004. All the maps generated under the Scheme were sent to respective State Town Planning Departments for their use in city planning.

ii. National Urban Observatory (NUO) and National Urban Information System (NUIS)

During the Tenth Five Year Plan (2002-2007), National Urban Information System (NUIS) was launched in March 2006 to integrate spatial data (Urban Mapping) and attribute data (National Urban Observatory) schemes in one scheme to develop GIS databases at 1:10000 and 1:2000 scales for 152 towns/cities.

It helped to create Urban Spatial Information System (USIS) to meet the spatial data requirements of urban planning and National Urban Databank & Indicators (NUDBI) for development of town level urban database to support development of indices through a network of Local Urban Observatories (LUOs) and National Urban Observatory (NUO) program.

iii. Bhuvan Geo-portal

Under NUIS, the Base Maps of the scale 1:10,000 for 152 towns are available on this portal with Base Layer, Thematic Layer and Administrative layers. Bhuvan Apps can be downloaded on compatible mobile software and both pictorial data and attribute data can be uploaded from the fields.

Example: In Uttarakhand , post disaster mitigate actions were taken by Bhuvan. The Bhuvan developed customized applications called “Mapping Neighborhood in Uttarakhand (MANU)” to collect data and photo, upload on portal, etc. to enable reconstruction and rehabilitation exercise after June 23, 2013 tragedy due to cloudburst caused devastating flood and landslide.

iv. Formulation of GIS based Master Plan for 500 Cities as Atal Mission for Rejuvenation and Urban Transformation (AMRUT) Sub-scheme

The sub-scheme is envisaged as a state driven program with an outlay of Rs 515.00 crores to develop common digital geo-referenced base maps and land use maps on Geographical Information System (GIS) platform using very high resolution satellite data .The creation of geospatial data at the scale of 1:4000 is done as per Design & Standards prepared by the Govt. of India. Further, the formulations of Master Plans have been done by using geospatial database on the GIS base map and sector-wise data analysis.

v. Smart Cities Mission

It is a bold and new initiative for smart solutions in urban areas. It is meant to set examples that can be replicated both within and outside the Smart City.

Geo-spatial Components: GIS Applications may be useful for site identification, selection, evaluation, etc., planning, design & visualization of cities, construction & project management, GIS facility management information system, etc.

vi. Pradhan Mantri Awas Yojana (Urban) – Hosing for all Mission by 2022

The Mission provides central assistance to all eligible families/beneficiaries across all 4041 statutory towns for ensuring housing for all in urban areas to be implemented during 2015-2022. Geo-spatial Components:The Central Govt. has envisioned that individual houses should be tracked through geo-tagged photographs, for effective monitoring and asset mapping. For effective tracking and development, MoU has been signed with NRSC Hyderabad.

vii. Heritage City Development and Augmentation Yojana (HRIDAY)

The Scheme is aimed at preserving and revitalizing the soul and unique character of the Heritage Cities in India. 12 cities have been selected under HRIDAY.

Geo-spatial Components :GIS based mapping of cultural heritage city, natural heritage assets, digital & GIS mapping of historical location (Intellectual Access), etc. are useful to achieve the objectives.Applications of Mobile Phone Technology (MPT) and Information and Communications Technology (ICT) may help in mapping.

viii. Swachh Bharat Mission (Urban)

To accelerate the efforts to achieve universal sanitation coverage and to put focus on sanitation, the Central Govt. launched the Swachh Bharat Mission (SBM) on 2nd October, 2014. The Mission aims to achieve a Swachh Bharat by 2019.

Geo-spatial Components: Apps are developed which help to upload the photographs, geo-tagged photographs, etc. The citizens may use Apps to upload real time photographs. It helps ULBs to identify lack of services and accordingly improvements are undertaken by ULBs.

Concluding Remarks: The National e-Governance Plan (NeGP) , 2006 is an initiative undertaken by the Govt. of India to provide all government services available to the citizens via electronic media. Under E-governance in Urban Services, GIS mapping of roof top for solar panels (by using ArcGIS Desktop tools, ArcGIS Spatial Analyst, etc.), GIS mapping to assess risk and predict of the outbreak of disease in space and time, mapping of spatial distribution of health facilities by collecting GPS points, etc. are effective tools to take in decision making process.

The use of geospatial technology in urban mapping and city planning has contributed to in many ways such as formulation of Master Plans for decision-making, effective land use management and utilization, monitoring of spatial growth, etc.

Further, it is need of the hour that Geospatial technologies like Drone/ UAVs along with Geographic Information System (GIS) can provide input for preparation of base maps. Drones/ UAVs are economical alternatives also. Furthermore, urban-geo-data gap needs to be minimized by framing city level data policy and data Co-ordination as well as strengthening capacity building of stake holders in Planning Process.

GIS based decision support tool for Avalanche Risk Assessment along Amarnath yatra route, India

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Avalanches, a supremely dangerous phenomenon kill many people worldwide each year. Lakhs of pilgrims go for Amaranth yatra every year in the month of July-August, to pay obeisance to Lord Shiva. While clearing the snow covered routes for pilgrims, avalanches pose major threat to road clearing party. Assessing avalanche Hazard along Amarnath yatra route is important because it is a matter of lakhs of lives who stride through difficult mountain terrain to reach the holy cave. So knowing the sites which are prone to avalanches along the yatra route will provide an important safety measure to the road clearing party and pilgrims. The aim of the present study is to identify potential snow avalanche sites along Amarnath routes in Jammu and Kashmir (J&K), India by combining causative terrain parameters in GIS.

During winters, snowpack on mountain slopes becomes unstable because of increasing snow load. Terrain characteristics play a very crucial role in the stability of snowpack. Therefore understanding the role of terrain parameters is very important while assessing the vulnerable areas with respect to the avalanches. The Geographic Information System (GIS) enabled with powerful terrain analysis and visualisation modules is an important tool for avalanche hazard analysis and decision making. Along with GIS, Analytical Hierarchy Process (AHP) is a very useful method for complex decision making and identification of avalanche prone sites in the mountainous terrain. Researchers have tried using topographic parameters, Fuzzy logic models etc. for avalanche susceptibility mapping in recent past but identifying particular sites prone to avalanches using drainage networks and mountain ridges along with other terrain parameters i.e. slope, aspect, curvature and elevation has not been explored much. Despite advances in understanding of favourable terrain characteristics for release of avalanches, predicting the locations of individual avalanches is still a challenge. Here the attempt has been made to refine the approaches used by previous researchers, by considering drainages and ridges for identification of avalanche sites. Terrain parameters are used here because they can be easily obtained from Digital Elevation Model and do not undergo any change easily just like meteorological and snowpack parameters. Potential terrain parameters are extracted using ASTER DEM. Parameters are then classified into different classes on the basis of their role in avalanche formation. Weights are assigned to parameters and ratings to different classes on the scale of 0 to 9. Consistency of weights is checked using consistency matrix. All the parameters are integrated together and weighted sum is calculated which gives final avalanche hazard index (AHI). AHI is reclassified into four classes No, Low, Medium and High to assess avalanche hazard regions and demarcate avalanche sites. Final output map is shown in Figure 1.

The weight vector calculated using consistency matrix shows drainages and ridges are the most significant variable for avalanche assessment. The second most significant parameters for avalanche assessment are slope and plan curvature. The elevation is least significant variable for avalanche assessment. In the combined output avalanche susceptibility map, avalanche sites along the route are clearly specified by high danger pixels. As we move along the route we can see probable avalanche sites i.e. cluster of high and medium danger pixels. In order to validate the results, avalanche sites as specified by the output are compared with pre-registered avalanche sites along the route. High danger pixels forming clusters are correlated well with existing avalanche sites (Figure 1). Accuracy assessment was done using area under the curve technique. The results are also validated by doing recce. It is observed that along with slopes, drainages and mountain ridges are also the significant terrain parameters to assess the avalanche sites. This tool provides best approach over traditional methods. Resultant hazard maps will be useful for Shri Amarnathji Shrine Board (SASB), which oversees pilgrimage arrangements, and policy makers for mitigation of snow avalanche hazard. The GIS tool along with remote sensing imagery of Sentinel-2, Landsat and MODIS is being used for operational avalanche hazard assessment and generation of avalanche forecast during road clearing operations of Amarnath Yatra route every year. This provides a very effective method to assess high danger areas in remote locations where no past avalanche data is available. The final avalanche hazard maps can be used for operational purpose by disaster response teams to warn and educate people about avalanche hazard areas.

Output Avalanche Susceptibility

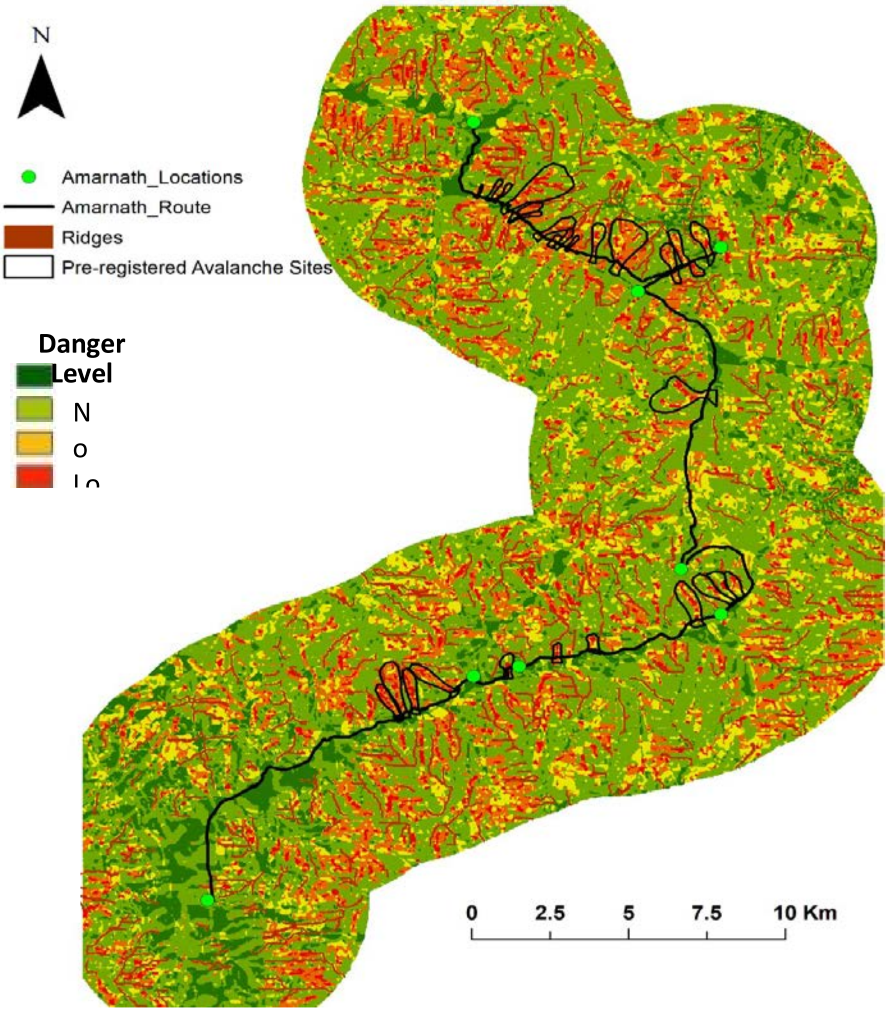

Figure 1: Final output map showing probable avalanche sites (high danger

Urban Planning Using Google Street View Images

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Urban planning is a technical and political process that focuses on the development of the built environment and land use in urban areas, as well as other natural factors. It is a laborious procedure to travel street by street and take note of the vegetation structures in order to improve the region. With the release of Google Street View Images in India (released on August 1st, 2022), users could acquire a 360-degree view of a location in Google Maps.

GMaps API allows developers to extract GSV Images which can be used to analyze the street for urban planning for vegetation cover or otherwise Green View Index. The images are extracted using the above API and then are preprocessed, segmented and finally masked using Deep Learning and Image Processing techniques.The masked images can be used to demarcate between green and non green regions. The vegetation cover is calculated using the green view index to show how greener the area is. This study will serve as a recommendation to the urban planning authorities to plan out more efficiently and modify the environment to cater to modern-day green developments by leveraging newly released Google Street View Images.

Geo-Portal Application real time Statistics and Analysis platform

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Web Geo-Portals are playing a key role in the dissemination of GIS and related applications to the scientific community for various end use. Apparently the usage and access has increased significantly now a days with the advent of feature rich GIS datasets and navigation tools. The usage of these portals is increased due to the increased popularity of Remote Sensing applications in various domains using satellite data, building governance applications, Crowd sourced point of interest data and Disaster management support services. Most of the applications are hosted in a specialized environment with proper layered security mechanisms. However some of the public faced application are prone to cyber-attacks to exploit the intended purpose. This paper explains about the collection and process in near real time analysis of the collected data from various web applications hosted in data center. This information is processed with mathematical and logical evaluations using Open source tools like apache Kafka and elastic search database and visualized in Kibana Platform. By using the data streaming software, logs will be fetched from each server and stored in the database with proper indexing using python scripts. This indexed data will be processed through statistical software tools to get the required output that can be visualized using customized dashboards. This information will be used to identify the popular content of the site in which users are interested and to make the necessary improvements for better user experience and ease of access with necessary security measures. This platform delivers the geo-location information and tracks user activities to eradicate any malicious threats. This platform helps in planning and taking decisions for optimization of resources and improved with quality and availability of services.

Better decision making of soil and water conservation through democratize scientific information

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Foundation for Ecological Security

Foundation for Ecological Security (FES), a registered Society, is committed to strengthening, reviving, or restoring, where necessary, the process of ecological succession and the conservation of land, forest and water resources in the country. FES enables rural communities to secure legal rights to their Commons, prepare resource management and governance plans, and access public investment to support environmental improvement. Concurrently, FES: â€¢ Engages with government to implement policies and programmes that promote the local management and governance of Commons. â€¢ Channels information systems and technology to improve civic engagement. â€¢ Partners with research institutions to improve understanding, and bring rigour in field action. The India Observatory is a collaborative tech initiative of FES that aims to demystify and present comprehensive information on Indiaâ€™s social, ecological and economic parameters on a single spatial and temporal â€˜Data Platformâ€™. India Observatory has also developed a set of unique platforms and tools namely Indian Biodiversity Information System (IBIS), Composite Landscape Assessment and Restoration Tool (CLART), Integrated Forest Management Tool (IFMT), GIS Enabled Entitlement Tracking Tool (GEET), etc. addressing specific issues. These are designed to supplement local level decision making by village communities, Panchayats, NGOs and government officials. In the landscapes where FES and partners work, degradation of land and scarcity of water are two major issues facing the communities. These have implications not only for the ecology but also for the livelihood security of the communities. Restoring soil, water and biodiversity is therefore an important strategy for FES and its partners. The Governmentâ€™s flagship MGNREGA programme also invests heavily in this area. However, lack of local technical capacity in designing interventions at the community level, erosion of indigenous knowledge, lack of community participation and vested interests at various levels of decision-making lead to flawed planning and implementation. This leads to wasted resources and further worsens the status of the communities and the natural resources. Supporting the planning of appropriate interventions by village communities involves providing engineering and other scientific inputs as well as dealing with the techno-bureaucratic requirements related to designs and estimates for various interventions that are necessary for leveraging government programmes such as MGNREGA. It is time and resource intensive to build and maintain these capacities at the village level on a large scale with due recognition by the local authorities. Composite Land Assessment & Restoration Tool (CLART) was developed by the IO to cater to the need for a tool that could be used by village level resource persons to plan and design various soil and water conservation structures on a large scale. CLART is a GIS-based tool to help in the planning of soil and water conservation measures. The treatment plan for the area therefore needs to be made after assessing the different physical properties of the land. There are levels of complexity to understanding the nature of recharge potential of a specific area where rock type, slope and landuse/landcover varies. To aid in this process, a composite approach has been identified with the help of spatial data of different resolutions but at a uniform scale under the GIS umbrella and made available through an android application (GIS enabled) for informed decision making in the field. As of 30th September 2022, CLART has been used to appropriately locate and design more than 2 lakh interventions in nine states of the country by FES and partners (including 3 State Governments). CLART has undergone rigorous field testing by government agencies and has successfully met their standards. CLART has been integrated into the NRM planning process of the Government of Meghalaya as part of a four-way partnership between the Institute of Natural Resources of the Government of Meghalaya, Arghyam, FES and Socion. The partnership aims to unearth and enable new (digitally reimagined) means to empower and enable community and institutional actors to work together in planning and implementing NRM initiatives that may result in positive economic and ecological outcomes for individuals and communities across the state. An integrated web-based information system built covering various levels in the administrative hierarchy, with CLART being used at the village level, builds transparency and trust in the system. All field level NRM plans made by village communities with the facilitation of Village Resource Persons (VRP) are based on CLART and any user in the system is able to compare the proposed intervention against the CLART recommendation. Sanctioning of plans or recommending midcourse corrections becomes easy as the plans including photographs, maps and other details are all available on the platform. This saves time and effort and ensures optimum use of resources in the field. The capacity building of the VRPs can also be tracked in the system. The pool of VRPs are also discoverable by any other programmes/departments that would like to utilise them. Widgets allow embedding of the GIS based interface to the system in any website, say of another department, to allow open sharing of relevant information. As of September 2022, 47,177 community NRM plans have been facilitated in Meghalaya with the help of CLART. Following the success in Meghalaya, three state governments have expressed willingness to explore similar collaborations. In Karnataka, CLART based MGNRENA implementation is being undertaken in eight districts and is due to be extended to all districts in the state. Based on an open source philosophy, CLART provides an example of the potential that Information Technology has as a catalyst in the economic and ecological development of the country. By mainstreaming the tool in the functioning of government programmes, optimal use of scarce resources has been ensured, while also building trust and transparency among all the stakeholders involved in the process. As such CLART also stands as an example of the application of the Integrated Geospatial Information Framework particularly aspects such as Governance and Institutions, Data, Innovation, Standards, Partnerships and Capacity & Education.

Bhuvan CDMA
A Geospatial Application for Urban Tax Planning

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Property tax is the primary source of revenue for municipal bodies in India. Urban Local Bodies (ULBs) are facing issues in property tax collection and the primary reason is a lack of count of assessed properties and portion wise information of each property. Property tax information on the properties is mainly based on manual efforts, which often leads to erroneous data, redundancy and failure to appropriate tax collection. Geographical Information Systems (GIS) consists of technology, personnel, and resources to create, maintain, visualize, search, and share geospatial data and services.

Geo-tagging of properties, along with portion wise details and tax information is a major step in creating and maintaining the property tax database. Geo-tagging is the process of appending geographic coordinates to media and additional information based on the location of a mobile device. The mobile application has been enhanced using geo-fencing concept, which creates a virtual perimeter for a real- world geographical area. All the portions in every property are collected using geo-fencing within a certain distance from the property location. Properties have been categorised into commercial, residential and mixed property. Based on selection of the category, each portion can selected as commercial, residential portion. The details like address, floor plan details can be filled accordingly for each portion and updated to the server. Facility has alaso been given to link water connection details to the property to avoid irregularities. All the details updated to the server are then moderated by ULB level officers to avoid duplicates and errors in the updated data. Moderation of information plays an important part in collecting authentic information. In the web application, user hierarchy for state level, ULB level, Revenue officer are created using which different logins will have different roles and functionalities.

Bhuvan provided various geospatial applications, tools, API, OGC services etc. towards fight against COVID-19 pandemic developed using Open Source Geospatial solutions like OpenLayers, MapServer, GeoServer, PostgreSQL with PostGIS, Bootstrap, Vuejs, Cordova, location based technologies etc. OpenLayers is a client side JavaScript library to put a dynamic map in any web page helping highly interactive web-mapping interfaces. Mobile apps development used Apache Cordova an open-source mobile development framework, which embeds the HTML5 code inside a native WebView to access the underlying hardware i.e. camera and GPS. GPS enabled smart phones make it possible to implement geo-tagging, geo-fencing and integrating with near real time data transfer and management at server side provides maximum benefits in terms of visualization, monitoring and management. Apache httpd, Tomcat are used as Web and Application Server for serving the content. PHP is used as backend scripting language. Along with these, JASIG CAS is used as Central Authentication Server supporting single-sign-on. JQuery, Vuejs, Bootstrap, jsPDF are some of the libraries used for developing rich GUI. Bhuvan applications & services are developed are adhering to web application security guidelines and served using https (TSL 1.2 standard) over the network from Bhuvan infrastructure configured in loadbalanced and high availability mode.

An integrated application is envisaged for Commissioner and Director of Municipal Administration, Government of Telangana for geo-tagging, visualization and moderation of all Assessments, Portions, Trades, Advertisements and Cell Towers in Telangana for 30 Districts comprising of more than 134 Urban Local Bodies under Phase-II. The aim of this project is to obtain the location information of all Assessments with measurements, Trade details, Advertisements, Cell Towers. On completion of this geo-tagging exercise enables CDMA department for taking up following activities. The review of all Properties for identifying under accessed and un-accessed Assessments, Trades. Linking of Water Connections, Trade with Assessments and providing new Connections & Licenses. GIS based Town Planning for the ULBs, Digital Door Numbering.

Mobile App supporting geo-tagging of Assessments, Portions, Advertisement, Cell Towers Assessments and Web Application supporting Registration, Visualization and Moderation of mapped profiles are developed. Data received from the CDMA and NIC Departments belonging to 134 ULBs are integrated and provided as services to mobile.

Under CDMA Phase-1 application more than 12 Lakhs existing and 20,000 new Assessments in 72 ULBs are mapped. Currently in Phase-2, more than 15 Lakhs assessments are geo-tagged across 134 ULBs till date. This helped department in identifying many un-assessed & under-assessed properties and supported in increase of revenue. Also paved the way for taking up new initiatives for planning and Department received 4 Awards for this initiative. The usage of this application over the years can gather information on development of different areas in each ULB. Transparency in tax collection and regular re-assessment of tax properties will impact business opportunities and governance in all ULBs. Till Sept 2022, more than 15.8 Lakhs Assessments are geo-tagged and it is in progress. This exercise enables for creation of unique database and helps in review of all Assessments, GIS based Town Planning for ULBs.

Sl.No:	358930
Assessment Number:	1177008084
User Name:	Ganesh
User Mobile:	9849694865
Bill Collector Name:	PAGADALA SRIHARI
Bill Collector Mobile:	8978087575
Application Version:	3.93
UUID:	ec9a361e29e155c7
Device Model Name:	vivo 1915
District:	RANGAREDDY
ULB:	BADANGPET
ParentId:	1177008084_1648282292020
Activity:	ExistingAssessment
Ownership Description:	State Govt. Building
Multi-Assessment:	NO
Owner Surname:	R
Owner Name:	VENKAT REDDY
Father Name:	JANGA REDDY
Door Number:	2-63.
Ward:	6
Block:	2
Zone:	6

Photo-1 Location Details

Accuracy (m):	3.9
Distance (m):	0.22
Altitude (m):	452
Direction (deg):	217.72
Captured Time:	2020-09-22 16:48:45

Assessmen

Enabling Transparency and Efficacy in Governance using Geospatial Technology: A Web- application for the State of Rajasthan

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The effective delivery of good governance requires integration of technology for efficient and transparent functioning mechanism in governmental work. One of the key applications of geospatial technology is to aid policy makers in taking spatially enabled informed decisions, i.e., *G-governance*. Thus G-governance is imperative for realizing the objectives of good governance. The present study is a novel open source based web-GIS application being developed for the State of Rajasthan. The aim of the web application is to bridge the gap between the political and welfare objectives of legislature. The information system has been generated as two web-applications on a single platform on the portal comprising electoral statistics at various constituency levels for the entire State and selected governance attributes relevant for developmental planning for Tonk assembly constituency of Rajasthan. The first application titled as the Electoral Information System (EIS) has been dynamically represented in four web pages displaying visualization, query, trends and comparison of electoral statistics across the elections at Lok Sabha and Assembly levels held post-delimitation (after 2008). The second application is a dynamic visualization of comprehensive electoral, demographic and development statistics upto village level for Tonk assembly constituency. This part of work includes generation of approximately hundred vector data layers stored in PostgreSQL/ PostGIS database published through GeoServer. Open source JavaScript library OpenLayers v6.4.3 has been used for application development. Geotagged polling booth locations, socio-economic amenities and assets have been mapped through extensive field survey and are published on the web portal. The study is an innovative application to showcase integration of multifarious types of developmental data and information readily accessible in desired form to the decision makers, academicians and other stakeholders. It will be helpful in redressal of identified issues of the constituency with increased efficiency, accountability and transparency. The portal will soon be available in open access public domain.

Technology Assisted Spatial Decision Support System for Livestock Management

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Livestock plays a significant role in the Indian economy. It provides livelihood to two- thirds of rural communities and employs about 8.8 % of the population in India. India has vast livestock resources, and the sector contributes 4.11% of GDP and 25.6% of the total Agriculture GDP. Livestock plays an important role in the economy of farmers. The farmers in India maintain a mixed farming system i.e. a combination of crop and livestock where the output of one enterprise becomes the input of another enterprise, thereby realizing resource efficiency. The livestock serves the farmers in different ways, such as employment, food and social security. However, the livestock sector faces several challenges such as low productivity, high economic losses due to animal diseases, inadequate infrastructure and human resources for support services and shortage of feed and fodder etc. Department of Animal Husbandry, Government of Kerala, is actively involved in the state's conservation and up-gradation of recognized breeds. The department also carries responsibilities like training the farmers and professionals, strengthening semen stations, organization of infertility camps, delivering breeding inputs at farmer's doorsteps, supplying quality semen for artificial insemination, and setting up strict quality control of services and inputs.

To efficiently monitor and maintain the day-to-day animal husbandry activities, a technology assisted spatial decision support system is required. *Bhumika,* a web and mobile based solution for the officials of the animal husbandry department, is initiated to capture the location of farmers engaged in animal husbandry farming and to build spatial decision support systems for ensuring traceability and identification of animals and their production zones, disease outbreak management, monitoring of activities such as vaccination, artificial insemination, insurance etc. *Bhumika* is built with the latest open-source technologies. The web application is developed using HTML5, CSS3 and JavaScript at the frontend and PHP at the backend. The data collected is stored and processed in PostgreSQL RDBMS with a spatial extension named PostGIS. The application uses RESTful web services to connect and communicate with the android application, which is used for the data collection. The whole application is hosted and maintained in a Linux Server running an Apache Web Server.

1. Geo-tagging of livestock farmers

An android-based application was developed to geo-tag the farmers. The application is installed in tablets. The tablets were distributed to livestock inspectors. The application works in online/offline mode.

2. Design and development of web-based portal

3. Development of a decision support system

Bhumika smartphone application is being used to identify and geo-tag the locations of all the farmers in the state of Kerala who are engaged in animal husbandry with their livestock details. An automatically generated unique identification number is provided for both the farmers and their animals, and the GPS coordinates are captured by a mobile application and stored in a database. The functioning of the disease outbreak management system is enabled by a GIS technique known as a buffer, which can be quickly identified in a ring of radius of distance from the affected animal at the center in which the disease is reported. A disease alert can be broadcast immediately to notify nearby farmers and confine the diseased individual to reduce the disease spread by relocating them.

Figure of Bhumika's web page / dashboard

A cloud based Mapping of Flood Disasters in Cities for effective preparedness

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Floods are the most common disaster that impact major livelihood in cities although people ready to face it. A cloud based automated geo - processing of flood inundation mapping is done using Google Earth engine (GEE) using Sentinel–1 Synthetic Aperture Radar - SAR images. GEE Provides a best platform for analyzing the flooded areas after the event and also based on the history of data available in GEE, Since Sentinel 1 provides polarization only in VH and VV modes the inundation is mapped using both modes and it is identified that VH mode over estimates the flood while the VV mode produces better results this has been validated finally the output is compared with the available Sentinel 2 optical image and an overall accuracy of 96% is obtained using VV mode of polarization which is very much also compatible with the available field observations over the inundated region. Since the entire processing in done in cloud servers and the entire process is automated, immediately after a satellite pass occurs the extent of flood inundation is automatically mapped which helps in a better way for decentralized effective planning of resources during disasters.

Data Science, Artificial Intelligence and Machine Learning

Building detection in very high resolution satellite data for Indian cities using deep learning

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Building detection in satellite data plays a very important role for urban planning, growth and monitoring. With the availability of very high resolution satellite data and drone data the conventional classification techniques is failing in providing the accurate results for the detection of buildings. In present scenario only manual digitization and classification techniques are being used, these techniques are very time consuming and cannot be up-scaled for the high volume of data. Recent development in the deep learning has given a way towards the automated feature extraction in multi resolution satellite data. With the availability of drone data, very high-resolution satellite data the automated methods like building wise segmentation, pixel-based segmentation are not providing very satisfactory results. Automatic detection of urban features like building plays an important research when ever urban feature monitoring is required. The recent research in deep leaning in branch of computer science has given the way to develop the algorithms which can help in automatic detection of building in satellite data. This research will provide the deep learning methodology to detect the building in very high resolution satellite data. The methodology has made use of supervised learning where 2d neural networks is trained using identified samples from satellite data and trained neural network is used for detection of building in very high resolution satellite data. Before starting of this work we have studied the research in field of object detection in satellite imagery. The Git hub has provided some content which has given the knowledge about the Image AI python library and tensor Flow which are good for object detection in Satellite data.. Based on study done under this research has given a view that 100% result may not be feasible for feature detection for example building detection in satellite data using methodology used in the paper .Further improvement in is required in order to get better results. The data in this study consists of optical satellite data and locations of samples for buildings/non-buildings. The satellite data having 1 m spatial resolution belongs to very high resolution optical satellite. The Training datasets are created using GDAL and OGR libraries from the satellite data. The total of 224 samples is being taken for this methodology out of which 47 are positive samples and others 177 are negative samples. The present methodology used the neural network with 3 convolutional layers using tflearn. The first layer has 32 convolutional filters with 3 filters, after this downsizing is being done and there will be two convolutional filters in cascade with 64 convolutional filters with filter size of 3. Further downsizing will provide fully connected network with 512 neurons with activation function followed by 40 percent dropouts. The last layer is fully connected network with 2 neurons and activation function to determine the category of the feature in the image. The model is trained for 70 epochs with each batch size of 66.After training of the model accuracy of 98% is achieved with validation datasets. The model is tried on satellite data having 1m or less than 1m resolution 75% to 80% of accuracy is achieved. The model can be improved by increasing the variety of samples for giving more accurate results. It can be made more generic so that it can be used for multi resolution satellite data. It can be further validated for detection of more features like trees, well, canal etc. The model can be used for auto detect of building in eco-sensitive zones also.

Semantic segmentation on multi-resolution optical and microwave data using deep learning

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Presently, deep learning and convolutional neural networks (CNNs) are widely used in the fields of image processing, image classification, object identification and many more. In this work, we implemented convolutional neural network based modified U-Net model and VGG-UNet model to automatically identify objects from satellite imagery captured using high resolution Indian remote sensing satellites and then to pixel wise classify satellite data into various classes. In this paper, Cartosat 2S (~1m spatial resolution) datasets were used and deep learning models were implemented to detect building shapes and ships from the test datasets with an accuracy of more than 95%. In another experiment, microwave data (varied resolution) from RISAT-1 was taken as an input and ships and trees were detected with an accuracy of >96% from these datasets. For the classification of images into multiple-classes, deep learning model was trained on multispectral Cartosat images. Model generated results were then tested using ground truth. Multi-label classification results were obtained with an accuracy (IoU) of better than 95%. Total six different problems were attempted using deep learning models and IoU accuracies in the range of 85% to 98% were achieved depending on the degree of complexity.

Design and Development of Automatic Indian Sign Language to Text Conversion Using LSTM from Video Sequences

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Indian sign language is used by hearing and speech impaired people to communicate with other people. This project presents a system that converts Indian sign language to text. Our project aims to develop a model that can help these people to communicate with those who do not understand ISL. Indian Sign language uses hand gestures, and these gestures are represented as a video sequence, and they contain both spatial and temporal features. In the gesture video, information lies in the sequence as well and not just in the frame. A Recurrent Neural Network has time-based functionality and it uses the sequence information as well in the recognition task. For this, we are using LSTM (Long Short-Term Memory) model which is a type of RNN for the detection of hand gestures and converting it into text as it is able to learn long term dependencies. The sign to text conversion stage involves the creation of a dataset containing recorded videos of Indian Sign Language hand gestures. The pre-processing of the video gesture can be done using the Media pipe python library that detects the landmarks of the hands. Media Pipe library provides detection solutions for hands, face, pose etc. We are using Media Pipe Holistic Solution for obtaining the Key Points. Media Pipe Holistic utilizes the pose, face and hand landmark models in Media Pipe Pose, Media Pipe Face Mesh and Media Pipe Hands respectively to generate a total of 543 landmarks (33 pose landmarks, 468 face landmarks, and 21 hand landmarks per hand). The extracted landmarks or Key points are used to decode the sign language. After preprocessing the frames of the video, the sign language gesture has to be converted to text by training and testing/classifying using Neural Networks. We are planning to record 50 Video Sequences per gesture and the data from all the sequences is combines into an array and given to the LSTM neural network model for training and testing/classifying of our system.

Modelling Urban Sprawl of Mumbai Metropolitan Region (MMR) using ResNet34

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For many geospatial applications throughout the world, such as assessing urban sprawl using change detection, time series analysis, environment, and urban studies, land use/land cover (LULC) maps are a crucial prerequisite. The categorization of satellite photographs used in mapping LULC from remotely sensed images makes it feasible to detect rapid changes in large geographic regions. For supervised satellite image classification, several strong and effective techniques have been put forth. The machine learning and deep learning algorithms are gaining popularity for modelling change detection. Overcoming the drawbacks of basic Artificial Neural Networks (ANN) further the Convolution Neural Networks (CNN) have emerged as a key technique in the supervised categorization of satellite images. The accuracy of the model is impacted by the vanishing/exploding gradient issue caused by CNN with several layers. A novel architecture known as Residual Network (ResNet) was launched by Microsoft Research experts in 2015, which tackles vanishing gradient problem. Modern image classification techniques may be used to Resnet34, a 34-layer convolutional neural network. The Resnet34 was used for modelling remotely sensed data for performing classification, for finding urban sprawl using change detection. The objective of this study was to employ ResNet34 algorithm for LULC mapping. The study area considered is Mumbai Metropolitan Region (MMR), which is the state capital city of Maharashtra and the financial capital of India. To carry out the study, this work used free Landsat 5 and Landsat 8 satellite images with the Operational Land Imager (OLI) sensor. Images were exported from google earth engine. Google earth engine provides images from USGS. Two tiles were required to obtain the MMR region, which is the region under the study area. The ResNet34 algorithm was considered for modelling the data. Seven bands of Landsat 5 images and nine bands Landsat 8 images were considered. Out of the total data set available 65% of the total data was considered for training, 15% of the total data was considered for validation and 20% of the total data was considered for testing. The data (mosaic images) obtained from google earth engine was divided into 256 x256 tiles for ResNet34 model training. The training and testing data was implemented using fast.ai library. The model was used to predict four classes as Water, Built up, Agricultural and Barren land. The Hyper parameters used by the model were Patch Size â€“ 256x256, Number of epochs â€“ 30 and Learning rate â€“ 0.001 The model was trained on 172 training chips of 256x256 size for year 2000, 2010 and 2020. The Kappa coefficient and Overall accuracy obtained for the model were 0.939155 & 0.963636 for the year 2000, 0.890948 & 0.921729 for the year 2010 and 0.784295 and 0.859749 for the year 2020. The details in changes for the years 2000, 2010 and 2020 were also found for each class.

Building segmentation using deep learning and applications

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The task of segmenting buildings from high resolution satellite imagery has been a challenging task. Many people have attempted the problem with varying level of accuracy. The main difficulty in solving this problem is small and random spread of building in different areas. Differently colored roof tops presents another challenge in building identification. Demarking the buildings manually in a high resolution, densely populated urban area image is quite difficult and time consuming. In this paper we present a fully automated method of building extraction using state of the art U-NET, a fully convolutional neural network for building segmentation from high resolution, multi-spectral, satellite imageries. U-NET has been used from a long time in segmentation of medical images. The novelty of this paper is to tune the network and make required changes to it to adapt it to segment high resolution satellite imageries and use a novel threshold selection method using F1 score as selection criteria and development of a unique method to correct shape of detected buildings and find various applications in this domain. Various challenges faced during the process and algorithmic strategies employed to tackle the difficulties has been discussed in this paper.

Land Cover Classification of Mid-resolution RS Datasets using Machine Learning Techniques

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Over the last two decades, the rapid uncontrolled exponential in population growth and the industrial expansion in terms of development in developing countries like India is noticeable in recent times which inherently accelerates the rate of change in Land use and Land cover (LULC) in a bigger way. The accurate quantification of spatiotemporal variability and understanding of the change dynamics of a landscape to analyze and manage the Land transformations, various climate change studies, water resources, and related science and engineering disciplines is indeed a potential research area for Earth observation applications. Quantifying the variability in the Land use and Land cover (LULC) classes in the means of classifying or labeling the different land cover features on the Earth's surface in the most accurate way by examining and analyzing the performance of the different supervised algorithms is the key challenge in a heterogeneous landscape like India. This study has focused on the comparison of conventionally used visual interpretation techniques along with three different commonly used supervised classification algorithms Random Forest (RF), Multi-layer Perceptron (MLP) and Support Vector Machine (SVM) in terms of the overall accuracy of classification, input parameters requirement and hyper parameter tuning (in detailed for RF), time of execution, etc. using mid-resolution (24m.) LISS-III multispectral data from Resourcesat-2.Random Forest classifier performed as the best classifier with an overall accuracy of 0.9 followed by MLP (0.89) and SVM (0.79).

Satellite Image Classification using a Hybrid Optimization method by Different Genetic Optimization Algorithm

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This research proposes a novel intelligent prediction model for satellite image classification based on Wavelet Neural Networks and a metaheuristic algorithm. The satellite photographs contain a massive amount of data that can be utilised in a variety of ways. Due to the large volume of data and variety of the data, analysing it is a time-consuming task. The Evolutionary Multi-Objective Seagull Optimization Method (EMoSOA) is used to train a Wavelet Neural Network (WNN) in this paper. The Wavelet Neural Network (WNN) is a novel branch of ANN theory that is built using the wavelet transform as the ANN's pre-processor. The WNN is better than the traditional ANN in modelling precise and convergence rates and learning memory ability and accuracy. WNN has proven advantageous in addressing uncertainty problem. WNN is an artificial neural network model based on a mother wavelet analysis instead of the conventional sigmoidal function. Therefore, the network is trained using the Evolutionary Multi-Objective Seagull Optimization Method (EMoSOA) algorithm to improve the accuracy of satellite image classification. In this algorithm, a concept of dynamic archive is introduced, which has the feature to cache the non-dominated *Pareto* optimal solutions. By simulating the migration and attacking behaviours of seagulls, the roulette wheel selection approach is used to pick the most successful archived solutions. The proposed method is applied on pre and post flooding Landsat 8 Operational Land Imager (OLI) images of New Brunswick area. The method was applied to identify and classify the land cover changes in the area induced by flooding. The images are classified using the proposed method and a change map is developed using post classification comparison. The change map shows that a large amount of agricultural area was washed away due to flooding. The measurement of the affected area in square kilometres is also performed for mitigation activities. The results show that post flooding the area covered by water is increased whereas the vegetated area is decreased. The performance of the proposed method is done with existing state of the art methods.

Artificial Intelligence (AI) and Machine Learning (ML) for Remote Sensing Applications in Agriculture

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Modern agricultural technologies enabling precision farming also now termed as ‘Digital Agriculture” relies on data-driven approaches for enhancing crop productivity and minimizing environmental impact. Artificial Intelligence (AI) and Machine learning (ML) tools as part of digital agriculture have variety of potential applications togather with remote sensing for agriculture. AI has been seeing a lot of direct application in farming. AI-powered solutions will not only enable farmers to produce more with less, but it will also improve the quality and ensure faster go-to-market for crops. Artificial Intelligence can offer an effective and practical solution for the problem and introduced Machine Learning (ML). Machine learning algorithms use historical data as input to predict new output values. In agriculture, advanced remote sensing technology such as Unmanned-aerial vehicle (UAV), hyperspectral imaging, ground sensor network and publicly accessible big-data employed with intelligent crop simulation model and machine learning algorithms have been utilized to help both policy makers and farmers to make better decisions on crop assessment as well as decisions on crop/soil management. As of now available satellite imageries (like LISS III, Landsat and Sentinel) and other datasets are being extensively used for monitoring crop growth at the landscape level, but commercially available imagery and UAV commonly called drones, facilitate a higher level of precision in agricultural data by creating an opportunity for real-time monitoring. Drones can be utilized for detailed analysis of a field for crop and soil nutrient monitoring

In general, AI and ML tools togather with remote sensing imageries witnessed immense potential in the crop type mapping, yield prediction, water management, crop disease detection, soil management. Crop type mapping and yield estimation s of high importance for yield mapping, yield estimation, matching of crop supply with demand, and crop management to increase productivity. Nihar et al., 2022 utilized satellite based images (Sentinel 1 & Sentinel 2) and machine learning methods [Random forest (RF) & Support Vector Machine (SVM)] to segregate plant and ratoon sugarcane fields at catchment level in Saharanpur region of Uttar Pradesh. Sentinel-2 along with ML methods has promising capabilities and is a convenient asset in delineating small sized farms and classifying sugarcane crop types. Predicting crop yields on operational scale realized through semi-empirical efficiency based models amenable to satellite observations for major crops (wheat, mustard, rice etc), machine learning based approaches (RF/SVM/ANN) have gained immense importance crop forecasting yields of high value crops like sugarcane and cotton as raw-material for consumer industries (Prasad et al. 2020, Ashmitha, 2021). In the similar way, machine learning methods are effectively utilized to predict the disease in rice (Ramesh & Vydeki, 2019), wheat (Goyal et al., 2021), tomato (Agarwal et al, 2020).

Agriculture is the biggest water-consuming sector and requires precise, efficient and smart irrigation delivery. Smart Irrigation system was developed by Deshwal in year 2018 (https://innovate.mygov.in/innovation/smart-irrigation-system-using-arduino-and-moisture-sensor/) using Arudino and moisture sensor. AI-based irrigation system leverage to minimize the use of water and also optimize the water resources without wastage. AI systems can detect the groundwater levels and also estimate the agricultural needs to balance the usage of water by guiding sprinkler systems. Integrated approaches that uses combination of geospatial data (remote sensing, soils, topography) and big-data driven climate models(WRF/RegCM) and crop simulation models (EPIC/DSSAT) togather with ML technology has been paving way for developing early warning indicators of drought and support food security and agro-climatic risk assessment.

Potato Leaf Disease Detection using Deep Learning

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Potato is a widely consumed staple food that has risen to become the world's fourth most consumed staple food. Furthermore, global demand for potatoes is increasing significantly, owing primarily to the global pandemic coronavirus. However, potato diseases are the leading cause of harvest quality and quantity declines. Various diseases, such as early blight and late blight, have a significant impact on the quality and quantity of potatoes, and manual interpretation of these leaf diseases is time-consuming and inconvenient. Diseases in potato plants, fortunately, can be identified based on leaf conditions. As a result, in this paper, we present a system that uses deep learning to classify two types of diseases in potato plants based on leaf conditions, using the GoogleNet, Resnet50, and the VGG16 convolutional neural network architecture model to create an accurate classification system. This experiment achieved 97% accuracy for the first 40 CNN epochs, indicating the feasibility of the deep neural network approach.

Analysis of Machine learning-based classification algorithms for ship detection in LISS IV remote sensing data

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One kind of transportation in the ocean is the ship. In order to make decisions for real-time warfare scenario awareness and commercial ship. This application of ship detection and categorization provides crucial information. A multispectral channel sensor with a 5.8 metre resolution per pixel and a 23 km swath of resourcesat-1 is the Linear Imaging Self Scanning Sensor (LISS-IV). Instead of merging all bands like an RGB image, the red band (0.62 -0.68) spectral image is suited for ship identification in the ocean. Based on the electromagnetic wavelength, a ship's reflection on water and water reflection vary in a red band. If the image processing algorithms

Effect of Loss Function on Performance of Semantic Segmentation Model for Building Extraction

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Building extraction is a highly demanding task in satellite image applications. It helps to obtain morphology, location, and other information about buildings from satellite images, which is significant for environment monitoring and construction of human activity areas. In recent years, deep learning based semantic segmentation methods have gained much attention in remote sensing field and achieved great breakthrough. Compared with other semantic segmentation methods, convolutional neural network (CNN) based semantic segmentation has shown effectiveness in building extraction due to its powerful feature extraction techniques. However, there still exists information loss problem which causes performance degradation. To deal with this situation, researchers have proposed several loss functions to improve the performance on building extraction. In this paper, we aim to present the effect of different loss functions on performance of semantic segmentation model for building extraction. We have used well-known semantic segmentation model UNet and explored six commonly used loss functions viz. dice loss, Jaccard loss, binary cross-entropy loss, weighted binary cross-entropy loss, focal loss and Tversky loss. The experiments were conducted on two publicly available satellite datasets namely WHU-I and WHU-II. The experimental results show that Jaccard loss has performed better for both the datasets in comparison to the other loss functions.

Deep Learning Model for Object Recognition in High & Medium Resolution Remote Sensing Images

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With increasing number of high resolution earth observation satellites, many areas of earth are being covered on a daily basis. Automatic information extraction from remote sensing imagery has become imperative to provide timely information for planning and decision making in many applications like resource monitoring and disaster management. Deep learning methods based on Convolutional Neural Networks(CNNs) have been used for object detection. However, many practical applications require recognition of subcategories of objects. Model for object recognition based on CNNs is developed and presented in this paper. The dataset for training consists of images of multiple resolutions of PAN and multispectral sensors containing different types of objects. Use of non-linear activation functions like RELUs make the solution space non-convex and minimum value of the loss function becomes dependent on several model hyper parameters and variable initialization. Multiple models with different combinations of augmentation methods, variable initializations and model hyper parameters have been tried for object recognition task. The trained model shows promising results with good precision and recall for object recognition of different types of aircrafts.

Deep Learning Based Automatic Change Detection for Very High Resolution Remote Sensing Images

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Change detection based on remote sensing is having important role in the field of resources management, monitoring and planning etc. Change detection from multi-dated images will bring the intelligence in terms of land cover changes, new deployments, new constructions happened over a period of time. Changes detection also enables to carry out time series analysis and can provide cue to decision makers. Due to availability of multiple very high-resolution satellites orbiting in space and day by day huge volume of data is acquired, there is a need for automatic change detection for high resolution imagery applications. Change detection from remote sensing images is a very challenging task because of high variability due to different conditions of imaging like atmospheric changes, seasonal changes, view angle differences and unknown dynamic conditions. Quality of change detection also depends on registration accuracy between images.

There are various image processing methods of change detection like pixel-based change detection, post classification-based change detection and object-based change detection. These algorithms have its own advantages and limitations. These algorithms suffers from more false alarms due to view angle variability, time and quality of imaging. There is a requirement to develop robust technique to reduce the false alarms and to improve the generalization capability across sensors. In recent years, development of artificial intelligence (AI), machine learning (ML) and deep learning (DL) technology have gain rapid pace due to availability of high computation power and GP- GPUs.

The presented paper proposed methods was based on deep learning-based change detection techniques for very high-resolution images of less than 1 meter. In proposed method, residual blocks and dropouts was added in network to increase the accuracy and to control the vanishing gradient problem. To achieve trade-offs between performance and speed, different network structures and hyper-parameters settings was determined. Different quantitative analysis matrices were used to measure the performance of the model. Trained model attained sensitivity of 0.83, precision of 0.88 and F1 Score of 0.857 on objects of greater than 2 meters. Approach, analysis, results and quality parameters are presented in the paper in detail. Proposed deep learning model is a lightweight structure, yet demonstrates better change detection quality. Finally the changes are saved in a shape file along with its metadata which can be used as intelligence by decision makers. In addition, promising directions for future research in this area is discussed.

U-Net based surface Water mapping using Sentinel 1 and NOVASAR data

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Synthetic Aperture Radar has been widely used for applications like monitoring flood and land subsidence. Generating timely surface water maps can be helpful in these for easy analysis and interpretation. Conventional methods like Otsu thresholding have been followed till date to classify surface water from the rest. In this study, a deep learing based U-NET network is used to come up with more accurate surface water maps from the Sentinel 1 and NOVASAR data. The application of this method on Sentinel 1 data over the Poyang region of China shows that it could facilitate surface water mapping with an accuracy of 48%. The study further aims at generating maps using NOVASAR data in Idukki distict of Kerala which has been hit by floods in the past few years.

A novel method to generate high precision deep learning based object detection models

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Object detection in satellite images is a challenging task. There are many Deep Learning based algorithms that perform object detection in satellite imagery with good accuracy but along with the objects they detect lot of false positives too. The presence of false positives is a major problem when object detection is to be automatically applied on a huge datasets and results have to be used to make decisions in critical applications. In this paper, we propose a new method of intelligent object simulation to generate additional training datasets to reduce the false positives to almost negligible amount with iterative model training. The approach can be embedded in any object detection chain that uses supervised deep learning algorithm. This paper focuses on removing the false positives through the proposed method to increase precision and also improve the model through image augmentation techniques. This paper also does a comparative analysis of various augmentation techniques and their impact on the learned model.

Unsupervised change detection in multi temporal optical satellite imagery using multi scale convolution neural network

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Very-high-resolution imagery can provide abundant information about ground details and spatial geometry. Change detection in multi-temporal optical VHR images is the process of identifying changes between scenes of the same location acquired at different times and plays a very significant role in various decision making applications. Many change detection techniques ranging from simple differencing to Machine Learning techniques have been described in literature. Nevertheless, traditional change detection methods can neither take full advantage of spatial context information nor cope with the complex internal heterogeneity of VHR images. In this paper, a powerful feature extraction unit is adopted for change detection in multi-temporal VHR images that extracts features at multiple scales. As a commonly used convolution unit, 3×3 convolution kernel could extract spatial-spectral features from VHR images. However, the 3×3 convolution kernel has obvious disadvantages in feature extraction of VHR images as they could only extract single scale spatial spectral features in the same layer. But in VHR images, there exist different features, varying from small scales to large scales. Considering the varying scale of VHR images, a multi scale feature extraction mechanism is adopted in this paper. Labelled images for change detection using satellite imagery are scarce and costly to obtain. However, there is a wealth of unlabeled images being generated every day. In order to leverage these data sets to learn an image representation more adequate for change detection, a self-supervised learning method is adopted to train the model. FCM algorithm is utilized to select pixel of interest that have high probability of being changed. The CNN model is trained using high probability pixels. In the inferencing phase, the trained model is used to get the changed and unchanged pixels for the whole image. The proposed method is found to detect meaningful changes without any manual threshold requirement.

A comparison of pixel-based and object-based image analysis with Machine Learning Algorithms for Heterogeneous Horticultural landscapes

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Crop intelligence information for horticultural crops is critical for production related policy decisions and market led interventions. Current literature reveals that mapping of banana crops is scarcely studied in heterogeneous cropping areas. Mapping of crops in such geographical locations is a challenge using conventional imaging processing algorithms. Towards this machine learning algorithms (MLA) may provide better insights. The objective of this paper is to map Indian banana crop by applying advanced MLA on Sentinel2 satellite data of Theni district, Tamil Nadu. Banana crop pattern was analyzed using three supervised MLA: Classification and Regression Trees (CART), random forest (RF) and support vector machine (SVM). Pixel and object based classification approaches were also executed on time series datasets for 2017-2018 collected over the same region. The overall classification accuracy for the classifiers depict

Computer Vision and Geoanalytics

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Computer Vision is a technology that uses artificial intelligence (AI) and many other inter disciplinary fields to train computers for interpreting digital videos and images. AI based developments and research with large amounts of data sets of sub meter resolution images along with 3D imagery with the help of geospatial data analytics will revolutionise geospatial applications in the long run. Model development and timeline solutions will benefit geospatial applications for societal needs. In Human Vision eyes are the sensors and Brain is the processor for interpreting images with domain knowledge models stored in the memory. Computer Vision is also technology for developing suitable models with Physics, Mathematics and Signal Processing for application to Pattern recognition, Image processing with AI techniques for Computer to interpret.

Geoanalytics is already popular in Geospatial applications. By considering geo-location and other spatial information, the applications are extended to number of areas like target mapping, formatting and annotating with layers and target highlighting. Many tools are also being marketed under Geoanalytics by many vendors.

Computer Vision with Geoanalytics gives an opportunity to develop models required to be automated and interpreted computer. This paper deals with advantages in geospatial applications for Computer interpretable models with Computer Vision and Geoanalytics.

Start-up and Innovative Geospatial Technology

Drone Image Derived 3D Point cloud for Infrastructural Change Monitoring in North Eastern Region

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The north eastern region of India is undergoing major infrastructural development projects towards increasing sustainable developmental goals. But the positive impacts of these projects can be difficult to verify with the traditional way of monitoring and evaluation methods specially when the projects interventions areas falls in the difficult and inaccessible terrain areas of the region. Visiting individual project sites and doing in-situ examination will be costly. The newer areas in the data acquisitions methods using multi-pronged approach and their analysis using latest web and geospatial technologies can make a quick and quantifiable change monitoring of the projects. There has been increase use of drone for large scale mapping and monitoring activities. Drones can be deployed for mapping of inaccessible terrains with complex environmental conditions that prevails in the areas of North Eastern Region. The images captured by drones and its corresponding 3D models are critical in tracking and regular monitoring of large scale Infrastructure based projects in the region. Further visualization of such 3D physical models of the area with analytical tools will enhance in overall decision making process. In such scenarios, drones can be deployed for 3D mapping of the area periodically and reconstruct 3D scenes of the project sites. Computer vision tools and algorithms can be used to reconstruct cost effective, yet high quality 3D point clouds from the drone 2D images. These 3D Point clouds can then be compare to perform structural change assessments and therefore track changes in the surface features. In this paper, we are trying to assess the benefits of drone mapping and its products for infrastructure monitoring. A process pipeline has been developed to reconstruct the 3D point cloud, compare the geometric parameters of 3D point clouds derived from Structure from Motion to highlight the change and a framework for interactive point cloud visualization, analysis for management and monitoring of project.

IoT Sensors in Agriculture

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The Internet of Things (IoT) is an emerging technology trend with potential uses in virtually every industry. When devices are linked to the web and to one another, they boost the intelligence of the entire network. We've integrated IoT into every facet of society, from urban planning to private residences to commercial enterprises. As the world's population is expected to reach a peak of 9.6 billion by 2050, the agriculture industry will need to supply at an even faster rate, making the use of IoT in agriculture and farming practices a necessity. The Internet of Things (IoT) and other cutting-edge technologies make this a reality today. With the help of the Internet of Things, farms can function without human labor. It can be used in livestock management, greenhouse agriculture, farm administration, and other areas beyond the primary ones. Sensors are the backbone of the Internet of Things (IoT), as they are the devices responsible for gathering the vast majority of the data that is then analyzed in order to produce the desired results. Sensors are commonly employed in the agricultural sector to collect data on nutrient, phosphorus, and potassium (NPK) levels, as well as disease and soil moisture. Its potential in agricultural settings is investigated here. Precision agriculture, a form of smart farming, gets its name from the fact that it relies on very specific data to make decisions. It demonstrates the various sensors used to aid the Internet of Things and agriculture, as well as their applications, challenges, advantages, and disadvantages. Keywords: Agriculture, IoT technology, Precision, Sensors, Analysis

The interactive map-comparing web framework for cloud-based web-map services

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The development of cloud-based large data processing, generation of geospatial data from multiple platforms and availability of canvas-based web technology on edge devices has resulted in the multi-source map availability to a geospatial data user. The cloud-based dynamic web-map service provider delivers a web-map consumed by a web client executing on a web browser to such users. One of the long-term research challenges identified under the of big geospatial data processing and handling is meeting the expectation of interactive tools of representation for cartographic visualisation, which can evaluate spatial data in runtime. The tool should provide easy access to multi-scale data on the same platform. It should also allow the end user to choose the map to fulfil one's needs based on the principle of "deems to be suitable for purpose". Currently, available tools such as swapping or flickering tools require focused visual comparison of the maps layer. The functionality of the such tool is minimal. However, the end-users should have a tool to ascertain the quality of a map on the "Measurable Value" based on spatial information differences observed on a larger spatial extent. The measurable value is not provided by any of the currently available layer comparing tools. The current work highlights the development of a web-map comparison library which can interactively assess the difference in spatial information of diverse map service providers. The currently developed generic framework integrates image-based methods to extract the difference in the spatial information present on various map providers' platforms. The image-based comparison techniques include pixel-based or object-based. It can highlight the difference in map content using the colour similarity measures to the map user as part of the geospatial analytical platform. The current work implements the inexpensive java scripts-based library, which the web map visualisation client can execute on a web browser. The colour-based similarity-based measures have been implemented, highlighting the differences observed in different cloud-based maps. The framework has been tested on the Openlayer-3-based map visualisation platform. The computation framework tries to confront the one of the basic needs of building the web-map comparing analytical tool for providing the overview of differences in map contents. It can also highlight various temporal patterns for map service delivering the product like NDVI as part of interactive web map data visualisation. Such tool can be helpful to the various map user who would like to have the quick analytical overview of various map.

Impact of Urbanization and Vehicular Traffic in hilly town and implementation of Urban Green Space using geospatial techniques.

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According to the United Nations, the expanding urban population accounted for 55% in 2018 and is expected to rise to 68% by 2050. One of the many consequences of urbanization is the expansion of cities into rural areas, which leads to the transformation of lands from natural surfaces to developed surfaces, and an increase in impervious surfaces, such as stone, concrete, asphalt, metal, and other materials with a tendency to trap heat and overheat, that release heat more quickly. The condition of urban ecosystems affects human well-being and how cities impact their surroundings. As a result, significant changes in the urban climate may occur. Research has shown that cities are almost always warmer than their surroundings, and the phenomenon is known as the **Urban Heat Island (UHI)**.

Temperature-related studies are critical in the current global warming scenario, where air temperatures in urban areas are also rising due to global warming. One of the reasons for creating UHI is the transformation of natural permeable surfaces into impermeable surfaces, which is often the cause of urban outdoor thermal discomfort. UHI effects are co-created by the anthropogenic heat generated by vehicular traffic, industry, and domestic and other buildings (e.g., winter heating, air conditioning in summer), urban geometries (e.g., reduced convection), and other factors]. One of the urban design elements that positively modify the urban microclimate is **Urban Green Spaces (UGS)**.

Urban green space (UGS), composed mainly of vegetation, such as grasslands, forests, and green belts, is considered a practical approach to mitigate the UHI effects. It is because UGS can affect humidity and albedo of the land surface, which leads to reduced LST, found that UGS has a significantly negative correction with LSTin summer. Furthermore, configuration (e.g., shape, aggregation, and connectivity) ofUGS is emphasized as another key factor thatcan also influence LST. Generally, the more complex the shape of UGS, the better the cooling effect. It is found that UGS has a significantly negative correction with LSTin summer. Furthermore, the configuration (e.g., shape, aggregation and connectivity) ofUGS is emphasized as another key factor that can also influence LST. Generally, the more complex the shape of UGS, the better the cooling effect.

The city of Dehradun has been selected for a detailed investigation. The various aspects of land use change, and hydro-meteorological parameters need to be assessed and correlated to identify suitable spots for Urban Green Space to mitigate the effects of LST. Further, the impact of vehicular traffic is to be considered as it adds significantly to the rise in temperature and causes changes to climatic condition. An alarming increase in vehicle traffic has been observed in the city after the growth in population, urbanization, and industrialization process. A growth of about 362% was registered in the registration of vehicles in the last decade. A significant rise is also noticed in the number of vehicles elsewhere but plying on the roads of Dehradun city and emitting a massive amount of heavier particles, hydrocarbons, NOx, carbon trioxide (CO_3), CO_2 (CO_2), etc. The city's Suspended particulate (SPM) concentration exceeds the National Ambient Air Quality Standards. Also there is raise in temperature in the city last three decades. During 2003–2005, the extent of SPM increased from 250 to 400 μg/m3 in the city due to recent multiplying population growth, urbanization, and industrialization. Studies carried out earlier by the authors' show that during the last 2 decades, there is a 200% rise in urban area and that there has been considerable conversion of fallow land into urban area the conversion rate was 28.187% from 1998 to 2008 and 49.205% from 2008 to 2018.

This study will provide scientific guidance to urban planners on how to mitigate the UHI effects among different urban blocks through the rational allocation of UGS, especially in hilly cities, where wanton and rapid urbanisation is taking place.

Assessment of geospatial risk associated with property management in India

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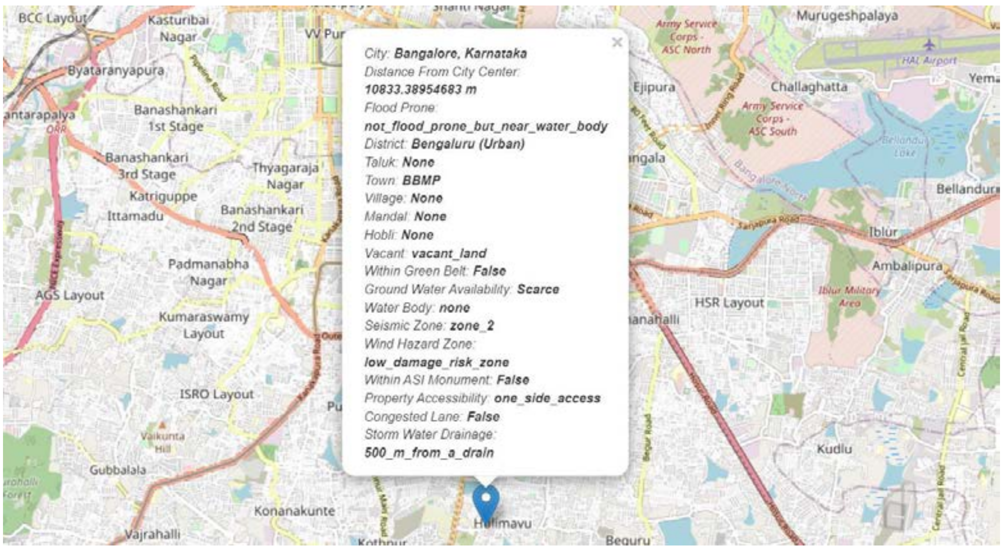
Given that India's home loan market is expected to double in the next 5 years [1], the significance of identifying property risk at scale becomes high. Encroachment of water drains [2] or lake beds, flood risk and water availability among others are important signals of risky properties for early detection by loan crediting agencies. To discourage property development in such locations, early detection is required such that the borrowers/creditors/insurers are informed about the risk associated with such investments. One one end, the borrowers are at the risk of action from creditors for default due to property damage from preventable causes like flooding. On the other end, they are at the risk of municipal authorities razing down the properties if they are built illegally or getting trapped for bribes by people hiding or distorting facts. On top of that, the highest amount of loan defaults are also seen in semi-urban and rural borrowers making the issue sensitive [3].

In order to provide a response to this need, an application programming interface (API)-driven solution for quantifying geo-spatial risk named GeoRisk is presented for looking at properties spanning a large area of interest. Apart from the risk factors like water availability mentioned before, our algorithms are also detecting property accessibility, road width, administrative level, seismic zone, cyclone hazard, proximity to Archaeological Survey of India monuments and green zone status of any property in the area of interest. The algorithms are demonstrated to work with known public/open datasets and sample solutions are provided for verification. We are using open source tools such as Shapely and Django that help us write the required geospatial algorithms which helps us identifying and operating between a lot of layers of data. These algorithms take care of doing the spatial operations of overlapping, distance matrix, and all other requirements. A sample API response for a randomly chosen property point is shown in Figure 1.

Figure 1 Sample API response over a property of interest



Considering the momentum of growth of geospatial technologies in the recent times, more data is being made available by the Indian government, organizations and individuals from this sector. As a pre-requisite, we have also worked on generating the required data using the raw datasets from the above mentioned sources. These datasets are generated by using algorithms and geo-processing tools such as interpolation, change-detection, raster-vector conversions, spatial cropping, land use classification, and precise geospatial intersections. All of which were achieved by using open source tools. For example, the difference in lake bed water body over a period of two decades can be used to identify areas where encroachment can be checked. Satellite imagery datasets separate from the above-mentioned are also available to be used for further insights being available. The datasets the cover Karnataka, Kerala, Andhra Pradesh, Telangana, Tamil Nadu, Maharashtra and Gujarat. The rest of India is planned to be integrated into the GeoRisk API very soon.

An interactive interface to test and visualize the solution is also provided for checking testing the validity of responses over areas of interest. The user interface can be accessed through a browser making it compatible with Android, Mac, Windows, or any other Operating System.

Edge Computing for Remote Sensing Satellites: Bringing Innovative Technologies to Space

Adithya Kothandhapani1, Vishesh Vatsal2

Affiliation: SkyServe (Hyspace Technologies Pvt Ltd)3

Several countries are now starting their own remote sensing programs, and there is an explosion in commercial Earth Observation constellations - each proposing to add exabytes of new data to existing petabytes of un-used data from existing and historical remote sensing programs. These recent developments will lead to a runaway scenario where the amount of data collected will quickly exceed the data that can be actioned upon. It is the need of the hour to make the data collection process smarter and process the data in a way that does not penalize the users due to inefficiencies in the collection process.

Coming to the present, market intelligence says that despite several commercial satellite companies offering tasking capability for their assets in orbit, around 40% of tasking requests are unfulfilled. These are willing customers who have been refunded their payments because their requirements could not be met. Digging deeper, some of the reasons for non-fulfillment are: (a) prioritization of a higher-value tasking request on a constrained uplink/downlink budget, (b) open-loop image acquisition process that can be verified against requirements only on ground, (c) constrained onboard storage that prohibits optimistic imaging of targets that have been forecasted to be cloudy.

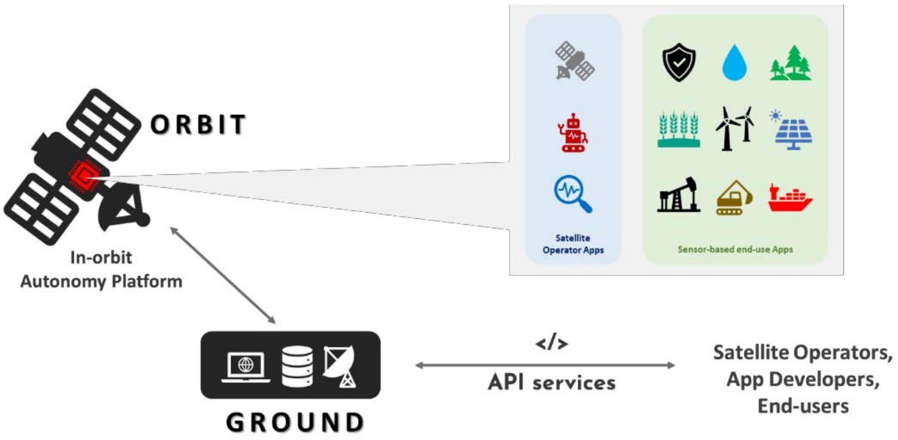


Figure 1: Overview of the platform and services rendered by SkyServe

SkyServe has developed key technologies and a commercial solution to close the current gap in supply as well as make the industry ready for the upcoming challenges of tomorrow. Leveraging the advances in edge-computing, which has helped resolve communication bandwidth bottlenecks for Internet-of- Things (IoT) projects, SkyServe is set to demonstrate in-situ processing of satellite sensor data, i.e., on the satellites themselves. While the solution itself has technically challenging aspects, it has multi-fold benefits to all stakeholders in the Remote Sensing domain. (a) Satellite operators can reduce ground station time, increase the revenue per orbit, use lower bandwidth communication systems, manage satellite constellations with a smaller operations team and penetrate new markets that include non- experts. (b) Geospatial analytics teams can reduce their data purchase expenses, reduce data preparation or pre-processing overheads, and offer responsive solutions that are closely integrated to the sensing systems. (c) Expert end-users who know exactly what they need in terms of specific bands, pixel regions of interest and frequency of observation will pay only for what they need – if and only if it meets their requirements (cloud-free pixels). Lastly, (d) non-expert end-users who need to integrate quantitative insights from within a region of their interest into larger systems can select from a list of application outputs (e.g., pest infestation finder, water body detector) and receive the edge-computed results without having to process any sensor data.

The technology required to provide a service such as that being built by SkyServe is not completely but is certainly not commonplace in the space industry. Commercial off-the-shelf (COTS) high throughput processing systems capable of upwards of 1TFLOPS consuming electrical power that can be supported by most small satellites are based on processes with 10nm or smaller feature sizes. These advanced components are generally vulnerable to the effects of the space environment but are increasingly being built to withstand extremes in mechanical loads as well as designed to work reliably through a wide range of temperatures. By making careful design, manufacturing, and packaging choices, SkyServe has produced Orbital Edge Processor, a space-ready versions of COTS data processing systems with in-built Graphics Processing Unit (GPU) acceleration capability for highly specialized Artificial Intelligence, Machine Learning, and parallel computing requirements.

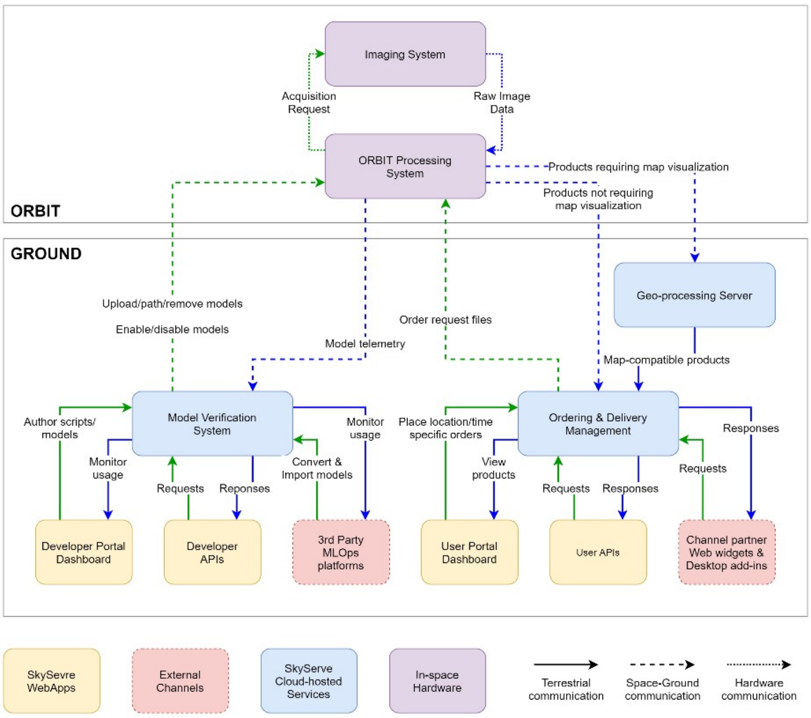


Figure 2: Concept of Operations for the SkyServe system that manages ORBIT and GROUND segments

Hardware is only the enabler. Actual disruption comes with SkyServe's software both on the satellite and on the ground. Providing the tools and services needed by both expert users and non-experts to fulfill their requirements with regards to satellite sensor data is the key to making both the technical and commercial ends of the solution to work. By bringing in subject matter experts to import their algorithms and models that cater to specific industries, an automatic quality checking cycle is set up as preference is given to applications that already have paying customers. End-users on the platform can either order insights from these industry-specific Applications, or request for image products which leverage SkyServe's in-house utilities, such as (a) cloud and cloud shadow segmentation, (b) atmospheric correction, (c) area of interest extraction, (d) geo-referencing and (e) smart discard – which work together to deliver the most cost-efficient products.

Figure 2 illustrates how developers of Applications and consumers of Insights interact with the SkyServe platform. The platform itself is composed of:

a. GROUND system, which is a combination of cloud and web-hosted technologies that interface with users (developers and consumers combined)
b. ORBIT system, which is an edge-computer capable of producing image data products at different levels of processing from raw multispectral satellite imagery and can run custom algorithms and AI/ML models on these images to extract actionable insights.

Through GROUND, one can access the platform as either a Developer or a User:

a. Developers are specialists/subject-matter experts that author algorithms and AI/ML models that ingest raster data and produce derived raster products, vector outputs and other intelligence while catering to a specific user-industry. Developers can access functionalities through:
    i. Developer Portal - a web-based GUI to develop and submit code and models for custom Applications, monitor the verification process and access usage statistics when the Applications are deployed to ORBIT
    ii. Application Programming Interfaces (APIs) - mechanisms for developers to integrate SkyServe's Application submission, monitoring and verification services into their own products
    iii. 3rd party model conversion services - developers on existing MLOps and GIS platforms can publish their models for automated conversion to supported model formats for eventual deployment to ORBIT
b. Verified Applications are deployed to satellites hosting ORBIT units onboard. Developers can deploy, patch/modify as well as clear Applications from ORBIT on the fly. A deployed Application can also be enabled/disabled from use if required. Developers can monitor the performance of the Applications to schedule improvements, as well monitor usage statistics that helps understand their revenues (if being used to provide a commercial service).
c. Users are those that consume data products and insights from the platform through:
    i. User Portal - a web-based GUI to order and receive from a list image products and insights for a specified location, date range and monitoring frequency
    ii. APIs - mechanisms for SMEs and enterprises to integrate (ordering of)

insights into their product or workflow

iii. 3rd party web and desktop GIS software - proposed interface for ESRI's users to order, receive and visualize image products and insights on ArcGIS Online

d. Once an order is placed on the platform through any one of the paths, a schedule for the satellite is generated so that it images the area specified within the specified period, passes the raw data to ORBIT where it is checked for usefulness (e.g., coverage, cloud cover) and put through a processing pipeline. Based on the requirement specified in the order, further processing is done using one of the SkyServe or Developer published Applications and the resulting data is compressed and encrypted before being transmitted to the User. If a more advanced image product is requested, the transmitted data is re-processed using DEMs, additional GCPs etc. on the cloud before delivery to the User.

Application of Advance Geospatial Techniques and Cloud Computing Methodology in Characterization of Braided River Morphology

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The morphology of a large braided river like Brahmaputra highly depends on its energy expenditure mechanism during the flooding events. In this study, we have considered the in-stream vegetation as a filter and try to understand how it controls the morphological processes in the river. Moreover, this study attempts to conceptualize the possibility of hierarchical (or overlapped) dissipation of energy. The spatiotemporal vegetation dynamics has been obtained through the high-resolution satellite imageries processed in Google Earth Engine (GEE) cloud computing platform. In addition, field observations were conducted and included in the analysis to improve understanding of the river's ecosystem. To estimate the area of sand-bars and vegetation cover dynamics, both Modified Normalized Differenced Water Index (MNDWI) and Normalised Differenced Vegetation Index (NDVI) were used. Numerous geomorphic stages have been observed as a result of the braided belt alteration, and a significant amount of energy have been dissipated through this process. Bar assemblages and confluence-bifurcation nodes also dissipate the energy and signal the mega-channel form and channel-in-channel physiography. As a final component, vegetation acts as a filter for the system, and its bio-morphological properties helps in stabilizing the geomorphic units. This study can be utilized to develop a nature-based solution to monitor the river health.

Climate Risk and Climate Resilience

Geospatial Technology & Artificial Intelligence Based Alert System for Predicting Vulnerabilities Due to Climate Change Triggered Hazard

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The primary objective of the present work is to propose a technology based alert system that would cater to understand the vulnerabilities caused by hazards triggered through Climate Change in the study area and propose an Artificial Intelligence based model for live prediction of climate change hazards based on the depicted vulnerability. The scope of the research is to carry out accurate delineation of the vulnerable areas and categorize them based on degree of vulnerability and to link them with threshold values of triggering factors within the selected study area. In order to achieve this objective, different geo-statistical techniques have been employed on ArcGIS platform to determine the impacts of various causative spatial parameters. The hazards considered are mostly landslides, mudslides, and flash floods etc. that are triggered by climate change cloud burst. The governing parameters considered in the present investigation comprise various soil parameters such as soil depth, stoniness, hydraulic conductivity, soil drainage characteristics, soil erosion characteristics, surface texture and depth texture in addition to lithology, foliation, slope, drainage network, road network with land use and land cover pattern. Thirteen different geo-statistical techniques have been employed in order to assess the vulnerability of the different land parcels of the study area based on the Landslide Information Value (LSIV) computed for each land parcel. The percentage of vulnerability that is computed as the percentage of area falling in higher three vulnerability zones and the landslide density computed for each vulnerability zone are also considered as potential indicators. Finally a Geo-spatial Technology and Artificial Intelligence based model is proposed by linking the databases server, application server and all the connected automatic weather stations.

Are there monthly anomalies in Landsat derived Land Surface Temperature? A comparison between three cities in India

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[1] Wildlife Institute of India, Dehradun

One of the negative impacts of urbanisation and poor urban policies is Urban Heating leading to the Urban Heat Island (UHI) phenomenon. This phenomenon is seen as the difference in temperature between urban areas and surrounding non-urban areas, and was first termed as UHI effect by Manley (1958). It occurs as a result of increasing Land Surface Temperature (LST) due to loss of vegetated land cover and increase in impervious low albedo building materials. Therefore, it is essential to study the spatial variations of Land Surface Temperature and identify the Urban Heat Islands, this will enable implementation of suitable mitigation plan and adaptive measures in the field of urban planning and urban ecology. Studies on UHI phenomenon uses satellite derived surface temperature, measured by using LST derived from thermal bands of satellite data. Sensors like Landsat series provide spatial and temporal resolution for calculation of LST and UHIs.

The present research work is an attempt to study and report the anomalies in Land Surface Temperature variations in three Indian cities, with different climates-Dehradun, Uttarakhand where the climate is mostly temperate, Bhopal, Madhya Pradesh with subtropical climate and Kochi, Kerala where the climate is tropical. We used thermal infrared (TIR) data and NDVI values derived from Landsat 8 to calculate LST. The Land Surface Temperature values were calculated using split window algorithm for a time period from January 2013 to September, 2022. For the 3 cities, 520 different cloud free images were used and monthly average NDVI and LST values were generated. We have also identified Urban Heat Islands in the three cities for March 2022.

Our results revealed that the Urban Heat Island Effect is quite prominent in the three cities, thus making LST an important aspect for urban ecology. Under normal conditions, the lowest temperature is expected to be in the month of December-January. However, our results shows that abruptly low temperatures are recorded in the month of July-August. Some major questions that arise from the findings and which needs to be addressed are – what is the cause of these anomalies? Are these variations due to the TIR bands of NDVI values derived from Landsat data? And whether accurate annual mean LST can be calculated from Landsat derived data?

As supported by our finding, the anomalies in LST exists because it is calculated using NDVI. During monsoon period and immediately after it, the vigour of the vegetation is expected to be high, therefore the NDVI values should be close to 1. However, high cloud cover and moisture content in the atmosphere during this period interferes and leads to anomalies and abrupt NDVI values. Such errors have not been reported earlier. It is important to take into account that monthly anomalies exist in satellite data derived indices and LST values, and the time period could vary depending on regional climate conditions.

Spatiotemporal variability of extreme temperature indices and its relation with forest fire incidences over different Biogeographic Zones of India

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Forest fires in India cause huge monetary damage which are caused mostly by anthropogenic activities, but the changing climatic variables are worsening these events by increasing its frequency, intensity, and duration. Temperature is an important climatic factor that contributes both directly to forest fires and indirectly through controlling vegetation growth. The variables temperature and active fire points used in the study are derived from the satellite-based remote sensing method which helps to monitor the changes both spatially and temporally, a great advantage over the uneven distribution of meteorological stations in India. This creates a huge amount of data with fine spatial and temporal resolution that contributes to the climate information, crucial for backing climate change adaptation strategies bringing in climate resilience. In this study, spatiotemporal variations in Land Surface Temperature (LST) and their relationship with forest fires were examined in different Biogeographic Zones (BGZ) of India. Daily gridded (10*10 km) temperature data were analyzed for the forest fire season from 2017 to 2022. In India, fire seasons vary by region depending on local cultural practices from February - June. MODIS LST data was extracted from Google Earth Engine (GEE) through python API and active fire data was from NASA FIRMS VIIRS product and then forest masked. ArcGIS was also used for analysis and map making. The temperature indices considered are taken from the Expert Team on Climate Change Detection and Indices (ETCCDI). Correlation of the extreme temperature indices was done with the total forest fire counts in each BGZs. Time series analysis of the temperature indices and fire counts of each BGZ was done. Spatial and temporal variability of LST in the forest fire season was analyzed using the coefficient of variation (CV). The analysis showed that maximum forest fire counts occurred in the Deccan Plateau and it also witnessed a great spatiotemporal variability as shown in the Figure 1. March witnessed the highest number of forest fire incidents. Trans-Himalaya, Desert and Coastal zones are least affected by the extreme temperature change and also, they contain very less percentage of fire prone forests. The study concludes that the number of summer days affect fire frequency and severity of fires in most of the BGZs of India.

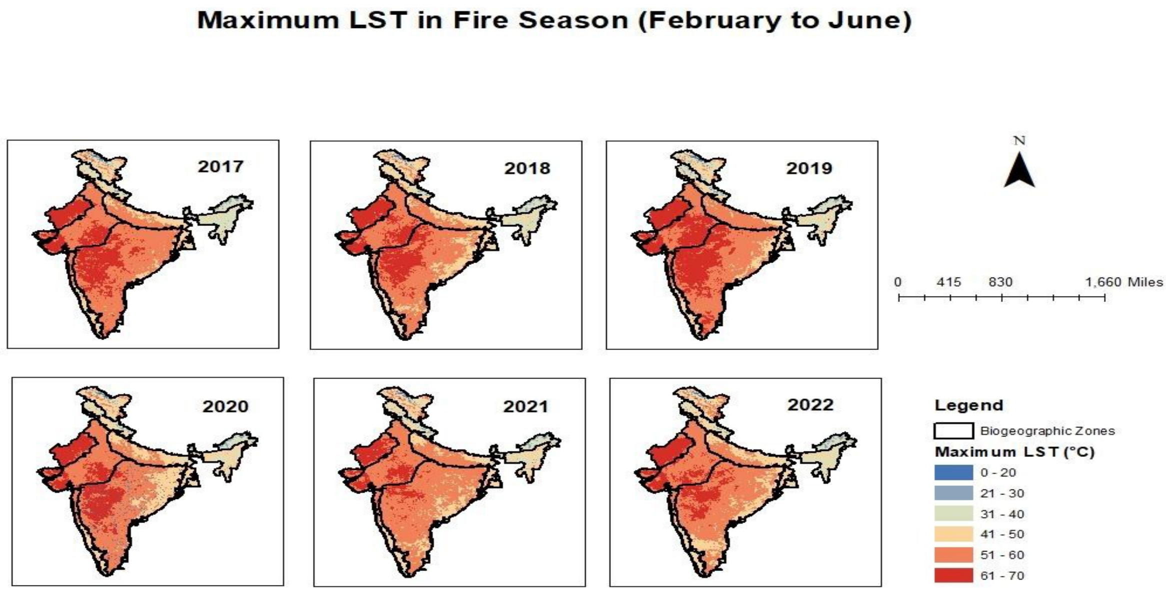

Figure 1: Spatiotemporal variation of maximum LST in Fire season in India.

Local and community based climate resilient adaptation programs – Government of Assam initiatives, a step towards India's net zero commitment by 2070

Smt. Laya Madduri, Dr. Jaideep Baruah and P.L.N. Raju
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Climate change impact is felt across India and world over with extreme weather events of rainfall, thunder storms, lightning, heat waves, severe drought conditions, shifting of seasons, etc. India's Prime Minister addressed 6th session of the Conference of Parties (COP26) on October 2, 2021 and committed towards climate response actions. India's cabinet approved (August 2022) updated Nationally Determined Contributions (NDC), to be communicated to the United Nations Framework Convention on Climate Change (UNFCCC), translating Prime Minister's 'Panchamrit' announced at COP-26 into enhanced climate targets, to reduce emissions intensity of its GDP by 45 percent by 2030 taking 2005 as basis levels, 50 percent cumulative electric power installed capacity from non fossil based energy resources by 2030, a step towards achieving India's long term goal of reaching net-zero by 2070 and PM's concept of mass movement for 'LIFE'– 'Lifestyle for Environment' as a key to combating climate change".

Assam state initiated many steps towards climate adaptation and resilient actions. The first step towards is setting up of a separate Climate Change Directorate under Science, Technology and Climate Change Department (STCCD) with cabinet approval in 2021. ASTEC (Assam Science Technology and Environment Council), AEDA (Assam Energy Development Agency) and ASSAC (Assam State Space Application Centre) under STCCD are playing important role towards climate resilient activities by creating awareness, conducting training programs, establishing eco-clubs at school level under National Green Corps, extending technical support in installing solar street lights, floating solar power plants and solar powered water pump for farmers, providing base geo-spatial data sets, developing mobile apps for geo-tags and maintaining dashboard etc. Assam is rich in natural resources and plentiful of rainfall. Tree plantation and increasing the tree cover inside and outside the forest area helps in carbon sink. Towards this the following initiatives are taken up:

Chief Minister's Institutional Plantation Program (CMIPP)

Plantation and natural regeneration of plants is the key to mitigate the climate change. AMRIT BRIKSHYA – CMIPP (Chief Minister's Institutional Plantation Programmes is launched by Assam on July 17, 2022 and continued till August 15, 2022 to coincide yearlong celebration of Azadi ka Amrut Mahostav. In a short time more than 2,44,726 saplings are planted in all office premises, including educational institutions under Govt. of Assam, autonomous organisations, panchayati raj institutions / ULBs. Total 2914 hectare area is planted with 63387 medicinal plants, 138023 fruit bearing, 37869 flower plants and 34969 landscape plants. The plan is to nurture for next three years, geo-tag using mobile app and monitoring the growth in the dashboard geo-portal, to achieve in tree cover, enhance carbon stock and save our environment and the overall goal of mitigating climate impact.

Chief Minister's Fellowship program for Climate Resilient Villages

A pilot initiative is taken up by Govt. of Assam, providing 100 no. of fellowship at PG/UG level in 100 most climate vulnerable villages of three to six months duration to carryout research, inventorying traditional practices of agriculture, biodiversity, water management / irrigation, etc. Mentors are also identified for ideation and guide research students of 50 groups of two each in assessing the climate change vulnerability and resilience of villages. They are expected to come out with scientific interventions to make the village's climate resilient. It is also proposed to take up capacity building activities towards climate resilient villages.

Realising the importance Assam Government is in the process of initiating agro-forestry in the degraded forest areas, community owned village Grazing Reserve (VGR) and Professional Grazing Reserve (PGR) land and individual farmers' land etc. It is expected to increase the farmers' income by 1.5 times and also help the government in increasing tree cover, carbon stock towards climate mitigation activities.

Assam government will adopt the India's updated NDC and will be implemented under different programs and schemes of Central Ministries with a target period till 2030, across many sectors including water, agriculture, forest, energy and enterprise, sustainable mobility and housing, waste management, circular economy and resource efficiency, etc. All these are India's initiatives at domestic level. However to achieve net zero needs huge funding from UN and other sources commitment from developed countries as they are hugely responsible in large carbon emissions.

Sustainable Development Goals

Geospatial Monitoring of Sustainable Development Goals (SDG) Indicators

Nitin Mishra, Kalyan Deep K, R.N. Anjani, Dr. S.S Rao, Dr. T. Ravishankar
NRSC, ISRO

All United Nations (UN) member states have pledged to fulfill 17 Sustainable Development Goals (SDG) for agenda 2030 which provide a shared blueprint for peace and prosperity for people and the planet (United Nations, 2015). These 17 SDG Goals are further categorized for 169 targets and approx. 230 Indicators for monitoring and reporting the progress. In part of Natural Resources Census programme of ISRO, Land Degradation(50K), Land use/ Land cover(LULC) 1:250K, LULC 1:50K and LULC 1:10K Nation-wide geospatial datasets have been generated using IRS sensors data and hosted in Bhuvan platform of ISRO for understanding the Indian landscape. These datasets are used for monitoring of SDG indicators 15.3.1 and 15.1.1 as preliminary assessment. These outputs can be value added further based on available geospatial datasets for improved assessment at sub indicators level based on defined methodology provided by custodian agencies. Generation of SDG Indicators using remote sensing and GIS datasets aids in the faster implementation for country wide SDG indicator assessment especially in India where surveying is very complex job because of diversity in culture & geography and huge population.

Village Level Impact Assessment of MGNREGA using Geospatial Tools: a Case Study

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Globally, rural redevelopment has been the priority of the nations. However, the success of these goals and targets would depend on developing the rural areas inhabiting most of the world's poor lives. The 2030 Agenda for Sustainable Development, with its ambitious 17 goals and 169 targets that came into force on January 1, 2016, aims to end poverty, protect the planet, and ensure prosperity for all. More resources would need to be allocated for investment in rural areas, not just because it is where most of the poor reside but also because these areas have great potential for economic development. Indian rural landscape comprising around 600,000 villages spread across its length and breadth against 500 odd cities offers immense challenges and opportunities for sustainable development. The government has been keen on providing an enabling environment for rural growth by emphasizing policy and legal reforms. The Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) is a legal and demand-driven framework mandated to provide guaranteed wage employment to every adult in a rural household by creating sustainable and productive assets directly impacting agriculture and allied activities. There are multiple studies on the positive impacts of poverty alleviation, women empowerment, and the socio-economic status of marginal populations. Spatially explicit studies highlighting the impacts on landscape rejuvenation in terms of enhanced vegetation and water resources are either lacking or limited. Geo-information technology provides a unique tool to study the landscape level changes resulting from the soil, water, and vegetation interventions encouraged and implemented under the MGNREGA. The current study is taken up in the Bandlapalle village of Anantapur District of Andhra Pradesh, India. The village is the first to roll out MGNREGA and a success story of changing into drought-proof from earlier drought-prone, prior to scheme implementation. We used geospatial inputs to map the spatial footprint of vegetation and water-related changes that, in turn, have led to additional agriculture and self-reliance in terms of water reliance in the study area. We studied the change in land use and land cover in the village using the latest Sentinel 2 satellite data and a survey of India's topo map as a baseline. Using the Google Earth Engine platform, we analyzed the multi-temporal multi-season moderate resolution Landsat satellite data covering the study area from 2006/7 till recently to derive Normalized Difference Vegetation Index (NDVI); Vegetation Condition Index (VCI); and Crop Index (CI). MODIS (MYD17A2H) satellite data was used to analyze the changes in Gross Primary Productivity (GPP). The Normalized Difference Water Index (NDWI) was used to map the impact on enhanced water retention. Results obtained show a significant increase in mean NDVI in all the seasons across the years, i.e., Rabi (0.65 - 0.79); Kharif (0.31-0.57); Zaid (0.15-0.27). The Mean Vegetation Condition Index also increased in all the seasons -Rabi (0.21- 0.59), Kharif (0.35 - 0.57) and Zaid (0.20 - 0.38). With no major change in the land use land cover, an increase of 16% in the agriculture area is witnessed in a triple crop increase from 84% in 2007 to 100% in 2021. The crop index value also improved from low to high in all the seasons from 2007-2021 with slight variation (may be due to scanty rainfall in 2019). In terms of water, the mean NDWI increased in Kharif (0.35 - 0.57) and Zaid (0.20 - 0.38) seasons except in Rabi (0.13 - 0.02). The Mean GPP also

increased in Rabi (94.94 - 184.25) and Kharif (227 - 218.25) from 2007-2021, with a decrease in 2019. The study thus demonstrates the indomitable utility of EO data-derived indices and geospatial analysis in the spatial mapping and quantitative assessment of the impacts of MGNREGA in a village landscape. The methods and parameters adopted in this study may be applicable for monitoring and evaluating all the villages implementing MGNREGA and reporting the impacts quantitatively, thus celebrating the success stories and replicating them in other villages for inclusive and suitable rural development across the country.

Challenges and Opportunities in Attaining SDG 14 A Review of India's Progress

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The seventeen Sustainable Development Goals (SDG) are designed to bring together developed and developing countries in forming a global partnership to achieve peace and prosperity for people and planet, now and into the future. “Life Below Water” is the 14th SDG and it focuses on the conservation and sustainable use of oceans, seas and marine resources for sustainable development. Based on current progress, India ranks 70th in the world for Life Below Water and is moderately improving in terms of its conservation efforts. At the same time, India is ranked 7th in the global climate risk. Global climate change being manifested as rising sea levels, increased ocean temperatures, storms and flooding puts the coastal and island communities of India increasingly at risk. Widespread conversion of coastal zones to other uses, despite the policies in place, has seriously reduced coastal protection making coastal states vulnerable to natural hazards. IPCC recognised that climate change acts as a threat multiplier to other drivers of poverty (2019). At a stage when India is actively developing its blue economy policy, climate change acts as a deterrent in sustainable ocean development. Coastal areas being a unique confluence of terrestrial and marine ecosystems, any activity undertaken there has a magnifying effect over them. Furthermore, goal 14 encompass the multidimensional aspects of ocean; the ecological, economic and social, which interconnects it with other SDGs and is closely linked to sustainable ocean development. It encompasses the production, regulation and provisioning component of the ocean. The delay in attainment of SDG 14 will endanger the attainment of other prominent SDGs like no poverty, good health well-being, clean water and sanitation, decent work and economic growth, reduced inequalities, sustainable cities and communities and life on land.

Unraveling the relationships between drivers of climate change vulnerability of forests in Nagaland

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Forests across the world stand at risk due to climate change. The Eastern Himalaya region (EHR) in particular is highly vulnerable as it is considered among â€˜biodiversity hotspotsâ€™, â€˜megadiverse countriesâ€™, â€˜global 200 ecoregionsâ€™. There are 25 ecoregions within the Eastern Himalayan region alone. Hence, vulnerability assessment of selected forest types of Nagaland to climate change was carried out through remote sensing using the IPCC framework of indicator-based vulenrability assessment. The present study attempts to understand the relationships between the indicators that drive the vulnerability of the selected forest types of Nagaland. The indicators are precipitation, temperature, Enhanced Vegetation Index, Net Primary Productivity, canopy height, soil moisture, topographical data such as slope and elevation, Palmer Drought Severity Index, species richness and Importance Value Index. The relationships are studied and visualized through spatial data and statistical methods such as linear regression on Google Earth Engine. The study provides a more clear picture of the indicators that drive the vulnerability status of the forests. Among the indicators considered in the study, the results showcase that precipitation and its related indicators are some of the main drivers contributing to high, medium or low vulnerability status of a forest type. Research in this field is of utmost importance as it will help in identification of drivers of climate change vulnerability in forests and thereby assist in directing the necessary resources and energy towards protecting the local, indegenous population from climate change related impacts.

Microwave Remote Sensing for Natural Resources and Disaster Management Services

Sentinel-1 SAR Interferometry for Land Cover Classification in a Shifting Cultivation Landscape of Tripura, Northeast India

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Shifting cultivation is characterized by rotation of cultivation and fallow in the same unit of land, which involves clearing certain patches of forests by slashing and burning, and thereon crops of the short span are cultivated followed by a long span of fallow period. This form of cultivation was sustainable in earlier times while there were enough forest areas available for the cultivators. Due to the increasing intensity of land use for this type of farming owing to population growth, shifting cultivation has gone beyond its sustainable capacity in many tropical regions. Therefore, even though this is the only farming activity of the ethnic minorities, shifting cultivation accounted for major deforestation and subsequent land degradation indicated by low fertility and accelerated soil erosion, resulting in reduced annual crop yields. Shifting cultivation, locally called 'Jhum', continues to be a dominant mode of food production in the hilly regions of Northeast India. It is the way of life of the indigenous communities and is closely integrated into their cultural identity, passed on from generation.

Due to the difficulty of terrain in mountainous regions, there are constraints in mapping shifting cultivation areas in Northeast India by conventional methods. Detection and mapping of shifting cultivation areas using geospatial technologies have proved effective through many studies across the globe. The majority of Northeast India shows the characteristics of a tropical climate, making this region hard to study using optical remote sensing data due to consistent cloud cover, which can last up to six months in a year. Hence, with the advent of active microwave sensors, Synthetic Aperture Radar (SAR), capable of acquiring data independently from daylight conditions and weather, can be an advantageous tool to map these vegetated areas. The launch of Sentinel-1 SAR satellites, which operate at C-band (5.405 GHz), enabled the availability of dense time-series data in dual-polarisation mode.

The present study was conducted in the Northeastern state of Tripura to evaluate the capability of SAR to detect shifting cultivation areas by integrating backscatter and interferometric coherence. A pair of Sentinel-1 SLC Interferometric Wide (IW) datasets were used for the dates 12 and 24 April, 2021 for this study to generate an Interferometric Landuse Image of the shifting cultivation landscape. The basic steps included the processing of the SLC images, co-registration of the images with sub-pixel accuracy, and InSAR (Interferometric SAR) coherence estimation. From the backscatter bands of both the images, average backscatter, and backscatter difference bands were produced. An RGB composite was generated using coherence image (red channel), average backscatter intensity (green channel), and backscatter intensity difference (blue channel), respectively, which produced an 'interferometric signature visualisation image' or Interferometric Landuse Image (ILU).

The datasets selected were from April, when usually the forest land is cleared for shifting cultivation and prepared for dibbling of seeds. The non-vegetated areas showed a bright tone in the coherence image, which indicated high coherence for the bare areas. The output was an image classifying the landscape into bare areas which are shifting cultivation clear-cuts, low canopy vegetation in shifting cultivation areas, and forest (Fig. 1). Shifting cultivation patches could be visualised from the bare and low canopy vegetation. This image was then compared with a Sentinel-2 optical image of the same time which confirmed that this method which uses interferometric coherence, average backscatter, and backscatter difference as composites, proved to be efficient in the detection of shifting cultivation patches. Therefore, it can be concluded that the C-band of Sentinel-1 has great potential in effectively detecting the shifting cultivation of tropical regions.

Polarization Signature based crop classification using L band Airborne SAR data

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The Polarimetric Synthetic Aperture Radar (PolSAR) has high potential for multi-crop discrimination based on scattering characteristics of various crop fields. While model-based decompositions followed by suitable classifier is usually employed to achieve the classification, newer approaches based on secondary indices, such as the Radar Vegetarion Index (RVI) etc., are also gaining in popularity. In this work we showcase an innovative methodology to achieve multi-crop classification using the information contained in the polarimetric signature of the targets. The polarimetric signature, established by vanZyl, is a characterization of the complete information a PolSAR imagery encompasses. This can be used to analyze the target without the need for any underlying simplifications or assumptions. We present an evaluation of the utilization of novel polarimetric parameters derived from the polarimetric signature (vanZyl type) and their value addition in comparison to the model-based polarimetric decompositions. The Polarimetric Signature (vanZyl et.al.) is generated by plotting the received power obtained at various combinations of transmit and receive polarizations (determined by the orientation angle and ellipticity of the respective polarization ellipses). The result is a three-dimensional surface with the x-axis representing orientation angle (Ïˆ), the y-axis representing ellipticity (Ï‡), and the z-axis representing the total backscatted power. Since there are two transmit and two receive polarizations to vary, we get a hyper surface in a 4-dimensional space which is hard to visualize. To simplify matters vanZyl proposed two signatures â€“ one where the transmit and receive are at orthogonal angles (Cross-Pol response), and another where transmit and receive are at the same angle (Co-Pol response) - generating two 3-dimensional surfaces. For non-stochastic targets, the samples of a given class have a similar signature pattern that we exploit for our analysis. Signatures are memory intensive and thus it is necessary to compress the information contained in them to relevant parameters that can be utilized for further analysis. To this end, the maximum power and the coordinates of the maximum power in the polarimetric signature (represented by a pair of angles (Ïˆm, Ï‡m)) are chosen for each Co- and Cross-polarization responses. These six parameters are henceforth referred to as the vanZyl parameters. The NISAR missionâ€™s L&S Airborne PolSAR dataset over Arkansas, USA, dated 17 July 2021, is used for the experiment. L-Band PolSAR data is used to generate Yamaguchi 4-component decomposition with desying operation (Y4R). Ground Truth has been acquired from Crop Data Layer of the year 2021 acquired from United Statesâ€™ Department of Agriculture and overlaid with Crop Calendar of the region at the same time of the year as the original dataset. Random Forest (RF) classifier is used as it has been shown to identify the best features that affect the identification of the class and produce a highly effective classification model for a vector of uncorrelated independent parameters. Number of estimators (individual trees) have been set to 100, as the results were optimum in this case. The RF classifier was run on the novel vanZyl parameters and a comparative quantitative analysis of accuracy has been carried out against the classification using the Y4R decomposition parameters and also against the combined use of both the parameters. The classifier has been trained on 7,67,410 pixels and tested using the sample size of 3,28,890 pixels. Eight classes to create regions of interest for training and testing namely, 0. Unclassified, 1. Water Body, 2. Woody Wetlands, 3. Urban, 4. Corn, 5. Rice, 6. Soybeans, 7. Cotton, 8. Roads. The classifications using RF was carried out for three cases - (1) The four Y4R decomposition parameters, (2) The six vanZyl polarimetric signature parameters and (3) The combined Y4R and vanZyl parameters. The overall accuracy (OA) of Y4R based classification scheme was 79.53% while the vanZyl parameters based framework achieved 85.50%. OA further increased to 92.26% when both the Y4R and vanZyl parameters were synergistically used, which is statistically significant. The Cohenâ€™s Kappa Score also improved from 0.74 (Y4R) to 0.81 (vanZyl) to 0.90 (combined), showcasing the role played by the novel parameters in bringing down the uncertainty in classification. We can see highest change in F1-score for Cotton which went from 0.5 in Y4R to 0.76 in vanZyl to 0.84 in Y4R and vanZyl parameters combined. Corn had an accuracy of 0.8, 0.84 and the F1-score of 0.85 and 0.86 for Y4R and vanZyl respectively; but combining them caused an increase in accuracy to 0.94 with F1-score of 0.95. For the â€˜Roadsâ€™ class vanZyl parameters reduced the F1-score to 0.59 from Y4Râ€™s 0.63, but when combined it has shown a considerable increase to 0.84. Rice fields were classified satisfactorily by all three methods, with the combined parameters giving accuracy of 100% and F1-Score of 1.0. Soybean fields were classified with an OA of 0.84 for Y4R, 0.92 for vanZyl and 0.94 for the combined case. In conclusion, the novel vanZyl parameters derived out of the polarimetric signature showed great promise in improving the classification accuracy of the multi-crop scenario done using established PolSAR techniques. In future work, more parameters shall be generated from the signature, which may further improve the target characterization and in turn result in better classification results as well. Also instead of a single maximum, there is scope for estimating multiple local maxima and their corresponding coordinates providing us with finer distinguishing power.

Classification of coastal mangroves using sentinel 2 data sharpened with Google Earth images

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About 3.4% of world’s mangroves have been lost in the past two decades due to various reasons including the damage caused by coastal developement and cultivation. In this study we compared the accuracy of classifying the Sentinel 2 multispectral data, RGB Google Earth Image and resolution merged/sharpened images of Sentinel 2 and Google Earth Images to map the coastal mangroves accurately for the study region of L-block Island of Sundarban, India. High-resolution RGB Google Earth (GE) Images at resolution 5m and 2m were downloaded, averaged and pan sharpened with Sentinel 2A bands of Green, Red, Near Infrared and Short Wave Infra-red (bands 11 & 12) having 20m resolution and GE images of 0.5m with Sentinel 2A bands of Blue, Green, Red and NIR having 10m resolution using weighted Brovey algorithm resulting into six data sets namely S2-20, S2-10, GEI(0.5), RM5, RM2, RM 0.5. Upon the implementation of maximum likelihood classification algorithm and estimation of the Overall Accuracy (OA) and Kappa coefficient (k) values ,RM 2 (OA: 98.5%,k=0.98) and RM5 (OA: 98.7%, k: 0.98) showed significant improvedment in accuracy when compared with the RM0.5(OA: 94.2%, k: 0.91) and GEI (OA: 92.5%, k: 0.87), S2-10m (OA: 87.5%, k: 0.86) and S2-20 (OA: 89.4%, k: 0.88). Resolution merged 2m and 5m were able to improve the classification coastal mangrove vegetation mainly due to presence of the SWIR bands coupled with these images.

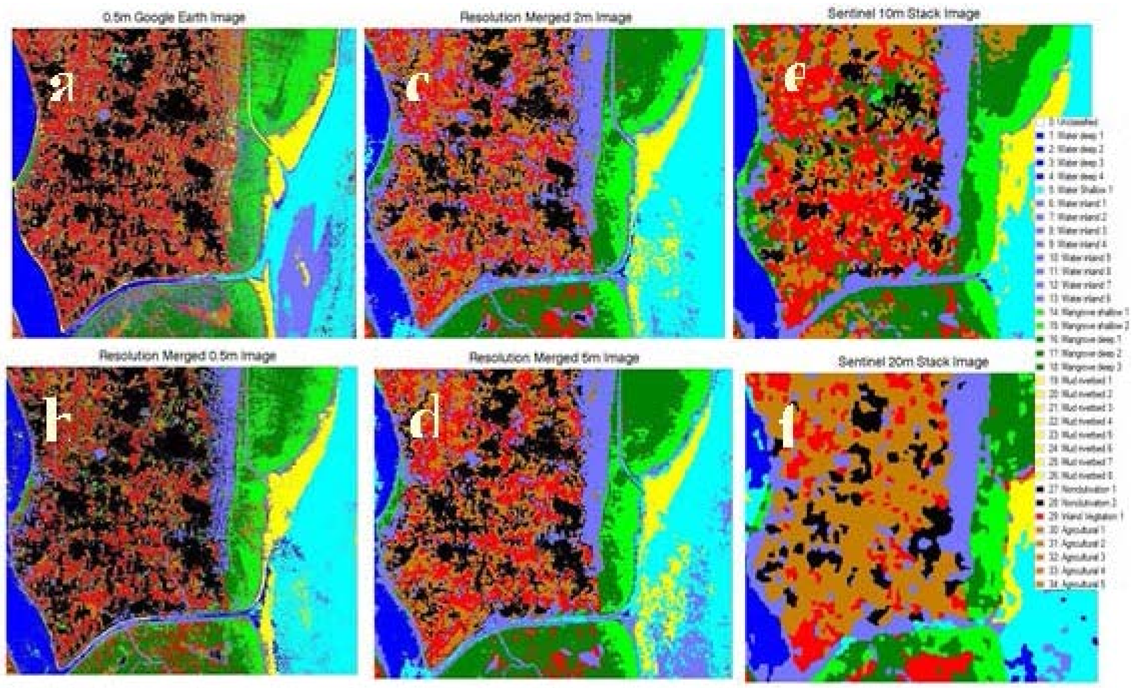

Fig 1 .Maximum likelihood classification output of different image set , (a) 0.5m Google earth Image, (b) Resolution merged 0.5m image, (c) Resolution merged 2m image ,(d) Resolution merged 5m image,(e) Sentinel 10m stacked image and (f) Sentinel20m Stacked image. The Legends are visualized on the right side

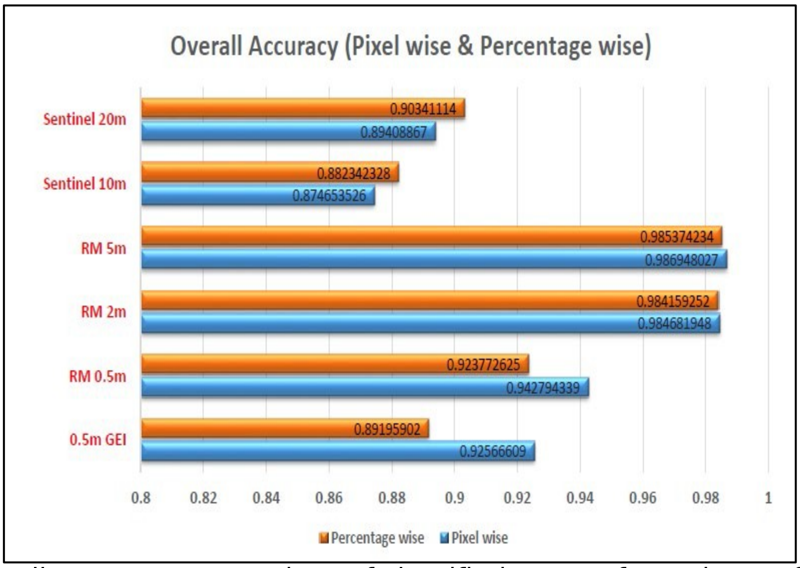

Chart 1. Overall accuracy comparison of classified rasters from the confusion matrix (pixel-wise and percentage-wise).

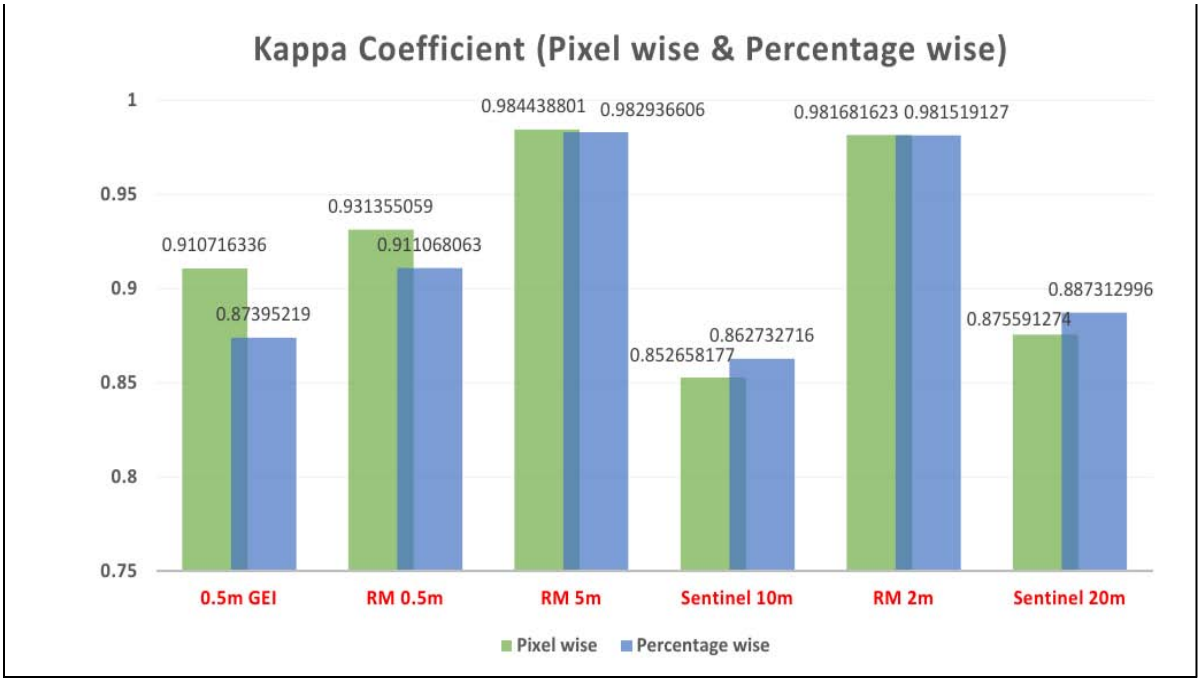

Chart 2. Kappa coefficient comparison of classified rasters from the confusion matrix (pixel-wise and percentage-wise).

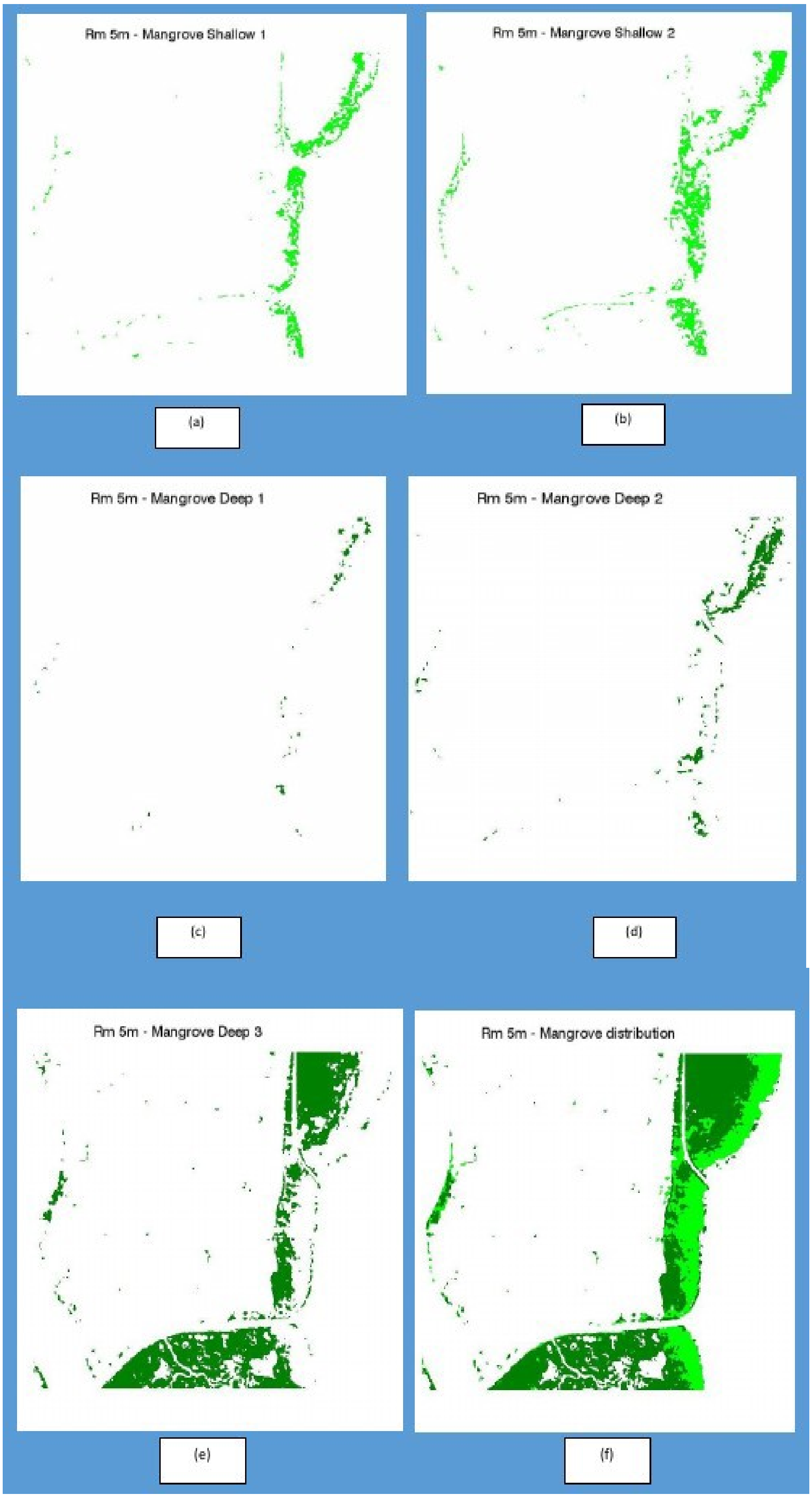

Figure 2. Coastal Mangrove spatial distribution of different classes of mangrove from RM 5m classification output. (a) Mangrove Shallow 1, (b) Mangrove Shallow 2, (c) Mangrove Deep 1, (d) Mangrove Deep 2, (e) Mangrove Deep 3, and (f) Total Mangrove distribution.

Debris flow volume estimation from UAV derived DEM

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Debris flow is a type of landslide that occur in rainy season when debris i.e. mixture of soil and rock saturated with water move down the slope in mountainous areas. The states of Kerala, Tamil Nadu and Karnataka have witnessed many such debris flows in the recent past. Nearly 7,000 landslides were identified during the monsoon of 2018, majority of them were debris flow and debris slides with entrainment along the channels. In 2019, the Puthumala and Kavalappara debris flows in Kerala combinedly resulted in 81 deaths. Further, in 2020, the Pettimudi landslide in Idukki district of Kerala killed around 70 people. These incidences make understanding and modeling of debris flows as the need of the hour.

One of the critical quantitative analysis parameters of debris flow modelling is the flow volume estimation. The debris flow magnitude can be defined by the total volume of material moved from the source area in upslope to the deposition area in downslope. Several methods exist to estimate the volume of debris flows (Gartner et al. 2008). These are commonly empirical estimation approaches and generally require a large amount of field data. On the other hand, a more precise technique of volume estimation can be done from the pre and post-event digital elevation model (if available) based on cut-and-fill assessment (Martha et al. 2010).

In recent times, very high resolution images from Unmanned Aerial Vehicles (UAV) were used to derive DEM using Structure From motion (SFM) technique. UAVs, equipped with optical cameras perform SFM photogrammetry, and have been applied to study landslides (Balek and Blahut 2017; Marek et al. 2015; Mateos et al. 2017; Rossi et al. 2016). The contribution of UAVs to study of landslides can have various applications: recognition, mapping, monitoring, and hazard analysis (Giordan et al. 2017).

The Puthumala landslide occurred around 17:00 hr on 8 August 2019, which buried a large area under debris. The total length of the Puthumala landslide flow from crown to end of the runout zone is ~2.9 km at a mean slope of 19.6˚. Joints, fractures, shallow rock and soil interface were observed near the crown of the landslide. At the runout and deposition, fragments of Granite Gneiss with yellowish brown soil deposited from detached rocks were observed. We have used pre and post-event DEM for the Puthumala landslide to estimate the landslide failure volumes. UAV data was acquired over the Puthumala landslide area on 22 March 2021. The resolution of the orthoimage of UAV is 8 cm and the grid size of the derived digital surface model (DSM) is 20 cm. The positional accuracy of the image is 1-2 m. For pre-event DTM, CartoDEM (2.5m) has been utilized.

As volume calculation must rely on the actual pre and post-landslide terrain surfaces, vegetation that may have covered the area before failure or possibly retained during the landslide must be corrected. In the area around the Puthumala landslide, dense vegetation cover with tall trees was observed. The height observed on the ground around the adjacent area of landslide, in conjunction with the size of the trees measured through the manual interpretation of orthorectified multispectral image acquired from UAV, was used to create a non-uniform vegetation-height surface. A total of 150 trees with a mean value of around 9m were used to create this non-uniform surface using interpolation. Thereafter, this surface was subtracted from the pre-failure DSM (CartoDEM) to create a vegetation-corrected DTM. As the trees were already uprooted during the landslide, vegetation correction for the post-event DSM was not needed. After vegetation correction, the volume of the Puthumala landslide was calculated by subtracting the post landslide DSM derived from UAV data from the prelandslideDTM, using the cut-and-fill operation in ArcGIS©. From the cut and fill analysis, it is seen that the estimated volume loss from the zone of depletion of the landslide is around ~9,00,000.0 m^3, whereas the volume gain in the zone of deposition is around ~ 15,80,000.0 m^3. The study demonstrates that UAV data can provide information about post-failure topographic changes. This can be used as input for estimating landslide volumes, as seen in the case of the Puthumala landslide.

Landslide detection using SAR amplitude data– Few case studies

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Plethora of solutions exist to detect and map landslides using Earth Observation (EO) data by visual interpretation of stereoscopic aerial photography and the semi-automatic or automatic classification of optical, monoscopic or stereoscopic imagery acquired by space, airborne, drone or terrestrial platforms. However, optical images have intrinsic limitations due to the cloud cover that is usually high during and after landslide events triggered by intense rainfall. Landslides mainly occur during the monsoon season in the Himalayas and Western Ghats mountainous regions. The unavailability of optical images due to cloud cover hampers the emergency response capacity for a landslide event. Synthetic Aperture Radar (SAR) amplitude images to detect landslides can mitigate the cloud coverage issue, since the SAR signal can image the ground surface day and night and in all weather conditions. The SAR antenna receives the returning signal (i.e., the “echo”) wherein strength of the echo depends on the properties of the scattering ground surface in relation to the radiation frequency (e.g., the dielectric constant, the terrain roughness), the distance between the antenna and the ground, and the satellite view angle. This is recorded in the “amplitude” of the electromagnetic wave. Currently, the use of SAR amplitude images for landslide recognition and mapping is not widespread. The acquisition geometry can affect the quality of the images over mountainous areas where landslides are likely to occur (Adriano et al., 2020; Mondini et al., 2021). Therefore very few examples exist on usage of airborne and satellite-based SAR data to detect, characterise, and map single landslides or single landslide events using ‘amplitude’ information of SAR data through quantitative parameters such as backscattering coefficients, entropy, pedestral height, and the Radar Vegetation Index (RVI) (Hung et al., 2002; Chigira et al., 2003, Oliver and Quegan, 2004;; Chen et al., 2006).

Under the disaster support management programme of ISRO, landslides have been identified as one of the natural disasters. Therefore at NRSC, damage assessment studies using post-landslide satellite images were carried out for several major landslide events in the past. Here, we present some recent examples of post-event landslide assessments using C, L, S and X band microwave data, broadly highlighting the advantage of one band over the other.

The incessant rainfall evoked a devastating landslide incidence on 06 Aug 2020 around 23:00 hrs at Pettimudi village near Munnar in Idukki District of Kerala. The hill slopes in this area have thick soil cover, which makes them prone to landslides after heavy rainfall (source: GSI). Post-event satellite image from TerraSAR-X (HH polarisation) was analysed for the affected region. Preliminary observations suggesteda large debris flow. The X band data appreciably identified the overall geometry of the landslide due to changes in surface roughness and moisture content of the landslide body.The path of flow and the zone of deposition was also identified. It is also seen that four houses are completely damaged by the landslide.

Similarly, another large landslide occurred near Tupul railway station in the Noney district of Manipur on 30 Jun 2022. The failure is rotational, and the crown is on an unstable slope near a fault line. The rock type is mostly sandstone and siltstone. RISAT 2BR2, X band data was acquired on 04 July 2022 over the affected area. Due to the range direction of the sensor, a part of the ridge line was geometrically distorted by radar shadow. However, the outline of the landslide and the zones of depletion and deposition were clearly seen in the imagery. The debris deposition on the downslope region was also seen clearly and river blockage can be identified.

The Puthumala landslide occurred around 17:00 hr on 8 August 2019, which buried a large area under debris. The total length of the Puthumala landslide flow from the crown to the end of the runout zone is ~2.9 km. Sentinel-1 C band microwave data were acquired over the affected region. Given the data's coarse range and azimuth resolution, standalone identification of the landslide was unsuccessful. However, the landslide body could be identified upon creating the difference image from pre and post event Sentinel-1 data. This was due to the change in backscatter properties of the landslide zone before and after the landslide event.

As a precursor to the upcoming NASA-ISRO Synthetic Aperture Radar Mission (NISAR), Dual frequency and left-looking L and S band Airborne SAR (ASAR) developed by ISRO was flown on 16 December 2019 in Gulfstream-GIII aircraft of AFRC, NASA. Data were acquired in centre frequencies at 3200 MHz (S-band) and 1250 MHz (L-band) with 40° look angle over the Rat Creek landslide on the California coast in the USA. The Rat Creek landslide occurred in the last week of January 2021 due to intense rainfall. Two co-polarised (HH, VV) bands and two cross-polarised (HV, VH) bands were acquired for both L and S band data. It is observed in the polarisation composites (RGB: HH-HV-VV) that the landslide affected area is mappable. However, due to the perpendicular look direction of the sensor with respect to the ridge line, the estimated backscatter coefficients were low.

From the above case studies, it can be inferred that landslides are seen due to changes in amplitude patterns in the X, L and S bands. The C band has not shown any clear signatures (more investigation is needed). Apriori information about landslide locations is required in all cases. Look direction is critical in landslide identification from SAR data. Slope Parallel look directions are best suited. Multi-band and multi-polarisation composites tend to enhance landslide geometry in an adequate look direction.

Comparison of ANN and XGBoost for landslide Susceptibility Assessment in Garhwal Himalayas

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The occurrence of landslides in various parts of the Himalayas is an everlasting perpetual phenomenon. However, an increase in their incidence and extent has been observed over time which seems to be induced by both natural as well as anthropogenic factors. Being part of the youngest folded mountains of the world, various ranges of the Himalayas have different composition materials leading to various levels of fragility. As a part of the developmental activities, road network is expanding rapidly into the hitherto remote areas but there seems to be a mismatch between the nature of mountainous terrain on one side and the quality of the technology and construction materials used on the other side. An increase in the number of landslides is observed during the monsoon season which cause frequent road blockades leading to disruption of transportation and communication in several parts of the region . Also, the security of the nation becomes a crucial issue many times because the roads leading to the international boarder along the Himalayan ranges get obstructed due to massive landslide. S Parkash (2019) concluded that the probability of landslide in Indian Himalayas is high to very high and it has the potential of causing significant loss of life, property and economy in the region. Thus, it is important to identify the areas susceptible to landslides and their probable impacts over space and time in order to monitor and avoid their catastrophic effects on nature and society. Numerous methodologies based on statistical and machine learning techniques incorporated with GIS have been applied for preparing landslide susceptibility map in various parts of the Himalayas. The present work attempts to compare the appropriateness of two advance machine learning techniques for assessing the landslide susceptibility in the Garhwal Himalaya part of the Uttarakhand state of India. The study is focussed on a section of the National Highway No. 58 connecting Gopeshwar to Mana village in Garhwal Himalayas (Fig.1). The study aims at testing the reliability of the results obtained through two relevant machine learning techniques for landslide susceptibility modelling. As a whole, Artificial Neural Network (ANN) has been applied in majority of landslide modelling studies but Extreme Gradient Boosting (XGBoost) technique has not been explored for landslide susceptibility map in Garhwal Himalayas. The Landslide Susceptibility analysis has been performed with the help of landslide inventories and 9 causative factors responsible for inducing the incidents. Landslide inventory was randomly divided into 2 parts i.e. 70% for training the models and 30% for validation of the results. Accuracy of the results assessed with the help of receiver operating characteristic curve (ROC) and area under curve (AUC) was found to be 83% for ANN and 89% for XGBoost. Present research found the robust technique of XGBoost more suitable for assessing landslide susceptibility in Garhwal Himalayas and this will be a used as prototype for future studies in the similar geographical regions. It is anticipated that this research will help administration, non-government organizations (NGO's), public-private development organizations and local residents to effectively manage the destructive impact

to identify risk areas and reduce damage caused. Furthermore, investigating for the type of landslide, cause of slope failure, extent and occurrence of the event can to be the scope of research.

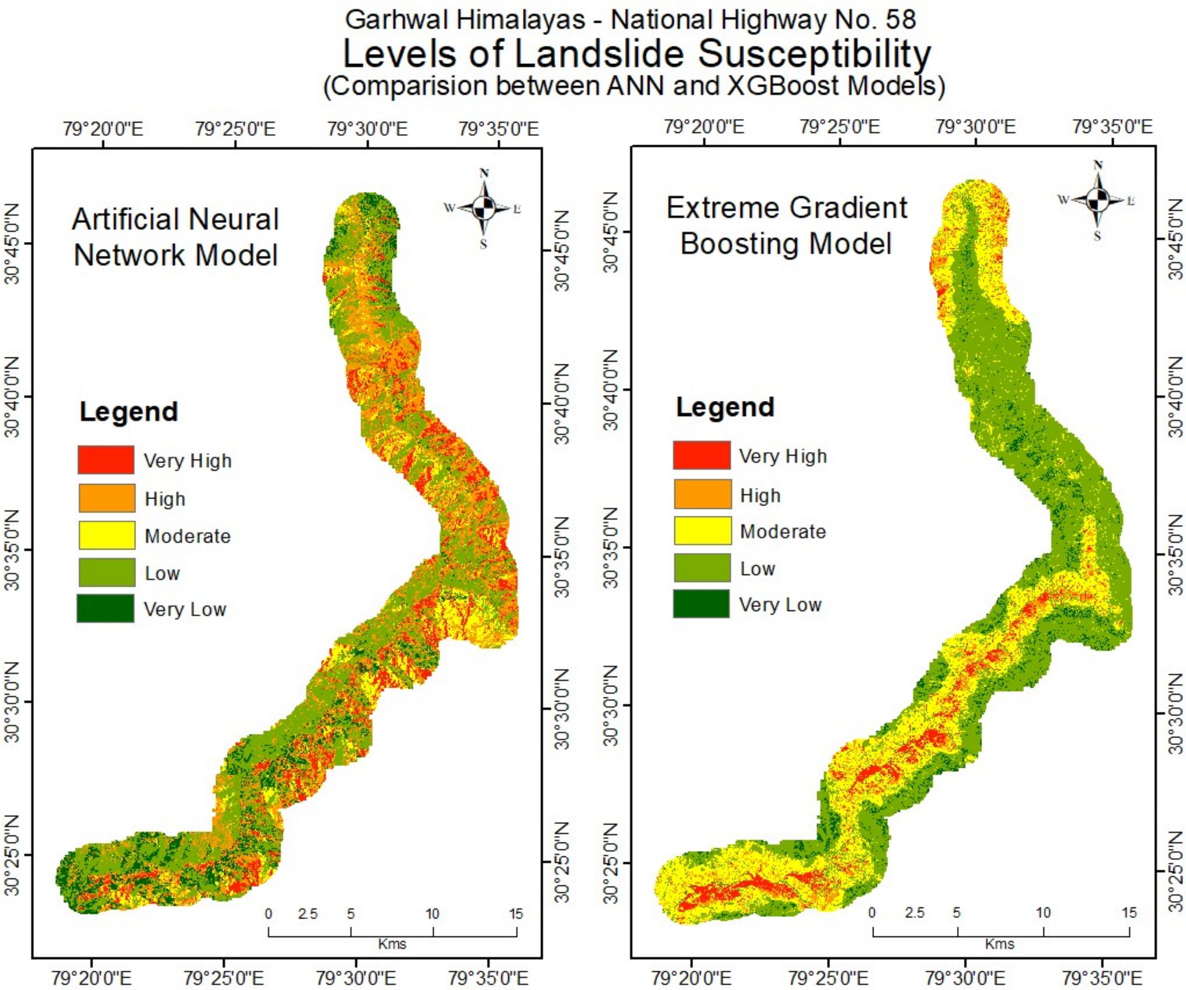

Fig.1: Levels of Landslide Susceptibility along N.H. 58 from Gopeshwar to Mana in Garhwal Himalayas – a comparison of ANN and XGBoost models

Connected Pixels Based Region Growing Algorithm for Water Extraction from EOS-04 Medium Resolution ScanSAR (MRS) Data

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National Remote Sensing Centre

The ability to identify and detect water bodies from SAR images in real time is critical for flood monitoring and water resource management. Traditional image classification methods are typically applied to large, open lakes and rivers, rarely focusing on complex areas such as urban water, and cannot automatically determine the classification threshold. These traditional pixel thresholding techniques tend to fail when applied over large regions because of their inability to account for the variations. Deep learning techniques are used recently, but these are usually computationally intensive and require large amounts of SAR datasets of various waterbody types, as well as heavy manual labelling work. Hence an automatic region growing approach for extracting water layer is ideal in these situations. In this article, the data from C-Band SAR data on-board EOS-04 was used for testing the proposed algorithm. The data from the sensor in MRS mode was used to generate high confidence and low confidence water pixels based on the backscatter. The high confidence pixels were modified by performing morphological erosion operations, filtering using slope layer and then used as seed pixels. Connected pixels approach was used for growing of water layer from seed pixels. In this approach, the seed pixels flow into their adjacent low confidence pixels and classify all the connected pixels as water. A classification accuracy of over 90% was achieved for the final water layer in most cases with kappa coefficient of 0.78. It is observed that this automated water extraction technique is better than traditional fixed thresholding approaches and can be applied in wide range of terrains with diverse inundation patterns.

Urban Flood Modelling Using PCSWMM and Geospatial Techniques: A case study of Hyderabad Metropolitan City

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Urban flooding is a major catastrophic event. Higher rainfall intensity in shorter duration, undersized drains, encroachments within the city and rapid urbanisation leading to lower rate of infiltration causes flooding. In this study, the zone 12 of Greater Hyderabad Municipal Corporation (GHMC), Telangana State, India has been take as the case study and the results obtained from simulation are reasonable good agreement with the observed data. The watershed has been delineated from DEM using PCSWMM simulation model. There are 388 sub-catchments, 289 conduits and 290 junctions have been extracted using ArcGIS software integrated with PCSWMM model. Drainage network cross section dimensions, percentage impervious of the sub-catchments and the curve number have been manually added in PCSWMM. The model was initially calibrated by using design storms later the recent flood event of 12th, 13th and 14th of October, 2020 has been assigned to the model, in which 9 rain gauges stations are created, each sub-catchment was assigned to its respective raingauge station with the help of thiessen polygons generated in Arc GIS and the integrated 1D-2D model was run for the October 2020 flood events. For validating the model, the observed flow data collected through the Ultrasonic Water level monitoring sensors installed at Begumpet Nala and also calculated the performance indicators such as coefficient of determination Nash Sutcliff Efficiency for model validation. It is observed from the simulated model results the waterlogged areas are identified in the few locations which could be caused due to poor drainage system and encroachment of urbanization and reduced the capacity of the drains.

Multi-frequency Backscatter characterization of flooded areas - A precursor study for NISAR mission

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Satellite remote sensing data, especially Synthetic Aperture Radar (SAR), has a high potential for mapping & monitoring floods in near-real time besides detection of water underneath the vegetation areas mainly because of its huge potential for acquisition of the Earth's surface independent of daylight and weather conditions. Many SAR missions like ERS, Radarsat-1&2, ALOS, TERRA SAR-X, SENTINEL-1 etc are successfully used for mapping flooded areas by many countries. The NASA-ISRO Synthetic Aperture Radar (NISAR) is a unique mission that will carry two instruments, the L-band SAR (24 cm wavelength) built by NASA and the S-band SAR (9 cm wavelength) built by ISRO and is scheduled to be launched in the 2023-24 time frame. With its global acquisition strategy, cloud- penetrating capability, high spatial resolution, and 12-day repeat pattern, NISAR will provide a reliable, spatially dense time series of SAR data which improves monitoring and assessment of the flood disaster and assist in response and recovery from natural disasters besides relief management. This paper discusses the characteristics of the backscatter response of the flooded waters in L, S and C-band SAR data from satellite data.

The analysis was carried out using the satellite SAR data for L-band (ALOS), S-band (NOVASAR) and C-band (RCM3) over Assam. The L, S & C-band intensity images were calibrated into sigmanought images using the incidence angle and gain offset values in the header file. Backscatter in the river water, flooded areas, and in the flooded vegetation were analysed using 10 Regions of Interest (ROIs) to obtain average dB values. The mean pixel values from each ROI were collated to obtain the representative mean pixel values.

Results

The backscatter of water is very sensitive to the frequency, polarization and incidence angle besides environmental parameters like canopy type, structure and density. Fig-1 shows the pre and post flood conditions in C-band. Smooth open water surface act as specular reflector and are therefore characterized by low backscatter (-30 to -45 dB) and appear as dark whereas land has a high backscatter (-5 to -15dB) and appear as bright. In the non-flooded condition, signal scattering is in the crown and on the ground.

In the flooded pockets where there is vegetation, L-band showed an increase of 2 to 3 db when compared to S-band due to increased penetration and due to strong double-bounce reflection between the tree trunks and the water surface. C-band showed low backscatter when compared to L and S-band (Fig-2). S-HH also revealed some penetration through the vegetation due to double-bounce scattering. C-HH revealed open flooded waters very well due to specular scattering. For a calm water body, C-HH was like a specular reflector and has a low backscatter between -30 to 40 dB when compared to L-HH and S-HH. However, for calm water, L-HH had a low backscatter when compared to S-HH which needs further in-depth study. S-band and C-band have a good potential in identifying the open flooded regions however they have intrinsic variations in the backscatter response.

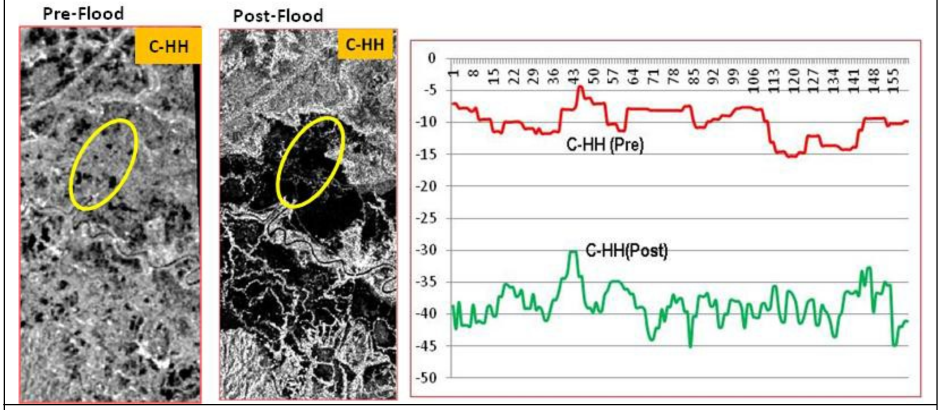

Fig-1. C-HH backscatter in pre and post flood condition

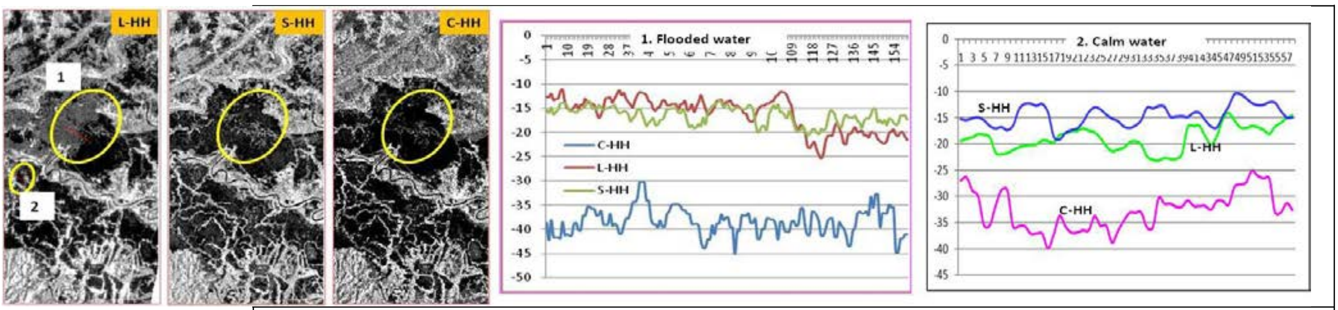

Fig-2. Backscatter response of flooded water and calm water in L,S & C -band

Estimation of slope movement by PSInSAR technique at Koteshwar reservoir area, India using Sentinel-1 dataset

Manoj Kuri
Engineering College Bikaner

The purpose of presented study was to investigate the practicality of Persistent Scatterer Interferometric Synthetic Aperture Radar (PSInSAR) technique, using radar imaging satellite Sentinel-1 dataset forthe estimation of movementat the slopes near Koteshwar dam and reservoir area. Koteshwar dam is located across the Bhagirathi River in Tehri district, Uttarakhand, India and is part of the Hydropower project of 400 MW capacity. Sentinel 1A dataset of 29 images acquired in Interferometric Wide Swath mode with HH polarization,is used for the PSInSAR processing. Mean Velocity map have been produced for the studyperiod of twenty months, from October 2015 to May 2017. At the dam site no displacement has been detected, but the reservoir slopes at few locations are identified as instable. PSInSAR results further revealed that there is substantial movement along the slopes of reservoir at few locations and maximum velocity is measured upto -60 mm/year in satellite Line of Sight (LoS) direction. Time series plots have been also generated for the selected locations, to determine the temporal behaviour of movement in satellite Line of Sight (LoS) direction. Keywords: PSInSAR, Slope movement, Sentinel-1

Flash flood simulation and inundation assessment in Song Watershed of Dun valley, Uttarakhand

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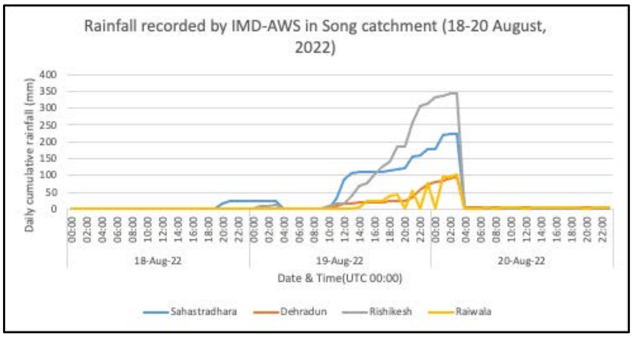
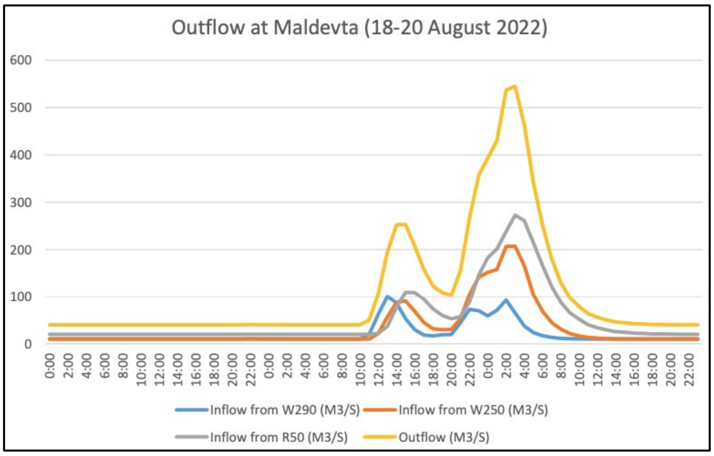
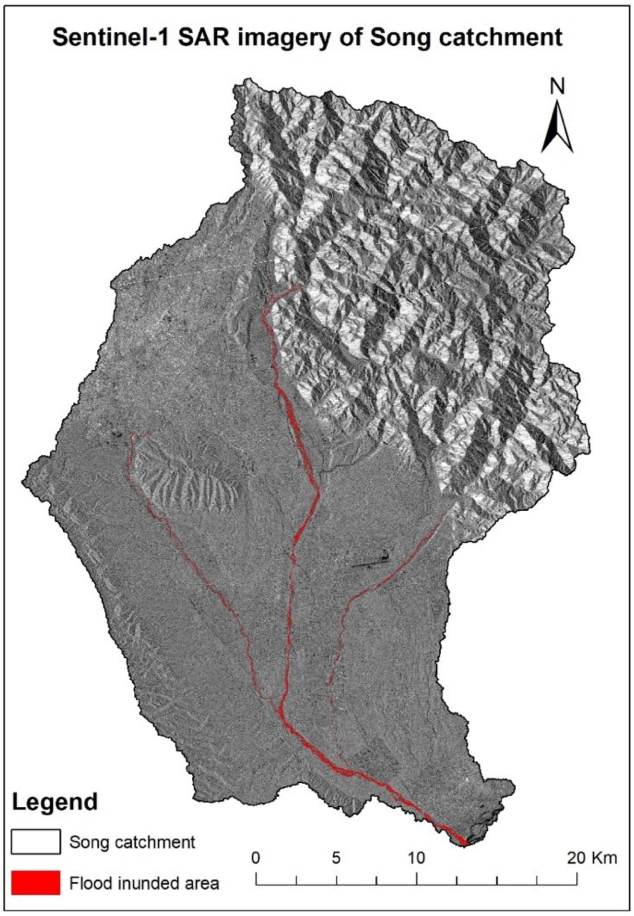
* Indian Institute of Remote Sensing (IIRS), ISRO, Dehradun, ** Uttarakhand Uttarakhand Space Application Centre, Dehradun

From the beginning of civilization, human societies are drawn to river courses for easily available water resources, fertile lands, which are essential for human survival. The areas near rivers are home to many human settlements and in many of these places are prone for flash flood risk, especially in hilly areas. Nowadays, increasing cloud burst events and unpredicted excessive rainfall has caused sudden havoc in many such vulnerable places of Himalayan region on 19-20 of August 2022, a flash flood event due excessive rainfall occurred in the Song River catchment (with area of 1043 sq km) of Uttarakhand. In the upper catchment, Maldevta village area faced heavy loss of infrastructure and some causalities. To assess flood intensity an event based HEC-HMS hydrological model has been setup for flash flood simulation. Pre and post disaster assessments have been done by analyzing Planet scope and Sentinel-1 synthetic aperture radar (SAR) imagery. Four AWS station data falling in the catchment was acquired and used for simulation. A maximum of 344mm and 225mm cumulative rainfall observed in Rishikesh and Sahastradhara area respectively on 19-20 August 2022. A field visit was conducted on 20 August 2022 for disaster site ground data observation. Planet scope satellite imagery acquired for pre and post disaster analysis of Maldevta area. At Maldevta, maximum increase of 170 m observed in cross section of the river after flood. A flood water discharge of 2473 cubic meter/sec observed at Rishikesh outlet of the Song River at 5:00AM on 20 August 2022. The simulated peak flood flow in the song river was estimated as 544.8 cubic meter/sec at Maldevta at 3: 00 AM on 20 August 2022 and an area of 18.11 Ha observed under flood inundation in planet scope image. An area of 5.36 Sq km. has been observed under flood by analyzing post disaster Sentinel-1 SAR imagery for the entire Song catchment. The catchment is found vulnerable and increasing unplanned settlements and human intervention coupled with changing climatic pattern makes catchment more sensitive to flooding disaster.


Rainfall recorded by IMD-AWS in Song catchment (18-20 August, 2022)
Daily cumulative rainfall (mm)
400
350
300
250
200
150
100
50
0
18-Aug-22
19-Aug-22
20-Aug-22
Date & Time(UTC 00:00)
Sahastradhara
Dehradun
Rishikesh
Raiwala


Outflow at Maldevta (18-20 August 2022)
600
500
400
300
200
100
0
Inflow from W290 (M3/S)
Inflow from W250 (M3/S)
Inflow from R50 (M3/S)
Outflow (M3/S)


Sentinel-1 SAR imagery of Song catchment
N
Legend
Song catchment
Flood inunded area
0
5
10
20 Km

Exploring the potential of EOS-04 (RISAT-1A) satellite data for Jute and Rice Crop Mapping

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Satellite based inputs on in-season crop parameters, pre-harvest production estimates, drought and floods are crucial for agricultural management and policy making. One of the prerequisites for assessing the above parameters is to generate an accurate crop map. Optical and microwave remote sensing data are used to generate crop maps. Due to the cloudy and hazy weather during the monsoon season, optical remote sensing is constrained. Microwave signals can pass through fog, haze, and clouds, making them ideal for mapping and monitoring crops in all weather conditions. Well established procedures are available for the mapping of rice and jute crops operationally in India using temporal Synthetic Aperture Radar (SAR) data. RISAT-1data was widely used for crop mapping and parameter retrieval. Following the discontinuation of RISAT-1 data, Sentinel-1 VH data has been extensively used. The recently launched EOS-04 (RISAT-1A) is a continuation of RISAT-1 and features imaging capabilities identical to RISAT-1 with additional advantage of imaging capability in full-polarimetry in multiple modes. The frequency of data acquisition is also improved to 17 days from 25 days of RISAT-1. The aim of the current study is to examine the potential of the temporal Medium Resolution ScanSAR (MRS) data from EOS-04 satellite for mapping of jute and rice crops.

Temporal MRS data available at 33m resolution with a 160km swath covering the parts of West Bengal (for jute crop) and Haryana (for rice crop) has been collected and analysed for the entire crop growing period. Pre-processing of the data like speckle filtering, Sigma0 conversion and temporal image stack was carried out. Analysis of the temporal backscatter profiles showed that the backscatter at both HH and HV polarization is found to increase sharply in the initial growth stages of jute crop due to vigorous vegetative growth in terms of crop height and leaf area. The HH and HV backscatter during the sowing period (April month) was found to be around -10 to -13 dB and -19 to -22 dB respectively. Further, the backscatter increased by 5-6 dB at HH and 6 to 8 dB HV polarizations during the first fortnight of May and no significant change in the backscatter was observed during May and June as there was no addition of canopy elements rather an accumulation of biomass of existing canopy structures. Based on the temporal backscatter response from jute crop, decision rules were formulated to classify the jute crop. Similarly, analysis of the temporal data over rice crop revealed that the transplantation of rice crop was at its peak during the second fortnight of July in parts of Haryana covering Hissar, Jind, Rohtak, Panipat, Sonipat and Jhajjar districts. The HH and HV backscatter were around -20 to -25 dB and -25 to -30 dB respectively during the transplantation of the rice crop and the backscatter was further gradually increased as crop progressed. Decision rule based classification on the temporal backscatter was used to delineate the rice crop using both HH and HV polarizations. The classification accuracy assessment performed for the jute and rice crop maps generated using three date data revealed that the jute crop could be delineated with around 85% and rice crop with 90% accuracy respectively. The results demonstrated the potential of the EOS-04 MRS data for the mapping of jute and rice crops which can be readily ingested into the existing operational models.

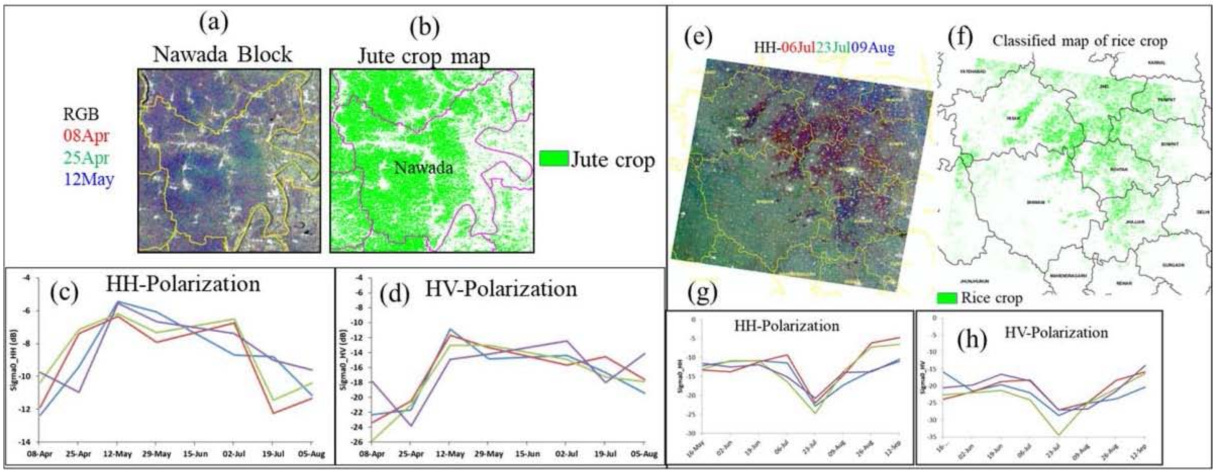

Fig: (a) RGB of temporal MRS data (b) Jute crop map (c) HH-backscatter profiles of Jute crop (d) HV-backscatter profiles of Jute crop (e) RGB of temporal MRS data (f) Classified map of Rice crop (g) HH-backscatter profiles of Rice crop (h) HV-backscatter profiles of Rice crop

Impact of Cyclone Titli on Vegetation Damage

Kadali Srikanth, Debadatta Swain
IIT Bhubaneswar

Due to climate variability, the intensity and frequency of the tropical cyclones (TC) are increasing and causing severe damage to coastal regions. TC's environmental and socioeconomic consequences might be mitigated through a variety of management strategies. In this study, the cyclone Titli was taken as a case study to analyze the impact on vegetation that happened on 11th October 2018. This study investigates the Land use and land cover (LULC) and Normalized Vegetation Index (NDVI) changes using high-resolution Sentinel-2 data. The results showed that the substantial changes in LULC before and after landfall, the dense and less dense vegetation has decreased by 65% and 68% respectively, and water body have increased by 58%. Most of the dense vegetation and less dense vegetation converted to fallow land over the study area and increase the fallow land cover by 436.85%. The pre and post-image comparison showed that mean NDVI values decreased from 0.72 to 0.65 after landfall. High vegetation damage was evident on the left side of the cyclone track as compared to the right. This study looks at the need for more geospatial technology in disaster effect assessments and the need to implement efficient, suitable, and long-term disaster management and mitigation approaches to avoid future disasters.

Monitoring Slow Landslide Movement along the Northern Railway Track in Jammu & Kashmir using SAR Interferometry

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Centre of Studies in Resources Engineering, Indian Institute of Technology Bombay*

Earth and Environmental Sciences, IISER, Mohali**

Landslides cause irreparable damage to human life and property. Many studies in India have confined to rock fall velocity modeling, remote sensing and GIS based approach, grid-based analytical approach, geological and geotechnical investigations, etc. In this paper, we have used advanced Synthetic Aperture Interferometry technique for monitoring both land subsidence and landslide movement in and around the railway network areas of Jammu & Kashmir. In this technique, some permanent structures, such as constructed houses, strong rock structure, hard barren land surface, are monitored continuously using radar images. European Space Agency under the Copernicus program is providing data from Sentinel-1A&1B satellites every 12 days. We have processed around 139 images (70 ascending and 69 descending) acquired from 2016 to 2019 over Sumber and Arpinchala test areas and analyzed the results.

Conventional differential SAR interferometry with two images with a long-time interval of one year and also short time interval of 12, 24, 36 and 48 days does not show much deformation. As the interval increases, coherence reduces and fringes are not visible due to deformation. Hence, the advanced differential SAR interferometry known as Permanent Scatterer (PSInSAR) techniques have been used for time series deformation of both test areas. Software used in this work SNAP-StaMPS, Gamma and LiCSBAS.

Mean velocity range for Sumber hilly area for a given polygon is about 0 to -2.4 mm/y using ascending pass data and it is +4 to -5 mm/y using descending pass data. The range for Arpinchala is -1 to -3.7 mm/y for both ascending and descending passes. Time-series plots for particular points at these test areas show a lot variation in deformation from 2016 to 2019 for 68 observations, particularly in the rainy season (downward motion) and winter seasons (upward). The maximum deformation range for Sumber is about -40 to +40 mm. Due to the direction of slopes, descending pass show more positive deformation. The average deformation around the centre of Sumber hill shows a linear deformation trend although some scattering of points is observed around least- square fitted line. The trend for Arpinchala is same with less slope. From the studies, it is concluded that the Sumber hill slope is not moving from top to bottom at great speed. The motion is more at the concrete embankment and it is localized.

Time series Sentinel-1 descending pass SAR data from 20-10-2014 to 02-07-2019 (75 images) are processed using Gamma software. Temporal coherence is used to select permanent scatterer (PS) points. Pixels with temporal coherence > 0.5 are selected as PS points for further analysis. Density of the PS points through StaMPS is higher than that of obtained using Gamma. The velocity observed by StaMPS and Gamma for Sumber landside is -2.4 to 0 mm/year and -3.0 to +1.8 mm/year respectively. The time series plots from two software shows different trends. Using StaMPS software, we observed up and down trend frequently, whereas smooth upward and downward motion is observed using Gamma.

Soil Moisture Estimation through Synthetic Aperture Radar (SAR) Data

Gavali Madhuri Dilip, Mr. Ashish Joshi
Indian Institute of Remote Sensing, ISRO, Dehradun

Soil moisture is the water present in pores or spaces between the soil particles. For Biological and Hydrological processes, plant life cycle (sustaining of the microorganisms and plants) soil moisture plays an Important and Fundamental Role. Soil moisture present within the upper part of the soil surface i.e., soil depth at 10 cm is called surface soil moisture. At 50 to 200 cm depth of soil, soil moisture that is present near to plant root zone is called Root zone soil moisture. The data on soil moisture is needful and important in the study of weather and climate, weather pattern development, Flood control, and runoff potential. This soil moisture information is very useful, for reservoir management, early warning for drought conditions, Crop yield Forecasting, Irrigation management, Implementation of Various schemes, and Insurance policies related to crops. Soil moisture estimation is very essential for Agriculture. Specially and Temporally Soil moisture is very dynamic in nature. Soil moisture estimation from ground-based observations is not so accurate, time-consuming, costly, and tedious process. So, in Soil moisture studies for large areas and in cost and time-effective domains, the Remote sensing technique is very useful. In this case, Microwave remote sensing technique has highly important to detect soil moisture through electromagnetic bands. The advantage of SAR is, it penetrates through cloud cover, and propagates through soil and vegetation cover and most important thing is that it has Sensitivity to Soil and vegetation moisture. So, using in situ data and SAR soil Moisture data we can measure soil moisture accurately and improve hydrological monitoring and predictions in irrigation. Because every crop requires a different amount of soil moisture. Nowadays we know how much water require for a particular crop. But using soil moisture data from SAR sensors we suggest to farmers how much water require for their crop in that particular situation or period. The major cause of Soil degradation is the absence of adequate soil moisture. With the help of an accurate estimation of soil moisture, prediction of the flood and landslides is possible. It can suggest to the farmer at which vegetative state required how much water can detect from accurate soil moisture data from SAR sensors. Using thermal infrared and Microwave (Active and Passive) electromagnetic radiation 1 to 5cm soil moisture near to soil surface study from space-born, air-born and ground base study has been taken up over 30 years. Different SAR satellites are used for the estimation of soil.

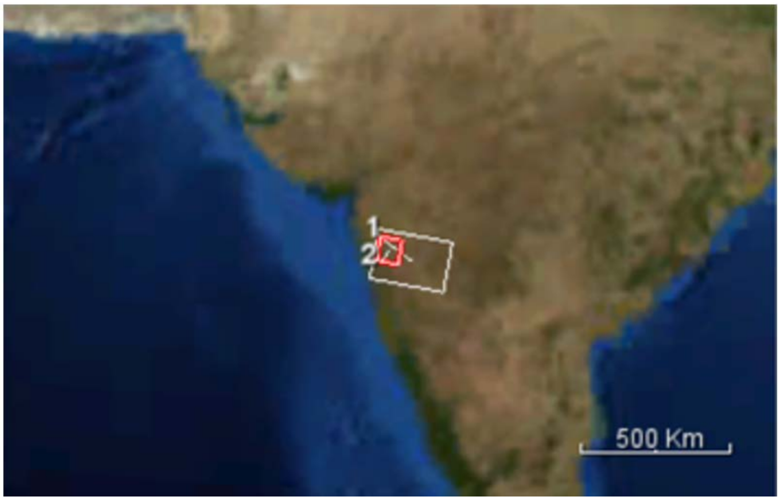
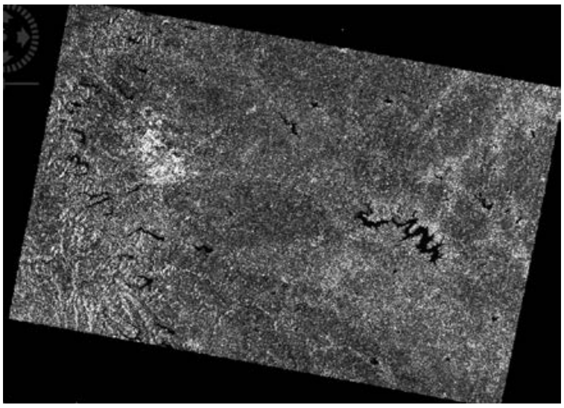


Figure 1 World view of Maharashtra

In this case study, ground truth data was collected from the flat plateau region of Ghumari, in the Maharashtra state, synchronizing with the corresponding satellite image of the Sentinel 1A and Sentinel 2A data. It has been discovered that the Backscattered value and soil moisture have a linear relationship.



Results

Study area Ghumari, Tal. Karjat, Dist.Ahmednagar, Maharashtra

Field No.	Survey No.	σ° Soil values	Soil Moisture (%)
2	11 / 2	0.06166	6.16
3	111 / 2 / 2	0.086504	7.11
4	111 / 2 /3	0.0481	5.29
5	291	0.076394	7.21

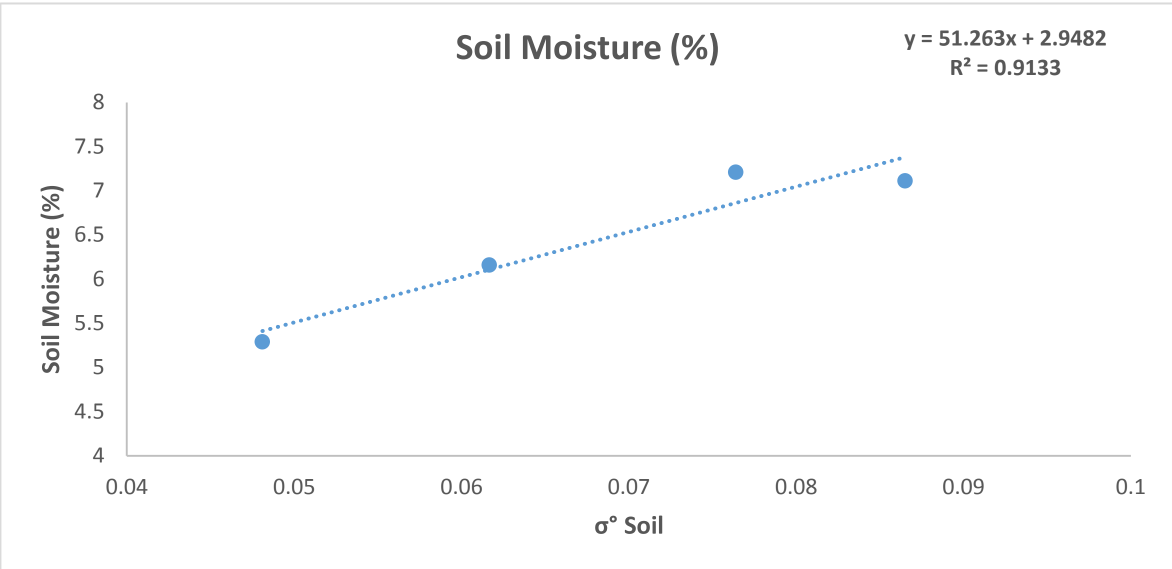


Figure 3 World view of Maharashtra

Rainfall induced landslides and their impact on large wood budget in a mountainous stream

Lasyamayee Lopamudra Sahoo, Somesh Kumar, Subashisa Dutta
Indian Institute of Technology Guwahati

Each year, flooding in India from extreme rains results in a loss of around $3 billion, which constitutes about 10% of global economic losses. The Himalayan rivers get flooded every year because of unusual rainfall and melting of snow mountains. Most of these rivers pass along the deep valleys with dense forest at both sides. Large trees from these forests and their broken parts also flow along with the high speed flood water. Floods can turn out to be more disastrous with additive factors like associated large woods travelling along with. These floating woods can be highly destructive because they make the peaceful waters capable of overtopping their banks and destruction of nearby structures. Thus it is of supreme importance to quantify the potential wood volume that may be recruited to the channel. Kameng river, a tributary of the mighty Brahmaputra, has been selected to be worked upon for this research work. The upper part of the river passes through valleys with mountains having very steep slope. Moreover, rainfall amount in this reason also considerably high which triggers shallow landslides. Thus the recruitment of woods into river channel is mainly due to the landslides. For better accuracy of wood volume quantification, we have identified the areas susceptible to rainfall induced landslides. The predictors of rainfall induced shallow landslides includes three broadly classified factors like topographical, environmental and hydrological factors. The topographical factors are mostly extracted from the DEM using GIS interface. Similarly the environmental factors include landuse landcover of the area and the hydrological factors include the rainfall intensity and distance of the point from the river. Initially, various data sources were used and introduced in ArcGIS including satellite images, time series observations, spatial data, and geological and topographic maps. In order to identify the landslide hazard area, a multi-parametric dataset containing satellite data and other conventional data including maps were considered for the demarcation of potential wood debris flow zone. Weights were assigned to different classes in each theme based on their relative importance towards sliding of earth and tree by applying the overlay analysis. Then, the susceptible zones were delineated by overlaying all the thematic layers of the weighted overlay method using the spatial analysis tool. Area of different susceptible zones are calculated separately and are overlaid with the value of tree density and canopy density to estimate the total potential volume of the wood recruitment. However, the probability of recruitment was decided based on the distance of the tree from river, height of the tree, slope and degree of landslide susceptibility of the area. Hence the actual volume to be recruited was found out by analyzing the probability factor with the potential volume of wood recruitment. Approximation of wood debris in a mountainous reach can be helpful in damage assessment which will lead to flood risk mitigation.

Maize crop phenological studies with Sentinel-1 polarimetric SAR data

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North Eastern Space Applications Centre

Crop phenological studies are essential for effective crop monitoring and management. Sentinel-1 C-band SAR data offers variety of possibilities for crop phenological studies owing to its wide range of polarimetric options. In this study, we investigated the prospective of H-A-Î± decomposition parameters for identification and monitoring of maize crop at various growth stages in Darrang district of Assam state. Five temporal datasets of Sentinel-1 C-band SAR data from December, 2020 (emerging stage V2 to V5) to March 2021(reproductive growth stage) have been considered. We analyzed the SAR back scattering (VV and VH) and H-A-Î± decomposition (Entropy, Anisotropy and Alpha) temporal profiles during the Rabi season of the crop that varies from November-December to February-March. The analysis revealed that the VV and VH back scattering from the maize crop are helpful for discrimination the maize crop from other two neighbouring crops i.e, rice and mustard but could not differentiate the variation in growth stages of maize. Among H-A-Î± decomposition parameters, Alpha (degree) showed the highest Coefficient of Variation (20.17 %) in the emerging stages (V2 to V5 stage) of maize, while the lowest CV measured (17.94%) in active growth or grand growth stage. Similarly the Entropy and Anisotropy also exhibited higher CV (12.74% and 13.25% respectively) in emerging stages and lower CV in grand growth stage (10.46% and 11.92% respectively). This result indicates that the significant variation in emerging stage of the maize crop helps in discrimination within growth stages using H-A-Î± decomposition of Sentinel-1 polarimetric SAR data.

A GIS-based Landslide Susceptibility Mapping to Highlight Potential Hazard Zones in Nainital District

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Landslide is one of the most vulnerable natural hazards, mainly in hilly regions. Numerous deaths and significant economic losses have been reported from landslides incidence [1]. Landslide-related losses are substantial in many nations due to the ever-increasing and rapid development of the steeper hilly terrain under a load of growing populations [1, 2]. For studying landslides, GIS and remote sensing techniques are frequently used. The area selected for the present study is Nainital District in Uttarakhand. Because of the hill, frequent landslides are occurring. Developing a landslide susceptibility map (LSM) for this region will reduce the likelihood of landslide occurrence. Remote sensing satellite data like ALOS PALSAR DEM with a spatial resolution of 12.5m of the study area is utilized to prepare slope, aspect, drainage density, lineament density, and curvature layers on the GIS platform. Geomorphology and lithology were procured from the Bhukosh portal of the Geological Survey of India, and Landsat-8 land use and land cover (LULC) was prepared with a spatial resolution of 30 m and assessed in GIS. The basic methodology is shown in the figure 1.

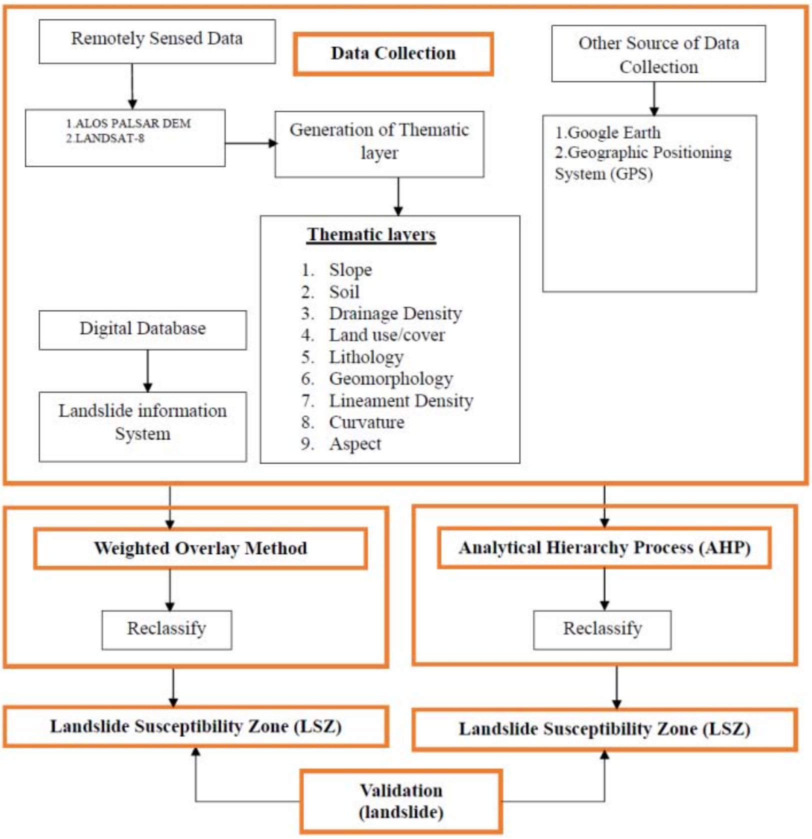
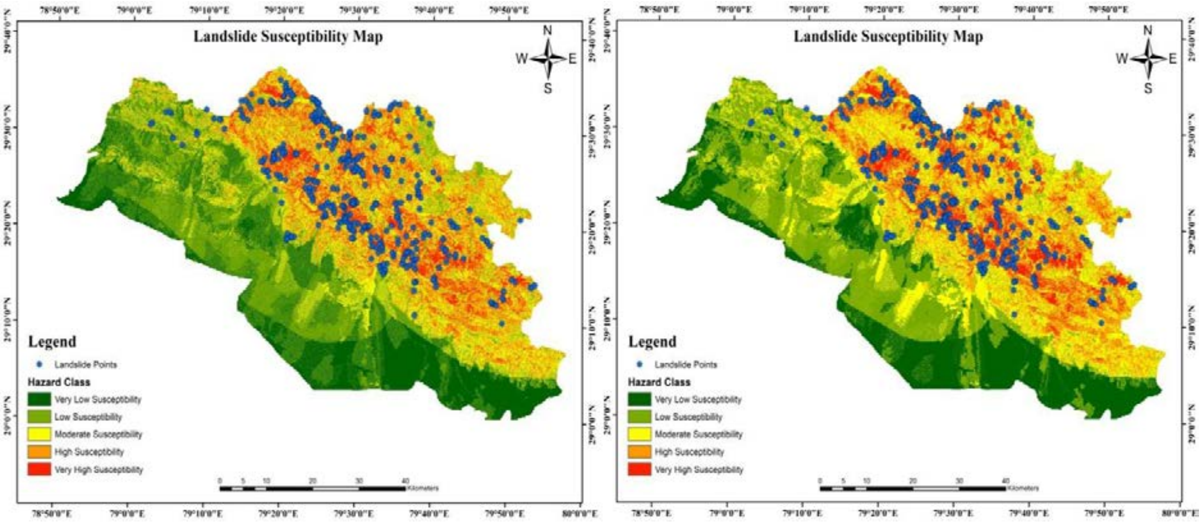


Figure 1. Overall methodological representation of the work

The Weighted Overlay and Analytical Hierarchy Process (AHP) method is used to analyse and prepare a Landslide Susceptibility Zone (LSZ) Map. In Weighted Overlay (figure 2), 4.9% of the landslide events lie in the low zone, 18.13% in moderate zone, 36.03% in high zone, and 40.93% in the very high zone. In AHP, 2.94% lies in low zone, 16.91% in moderate zone, 35.29% in high zone, 44.85% in very high respectively. In AHP (figure 2), 80.14% of the area lies in a high to very high zone, whereas in the weighted overlay method, only 76.96% lies in a high to very high zone. The Receiver Operating Characteristics (ROC) curve was used to predict the accuracy of the methods. The Area under the curve for AHP and weighted overlay is found to be 86.3% and 86.1%, respectively.



(a) (b)

Figure 2. Landslide susceptibility map of a. AHP b. Weighted Overlay

LHZ mapping is required to monitor and develop landslide-vulnerable area planning and disaster management. LHZ mapping is critical for identifying and forecasting potential sliding zones. The proposed LSZ map will help the administrator to decide to support and reduce physical damage to the Government and hence do sustainable future planning for the development of the society.

Effective Multi-Satellite Synthetic Aperture Radar (SAR) data planning for disaster support

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India is one of the most disaster-prone countries in the world. Being a monsoonal country, its location and geographical features render it vulnerable to a number of natural hazards such as cyclone, drought, floods, earthquakes, fire, landslides etc.;. ISRO provides the satellite based near real time information support to all users Departments, prior, during and after major natural disasters. As most disasters are associated with heavy rainfall and overcast cloud conditions, the satellites with SAR sensors are more useful than optical sensors.

Based on the user requests, acquisition planning should be able to handle - Multi-satellite scheduling for a single request and/or multi- target planning with single/multiple satellites. The scope of this paper is addressed to handle planning of a request through multiple satellites.

SAR microwave satellites which have the capability to image over all weather conditions in both ascending and descending nodes which plays a major role in disasters specifically in case of flood. The imaging modes have varying resolutions and swaths ranging from 1m to 50m resolution and 10km -220km respectively. Presently, data from Risat-2BR series and EOS-4 are being utilised for supporting these events. EOS-4, a Polar sun synchronous satellite, launched in Feb. 2022 is one of the prime Indian earth observation satellite equipped with C-band SAR sensor. Though the prime objective is catered for agriculture, the availability of multiple modes of data collection can be utilised in various applications like disasters, cartographic mapping, surveillance, etc.. This satellite has a reptevity cycle of 17 days.

Risat-2BR series is X-band SAR- data with multiple acquisition modes. These series of satellites have inclined orbits (±45deg. Inclination) there by providing higher receptivity of acquisitions. Unlike EOS-4, the imaging modes have varying resolutions and swaths ranging from 1m to 3m resolution and 5km - 50km respectively. In addition to these satellites, S-band NOVASAR satellite is also available for planning over India.

These gamut of satellites, provide data with varying frequencies of microwave SAR data i.e X-band, C-band and S-band which can be used for varied applications for disaster.

Timely planning of acquisition is very important for rapid response to disasters. An attempt is made to study, how IRS satellites along with SAR sensors can be effectively planned by complimenting and supplementing optical sensors to meet the near real time requirements of disasters in India.

Based on the user requirements, a schedule is generated on daily basis by considering the respective satellite and ground resources. In case of an occurrence of a disaster, using GIS model the earliest possibility of acquisitions is worked out to generate an optimal model across the satellites. Based on the event, specific mode is also attributed for checking the feasibility. This optimal model is worked out by considering the type of disaster, sub-satellite track of the satellite, the acquisition mode, roll tilt, time available to change the acquisition plan and the ground orbits availability to uplink the commands. Based on this model, the imaging plan is altered and re-generated. This model is being utilized effectively not only for providing quick response but also in regeneration of the schedule plan with minimal alterations.

The functionality of this model is to fetch the earliest date of acquisition for the event from multiple satellites. In case of EOS-04, which is a single satellite, based on its orbital pattern, we have the possibility of acquisition within 12hrs to 3 days. In case of Risat-2BR series, we have three constellation of satellites Risat-2B, Risat-2BR1 and Risat-2BR2 which aids in providing quick possibilities within a range of 90min to 3 hours based on the geographic location of the target.

Based on the events, differential priorities are assigned to each of the requests present on that day and weightages are calculated for same. Emergency requests are given highest priority. Priorities for various other user requests like ground truth survey events, specific time bound image captures followed by other user requests. Weightages are calculated based on the priority along with the following factors:

1. Type of request
2. Incidence angle
3. Polarization
4. Payload mode
5. Acquisition mode (NRT/RT/RR/RC)
6. Availability of nearest play back orbit in case of RC & RR modes
7. Availability of commanding orbits

Based on the above factors, a formula is worked out and a model is developed which aids in smooth planning of the events.

This model is tested on recent flood over Godavari basin and got satisfactory result. The user AOI requirement of data had a swath of 50km which was to be acquired in SPOT mode. The swath covered by the SPOT mode is 5km which needed 10 acquisitions for the entire to be imaged. By utilizing this model, the acquisitions were distributed across Risat-2BR constellation which yielded in quick coverage of the AOI. This resulted in planning of the complete user AOI along timely supply of the data to the user.

In case of SAR microwave satellites, this model has worked wonders for AOI based requests with large swaths. Planning was carried out across the dates within in user given period of interest so as to cover the entire AOI at the earliest possible dates.

Atmospheric Trace Gases and Aerosols

Ensemble Machine Learning Approach for PM2.5 Reconstruction using MERRA-2 and Long-term Analysis for India (1980-2021)

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Particle exposure affects more humans globally than any other air pollutant. However, due to expensive instruments and infrastructural deficiency, a high spatiotemporal network of monitoring stations is not possible, leading to data-scarce regions. Satellite and reanalysis datasets can be implemented to estimate particulate matter, but they do not provide surface concentration and needs to be reconstructed from the components. In this study, a machine learning (ML) framework is implemented to reconstruct PM2.5 from MERRA-2 data components, namely black carbon (BC), organic carbon (OC), dust (DUST), sea salt (SS), and sulfate (SO4). The ground level and respective MERRA-2 data were collected from India's 335 continuous ambient air quality monitoring stations (CAAQMS) for 2017-2021 at hourly resolution. Random forest (RF) performs better with train and test scores of 0.86 and 0.74, respectively, while the empirical equation provides an R2 of only 0.27 on test data. The estimated PM2.5 for Indian states from 1980-2021 indicates a significant increase in most cases. However, states in the Indo Gangetic plain such as Delhi, Punjab, Haryana, and Uttar Pradesh are the most polluted regions of India. The major shift in concentration is from 2000 onwards, which can be seen as a direct result of the economic liberalization policies implemented in 1991. The results provide evidence for the limitations of the broad application of the empirical equation and the feasibility of ML algorithms as a potential reconstruction technique for developing robust and accurate region-specific models from MERRA-2 data.

Impact of INSAT-3D atmospheric motion vectors in hybrid ensemble-3DVAR data assimilation systems in high resolution simulation of heavy rainfall event over NER of India

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The performance of any data assimilation (DA) system depends on the availability of observed data over the study area. In the northeastern region of India (NER), where around two-thirds of the region is covered by hilly terrain, the ground observation network is not sufficient enough to supplement the data assimilation requirements. Satellite observations are the best substitute in such a scenario. Satellite wind observations are also known as atmospheric motion vectors (AMVs) which are obtained by continuously tracking regions of clouds or water vapor through satellite images. They do not provide wind profile information but they furnish tropospheric wind information with good areal coverage, particularly over the data sparse region. INSAT-3D is an Indian meteorological satellite with imager and sounder onboard and three consecutive images from INSAT-3D at 30-minute intervals are used to determine the AMVs. In this study, two data assimilation systems, namely, three dimensional variational (3DVAR) system and flow-dependent hybrid Ensemble Transform Kalman Filter (ETKF)-3DVAR (HYBRID; hereafter) system available in the Weather Research and Forecast (WRF) modeling system are considered for the assimilation of INSAT-3D AMVs along Global Telecommunication System data. The basic difference between both the methods is 3DVAR uses a climatological static background error covariance (BEC) whereas HYBRID method uses both static as well as flow dependent error covariance estimated from ensemble members. The BEC is the most critical parameter of a DA system that regulates the importance of the first guess state relative to the observations by assigning suitable weight to the background field. The objective of this study is to evaluate the benefit of assimilation of INSAT-3D AMVs for high-resolution simulation of heavy rainfall over NER and also to inter-compare the performance of both the DA system using AMV data. Four heavy rainfall incidents during 2016 and 2018 are considered in this study. Four sets of experiments are performed with and without INSAT-3D AMV in both DA systems for each of the cases. Two experiments where only conventional observations and satellite data from GTS are assimilated are named as 3DVAR and HYBRID based on the type of DA technique. On the other hand, where the experiments use both GTS and INSAT-3D AMVs are named as 3DVAR-AMV and HYBRID-AMV. The initial and boundary conditions are interpolated from the National Center for Environmental Prediction (NCEP) Global forecast system (GFS) analysis and forecast at 0.25 deg x 0.25 deg gridded resolution. In each case, model initialization is done at 18 UTC of the previous day of the rainfall event and the 6 hour forecast from the model initial condition is used as the initial file for the first assimilation cycle at 00 UTC. The next assimilation cycle is performed at 12 UTC using 12 hour forecast from the previous assimilation cycle. Finally, the model is given free forecast for the next 24 hour from every analysis at 00 UTC. For the HYBRID simulations, 50 ensemble members are used for the estimation of flow dependent BEC. The ensemble members are generated using WRF-3DVAR CV3 BEC by adding 50 random perturbations. The results clearly show the significant impact of INSAT-3D AMV DA in the HYBRID DA system in rainfall simulation thereby reducing the wet bias observed in 3DVAR simulation substantially, mainly over western

Assam and some parts of Arunachal Pradesh. The statistical evaluation in terms of Equitable Threat Score and BIAS score further indicates modest improvement in rainfall simulation using AMV data in the HYBRID system.

Retrieval of Optical Radiative Properties of Atmospheric Aerosols from Sun-sky Radiometer over Desalpar

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Atmospheric aerosols, defined as the suspension of solid and/or liquid particles in the air, are important in the assessment of aerosol effects on the Earth-Atmosphere radiation system and validate the satellite products. Aerosols affect solar radiation and hence climate not only directly by absorbing and scattering radiation back to space but also indirectly by acting as cloud condensation nuclei. To estimate the aerosol perturbation of the Earth's radiation budget, knowledge of aerosol optical and microphysical properties currently represents a key role. In this work, An evaluation and analysis of aerosol data were carried out over the Desalpar site (23.74°N, 70.69°E, 30m m.s.l.), a remote site in western India during the period from December 2018 to July 2019 using the ground-based CIMEL CE-318 automatic Sun-sky scanning radiometer. Columnar particle size distributions and related parameters derived using inversion of sun/sky radiances were investigated in this work. Statistical analysis and time evolutions of the spectral optical depth, perceptible water, and derived Angstrom exponent (AE) are analysed. During this period, the average AOD_{500} and AE values are found to be 0.32 ± 0.21 and 0.92 ± 0.35, respectively. The observed values of AOD_{500} range from 0.03 to 2.37, and the values of AE vary from −0.10 to 1.80, indicating a large variability in aerosol content and size. Very low aerosol optical values were observed in the month of December 2018 with mean AOD_{500} of 0.22 at 500 nm. However, AE was very low with an average of 0.20 during July 2019. AE varies greatly over a narrow range of AOD indicating the occurrence of different types of aerosol particles. The seasonal variation of the monthly average AOD shows minimum values in the winter (December, January, February) and in the spring (March, April, May) season, while maximum values are in the months of the summer monsoon season (June, July, August). Dust strongly affects the region during the late spring and summer months when aerosol optical depth is at its peak. Distinct seasonal variation of water vapour content was also observed, with higher values in summer monsoon season. Figure 1C shows the daily and monthly mean variation of AOD_{500} and AE ($\alpha_{440\text{-}870}$) over the Desalpar region. It can be seen from the frequency distribution of AE (Figure 1B) that the AE ($\alpha_{440\text{-}870}$) fluctuates in the range from -0.10 to 1.80 during the measurement days. The aerosol-type characterization shows that the two main types of aerosols are present over the Deslapar region: Continental Clean (CC) and Maine (Mar) aerosols with an important fraction of 31.3% and 21.0%, respectively, with the influence of local sources of continental and polluted aerosols. Furthermore, Desert Dust (DD) is present in 3.5% of cases, while the Biomass Burning/Urban Industrial (BB/UI) has a very low occurrence in around 1.0% of the data over Desalpar. Moreover, this work could play an important role in validation of satellite products.

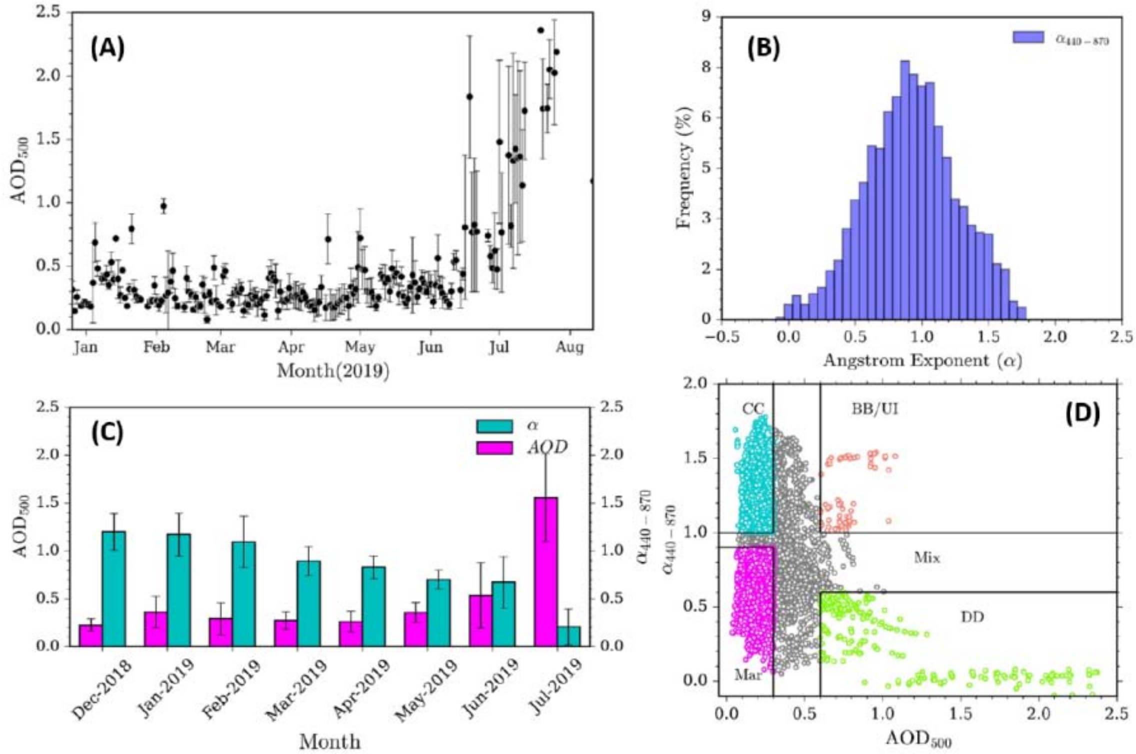

Figure 1. Time evolution of aerosol optical depth (AOD_{500}) and Angstrom exponent (A) Daily mean variation of AOD_{500}, (C) Monthly mean variation of AOD_{500} and Angstrom exponent (AE) for the period from December 2018 to July 2019, (B) Frequency distribution of AE at 440-870 nm, and (D) Scatter plot of AOD_{500} versus AE for identification of the dominant aerosols types at Desalpar. The labels stand as CC: Continental Clean: Mar: Marine: BB/UI: Biomass Burning/Urban Industrial: DD: Desert Dust and Mix: Mixed type aerosol.

A GIS based framework for the monitoring of air quality parameters in mega cities

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Air pollution is becoming a very severe problem for human beings in the big cities. Because of various activities of human beings, the man-made sources of pollution are posing various challenges to the ecosystem and persons residing in the big cities are subjected to various health hazards. Especially in metro cities in India, many of them crosses permissible limits of pollution in very frequent manner in a year. Pollution monitoring helps to measure and regulate the pollution levels in the area. Ground pollution measurement stations have been established in many states including metro cities. But a ground station has its limitation of area coverage for pollution measurement, availability for suitable place for establishing the station. Due to high cost for establishment and resources needed for AQI Stations, one cannot get the pollution data for every region or place.

The GIS based techniques can be helpful in the prediction of air pollution parameters for the areas, where the AQI monitoring stations are sparse. In a GIS based framework, with the limited ground stations, pollution scenario can be determined and visualized with the help of Spatial Interpolation Techniques. This work is focused on choosing the best suited interpolation techniques for air pollution parameter mapping in the study area located in the Delhi NCR region. Monthly consideration of pollution parameter concentrations parameters i.e., particulate matter consists $PM_{2.5}$ & PM_{10}, Nitrogen Dioxide (NO_2), Carbon Monoxide (CO) and Ozone (O_3) have been taken ranging from low, moderate and high pollution months for the year 2021. The investigation results have shown that, the Inverse Distance Weighted (IDW) and Kriging Ordinary spatial interpolation techniques are more appropriate for determining the pollution levels at a locations, where AQI station is not present. Also, the results have shown that pollutants like aerosols shows high variability in high pollution months. But the gases show a random pattern which can lead the further studies on gaseous pollution patterns and its mitigation.

Pollution monitoring & source tracker drone

Ran vijay
IIMT College of engineering

This paper proposes a worldwide system of geosmart devices that can sense and connect with their surroundings and interact with users and other systems. Global air pollution is one of the major concerns of our era. Existing Pollution monitoring source tracking drone systems have inferior precision, low sensitivity, and require laboratory analysis. Therefore, improved monitoring systems are needed. To overcome the problems of existing systems, we propose a three-phase air pollution monitoring system. An IoT kit was prepared using gas sensors, Arduino IDE (Integrated Development Environment), and a Wi-Fi module. This kit can be physically placed in Drone to monitoring air pollution. The gas sensors gather data from air and forward the data to the Arduino IDE. The Arduino IDE transmits the data to the cloud via the Wi-Fi module. We also developed an Android application termed IoT-Mobair so that users can access relevant air quality data from the cloud. If a user is traveling to a destination, the pollution level of the entire route is predicted, and a warning is displayed if the pollution level is too high. The proposed system is analogous to Google Traffic or the Navigation application of Google Maps. Furthermore, air quality data can be used to predict future air quality index (AQI) levels. Detecting pollution timely and locating the pollution source is of great importance in environmental protection. Considering advantages of the sensor network technology, sensor networks have been adopted in pollution monitoring works. In this paper, a survey on researches of pollution monitoring using sensor networks in environment protection is given. Firstly, sensors and pollution monitoring network systems are studied. Secondly, different pollution detection methods are analyzed and compared. Thirdly, an overview of state-of-art technologies on pollution source localization is given. Finally, challenges on pollution monitoring using sensor networks are presented.

A Study on Air pollution monitoring system using MODIS Remote Sensing Data and Image Processing Techniques

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Remote sensing image for air pollution monitoring system is an advanced technology to identify the large area of the atmosphere. MODIS data sets with spectral bands are suitable for the atmosphere pollution classification. This study is focused on industry area-based remote sensing images to detect the concentration of NO_2, CO, and SO_2. These are the major industrial waste mixed with the industry smoke. MODIS remote sensing data is suitable for greenhouse gas monitoring from the industry area. It has a 36-channel imaging spectrometer and itself first 20 bands to observe the solar radiation reflection of the physical properties and 16 thermal bands to identify the ocean and surface temperature. These bands having 250m(Band 1-2), 500m(Band 3-7) and 1km(8-36) pixel resolution. The image processing techniques such as classification and segmentation can segregate the area in the remote sensing data. There are supervised and unsupervised classification techniques suitable for remote sensing classification based on pixel-based and feature-based classification. K-means algorithms are considered for the unsupervised classification and the selection training feature is consist of the supervised classification. We can identify air pollution in remote sensing images using image processing classification techniques.

Spatial Asymmetry in the distribution of UTLS aerosols over Asian Summer Monsoon Anticyclone

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The closed large scale Asian Summer Monsoon Anticyclone (ASMA) circulation in the upper troposphere and lower stratosphere (UTLS) of the Northern Hemisphere forms in association with the Asian Summer Monsoon will confine the air mass inside and thereby results in the enhancement of the tropospheric species (carbon monoxide-CO, Water Vapor-WV and aerosols) concentration. In this study, by making use of GPH values obtained from NCEP-NCAR re-analysis data set for the period 2006-2020, the spatial asymmetry in the ASMA circulation is described by dividing the ASMA region into four regions namely North-West (NW: 32.5°-37.5° N, 40°-70°E), North-East (NE: 32.5°-37.5° N, 70°-100°E), South-West (SW: 27.5°-32.5° N, 40°-70°E) and South-East (SE:27.5°-32.5° N, 70°-100°E). Some recent studies revealed the spatial asymmetry of the ASMA and their influence of the distribution of the tropospheric tracers (chemical species and aerosols). However, they are limited to tropopause level only. Whereas in this study, firstly, the spatial asymmetry in the distribution of the tropospheric species (CO, WV) and aerosols is provided by making use of the MLS and CALIPSO satellite measurements for the period 2006-2020. The location of the maximum concentration of tropospheric species are not uniform with CO over 40°- 70° E longitudes, WV and aerosols over 80°-110° E longitudes.

Secondly, the vertical distribution of aerosols has been investigated using the satellite measurements over these regions during the period 2006-2020 by dividing the atmosphere into (1) Boundary Layer-BL (0-1.5 km), (2) Mid-Troposphere-MT (~1.5-8 km) and (3) Upper Troposphere- UT (~8-18km). We identified that, maximum aerosol concentrations are present in the MT and their contribution to the total AOD is highest (~50-80%) compared to BL and UT aerosols. We found the contribution of UT aerosols to the total AOD is ~10% particularly in the eastern part (NE/SE) of the ASMA but not in the western part (NW/SW). The CALIPSO observations showed an enhancement of aerosols throughout the upper troposphere over eastern regions (SE/NE) of ASMA indicating the transport of boundary layer air to the UTLS region across these regions. The influence of Bay of Bengal (BoB) convection and associated vertical updrafts linked with the monsoon on the UT aerosols of the ASMA regions has been investigated by making use of cloud fraction measurements from CloudSat and Pressure vertical velocity (ω) from NCEP-NCAR re-analysis. We identified that, the intense convection with strong updrafts over BoB is responsible for the UT aerosols over the SE region of ASMA. The descending limb of the monsoon induced circulation over the western region of ASMA (Arabian Peninsula and other Middle east countries) is the possible causative mechanism for the removal of aerosols in the upper troposphere. The findings about the spatial asymmetry in the aerosol vertical distribution over the ASMA will give an insight about the importance of the regional radiative forcing and their climatic impacts.

Variability of atmospheric CO_2 over Indian monsoon regions and its diagnostics based on Atmosphere Transport Model and satellite observations

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Atmosphere CO^2 is a major greenhouse gas which undergoes variability at different temporal and spatial scales. Seasonal and inter-annual oscillations are dominant modes of the CO^2 variability at the global and continental scales, mostly driven by natural processes and associated climatic extremes respectively. It also exhibits the long-term secular change, and has anthropogenic origin. However, the variability at regional scale, specific to Indian monsoon regions is sparsely understood mainly due to limitation in the observation and modelling procedure. In this regard, GEOS-Chem atmospheric transport model has been implemented at the regional scale over Indian monsoon domain to simulate atmospheric CO^2 at three hourly intervals in a grid of 0.25x0.3125 degree spatial resolution with 47 vertical levels from surface to 0.01hPa. The regional model has been initialised from the known physical state, and forced by the time varying fluxes of CO^2 derived from the global GEOS - Chem model output and the model parameters were tuned to suit the regional conditions. Analysis of the model solutions in terms of tropospheric CO^2 budget from surface to 650hPa were studied at inter-annual scale in conjunction with the observation from in situ sensors and data from the orbiting carbon observatory (OCO-2), Greenhouse gas Observing Satellite (GOSAT) during 2012-2020. The latitudinal distribution of XCO^2 averaged over Indian landmass shows distinct seasonal oscillations and inter-annual variability. There exist good agreement between the model and observations. All these coherently show strong latitudinal gradients with the seasonal amplitude varied from 3 ppm over the north India and decreases to 1.5 ppm over the southern tropical Indian Ocean. Using the model diagnostics corresponding to the model simulation, the role of various dynamical processes on the control of annual and inter-annual budget over Arabain Sea, Bay of Bengal, and India were analysed.

Monitoring of GHGs over the Indian region: Status, Challenges and Way forward

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Human activities have substantially increased the dry mole fractions of carbon dioxide (CO^2), methane (CH^4), and other greenhouse gases (GHGs) since the industrial era because of increased demand for energy needs. Before the industrial era, these GHGs increased due to land use changes and deforestation. Presently, more emphasis is given to CO^2 and CH^4 as they are the primary anthropogenic drivers of climate change. Their impact is expected to grow unless their emissions can be dramatically reduced. Thus, nations around the globe are concerned with this situation; many agreements have been signed, and so far, 26 meetings have been held by the Conference of the Parties (COP) under United Nations Framework Convention on Climate Change (UNFCCC) on climate change since 1995. As a result of the continuous effort of the sequential meeting of COP, emission reports are periodically supposed to submit to the UNFCCC to take actions toward reducing GHGs emissions. The goal is to limit the mean global temperature rise by 1.5°C or 2 °C by the end of the century. These emission reports are based on atmospheric chemistry transport models of “bottom-up” or “top-down” inventories. These inverse modeling communities required observed atmospheric CO^2 concentrations. Given this, the optimum ground-based monitoring of the CO^2 network over the Indian region is suggested for every 2°×2°, as demonstrated by Nalini et al. (2019). To monitor atmospheric CO^2 and CH4 precisely, continuous efforts are necessary. Increasing atmospheric methane has driven a 0.5°C global warming since 1850, making methane abatement a critical means to limit future warming (IPCC, 2021).

To understand the variability in regional surface GHG fluxes, high-precision GHG measurements were initiated by the National Remote Sensing Centre (NRSC) of the Indian Space Research Organization (ISRO), involving various research groups across the country. An enhanced performance model of the greenhouse gas analyser (GGA) instrument to obtain highly precise and accurate measurements was installed in the year 2013 at the National Remote Sensing Centre (NRSC), Shadnagar, to generate a long-term record of measurements conforming to standards set by the World Meteorological Organisation (WMO). Thus, now we have one decade of CO^2/CH^4 observations over Shadnagar. A calibration procedure to ensure the precision and accuracy of measurements was formulated using the National Oceanic and Atmospheric Administration-Earth System Research Laboratory (NOAA-ESRL) calibration gases bearing WMO certification. The annual mean CO^2 and CH^4 over the study region were found to be 394±2.92 and 1.92±0.07 ppm ($\mu \pm 1\sigma$), respectively, in 2014. CO^2 and CH4 show a significant seasonal variation during 2014, with maximum (minimum) CO^2 observed during pre-monsoon (monsoon), while CH4 recorded the maximum during post-monsoon and minimum during monsoon. Irrespective of the seasons, consistent diurnal variations of these gases are observed. Analysis of this study reveals that the significant sources of CO^2 are soil respiration and anthropogenic emissions.

At the same time, vegetation acts as a primary sink, whereas the major source and sink for CH^4 are vegetation and the presence of hydroxyl (OH) radicals. During strong El Niño in the preceding year (2015-2016), a spike in the CO^2 growth rate of 5.5 ppm year^{-1} was noticed in 2017 at the study site and observed at Mauna Loa with a growth rate of 3.03 ppm year^{-1}. Here, we compared the measured values of CO^2 and CH^4 with the simulated concentrations of CO^2 and CH^4 by an Atmospheric Chemistry Transport Model (ACTM). ACTM simulations captured the seasonal phases of CH^4; however, they underestimated the seasonal cycle amplitude of CO^2 by about 30%. We suggest including seasonal land-use land cover changes by incorporating the Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) in the model to improve its efficiency in capturing the seasonal phases of CO^2. NRSC/ISRO also carried out various airborne campaigns for aerosol studies. However, first time, we also collected and analysed the GHGs in the airborne campaign of 2016. Airborne measurements of the vertical distribution of atmospheric CO^2 were conducted over India in 2016 from a Super King Beechcraft 200 aircraft of the National Remote Sensing Centre (NRSC), Hyderabad to study the spatio-temporal distribution of CO^2 mixing ratios over the cities of Bhubaneswar, Varanasi, and Jodhpur in June 2016 using airborne measurements.

Results of the study suggest that the consistent long-term over the Indian region mainly focused on highlighting the variabilities associated with the local sources and transport. The data are needed to understand the long-term interannual and seasonal variability over the different geographical locations of India. Thus, it is advised to use various monitoring technologies, platforms, numerical simulations, and inventory compilation approaches to create a reliable GHG stereoscopic monitoring and evaluation system over India to constrain the Indian terrestrial surface fluxes better.

Monitoring of SMOG conditions over Delhi region using contemporary satellites

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National Remote Sensing Centre (NRSC)

New Delhi has found its place high in the list of one of the most polluted cities of the World. Though Delhi has a good to severe Air Quality Index (AQI) during major part of the year, it gets into the hazardous category during the post-monsoon and winter seasons. This is because New Delhi has been witnessing elevated levels of pollution during the onset of winter season every year. The worst ever air quality index of 999 recorded at Delhi in Nov 2017 resulted in the formulation of various mitigation strategies to combat the abnormal levels of pollutants in Delhi in the subsequent years. Towards this, remote sensing data from various platforms and WRF and NOAA HYSPLIT models have been utilized to monitor the episode of high smog conditions over Delhi during October-November 2017. The study revealed that the smog over Delhi region for an extended period is formed majorly by particulate matter and CO emissions due to agricultural residue burning from nearby areas during that period, compounded by the presence of dust and prevailing fog. Study also suggests that the wind pattern with reduced speeds at lower altitudes made it favourable for smog to sustain for extended period. It has been observed that Aerosol Optical Depth (AOD) increased 4.5 times on 7 November, 2017 when compared to decadal November average over the Indo-Gangetic Plains (IGP). Elevated levels of long lived CO are observed till mid-November, which can be due to emission from agricultural residue burning from nearby states. Study revealed that Carbon-Monoxide (CO) concentrations got enhanced by 1.2 times, on 1 November, 2017 when compared with previous 5 years satellite based observations. Air-mass trajectory analysis shows that atmosphere over Delhi region is influenced and characterized by the transported mass of aerosol particles due to agricultural residual burning from nearby states. Year-to-year variabilities in concentrations over the study site has been observed with highest levels of pollution during 2017 compared to other years.

Modeling Approach for CO_2 Concentration Retrieval for Point Source Emission using AVIRIS-NG

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The amount of carbon dioxide (CO_2) in the atmosphere can significantly rise as a result of emissions from various point sources including coal-fired thermal power plants. Due to the high cost and poor calibration, direct emission monitoring systems are not possible to establish at most sites to measure CO_2 emission. Hence, the remote sensing method to measure greenhouse gas emission from point sources is more suitable for detecting and monitoring gas concentration in the atmosphere. The availability of gas absorbing spectral channels in the satellite sensors allow measurements of greenhouse gas columnar contents. Atmospheric CO_2 concentration can be retrieved through prominent absorption features in the short-wave infrared (SWIR) spectral region by acquiring spectra in specific absorption bands around the 2.0 μm band. Band ratio is a suitable method for greenhouse gas detection such as atmospheric water vapor (WV), CO_2 and methane (CH_4) etc. This method uses a ratio of two or more bands, which gives the concentration of particular gas in a particular spectral band based on its absorption. In the band ratio method, the numerator is the measurement band which is most affected by the absorption of a particular gas and the denominator is a reference band which is free of any gas's absorption. CIBR (Continuum Interpolated Band Ratio) is a band ratio method that mathematically represents the depth of the absorption bands in the spectral radiance curve. The CIBR method overcomes the retrieval errors occurring in gas concentration values using two reference bands. In the present work CIBR method is applied to AVIRIS-NG (Airborne Visible/Infrared Imaging Spectrometer–next generation) an airborne hyperspectral sensor, for CO_2 plume detection at the coal-based thermal power plant. MODTRAN (MODerate resolution atmospheric TRANsmission) radiative transfer (RT) model is used here to simulate at-sensor radiance, which is further used for coefficients generation for the CIBR method [1]. Theoretical simulations are carried out by varying the CO_2 concentration and keeping all other parameters constant. Based on MODTRAN simulations and curve fitting coefficients, the CIBR index has been calculated from changes in radiance values in absorption bands. Further, the relation between the CIBR index and CO_2 content has been established. The methodology has been applied on selected test sites to generate CO_2 concentration values. Dhariwal thermal power plant located in Chandrapur district of Maharashtra (India) has been selected to apply our methodology. Input data for simulations such as sensor height, solar zenith, and spatial resolution has been obtained from the flight metadata files. WV values obtained from AVIRIS-NG data portal generated WV product. By removing background concentrations from the scene, CO_2 plume is enhanced. Our method successfully retrieves the CO_2 concentration emitted from the coal-fired thermal power plant. Methodology is based on Pandya et. al. (2021), which proposed the CIBR method to estimate CO_2 emission from Kota super thermal power plant at Kota (Rajasthan) [2]. The validation of the emitted plume has been carried out with wind speed and direction at the time of scene acquisition which were obtained from NASA's POWER API database system. This method successfully estimates the CO2 emission in the atmosphere at the location of a point source. This information may be useful in understanding the climate change of the location in consideration.

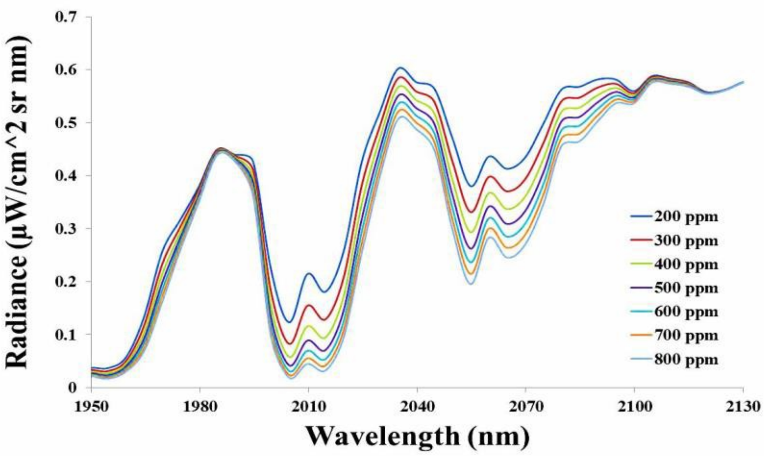

Figure 1: Radiative Transfer simulations of at-sensor radiance for varying CO_2 concentration in 1950-2130 nm CO_2 absorption region. A standard Tropical model atmosphere, with rural 23 km visibility aerosol model has been used for MODTRAN 5.3 simulations and simulated radiance convolved to the AVIRIS-NG spectral response.

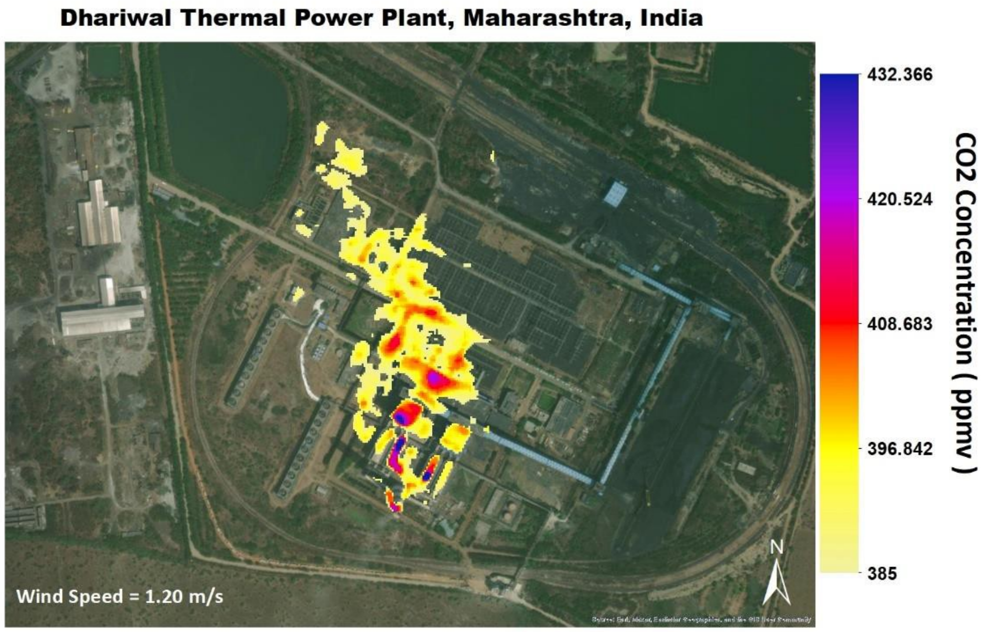

Figure 2: CO2 plume map for Dhariwal Thermal Power Plant (Maharashtra) with maximum 433.32 ppmv and 385.95 ppmv background CO_2 concentration. Map generated by overlapping retrieved plume on true color image of power plant obtain from Google earth imagery.

Cryosphere Processes and Climate Change

Glacio-Hydrological Modelling Approach for Assessing the Water Availability in Upper Indus Basin

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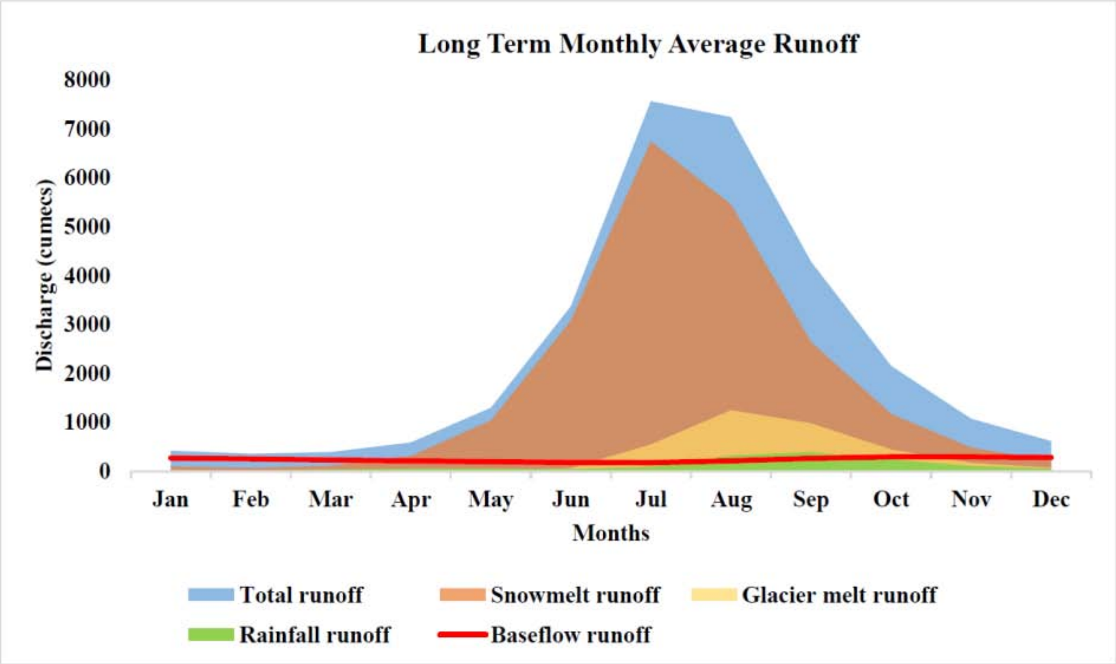
The Upper Indus River Basin is the major source of water to the millions of people. The river originates from Kailash near Manasarovar lake in Tibet and drains into the Arabian sea. The grave threat to this region's freshwater supplies is posed by climate change and increased freshwater demand. A deeper understanding of the regional water availability/variability in the Upper Indus Basin (UIB) is crucial for sustainable planning water management and policy making. The basin was delineated using Copernicus DEM, with Besham Quila as outlet having drainage area of about 1,64,829 km^2 . The challenge of delineating correct basin boundaries in the high altitude cold desert region of Tibet, where relative change in elevation is low at many locations, was overcome by using automated and supervised delineation which showed that Pangong Tso and some of the areas of western Tibet are not part of UIB, but the areas of internal drainage. This basin has major land use land cover (LULC) classes as, snow, glaciers, barren land, shrubs and water body. According to the global glacier inventory data from RGI- GLIMS, around 13% area of the basin is covered with glaciers and the long-term satellite data shows 70% of the area is covered with the seasonal snow. In this study, the large scale fully distributed cryospheric-hydrological model Spatial Processes in Hydrology (SPHY) was used to simulate the hydrological behaviour of the UIB. The basin was discretised at 1 km x 1 km spatial resolution. The meteorological data from ERA-5 was used to force the SPHY model setup for UIB. The model was run at a daily time step from 1985 to 2021. It was successfully calibrated and validated for the periods 1985– 1995 and 1995–2007, respectively, using observed discharge data of Besham Quila station. The SPHY model based computed river flow matched well with the observed river discharge with coefficient of determination (R^2) of 0.77 and 80 and model efficiency (NSE) of 0.73 and 0.77 during calibration and validation periods, respectively. The long term Annual Snow Persistence (LASP) maps generated through the model were comparable with the Moderate Resolution Imaging Spectroradiometer (MODIS) derived LASP maps. The runoff generated from different sources was analysed and it was observed that the Snow/ice melt runoff is the predominant source runoff compared to other sources i.e. Glacier melt runoff, Base flow runoff and Rainfall runoff. The Snowmelt runoff contributes to the 69% of the total runoff, while the Glacier melt was observed to be 17% of the total runoff, the base flow contribution was 9% and the rainfall runoff was observed to be the 5% of the total discharge. The runoff generated in this model is at a spatial scale which can be used for water-related planning, such as flood management, hydropower development and water resources use/protection, which may link

closely to water allocation decisions.

Figure 1 Long Term Monthly average Hydrograph at Besham Quila outlet



Assessment of glacial lake area dynamics and lake water surface temperature in Himachal Pradesh

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Glacial lakes are currently undergoing drastic changes in terms of their area and volume across the globe. Numerous glacial lakes are being formed as well. In the High Mountain Asia which includes the Himalayas, the total lake volume enlarged by 45% (Shugar et al. 2020). Such substantial changes are attributed to the changing climate scenarios. Climate change has a profound impact on the glaciers and glacial lakes especially the rise in temperature. Lake water surface temperature (LWST) is an important indicator of the glacial lake dynamics. LWST plays a significant role in the expansion lake as well as in the interaction of glacial lakes and glaciers. Recent studies have shown an overall noticeable warming trend in the lake surface temperature globally that is clearly a response to the current warming climate (W. Wan et al. 2018; Wei Wan et al. 2017). The present study intent to acquire an understanding of the glacial lake area dynamics as well as assess the response of glacial lakes to climate change where lake surface temperature serves as the indicator. The study aims at delineating glacier lakes and analysing the area expansion as well as assessing the trend in lake water surface temperature from 2000 to 2020 in the glaciated regions of Himachal Pradesh, India using remote sensing techniques. Landsat series of data from 2000 to 2020 have been used for the study. NDWI (Normalised Differential Water Index) approach has been utilized to identify the lakes and the delineation of lakes has been performed by manual digitizing. The lake water surface temperature has been retrieved using radiative transfer equation method. Statistical Mann- Kendell trend test as well as Sen's slope test has been carried out with two significance levels 0.05 and 0.1 to find out the trend in LSWT. The study has found that there is a huge increase in the total surface area of lakes. The total glacial lake area in Himachal Pradesh has expanded by 5.2 km^2 during the period of study from 2000 to 2020. 224 newly formed lakes have been identified in 2020 as compared to 2000. Samudra Tapu Lake has the largest magnitude of lake area expansion by an area of 0.6 km^2. Gepang Gath lake has the second largest area expansion with an increase of 0.5 km^2. Seven major lakes were chosen for the trend analysis in lake water surface temperature. In all the seven lakes LWST has an increasing trend. Four lakes show significant trend at 0.05 significance level and five lakes show significant trend at 0.1 significance level. LWST of Samudra Tapu Lake is increasing at a rate of 0.184°C per year (Fig.(2)) and for Gepang Gath Lake the rate is 0.301°C per year. Due to their rapid rate of lake extension, massive volumes, high peak discharges, and the existence of settlement in the downstream area, both of these lakes are in critical condition. (Kaushik, Rafiq, et al. 2020). Climate change has largely affected the western Himalayan region which is quite evident from the trend analysis of lake water surface temperature. It correlates well with the expansion of glacial lakes in the region. Glacial lake expansion is highly risky especially for the moraine dammed lake making them highly susceptible to GLOF conditions. The moraine dammed lakes Samudra Tapu and Gepang Gath having undergone huge area expansion as well as rise in LWST are under threat. The study highlights the importance of

lake water surface temperature as an indicator of climate change and in understanding the response of glacial lakes to climate change.

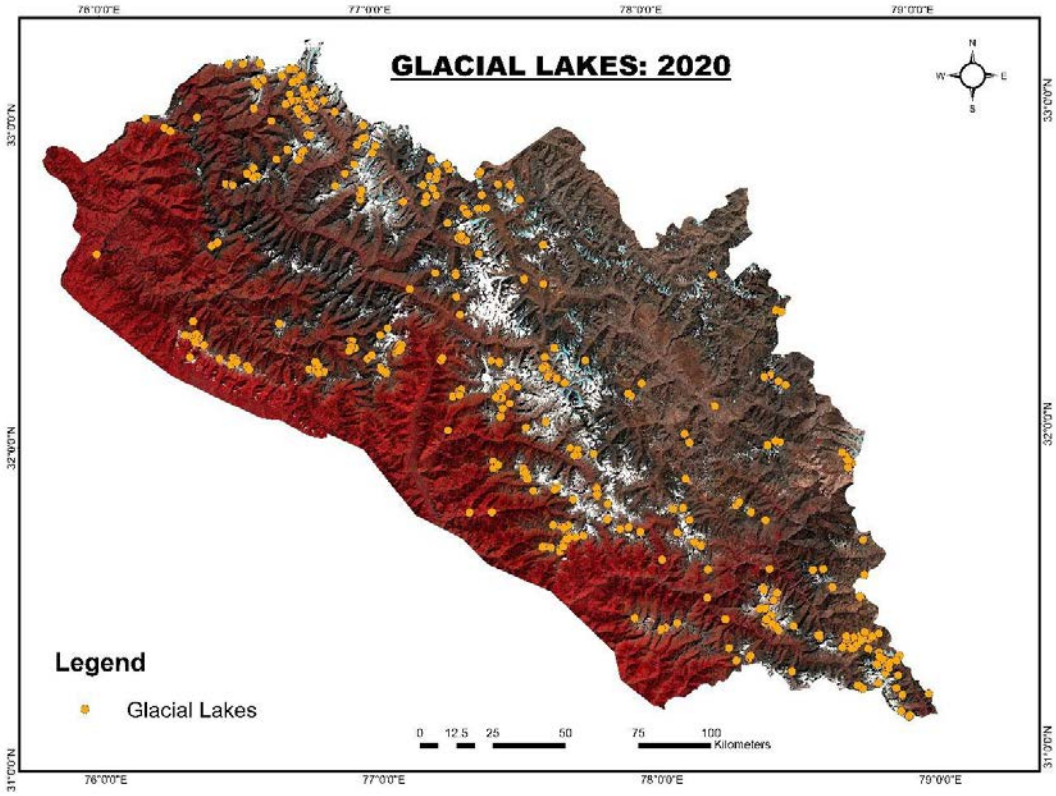

Fig. (1): Delineated glacial lakes for the year 2020

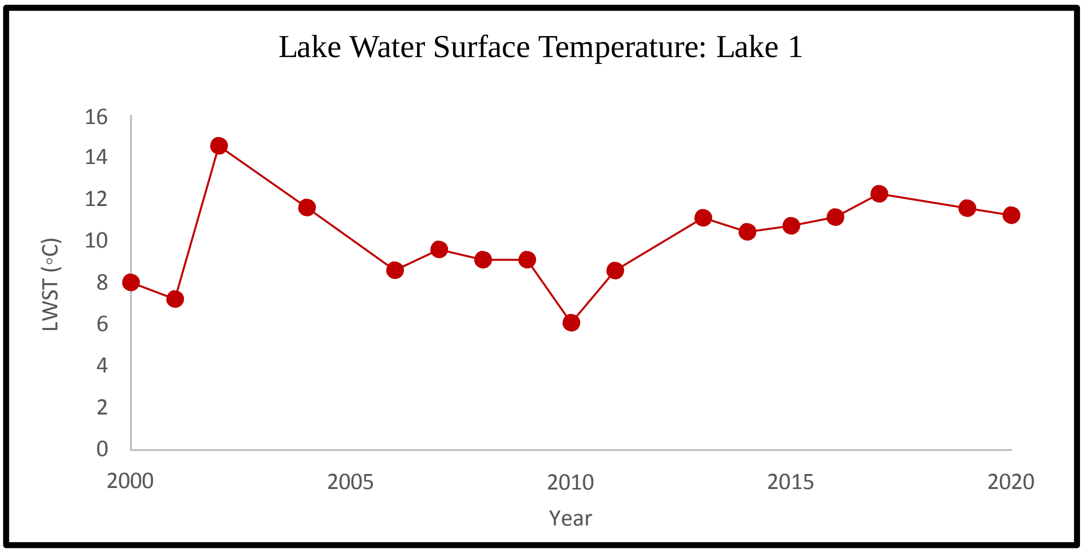

Fig. (2): LWST trend of Samudra Tapu lake from 2000 to 2020

Snow-glacier melt runoff separation and variability assessment under glaciers change in Himalayan Teesta river basin

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This study has been performed over the Himalayan Upper Teesta river basin (up to Teesta Lower Dam IV) to analyze the impact of snow-glacier changes on the melt runoff during (1996-2020). This study demonstrates the application of a fully distributed glacier runoff model viz. SPHY, which incorporates the variable degree-day factors-based temperature index model. This study characterizes the contribution of different runoff components (e.g. snow melt runoff, glacier melt runoff, base flow and rainfall induced runoff) at different locations. In this study, the different times (temporal) glacier maps (i.e. 2000 and 2020 years) have been prepared and then the two step computations (i.e. 1996-2010 and 2006-2020) have been performed to account the glacier area changes and their impacts on resultant different runoff components. The strength of the glacier melt induced runoff computation has been evaluated with reference to observed discharge at the outlet location, which showed a reliable agreement between modeled and observed runoff (ranges between ~84%). A noticeable reduction in the glacier areas has been observed (5% mass reduction in 20 years) in the Teesta river basin and it has been observed that the watersheds having large glaciers, the melt runoff has increased, while in cases of the watersheds having small size glaciers, the melt runoff has decreased due to reduced glacier cover. Overall, the snow-glacier melt runoff has shown noticeable variability in the basin. The glacier melt runoff is increased by ~1-2%, while snowmelt runoff has decreased by 3%. These observations have immediate consequences for policy making for the management of water resources in the glaciated catchments of the Himalayan regions.

Atmospheric Precursor Response to the Antarctic Sea Ice Record Low

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Antarctic sea ice expansion and recession are asymmetric in nature, with regional and temporal variations. The decade-long overall increase in the Antarctic sea ice extent (SIE) until 2015 showed a decrease in recent years since satellite records were available. The present study focused on determining the atmospheric forcing and climate fluctuations responsible for the lowest SIE record in February 2022. Here, the lowest SIE record was assumed to result from the sea ice recession that began in September 2021. The SIE reached a record low of 2.16×10^6 km^2 in February 2022, which was 43% lower than the mean extent of the previous February months since the satellite era. However, the second-lowest SIE was recorded from November 2021 to January 2022. The Weddell Sea, Ross Sea, and Bellingshausen/Amundsen Seas (ABS) sectors experienced the maximum sea ice change on a regional scale. The record-low SIE occurred when the Amundsen Sea Low (ASL) pressure center was intensified, with the Southern Annular Mode (SAM) at its positive phase. Together, these two climate fluctuations played a role in modifying the pressure and wind patterns in Antarctica. Further, the study investigated the Polar Cap Height (PCH), which demonstrates a strengthening of the stratospheric polar vortex and positive polarity of the SAM. Regions dominated by warm northerly winds produced decreased SIE. However, sea ice increased due to wind-driven sea ice drift towards the north.

AI-based extraction of glacial lakes in Himachal Pradesh

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The impact of climatic change in recent decades has significantly affected the cryosphere globally by altering the glacier and permafrost life cycle. The changes in the cryosphere have increased the risk of snow and glacier-related hazards such as snow avalanches, debris flows, and glacial lake outburst floods (GLOFs) in the mountainous region. As glacial lakes develop and expand in response to rapid snowmelt, the potential risk for catastrophic glacial lake outburst floods (GLOFs) increases in the downriver valleys. Recently the GLOFs have emerged as one of the devastating hazards causing massive destruction of infrastructure, disruption of socio-economic activities, and life loss. Some examples are the Parchu flood in Satluj Valley (2005), the Chorabari lake outburst in Kedarnath temple (2013), etc., impacting the downstream setting. So, regular monitoring of glacial lakes is needed to minimize the damage and evaluate these kinds of catastrophic hazards. The standard approach for delineating glacial lakes using remote sensing data involves using indices like NDWI, MNDWI, etc., and manual delineation and post-processing correction, rendering the entire technique semi-automatic in nature. Besides obtaining commendable results, these methods are time-consuming and need proper post-handling. In the present study, Artificial Intelligence(AI)-based algorithms are used to automate the entire process of glacial lake extraction from satellite imagery. Artificial Intelligence-based convolutional neural network (CNN), i.e. U- net architecture, was used to extract glacial lakes in Himachal Pradesh situated in Western Indian Himalayas from 2010 to 2020. we selected the Landsat satellite bands i.e., 3, 4, 5, and 6 to extract glacial lakes in the study area. Models output will be validated using Google Earth images and compared with accuracy metrics including precision, recall, and F-1 score. In addition, a collective approach has been applied to improve the precision with which we can identify the contraction or enlargement of glacial lakes. Associated with existing state-of-the-art techniques, our suggested approach accomplishes exceptional results and could be used for future glacial lake studies.

Aspect wise Monitoring and Estimation of Mass Balance of Glaciers of Baspa Basin, District Kinnaur, Himachal Pradesh, India using remote sensing techniques

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Himalaya has the largest concentration of glaciers outside the Polar Regions. Predominantly Himalayan glaciers are valley type in morphology and most of them are covered by debris. Therefore, they provide unique and complex interaction with climate. Melt water from these glaciers forms an important source of water for most of the North Indian Rivers. Based on the recent observations on the Himalayan Glaciers, it is observed that most of them are showing a retreating trend. Thus monitoring of these glaciers would be helpful to assess the future availability of Himalayan water resources. In the present study, the glaciers of Baspa basin, a sub basin of Satluj catchment have been studied in detail using remote sensing data verified through in-situ observations. The mass balance using AAR method has also been estimated for all the glaciers and was validated with that of the insitu observations at Naradu and Shaune Garang glacier. A total of 78 glaciers were identified from the Survey of India toposheets for 1962 and classified on the basis of different aspects. Aspect wise glacier area and percentage change in the glacier area was estimated based on the glaciers layers generated from IRS LISS III and Landsat images for the year 2001,2006,2011 and 2018 respectively. From the analysis , it was observed that a deglaciation or loss of 0.97% could be seen between 2001 and 2006, 1.02% loss between 2006 and 2011 and about 1.09% between 2011 and 2018 from image to image data analysis. In general a total loss of glacier area from image to image analysis between 2001 and 2018 is observed to be about 3.06% i.e. the 77 glaciers mapped in 2001 has total area of 158.53 km^2 has reduced to 153.68 km^2 and maximum deglaciation is observed to be amongst the southeast and southwest facing glaciers (7.98% and 7.93%) whereas the east facing glaciers shows a loss of about 7.26 % during this period. Further analysis reflects that between 2001 and 2006 per year loss is of the order of 0.31 % with the maximum is amongst the northwest facing glaciers where the loss per year is of the order of 0.082 km^2/year and the minimum is 0.018 km^2/year amongst the south facing glaciers. As far as the percentage change in 2001 and 2006 is concerned, it is of the order of 0.97 km^2 with the maximum change amongst the southwest and southeast facing glacier (2.54% and 2.52%) and the east facing glaciers shows a deglaciation change of 2.03% during this period. In terms of the north facing glaciers, they show percentage of 0.48% (2001and 2006),northwest (0,77%) and northeast (0.77%) loss in the glacier area in comparison to south facing glaciers which has deglaciated at the rate of 1.39% between 2001and2006 and west facing glaciers by 1.12% respectively. Likewise between 2006 and 2011,the percentage change is of the order of 1.02%(2006-11) with maximum is of the order of 3.41% amongst the southwest and 2.15% in southeast facing glaciers reflecting that there is slight increase in the deglaciation during 2006-11 in comparison to 2001-06 and slight reduction in southeast facing glaciers. The north, northeast facing glaciers shows a slight decrease in rate of deglaciation i.e. north (0.33%), northeast (0.64%) in comparison to

2001- 06 period where as the northeast facing glaciers shows an increasing trend of deglaciation (1.39%) in comparison to 0.77%(2001-06).Likewise the south facing glaciers deglaciated by 1.56% (2006-11) in comparison to 1.39%(2001-06) and west facing glaciers shows a reducing trend. As far as the per year loss between 2006-11 is concerned, total per year loss for all the glaciers of Baspa basin is of the order of 0.332 km^2 with maximum amongst the northwest facing glaciers (0.68 km^2/yr.) and the minimum (0.02 km^2/yr.) amongst the south and southeast facing glaciers. During the period (2011-18) total deglaciation is of the order of 1.09% between 2011 and18 and per year loss is of the order of 0.242 km^2 which is comparatively less than the preceding years. The maximum loss per year is within the northwest glaciers (0.044 km^2) and the minimum (0.021 km^2/yr.) in the west facing glaciers. As far as the percentage is concerned, the higher rate of deglaciation is reflected by the southeast facing glaciers which is 3.52% less in 2018 than 2011 and is comparatively on higher side than the preceding years trends. The east facing glaciers during (2011-18) shows a deglaciation of 3.34% which is also on higher side than the preceding years, whereas the southwest glaciers shows a deglaciation of 2.47% in comparison to 2.54%(2001-06) and 3.41% (2006-11) respectively. The south facing glaciers during the period (2011-18) shows a percentage change of 2.54% which is comparatively on higher side then the preceding years. The north facing glaciers deglaciated by 0.46% (2011-18), northwest by 0.59 % (2011-18) and the west by 0.91% (2011-18) respectively. Using Accumulation Area Ration (AAR) method, the mass balance for the glaciers of Baspa basin was calculated during the period 2014-17 and the results thus observed were validated with that of field based observations at Naradu and Shaune Garang glacier in the basin. The AAR method of mass balance appears to follow very closely the field method of mass balance in the Naradu glacier. The correlation of 0.50 for the Naradu glacier while 0.55 for Shaune Garang glacier respectively was found between the mass balance calculation by field method and AAR (Remote sensing) method for the 4 years (2013-14 to 2016-17), which suggests further validation for longer data series as well as to other glacial environment. With longer data of mass balance by both the method may also help in tuning the constant value of the formula of AAR method to give closer result to the field mass balance. Under this condition the AAR method can be applied to many other glaciers for deduction of mass balance where field observations are not being performed and also difficult for the field glaciological mass balance. The study would be useful in estimating the overall behaviour of the glaciers located in the valley and to assess the impact of climate change on the different aspects of the glaciers besides the applications of remote sensing methods in estimating the mass balance where field data is not possible by conventional methods. The change in glacial dimensions over a period of time would also be helpful in estimating the implications of the climate change on Himalayan glaciers in general and on the hydel power projects operating in the valley downstream for their sustainable water availability in the time to come.

Naradu Glacier is one of the north facing glaciers in the Baspa valley contributing its discharge to Baspa River, a major tributary of the Satluj River system. The monitoring has been done using base layer of 1962 based on Survey of India (SOI) topographic maps and satellite data of IRS LISS III & LISS IV for the year 1999, 2001,2004,2005,2007,2011 and 2013. For different intervals of time period, the reduction of glacier area of the order of 0.02, 0.06,0.04, 0.10, 0.05and 0.05 sq. km has been observed during the period 1999-2001, 2001-2004, 2004-2005, 2005-2007, 2007-2011 and 2011-2013 respectively. The dynamic movement of the glacier from 1962 (SOI) to 2013 (satellite image) reveals a total deglaciation of 1.35 sq.km and this loss in percentage is very high of order of 34%, whereas, a reduction in area of about 9% has been found for the recent period 1999-2013. The result clearly indicates that the Naradu glacier has shown a high deglaciation. The linear movement of the glacier has also been monitored based on the snout positions calculated from different sets of satellite data. The elevation of the snout has been calculated using SRTM data and contour values from the toposheet. Based on the above analysis using IRS LISS-IV satellite data, it has been found that there is a large reduction in the length of glacier quantified as 1892.78m, 246.61m and 52.24 m during years 1962-2004, 2004-2011 and 2011-13 respectively with the increase in elevation of the snout position. The glacier mass balance is also negative for the last 4 years (2011-12 to 2014-15) based on the field observation. Thus based on the investigations, it is concluded that the Naradu glacier has shown retreating trend both in terms of the total size of glacier as well as in its linear length.

Downscaling of GRACE and its utility in exploring cryospheric hydrological components

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Seasonal snow water is the crucial source of water in the upper Ganga basin of north western Himalayan region and it is of great significance to be estimated. In this study estimates the seasonal snow water equivalent (SWE) in the Upper Ganga River basin for the 16 snow seasons from the period 2001 to 2020 at 9 snow-glacier dominated watersheds. For this purpose, the spatially distributed Spatial processes in Hydrology (SPHY) model in conjunction of Gravity recovery and Climate Experiment (GRACE) satellite data have been used. This model separates the contribution of snowmelt, glacier melt, baseflow, runoff induced with rainfall from the total runoff at different watersheds. The calibration and validation have been done using observed discharge and GRACE satellite derived total water storage anomalies (TWSA). At Rishikesh outlet, the coefficient of determination R2 is recoded ~0.6 with respect to the observed discharge. The seasonal snow cover computed by SPHY is validated by snow cover derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) 8-day snow cover maps with a coefficient of determination 0.73 (2015). For validation purpose, the GRACE data is downscaled from 1° X 1° to 0.25° X 0.25° for working at watershed scale by incorporating simple Multilinear Regression (MLR), Random Forest (RF) and Support Vector Regression (SVM) machine learning models. For predicting downscaled GRACE data, a statistical relationship is established with Global Land Data Assimilation System's (GLDAS) soil moisture, canopy water, root moisture, and snow water equivalent hydrological variables with GRACE data and results have shown a well match between GRACE and GLDAS variables (the R2 varies from ~0.4 to 0.7). It is observed that the RF performed superior as compared to other methods in predicting the downscaled GRACE data in the upper Ganga river basin. The downscaled predictions at watershed scale combined with SPHY simulations for estimating the SWE. Results showed that the estimated SWE & TWSA (by the coupling of SPHY+GRACE) is found comparable with GLDAS SWE & TWSA, which is almost 33% underestimated than our computation.

Time series remote sensing data analysis for retrieval of non-climatic glacier parameters as a part of climate change indicators: A detailed analysis of Chandra River Basin (CRB), Himachal Pradesh

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The Himalayas assembles largest concentration of mountain and valley glaciers which replenishes the major perennial river systems of northern India. Recent trend of rapid and continuous recession, stagnation and resulted changes in Himalayan glaciers has drawn the attention of scientists and researchers worldwide. With increasing availability of space borne remote sensing platforms with high spatial and temporal resolution, allow users for fast and cost-effective ways to estimate glacier parameters in remote and inaccessible glacial terrains. An attempt has been made in the present study, to retrieve non climatic glacier parameters for glaciers of Chandra River Basin (CRB), in Lahul & Spitti district of Himachal Pradesh, categorised under same climatic regime using space borne remote sensing based observations. In this context, synergistic use of time series, multi sensor (active & passive) earth observation data such as LANDSAT-8, Sentinel-2, IRS P6 LISS IV and C-band Sentinel- 1a data and topographic derivatives from CARTOSAT-1, ASTER, ALOS, Tandem-X and STRM digital elevation models, were analysed to retrieve various non-climatic glacier parameters such as, accumulation-area ratio, seasonal and annual variation of ice thickness, surface ice velocity, debris cover extent, terminus changes, equilibrium line altitude for 2015-2018 time period for glaciers of Chandra River Basin. With careful observations, these remote sensing derived glacier parameters will help to evaluate and understand the status of glacier responses in terms of non-climatic topographic factors and in turn impact on glaciers due to climate change.

Chandra River Basin (CRB) of western Himalaya, Himachal Pradesh constitutes of about 428 mountain and valley glaciers (Glacier Inventory, GSI, 2009 & RGI v.6.0,2017). The study area covering 2422.1 km^2 is situated between 32°5'28"N–32°44'51"N latitude and 76°51'24"E–77°48'17"E longitude where the elevation ranges from 2800 m and 6300 m above sea level. Some of the prominent glaciers of this basin are Bara Shigri, Samudra tapu, Chhota Shigri, Hamtah, Sutri Dhaka, Batal and Gepang Gath. Famous Turquoise blue Colored Chandra taal lake is located in the eastern part of basin, in addition to two pro-glacial moraine dammed lakes near Samudra Tapu and Gepang Gath glaciers. Based on the temporal remote sensing based observations and topographic derivatives extracted from multi resolution digital elevation models, mean estimated Supra Glacial Debris (SGD), Peri Glacial Debris (PGD) covered area were 6.8 & 7.1 % of the total basin area respectively in 2016 (Fig.1).

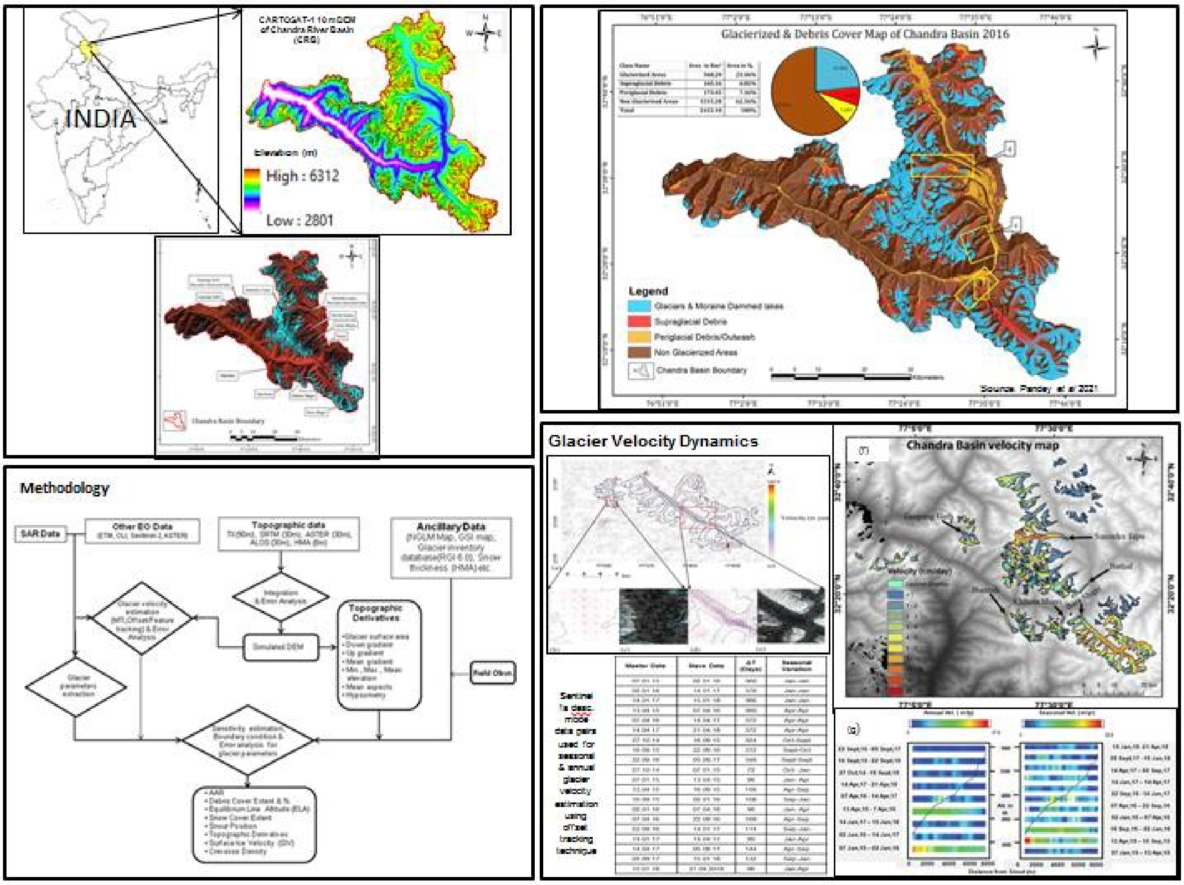

Fig. 1: Retrieval of non-climatic glacier parameters from time series satellite based remote sensing data for Himalayan glaciers: case study on glaciers of Chandra River Basin (CRB), Himachal Pradesh

Based on seasonal & annual glacier velocity, estimated using Sentinel 1a GRD high resolution descending mode data for 2015-2018 time period in Chandra River basin (CRB), it was observed that the glaciers velocities are mostly low and reduced as they get closer to the terminus because, in general, glacier velocity is controlled by thickness, steepness, density and ice mass. Besides this, it is also observed that large glaciers like Bara Shigri and Samudra Tapu are moving with the highest velocity among all the remaining glaciers in Chandra River-Basin (CRB).

Dynamics of Glaciers in Himachal Pradesh using Google Earth Engine

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Most of the world's glaciers are currently experiencing mass loss, which will contribute to a host of globally environmental impacts, such as increasing glacier meltwater, rising sea level, and increasing water scarcity, and Glacial Lake Outburst Floods (GLOFs). The accelerated glacier retreat due to the increase in global temperature caused by anthropogenic and natural causes is an essential indicator of climate change and climate variability. Glacier meltwater plays a vital role in providing water resources to population downstream of glacier mountain ranges. Therefore, it is an essential job to investigate the glacier variability and potential impacts on long-term sustainability of water supply. The standard approach for delineating the glaciers boundary is using machine learning tools and remote sensing data that involves using indices such as NDSI and NDWI, but these approaches require a large disk space to store various scattered data, which makes these approaches hefty and costly. Due to the increase in datasets and their required processing's in larger research areas, cloud-computing will more likely become a standard requirement. A cloud computing platform Google Earth Engine (GEE), that holds a large collection of satellites imageries, geospatial data catalogues and allows the users to visualize and analyze the data through a web-based system. In this study, GEE based algorithm and Landsat dataset are used to delineate glacier boundaries in Himachal Pradesh from 2010 to 2020. Results are further validated on Google Earth pro. Furthermore, these algorithms can be used again for future studies.

Analysing Temporal Trends of Climatic Variables and Its Relationship with Water Discharge for Dindori Watershed of Narmada Catchment

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Climate change has impacted forests creating severe implications on sustainable flow of water in adjoining river ecosystems. Such imbalance in the already sensitive eco-hydro-meteorological phenomenon entails research on understanding the impacts of climate change on river ecosystem. Majority of Peninsular and Central Indian rivers are forest-fed and the perennial flow is constantly threatened by changes in climate and forest. Therefore, the climate- forest dynamics affect the ecological, economic and social potential of river Narmada. This study analyses the temporal climatic trends of 65 years (1951-2015) over Dindori watershed (forest-dominated) in the upper catchment of Narmada River basin, Madhya Pradesh. The climate variables (precipitation and temperature) were analysed to assess the annual and seasonal trends of maximum, minimum and mean temperature (1°x1°) and precipitation (0.25°x0.25°) from available data sources (India Meteorological Department gridded datasets and station data). The non-parametric Mann-Kendall test and Sen slope estimate, which can detect the presence and magnitude of long-term monotonic trends, were used to assess the climatology. The results indicate varying trends for rainfall and significant decrease in annual and monsoon precipitation in station and gridded dataset. A significant upward trend in Tmax, Tmin and Tmean for seasonal and annual scale at different significance levels was also observed for the watershed. The impact of climate variables on water discharge of Dindori watershed was also assessed by correlation and regression analysis of the annual, monthly precipitation and water discharge for the time period between 2008-2015. A statistically significant relationship was found between the variables, which implied that changes in climate variables will have severe impacts on water flow of the watershed. The results clearly enunciate the presence of climate change in the upper Narmada catchment and highlight the importance of long-term climatic trend analysis with respect to water quantity variables at site-specific level. Such findings reinforce the notion that impact of climate change on the catchment of a river ecosystem at the regional level is necessary for planning effective management strategies for water and forest resources.

Lichen Probability Mapping in Antarctica Using Machine Learning On Satellite Remote Sensing Data

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Lichens are exceptional symbiotic organism (algae + fungi) known to be well adapted to the extreme environments and their peculiar lithic lifestyle, thanks to their low mineral nutrient demand, high freezing tolerance, and ability to do photosynthesis even at suboptimal temperatures. Even if lichen communities are known to be most resistant and adapted organisms to the extreme environments, our knowledge on their abundance in the peculiar niche of Antarctica is very limited. Moreover, sampling frequency and effort on collecting *in-situ* spectra of lichens are also scarce. Extensive lichen surveys were conducted as part of the 39th Indian scientific expedition and *in-situ* spectra (350nm to 2500nm) were collected in the rocky islands near Indian research station, Bharti, located in the Larsemann Hills, East Antarctica (around central longitude 76.20^{o} and latitude -69.40^{o}) during austral summer of 2020 (January 15, 2020 to February 17, 2020). Several islands at Larsemann hills were surveyed on foot to record presence of lichens. The smaller islands were surveyed in detail while straight line transects were conducted on larger islands to capture the variabilities in short span of time. GPS tagged photographs were taken to prepare GIS database of lichen occurrences. Sentinel-2 MSI: MultiSpectral Instrument, Level-2A, Surface Reflectance image collection (01 October 2020 to 28 February 2021) were used with total 14 selected bands (B-1 to B-12, B8A, and QA60). As this study aims to map the presence of lichen in a region that has a significant presence of snow, we added Normalized difference snow index (NDSI) as a band to segregate snow pixels for initial multiclass non-probabilistic classification. Our workflow consisted the following steps: (1) cloud masking, (2) data cleaning i.e. discarding

spectrally dissimilar points from the initial super-set of reflectance files, (3) calculating NDSI and adding it as a layer, (4) Generating multi-class classification outputs for the study area, (6) merging all classes except snow into a single class *"Non Lichen"*, to produce bi-class classification output that maps every pixel with a confidence value (between 0 and 1) depicting similarity of its spectral response to that of a lichen pixel. To prepare feature collection, at first, we used known representative data points collected from North Deception island for classes: Lichen (16 pts), Non Lichen (52 pts), Water (26 pts), and snow (13 pts).

We extracted wavelength and reflectance (350nm to 2500nm) from spectrometer data and created visualizations using MatPlotLib to understand their spectral responses. By doing so we were able to determine which bands would play an important role while segregating pixels based on their reflectance values available in the form of bands in the sentinel-2 dataset. While choosing points to train an initial model we eliminated points that had different spectral behavior as compared to other points.

We generated feature collections for lichen, snow, water, bare surface and trained a random forest classification algorithms implemented in google earth engine (GEE) and generated multi-class outputs. Having obtained laudable results for Deception Island, we repeated the process on the our study area (the Larsemann hills). For every pixel, the model predicted the class id with confidence values in case of lichen presence. This was achieved using 'set_output_mode' in GEE. It supports probabilistic outputs when the target variables assume only two values. We finally merged all non-lichen classes (snow and bare rocks feature collections) and produced binary pixels with a confidence value (between 0 and 1) for lichen class depicting similarity of its spectral response to that of a lichen pixel. Total 92 lichen points, 20 bare rock points and 74 snow points were used to generate the probabilistic lichen abundance map. Resubstitution accuracy of 98.31% was obtained with 10 number of RF trees. However, validation was done with geotagged ground photographs having 232 lichens, 20 bare rocks and 69 snow points (from satellite image) and achieved test accuracy of 80.87 %.

Glacier Lakes Mapping using Google Earth Engine in Himachal Pradesh

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Due to changes in climate, glacier recession, area of glacial lakes has increased rapidly in last few decades and consider as an important indicator of climate change. In response to climate change, the glaciers are now retreating and thinning which accelerates the evolution of glacier lakes and increases the risk of glacier lake outburst floods (GLOFs) in downstream areas. The flood and debris flow due to glacial lakes outburst has the potential to threaten downstream areas and causes serious damages to valuable properties, socio-economic activities and life loss. Some recent examples of GLOFs are the Chorabari lake outburst flood in Kedarnath temple (2013), the Chamoli disaster held on 7 Feb 2021 in Uttarakhand. Therefore, to understand the formation and development of glacial lakes, their regular monitoring is very important and also to mitigate the impact on downstream valleys. Because glacier lakes are often found in inaccessible regions, space-borne remote sensing offers a practical method for comprehensive mapping and inventorying of glacial lakes on a global scale. Conventional methods for mapping glacial lakes are manual delineation, using remote sensing indices such as NDWI and MNDWI. Besides acquiring great results, these processes are more time-consuming and need proper post-processing. One of the largest open-source systems, Google Earth Engine (GEE) stores massive amounts of satellite images and geospatial datasets that can be used by anybody for free to monitor and measure global land-surface shifts. This study uses Landsat datasets and GEE algorithms to map the glacial lakes in Himachal Pradesh from 2010 to 2020. Results are further validated on Google Earth pro. Furthermore, these algorithms can be used again and again for future studies.

Surge of Hispar Glacier, Pakistan, between 2013 and 2017 detected from remote sensing observations

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This study analyses the behaviour of an actively surging glacier, Hispar, in Pakistan using remote sensing methods. We used 15 m panchromatic band of Landsat 8 OLI from 2013 to 2017 to assess the changes in glacier velocity, glacier geomorphology and supraglacial water bodies. For the velocity estimation, correlation image analysis (CIAS) was used, which is based on normalized cross-correlation (NCC) of satellite data. On-screen digitization was employed to quantify changes in the glacier geomorphology and dynamics of supraglacial water bodies on the glacier. Our velocity estimates indicate that the upper part of the glacier is presently undergoing an active surge which not only affects the debris distribution but also impacts the development of supraglacial water bodies. Velocities in the actively surging part of the main glacier trunk and its three tributaries reach up to ~900 m yr^{-1}. The surge of Hispar also impacts the distribution of supraglacial debris causing folding of the medial moraines features present on the glacier surface. Changes in the number and size of supraglacial lakes and ponds were also observed during the observation period from 2013 to 2017.

Capturing the Properties of Zemu Glacier in the Sikkim Himalayas using Satellite Remote Sensing

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Sikkim Himalaya is the northeastern subset of the arcuate Himalayan belt, formed due to Cenozoic convergence between the Eurasia and Indian craton. Numerous glaciers concentrated in the northern portion of Sikkim drain their meltwater into the Teesta river, thus also termed Teesta basin glaciers. The largest among those is the Zemu glacier. Where field investigations are restricted in the Himalayan glaciated regions due to harsh weather conditions and natural hazards, remote sensing acts as an effective tool for the investigation of glaciers (Mondal and Bharti, 2022a; Mondal and Bharti, 2022b; Mondal and Bharti, 2022c). The present study attempts to investigate some of the crucial properties of the Zemu glacial body, such as surface mobility, glacial thickness, debris cover, and land surface temperature (LST). These properties help establish a first-hand understanding of a glacier which is vital in further analyses such as melt modeling, mass balance etc.

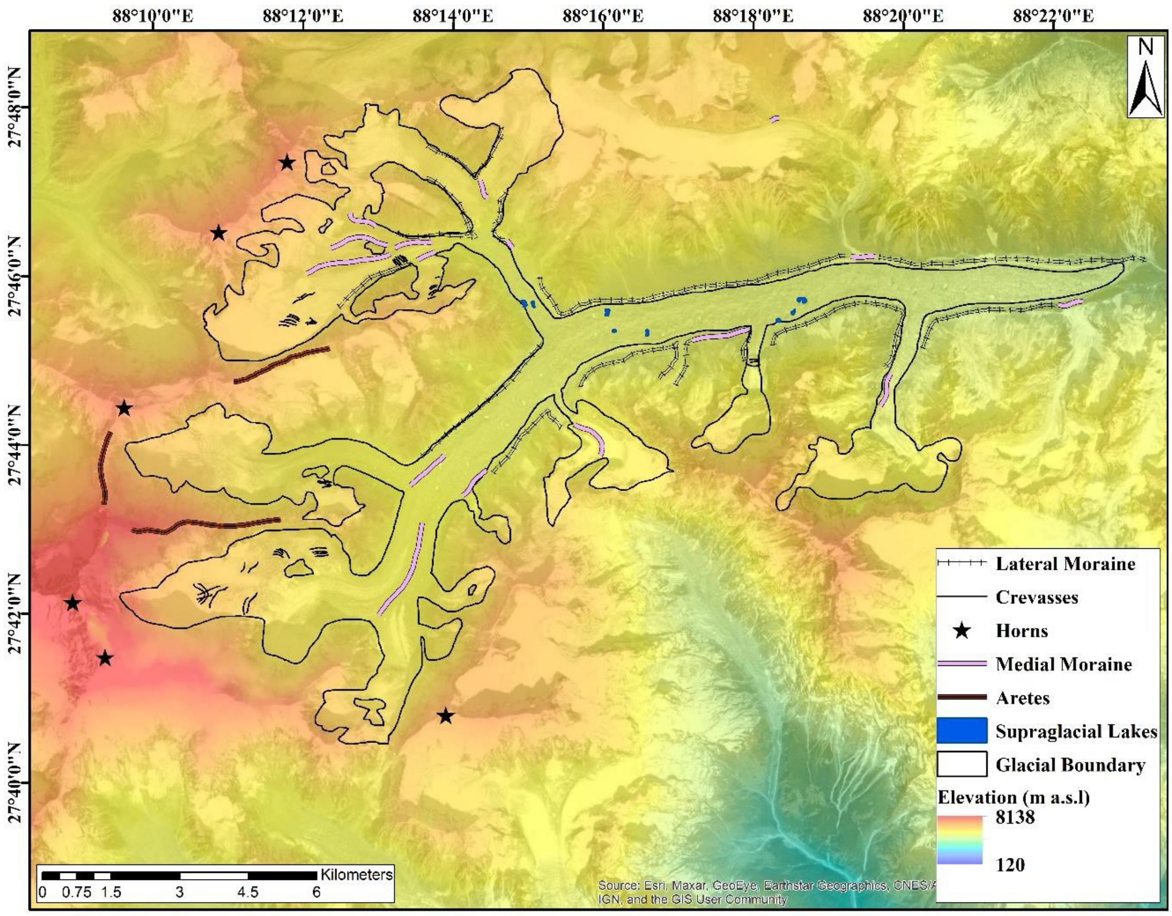

Figure 1: Study area map showing the geomorphological units of Zemu glacier

Zemu is a debris-covered valley glacier in the Sikkim Himalayas (Fig. 1). This glacier does not show any significant retreat in the last couple of decades due to the heavy dominance of debris near the snout (Basnett et al., 2016). Regarding the litho-stratigraphical characterization, the region belongs to a deeply faulted area. There are rock benches above the valley, possibly formed due to neo-tectonic upliftment. Horns can also be observed in specific locations around the glacial body. These features are formed when the glacier erodes multiple aretes, forming a sharp-edged triangular peak. Another important geomorphological feature of the Zemuglacier is supraglacial lakes.

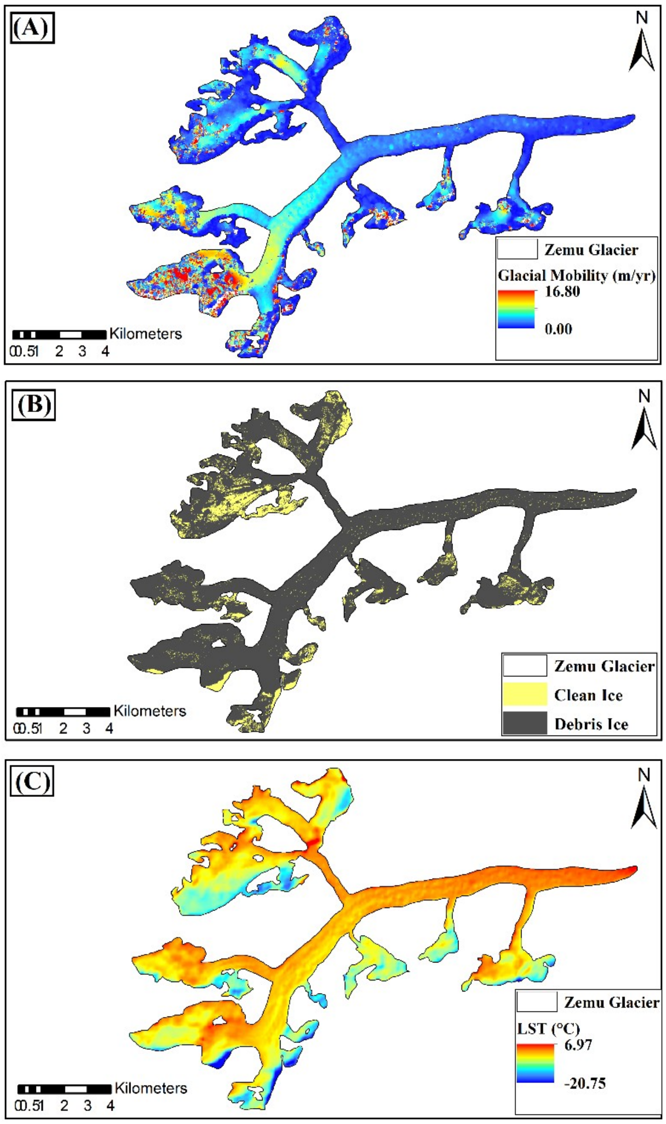

Figure 2: Map showing (A) annual surface mobility (2019-2020), (B) debris coverage (88.47%) and (C) LST within the Zemu glacial body

The study has been conducted using optical satellite datasets of Sentinel-2 MultiSpectral Instrument (MSI) dated 1st March 2019 and 29th February 2020 respectively. The datasets have been iteratively cross-correlated in the phase plane on sliding windows using the Cosi Corr extension to determine the best possible correlation, as shown in Table-1 (Leprince et al., 2007). The annual surface mobility of the Zemu glacial body shows a maximum velocity of m/yr with a mean rate of 2.2 m/yr (Fig. 2A). The regions of maximum velocity are mainly localized at the flanges that seem to be stabilized towards the main trunk of the glacier. The modeled glacial thickness shows a maximum glacial depth of 226.8 m with a mean glacial depth of 27.1 m. Flanges are captured with the dominance of clean glacial ice (Fig. 2B). The Zemu glacier can be considered a debris-covered glacier as a majority of the glacial area (60.7 Km^2) is covered with debris. The LST derived using Landsat-8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) of 10th March 2019 shows that the surface temperature within the glacial body fluctuates between -20.75°C and 6.7°C (Fig. 2C). The mean LST of Zemu glacier is -7.08°C which is below the melting point (0°C). The distribution of LST within the glacial body follows the observations from debris mapping and surface mobility. The lowest LST has been captured within the flanges where maximum glacial mobility and the presence of clean glacial ice have been observed. Moving towards the main trunk, the LST increases and exceeds the melting point.

Table-1: Details for sub-pixel correlation in the estimation of glacial mobility

Algorithm Preference Type	Preference
Master Data	Sentinel 2 MSI (01-03-2019)
Slave Data	Sentinel 2 MSI (29-02-2020)
Correlator Engine	Frequency
Window Size	32
Step Size	2
Robustness Iteration	4

The final equation used in the modelling of glacial thickness is shown in equation-1

$$H = \sqrt[4]{\frac{1.5U_s}{Af^3(\rho g sin\alpha)^3}} \qquad (1)$$

Here, '*US* ' represents the annual glacial mobility (m/yr), '*A*' is the Creep parameter that depends on grain size, impurity, temperature and glacier type (temperate glacier) and is considered to be 3.24×10^{-24} $Pa^{-3}s^{-1}$. '*f*' is scale factor which is the ratio of driving stress and basal stress along the glacier (0.8). 'ρ', 'g' and 'α' represents the ice density (between 830 to 923 kg/m^3), acceleration due to gravity (9.8 m/s^{-2}) and topographic slope of the Zemu glacier. The debris cover of the Zemu glacier has been derived using snow darkening index (SDI) as shown in equation-2.

$$H = \sqrt[4]{\frac{1.5U_s}{Af^3(\rho g sin\alpha)^3}} \qquad (1)$$

Here, '*Band3*' and '*Band4*' represent the green and red bands of Sentinel-2 MSI dataset used.

Therefore, it can be concluded that the Zemu glacier, one of the largest glacial bodies of the Sikkim Himalayas, has a large fluctuation in its glacial properties. Satellite remote sensing is a potent tool in investigating some prominent properties. Thus, rather than treating the Zemu glacier as a single unit, it is more appropriate to consider the glacial body as the main trunk connected with several flanges. Where the flanges have a different composition in clean ice and debris cover, their thickness, surface mobility, and LST vary significantly.

Understanding the dynamics of the Zanskar group of glaciers using surface velocity derived from remote sensing data

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University of Kashmir

Glaciers are mostly in high altitude regions of the earth and in polar regions. These are vital to mankind as they control the global hydrological cycle, maintain the global sea levels and supply fresh water to rivers. In the wake of climatic variations arising due to increasing concentration of greenhouse gases in the atmosphere resulting in global warming and its implication of various resources, glaciers are increasingly being monitored worldwide. The Himalayan Mountain system hold the largest concentration of glaciers outside the Polar regions. Snow and ice melt from these glaciers is used in catchment and alluvial plains of three major Himalayan River systems that of Indus, Ganges, Brahmaputra. Additionally, the change in the extent of these glaciers is understood to be sensitive indicators of climate variation. Therefore, monitoring dynamics of these fresh water resources is required to understand the impact of global climate change. Zanskar region is a high-altitude semi- desert; lying on the northern flank of Great Himalayan Range which acts a climate barrier shielding the area from most of the monsoon and creates a rain shadow zone. The elevation ranges between 3903 to 6305 m as and has maximum slope of 87̊. This study analyses glacier flow dynamics of Zanskar group of glaciers of western Himalaya by means of remote sensing data. Landsat 8 OLI images were used to calculate ice velocities using CIAS that works on principal of normalized cross correlation. This algorithm has been used to investigate earth mass movements such as glacier flow. Same data was used to calculate ice thickness using Laminar Flow Equation (Cuffey and Paterson, 2010). The 17 glaciers with area larger than 1 km^2 have been selected for velocity estimation. Our velocity estimates suggested reduced ice movement in debris covered velocity between 2013 – 2017 and from 2018 – 2020 in all glaciers, between 2017 – 2018 velocities were maximum in all of these glaciers including clean ice glaciers owing to extreme rise in temperature. Ice thickness showed decreasing trend until 2017 and then it increased between 2017 thereafter it started to decline again. Glacier volume was also calculated using ice thickness and area of a glacier as input. The results concluded that Drang Drung Glacier had the maximum amount of volume that is, 0.69 km^3 and Glacier with RGI ID 50-14.18725 had the minimum amount of volume that is, 0.02 km^3. The Randolph Glacier Inventory (RGI) was manually corrected at 1:10000 using Landsat 8 OLI and Google Earth. Most of the changes were seen at snout and along the valley walls. Debris cover was mapped at one year difference and images of post melting season were used. Temporal variations showed that total debris cover in the region increased from 36 km^2 in 2013 to 53 km^2 in 2020.

Assessing Climate change using different Meteorological Parameters over Bhubaneswar and surrounding

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Climate change and its uncertainties have severe direct and indirect consequences for sustainable urbanization. To quantize the adverse effects of climate change, measurements of spatial evolution of meteorological variables have become important in studying the climatological conditions of highly developing cities. Meteorological conditions like air temperature, relative humidity, precipitation, surface pressure vary significantly due to adverse anthropogenic forcings. The development of Geographical Information System (GIS) and integrated statistical methods have proved to be a robust tool in the analysis of climatic variables. The aim of this study was to identify near-term and long-term climate change in Bhubaneswar using weather data for the last three decades (1991â€“2021). The analysis focused on Bhubaneswar city and its surrounding areas of Cuttack and Puri as the climatic conditions of these regions are changing at an unprecedented scale. Meteorological observation data from MERRA2 and ERA5 reanalysis datasets were obtained for the period of 1991-2021. Statistical anomaly and trend analysis was performed on these data over the study area to assess information about accelerated increase or decrease in the atmospheric parameters. From the preliminary analysis, it was observed that Puri received the most amount of rainfall and experienced higher average temperature, wind speed and cloud cover, followed by Bhubaneswar and Cuttack in September, 2021. However, Bhubaneswar had higher morning and evening relative humidity, whereas Cuttack experienced the highest variability. Decadal anomaly was calculated for every 5-year interval (1991-2021), that is for the years 1991, 1995, 2000, 2005, 2010, 2015 and 2020. During these years, March 2010 witnessed the highest anomaly in temperature over the study area, due to an intense El-Nino condition in the Pacific Ocean. The month of March 2020 experienced a cooldown in temperature, as well as the highest positive anomaly in total precipitation compared to the 2011-2020 averages. Such long-term climatological data analysis can identify risks for planning appropriate adaptation and mitigation policies.

Snow depth retrieval in Polar Ural using L-band SAR

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Snow accumulation is a significant factor for hydrological planning, flood prediction, trafficability, avalanche control, and numerical weather or climatological modeling. Current snow depth methods fall short of requirements. This work explores an approaches for determining snow depth using regression analysis technique in case of Polarimetric SAR data. Ground snow depth measurements have been used to verify the results. Snow Depth Inversion Models pertaining to coefficient of correlation of about 0.75 are obtained for glaciers and about 0.80 are obtained for lake region. The estimated average depth for Ural Glacier for 18 May 2019 data was estimated to be 6.55 meters with mean absolute error of 0.24 meters and for 6 April 2019 data estimated depth was 6.44 meters with mean absolute error of 0.28 meters. Similarly, for Podkova Lake estimated average depth was 1.59 meters and mean absolute error was 0.42 meters for 18 May, 2019 data and for 6 April, 2019 estimated depth was 1.35 meters and mean absolute error was 0.22 meters. The GPR mean depth for Lake area was 1.57 meters and for Glacier area was 6.54 meters. The technique has been promising but still requires more research to refine its accuracy.

Estimation of Surface Ice Velocity of Drang Drung Glacier, Western Himalaya using COSI-Corr from Landsat Images

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A sizable population in south Asia receives water from the Himalayan glaciers for a range of uses and ecosystem services. Therefore, understanding and forecasting future cryospheric melting trends depends on regional monitoring of glacier melting and identification of the sources. Glaciers produce freshwater and regulate the global water cycle. Regional glacial retreat, volume, and mass changes, which also control the general health of the glaciers, have a direct impact on sea level rise. Field observations for measuring the surface ice velocity of glaciers are nonetheless hampered by the glacier domains rocky terrain and severe climate at high altitudes. The present study endeavours on computation of glacier surface ice velocity of Drang Drung glacier (Area ~ 68 sq.km, length ~ 23.34 km, snout altitude ~ 4160 m and avg. relief ~ 5185 m) in Zanskar valley, Ladakh. Landsat-8 (30 m resolution) satellite data has been used for mapping and deriving surface ice velocity using COSI-Corr an add-on module of ENVI image processing software using the cross correlation of Landsat 8 images of September 2019 and 2020. COSI-Corr provides three bands i.e., east-west displacement, north-south displacement and signal to noise ratio. Most notably, the signal to noise ratio aids in determining the quality of image correlation. Using the SRTM 90 m global DEM, the geo-morphometric parameters of the glacier surface have been determined. Further, the relationship between the surface ice velocity and various geo-morphometry characteristics including size, area, slope and aspect has also been delineated. ArcMap 10.8 and the ENVI platform have been used for all calculations and processing and it is found that the surface ice velocity ranged between 28 m/yr. near snout region to 140 m/yr. in the upper reaches of accumulation zone. It has been observed that one of the primary elements on which the velocity depends is the glacier's slope; the steeper the slope, the faster the glacier moves and the more ice it transports to the ablation zone.

Snow Cover Area variability during heatwave in early summer 2022 over North-west Himalayn sub- basins

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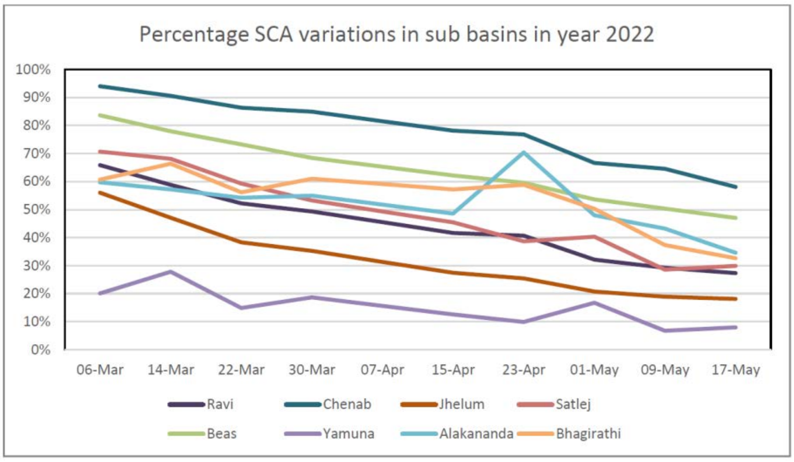
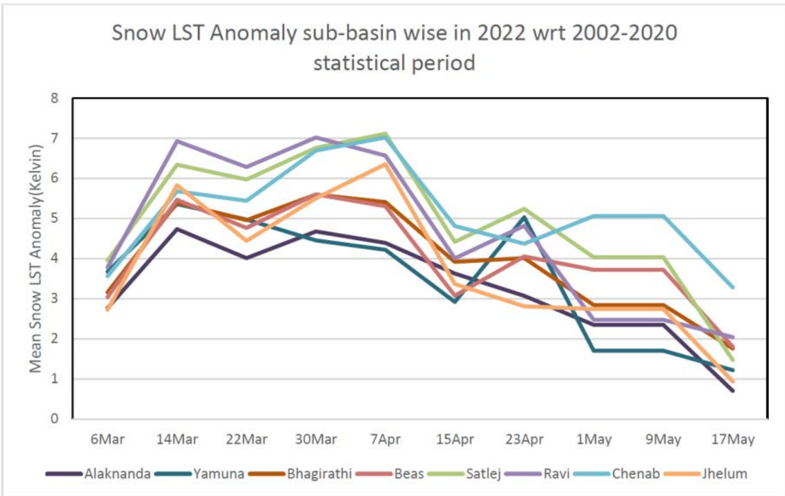
Himalayan mountains are considered to be the water tower of Asia. Indian Meteorological Department (IMD) declared Heatwave spells from March 2022 to May 2022 over India. Heatwave spells in this period caused accelerated depletion in Snow Cover Area (SCA) over the Himalayan region. This study highlights the SCA variability with respect to anomalies in Land Surface Temperature (LST) using MODIS 8-day composite datasets, namely MOD10A2 and MOD11A2. Sub-basins Jhelum, Chenab, Ravi, Beas, Sutlej, Bhagiratha and Alaknanda are analyzed to demonstrate the differential effect of heatwave over various sub-basins of North-west Himalaya. In this study we explore the timeseries SCA variability with respect to temperature variations during the heatwave spells over North-west Himalayan sub basins in the context of SCA variability between 2002-2022.





Climate and Land use change scenarios on the Hydrological Response of Suketi Watershed, Himachal Pradesh, India

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The current study aims to examine how changes in the climate and land use affect the hydrological behavior of the Suketi River basin, Mandi (Himachal Pradesh), India by hydrological modeling. The Soil and Water Assessment Tool (SWAT) was used to make the hydrological model and hence to simulate the discharge, which was calibrated and validated using the observed discharge data from the Mandi gauge site. The Suketi river basin mainly encompasses a central intermontane valley surrounded by mountains in the region of lower Himachal Himalaya. Morphometric analysis of the basin revealed the river as a 7th-order river. It has a 349 km^2 region of surrounding mountainous terrain and a 79 km^2 inter-montane valley in the center that is commonly referred to as Balh valley. While the mountains range in height from 800 to 2,900 meters above mean sea level (msl), the Balh valley has an average surface elevation of roughly 790 m above msl. The study employed 0.25-degree gridded precipitation data from the Indian Meteorological Department (IMD), the gridded surface temperature at a resolution of 0.1-degree spatial resolution obtained from ERA- 5, soil classification from NBSSLUP, and ISRO-GBP land use/land cover. Along with climatic and hydrometeorological data set digital elevation model from SRTM 30m was utilized for the study. The analysis shows a positive shift of +0.6% in Built-up area, +0.7% in Barren land, and +0.24% in water bodies which is an indication of the construction of reservoirs and lakes. However, there was a decline in the classes of Forest, and agricultural land with -0.14%, and -0.03%, respectively. The calibration and validation results for the monthly flow demonstrated a strong correlation between the measured and simulated streamflow and the model performance assessment; for calibration, the coefficient of determination is 0.88, and Nash Sutcliffe efficiency is 0.68, and for validation, the coefficient of determination is 0.79, and Nash Sutcliffe efficiency is 0.70. There is a strong correlation between rainfall and surface runoff in the watershed during the calibration and validation period, with a percentage of fit greater than 85%. For the land use/cover periods of 1985, and 1995, and 2005 the annual surface runoff is 110 mm, 120.65 mm, and 101.5 mm, respectively. Under climate change scenarios, the mean annual discharge increases between 0.40 to 7.9%, but under land cover change scenarios, it could decrease by 8% by the middle of the twenty-first century. Less impact of land use is an indication of reforestation at some places for horticulture practices in the region especially. Seasonal changes in discharge are more prominent than yearly variations under all climate

change and land cover scenarios. Though significant changes were found as decreasing forest cover and increasing built-up areas, the results imply that basin hydrology is more susceptible to climate change than changes in land cover.

Spatiotemporal changes in land terminating glaciers in contrasting topographic zones of Jammu and Kashmir region

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Glaciers are dynamic bodies of ice which have changed in the past and will continue to change in response to climate change. Glaciers are important indicators of climate change and are also referred to as terrestrial thermometers. That is why it is important to monitor and understand the glacial dynamics. Glaciers have been retreating worldwide since the end of the Little Ice Age (around 1850), but in recent decades glaciers have begun melting at rates that cannot be explained by historical trends. The spatiotemporal behaviour of glaciers in the Himalayas has varied greatly in response to reported climate regimes and other regulating factors such as topography, debris cover, and glacier morphology. The presence of a thick layer of debris, which is widespread on Himalayan glaciers, further complicates the dynamics and rate of mass loss of lake-terminating glaciers. The low-gradient, debris-covered portions of many Himalayan glaciers are preconditioned for meltwater ponding and eventually proglacial-lake development, which is commonly caused by the deepening and coalescence of supraglacial lakes which are bounded by a stagnant, ice-cored moraine dam. The stresses at the bed and the terminus of the glacier are two key factors which make lake-terminating glaciers distinctively different from their land-terminating counterparts. Monitoring the glaciers to understand their behaviour in different topographic and climatic regimes is important to assess the overall reservoir health. In this study, glacier retreat has been estimated for 343 land-terminating glaciers in the vicinity of 334 lake-terminating glaciers and their associated proglacial lakes in Jammu and Kashmir to understand the differential glacier dynamics in contrasting topographic and climatic regimes. Glaciers have been categorized into different basins including Gilgit, Lower Indus, Jhelum, Chenab, Shaksgam, Sulmar, Shyok, Upper Indus and Sutlej Upper basin. The Ravi basin was excluded from the analysis because of the absence of lake-terminating glaciers in the basin. The glaciers were assessed for area change, frontal retreat and the impact of topographical parameters (elevation, slope, aspect) on glacier recession over the past 20 years (2000-2020). The glaciers have been monitored at two points in time viz 2000 and 2020 using earth observation data. The multispectral datasets of Landsat viz Enhanced Thematic Mapper (ETM+) and Operational Land Imager (OLI) and Sentinel 2A have been used to map glacier boundaries for the years 2000 and 2020 respectively. Satellite data coupled with DEM information and high-resolution Google Earth data were used for delineating and validating the glacier boundaries. Satellite data analysis revealed that over the 20 years, the glacier cover reduced to 25.85 km2 indicating a loss at a rate of 0.25 % a-1 over 20 years. The maximum glacier melt has been found in the Chenab basin at a rate of 0.40% a-1, while the least glacier melt at a rate of 0.11% a-1 has been witnessed in the group of glaciers in the Sulmar basin. The snout of the glaciers has also shown a remarkable retreat in the group of glaciers over the 20 years. Results conclude the average frontal retreat of 66.09 m in the glaciers of the study area. Like the glacier area recession, the relatively higher glacier snout retreat of 102.8 m was observed in the Chenab basin and the lowest glacier snout retreat of 38.75 m was observed in the Sulmar basin during the study period. Glacier recession was further correlated with topographic parameters (elevation, slope, aspect) which revealed that the glacier recession in the study area does not show any significant correlation (r = -0.012) with mean glacier elevation. The mean glacier slope shows a negligible correlation (0.004) with the glacier area change. The glaciers with east, south and north-facing slopes lose area slightly faster than glaciers with other-facing slopes. A clear correlation was observed between the glacier size and the glacier area change indicating that the smaller glaciers were more susceptible to recession than the larger glaciers. Further, we can do the comparison of land and lake-terminating glaciers to understand the behaviour of land and lake-terminating glaciers whether they behave similarly or differentially and how similarly or differentially they behave in contrasting topographic and climatic zones of Jammu and Kashmir.

Desertification, Land Degradation and Droughts

Development and Comparative Assessment of Yield Modelling Techniques for Rabi Pulses using Geospatial Techniques and Ancillary Datasets: A Case Study for Drought Affected Region on India

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Pulses crops have the potential to help in addressing future global food security, nutrition and environmental sustainability and itâ€™s need has been acknowledged through the UN declaration of the 2016 International Year of Pulses. Hereafter, crop production and crop yield is as crucial as for main food grain crops. Crop yield is a very crucial factor in agriculture for achieving the goal of sustainable development. It plays a pivotal role in various policy makings (FAO 2016). Crop yield is essential for the national economic interest, so crop monitoring and yield estimation are crucial for various operational programs. Crop yield is majorly affected by various environmental factors while crop growth and development is influenced by weather, as a result causing significant intra-seasonal yield variability. Also, interacting with the weather, spatial variability of soil properties cause spatial yields variability. Crop agronomic management (e.g. sowing, irrigation, tillage, fertilizer application, and chemical application) can offset yield loss due to weather effects. Remotely sensed data have emerged as a powerful tool for yield modelling because of their unparalleled advantages, such as obtaining crop-specific information with adequate spatial and temporal coverage. Spectral components analysis provides a structure within which to examine a large number of relationships that describe the photosynthetic size, growth, water use and crop yield affected by their environment and stresses. There is a massive amount of remote sensing data available in the present day, which is multi-temporal and multi-spatial meteorological satellite data from various EO missions has shown to be thriving in crop area estimation, yield prediction. Various crop yield models have used by several researchers, which cater the difference because of available datasets or spatial variables or ancillary datasets along assumptions and limitations of each model viz. spectral indices based yield model (Dubey et al. 2018), weightage based statistical yield model (Fisher 1924; Hendrick and Scholl 1943; Agrawal et al. 1986; Ghosh et al. 2014), light use efficiency based yield model (Patel et al. 2006; Xin et al. 2013; Prasad et al. 2022), crop simulation model (Xie et al. 2017; Prasad, Patel, Danodia, et al. 2021; Gumma et al. 2022), crop phenology (Araya et al. 2017; Prasad, et al. 2021), machine learning techniques (Guo et al. 2021; Medina et al. 2021; Nihar et al. 2022), etc. While a very few were done on comparative assessment of various model (Morel et al. 2014; van Klompenburg et al. 2020; Prasad et al. 2022). This research study compares different models to develop the regional competitive crop yield model for Rabi pulses crops viz. Gram and Field pea for the Bundelkhand region of Uttar Pradesh, India which is the most affected region due to prevailing drought prone situation. In this study, historical datasets of various Earth Observation (EO) satellites and ancillary datasets were in development of crop yield models. Four crop yield models viz. Weightage Statistical Yield Model (WSYM), Random Forest (RF) based approach, Stepwise Multiple Linear Regression (SMLR) and phenological metrics based yield model (PYM), have been developed and validated using various indices extracted from weather and spectral parameters such as temperature, rainfall, land surface temperature and NDVI. WSYM, which had an RMSE of

0.040 tones hac-1 and 0.037 tones hac-1 for Gram and Field pea respectively, while PYM also has the significant accuracy with RMSE 0.076 t/ha and 0.063 t/ha for Gram and Field Pea. RF approach had RMSE of 0.108 t/ha and 0.152 t/ha where the SMLR model had RMSE of 0.078 t/ha and 0.115 t/ha for Gram and Field Pea, respectively. Henceforth, it has been observed that remote sensing data can be used as a successful substitute for ground-based observations and can be used to predict the crop yield at acceptable accuracy regionally. This study will significantly help in crop yield modelling and early prediction of the crop yield that can be used as a key strategy for policymaking to prepare suitable and efficient Import â€“ Export exercise.

Data Science / Machine Learning Perspective: Landslide Susceptibility Mapping

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Even though landslide is often underestimated when compared to other related phenomena such as flood, earthquake, volcano, storm and so forth but still landslide comes in the top seven natural hazard. Landslide Susceptibility Map is the classification of volume(or area)and spatial distribution of landslides that exist or potentially may occur in an area and should not be confused with landslide hazard zonation which includes time dimension as well. Till the late 90s, researchers have used extensive field-based methods due to the non-availability of technology. With the availability of remote sensing data and computing power, a lot of research took place in this field of landslide susceptibility map creation using remote sensing data and applying novel machine learning/ data mining techniques.

Issues/challenges faced during the research for creating landslide susceptibility mapping include:

1. Quality and Quantity of remote sensing data
2. Selection of Causative factors / independent attributes
3. Thematic classification and deriving higher order features based on remote sensing data.
4. Feature engineering
5. Learning from Imbalanced Data (sampling strategies, model assessment measures, stratification, weighted learning, etc.)
6. Algorithm selection (conventional statistical methods, parametric, non-parametric methods, and their ensembles) and performance parameter/ hyper parameter tuning
7. Computation resources

A case study of landslide susceptibility mapping for Rishikesh to Gangotri axis with a buffer area of 3 km on each side is conducted and obtained results in terms of overall accuracy, Area Under Receiver Operating Characteristics (AUROC) outperformed most of the published research.

Assessment and Monitoring of Multi-Aspect Drought Severity using Geo- spatial Technology in Cheyyar Watershed, Palar Basin, Tamil Nadu

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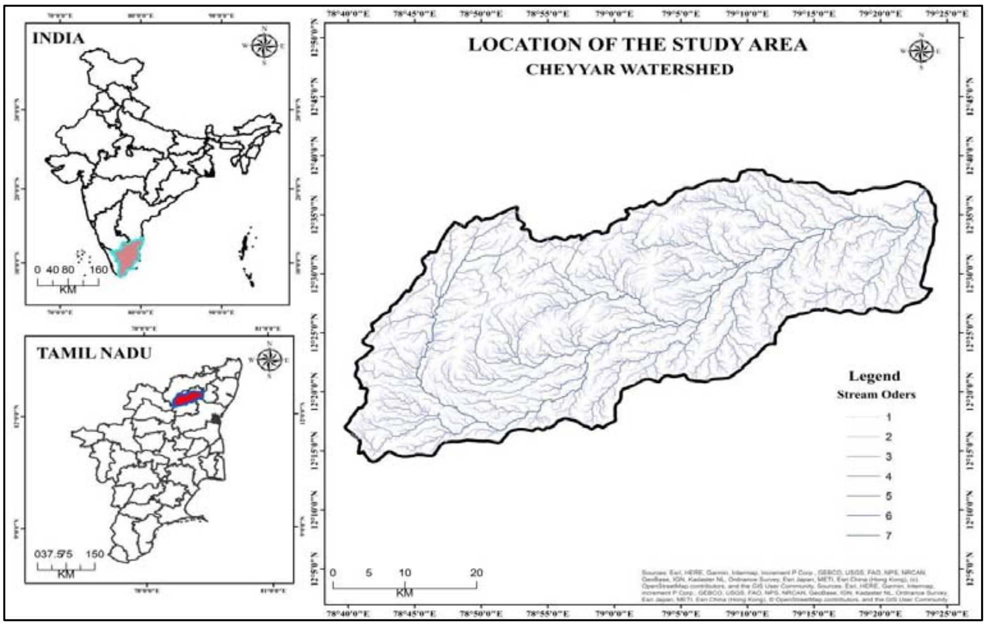
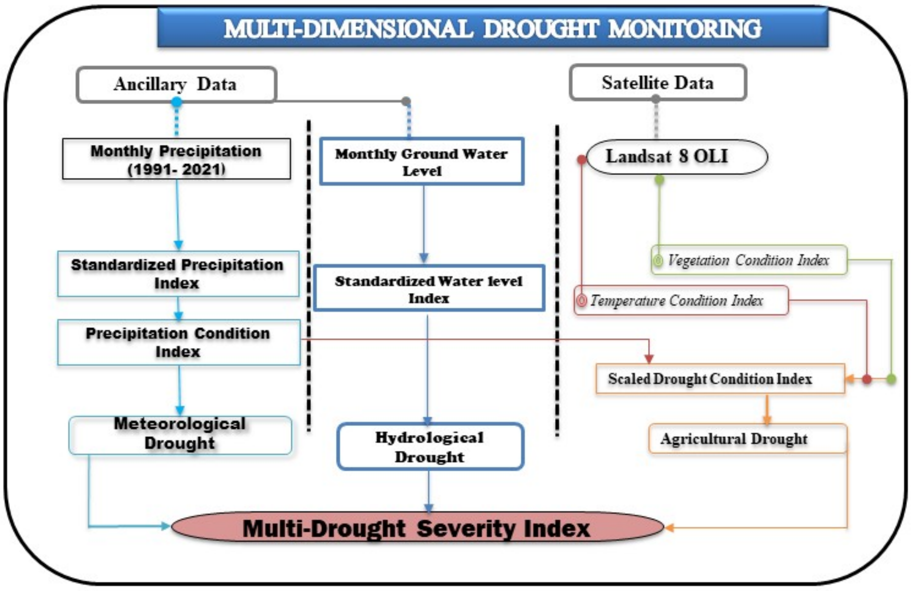
It is difficult to determine the beginning of a drought, and it takes several weeks, months or even years to assess the drought by people. In recent years, different types of severe drought events have occurred. Drought is the most devastating event with significant adverse effects like economic loss, environmental loss and social impacts. The wider the drought phenomenon than it is said to be the most dangerous natural hazard. A drought can lead the living being to a loss of appetite, a mass of people migrate and loss of life. Agricultural and vegetative drought is always manifested by meteorological and hydrological droughts. The Cheyyar Watershed is a part of Palar Basin, originating from Jawadhu hills, a part of the Eastern Ghats of Tamil Nadu. The study area covers an area of 2072 sq.km. The mean annual rain of the study area is around 970mm per year and the study area receives most of the rainfall in Northwest monsoon season. Over the decade, drought has been one of the most damaging natural disasters the study area faces. Since agriculture is the dominant economic activity in the study area, any drought can easily affect the agricultural productivity and economy of the people. So this study focused on analysing multi-aspect drought severity from 2017 to 2021 using various drought indices.

In this study, the Geographical Information System (GIS) and Remote Sensing (RS) are effectively used to analyse various drought indices and prepare maps using Arc GIS 10. The Normalised Difference Vegetation Index (NDVI), Land Surface Temperature (LST), Temperature Condition Index (TCI), Vegetation Condition Index (VCI) and Vegetation Health Index (VHI) are the indices used to examine the Scaled Drought-Condition Index (SDCI) that can quantify the agricultural drought in the area. To assess the meteorological drought, Fourteen rainfall stations have been selected for the present study; four stations belong to the Cheyyar Watershed, and the remaining ten are the outer stations of the study area and the Standardized Precipitation Index (SPI), Precipitation Condition Index (PCI) are calculated by using the past rainfall data for 30 years (1991 – 2021). The hydrological drought is determined by executing the Standardised Water-Level Index (SWI) by using the groundwater level data. Finally, by integrating SDCI, SPI and SWI, the Multi-Drought Severity Index (MDSI) has been evaluated to quantify the study area's multi-aspect drought severity.

By examining the results in the past five years, the SPI was severely dry during 2019 and extremely wet in 2018. By considering SWI, no drought event was recorded in 2021 and an extreme drought event was witnessed in 2017 in the pre-monsoon. However in the post-monsoon extreme drought event occurred in 2020, and no drought event happened in 2021. In the case of agricultural drought 2017 is found to be the highest recorded drought condition in the study area. From 2017 to 2021, the study area recorded a moderate drought event. The overall drought has been examined using MDSI. It clearly shows that the study area is affected by very high to high severity of drought condition, notably in the plain agricultural area of the study region. In case of late arrival of the monsoon winds, the severity of the drought gets aggregated in upcoming years. So it is essential to mitigate and take conservation measures to face the drought condition. The severe effects of drought can be reduced by adopting a few methods like rainwater harvesting, drip irrigation, etc. This study will be helpful to policymakers in adopting new approaches to overcome the effects of droughts.





Comparison of Standardized Precipitation Index (SPI) and Standardized Precipitation Evapotranspiration Index (SPEI) for drought monitoring in Marathwada region of Maharashtra

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The drought event is a naturally occurring phenomena caused mostly due to exceptionally low precipitation and has a significant influence on the region's agricultural productivity. Socioeconomic situation of people who are directly or indirectly dependent on agriculture for a living will be affected severely. Precipitation being the most important component for drought trigger, any decrease in precipitation leads to drought conditions. WMO (World Meteorological Organization) adopted the Standardized Precipitation Index (SPI) as the primary indicator of drought using solely precipitation as input. However, SPI is purely based on precipitation, ignoring the impact of other parameters such as temperature, wind speed, evapotranspiration, etc. It has been observed that a significant increase in temperature can impact the severity of a drought. In recent years, increase in the average temperature of the earth is being observed, and researchers predicted that this trend will continue, which might lead to an increase in the major components of hydrologic cycle i.e., evaporation and transpiration. Consequently, it is essential to account temperature effects while computing the drought index. The Standardized Precipitation Evapotranspiration Index (SPEI) originally developed by Vicente-Serrano et al. (2010) that integrates evapotranspiration as an input can be of great use for drought monitoring. Specially, this index indicated the influence of global warming on the drought severity. Drought intensity in India has increased and is likely to increase further as a result of climate change. The Marathwada region of Maharashtra state is one of the India's most severely hit areas, with over 1500 farmers committed suicide during the terrible drought year of 2014-15. The Marathwada region's water and agricultural crises are on the rise and as a result of more frequent and severe droughts, which are predicted to worsen in the near future owing to climate change. The Marathwada region is located in India's semi-arid region, which, according to worldwide drought monitoring research, is a hotspot for an increase in more frequent and severe droughts. The study aims to monitor drought at 1 km resolution using the SPEI and SPI at two time-scales i.e., 3 and 6 months representing meteorological and agricultural drought respectively for the Marathwada region of Maharashtra. The downscaled Integrated Multi-satellite Retrievals for Global Precipitation Measurement (IMERG-GPM) at 1 km spatial resolution has been used as input for the precipitation. The Hargreaves method of potential evapotranspiration estimation which uses two climatic variables i.e., air temperature and solar radiation were used for calculating potential evapotranspiration. The drought events detected by SPEI were compared with that of SPI to investigate similarity and dissimilarity in spatio-temporal pattern of drought events detected by these indices. The three drought characteristics namely severity, frequency and area under drought were compared. The result shows that SPEI could detect more number of

droughts over the years compared to SPI over the entire study area for both meteorological and agricultural drought. The difference in frequency of detected droughts was greater for agricultural in comparison to the meteorological drought. The total area under drought was found to be much higher for SPEI compared to SPI based analyses for both types of droughts. Specifically, substantially large area was found to be under drought using SPEI in the study area in 2001-2005, 2008-2009 and 2014-2017. The study area was severely affected by drought in the years 2001-2003 and was successfully detected by SPEI Similarly, the year 2014-2015 had a substantial part of study area under the moderate and above severity category of droughts for both meteorological and agricultural droughts, which SPI could not adequately represent. The differences could be attributed to the fact that the SPI is solely based on precipitation, whereas the SPEI incorporates climatic variables that aid in capturing the impact of climate change on drought. The SPEI index can be considered as preferred indicator in agriculturally dominated areas since irrigation scheduling during drought years is critical in these areas.

Identifying Landslides from Open-Source Satellite Imagery Using Cloud Computing

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WL and slides are one of the most devastating yet understudied hazards. The landslide database is one of the primary requirements for landslide modelling as well as hazard studies. The landslides database in India is incomplete since most of the landslides are never recorded. This study presents an overview of the framework to identify landslides using open-source optical and SAR data. We firstly subset the areas which are likely to face landslides using the India landslide susceptibility data. This helps reduce the computational overhead significantly. Then we develop rainfall characterization for landslides using historical landslides from the COOLR landslide database and corresponding rainfall using CHIRPS data. The rainfall characterization helps us develop an idea about rainfall exceedance for landslides. Once the rainfall exceeds a given threshold, we subset the nearest available cloud-free optical images as well as SAR images. The areas that face landslides have a high surface change which can be seen in the backscatter value of SAR images as well as the reflectance of optical images. After identifying the possible landslide locations, the proposed algorithm merges the pre and post-landslide images and topographical variables to create a data vector. We then use supervised machine learning algorithms to segment the images into landslide and non-landslide areas. The methodology is tested on previously well-identified landslides using metrics like IOU. The above methodology is developed using the cloud computing infrastructure of google earth engine.

Development of Forest Loss monitoring system over North Eastern Region of India using Google Earth Engine

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North eastern region of India is known for its diversity and vegetation richness. It is one of the global biodiversity hotspots. Unfortunately the region has encountered severe forest loss due to several activities like shifting cultivation, tree felling, anthropogenic pressure and natural calamities which is affecting ecosystem functioning. Regular monitoring of the forest cover can be helpful to overcome the problems related to deforestation. Present study is carried out to monitor forest loss in the north eastern region of India which includes the states namely Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. Sentinel 2 satellite data has been used for the assessment of forest loss in the region. Two time period (year) satellite data of the same season was used to analysis the change in the status of forest cover. The pre deforestation image was masked out with the forest cover to minimize the error due to similar signature i.e. agriculture or other vegetation classes. The forest cover data was used from the Forest Survey of India. Normalized Difference Vegetation Index (NDVI) was used to highlight the vegetation properties in the study area. Difference of NDVI was computed between two time period data and threshold of difference of NDVI was used to demarcate forest loss area. The region having more than 0.3 difference (threshold) in the NDVI was categorized into forest loss. Apart from NDVI, Normalized Difference Snow Index (NDSI) was also computed for the removal of snow area which also contributes as error to forest loss. Total 2344.79 ha forest was lost during year 2020 in the entire North Eastern region, where Arunachal Pradesh was found to have maximum loss (749.11 ha). In year 2021 total 4358.76 ha forest was lost and its major contribution was from Mizoram which accounted for 1167.36 ha. To assess the accuracy of the product random points were generated on the forest loss area and checked with high resolution satellite data and Google Earth image. Overall accuracy of the product was found to be 92%. A Graphic User Interface based forest loss monitoring system has been developed for the study area. The forest loss information can be generated for the year 2020 and 2021. The application can also be used to download the forest loss of the desired time period and desired area. The output of the present study can be utilized by the state forest department for better implementation of forest management activities.

Spatial Analysis of Precipitation, Drought and Groundwater level in Tamil Nadu State – A Geoinformatics Approach

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Changes in climatic conditions have been frequently recorded throughout the world in recent years at varying degrees of intensity. These changes affect a large group of people worldwide in many ways, notably in tropical semi-arid regions. In India, climate change has heavily affected monsoon rainfall, leading to the frequent occurrence of drought events. In this scenario, groundwater extraction has increased exponentially in need for freshwater, leading to groundwater depletion and potentially depleting a region's ecosystem. For the sustainable development of such regions, interdisciplinary studies could bring meaningful results. The influence and relationship between precipitation, drought and groundwater level are well known and there is a need for scientific investigation through modern methods. The current study attempts to investigate the spatial patterns of these factors in terms of temporal variation and to model the association between them. The study used multiple data sources to investigate at block level for the Tamil Nadu state in India. The CHRS/TRMM data are used to analyse precipitation; along with it, soil moisture, vegetation, and evaporation indices are derived from various satellite image sources and are additionally used to examine drought occurrences. To assess groundwater level fluctuations, Central Ground Water Board (CGWB) data are used for the periods from 1991 to 2021. The study extensively uses models and techniques to analyse the data and to perform predictive analysis for each variable. The Analytic Hierarchical Process (AHP) approach has been adopted to perform a compound analysis of all the variables. The results quantify spatial patterns and the underlying association between the variables. The study also reveals the temporal aspects and the changing characteristics of each variable over the study period and its precise implications in the future.

Use of Cartosat Imagery for identifying erosional surfaces in the Pokso sub-watershed, Jharkhand

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Bankura Zilla Saradamani Mahila Mahavidyapith

Soil erosion is a dominant environmental problem in the sub-humid, sub-tropical regions of India, especially during the high intensity monsoon seasonal rainfall. Dominance of sheet, rill and gully erosion have been reported in different parts of the Chhotanagpur Plateau region, especially in Jharkhand. Remote sensing data have proved to be of great aid in the assessment of various erosional surface features. The present study, therefore, attempts to identify the different erosional surfaces in the Pokso sub-watershed, Jharkhand, using Cartosat stereopairs of 2007 and 2018. Different image processing techniques viz. object-based image analysis and band ratioing have been used to categorize the sheet, rill and gully erosion areas. Leica photogrammetry suite (LPS) in ERDAS Imagine software was used to generate high resolution digital elevation models (DEMs) from the Cartosat stereo pairs for both the years to detect the changes in the erosional surfaces. The results were validated from the temporal datasets of Google Earth images. Multispectral LISS-III images were pan-sharpened by Cartosat images for identifying areas of afforestation and other soil conservation measures. It was observed that various afforestation and erosion control measures helped in reducing the effects of sheet and gully erosion. Subsequently the gullies were classified as permanent and filled or disappeared gullies.

Sensor Technologies and Data Processing

Pre-Flight Radiometric Calibration of OCM-3 and Estimation of its Calibration Uncertainty

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The Ocean Color Monitor-3 (OCM-3) to be flown in EOS-06 mission is an enhanced version of OCM-2 with modified spectral bands aimed for oceanographic applications and services. OCM-2 payload [2] has 8 spectral bands with wider bandwidth (20-40 nm) whereas OCM-3 has 13 narrow spectral bands (10-40 nm) with improved signal to noise ratio (SNR) for optimal usage of available marine resources and fulfilling new challenging scientific requirements [1]. The improved spectral bands with higher SNR (>800) will lead to better delineation of ocean products such as bloom detection, chlorophyll fluorescence detection and better atmospheric correction. As a part of ground based performance evaluation at Space Applications Centre (SAC), Pre-flight radiometric calibration exercise was carried out for all thirteen spectral bands. From the measured data, calibration coefficients are derived for all 4000 pixels, which is used to relate the digital count to input spectral radiance during on-board operation. This paper presents the analysis of acquired data to obtain payload response with input spectral radiance from integrating sphere. A methodology is developed to estimate radiometric uncertainty due to instrument response for all spectral bands. This paper presents the results obtained from data analysis viz. linearity and calibration uncertainty at Sea radiance for the corresponding spectral band, which is very helpful to determine accuracies of Ocean data products.

First operational Surface Reflectance products from Resoursesat-2A Sensors (AWiFS and LISS-3)

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The satellite images are attenuated by molecular, aerosol scattering and absorption by trace gases present in the atmosphere. More importantly Signals recorded from the satellite or airborne platforms in visible and near infrared region is a combination of surface, atmosphere and sensor contribution. Thus, to enable quantitative studies of the earth, the atmospheric component needs to be removed from the measured signal. The process of removing atmospheric contribution is commonly referred as atmospheric correction or atmospheric compensation. Products which are corrected for atmospheric perturbations are called Surface Reflectance (SR) or Bottom of Atmosphere (BOA) products. Surface Reflectance (SR) or atmospherically corrected product is the basic input for retrieval of any biophysical parameter from remote sensing images.

Atmospheric correction of optical remotely sensed data can indeed be categorized into two major classes: Relative atmospheric correction based on image processing and Absolute atmospheric correction on the other hand is based on the physical process of Radiative Transfer (RT) and is, therefore, very complex and it requires a great amount of information regarding sun-surface-sensor geometry, atmospheric condition at the time of data acquisition, spectral and radiometric specifications of the sensor.

Fully automated chain is developed based on Second Simulation of the Satellite Signal in the Solar Spectrum (6S) RT code to generate SR products from Resoursesat-2A AWiFS and LISS-3 sensors. This chain is spilt into two live parallel components which are made operational; First component retrieves the daily atmospheric data viz. Aerosol optical depth (AOD), Water vapor (WV) & ozone from Terra-MODIS level-2 data products over Indian sub-continent and processes and arranges into finer grid. Second component supplies this data along with Resourcesasat-2A sensor data to 6S-RT and derives surface reflectance per pixel basis for four spectral (Green, Red, NIR and SWIR) bands.

The accuracy of SR products is validated with both In-situ and contemporary satellite measurements. In-situ measurements are handheld spectro-radiometer measurements over pseudo invariant targets like Thar Desert, red and black soil of calibration-validation site at shadnagar, snow & glaciers at Gulmarg. The correlation (R2) with ground measurements is about 90% for all spectral bands. The accuracy of the product is also assessed by comparing RS2A SR values with Landsat-8 OLI sensor over various land use land cover targets and found a good agreement with R2 > 90% . In addition to this, Intra sensor validation is also carried out by comparing the SR products from L-3 and AWiFS of same date of pass and the correlation is about 97%. The stability and consistency of the SR products are also checked by comparing reflectances of pseudo invariant targets of different dates loaded with various levels of aerosol concentration. The measured variability is better than 4 % which indicates the accuracy and reliability of the atmospheric correction prodedure.

Improvements in geo-physical parameter retrievals when SR products are used are analyzed by comparing normalized difference vegetation index (NDVI) from both SR and Top of the atmosphere (TOA) reflectance products. It is found that SR products account for dynamic changes in vegetation 20% better than TOA products. Surface Reflectance also plays a major role in realizing analysis ready data (ARD). SR products from Resoursesat-2A sensors (AWiFS and LISS-3) are available on ISRO’s Bhoonidhi portal.

Evaluation of Scientific CMOS Image Sensor for Space Application

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The use of commercial off-the-shelf (COTS) image sensors for space applications is growing due to their high performance, low cost, and short development time compared to space-qualified sensors. However, the use of these COTS sensors comes with an inherent risk of poor long-term reliability and radiation damage in the harsh space environment. This risk can be mitigated by carrying out proper screening and qualification tests and evaluating these image sensors for their worthiness for the intended application. The subject detector is a 5.5M pixel scientific-grade CMOS image sensor. It is based on a 5T pixel architecture with a pinned photodiode and transfer gate. The sensor has on-chip dual column level amplifiers and 11-bit single slope analog to digital converters (ADC) for high-speed readout and wide dynamic range. The operation of the sensor is programmable and controlled by on-chip digital control modules. This sensor was chosen for its large format, ultra-low noise, and extreme low-light sensitivity. This paper discusses the screening and qualification philosophy along with electrical and optical performance tests carried out on this scientific image sensor for evaluating its suitability to survive the harsh space environment.

Radiometric Characterization of Resourcesat2A LISS-3 Sensor using PICS

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Onboard sensors on Resourcesat-2A (RS2A) have been serving the user community for various applications as a continued data service to Resourcesat-2. Users also tend to include different satellite datasets in their studies for obvious reasons like the cloud cover, temporal resolution, etc. In recent times, data from Landsat-8 has gained popularity for its stable performance. This study brings out the radiometric calibration assessment of Linear Imaging Self-Scanner 3 (LISS-3) of RS2A with Landsat-8 Operational Land Imager (OLI), based on the coincident and near coincident image acquisitions over the Arabia-2, the Pseudo Invariant Calibration Site (PICS) in North Africa, between 2019 and 2022. The coincident acquisitions display an agreement of 95%, 89%, 90% and 98% for Green, Red, Near IR and Short wave IR bands, respectively, for the spectrally similar bands of Landsat8 OLI.

Radiometric Normalization for SAR Imagery

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Synthetic Aperture Radar (SAR) is an active imaging instrument where accurate antenna pointing at time of illumination and precise opening of data window while receiving determines the radiometric pattern achieved in the data. Antenna pointing becomes even more important for longer wavelength SAR systems where reflector based antenna system are employed as compared to phased array antenna system.

Statistical approach to antenna pattern correction is biased towards the terrain acquired in the data and hence antenna pattern generated in lab environment before satellite launch is best suited for purpose of precise radiometric correction in elevation. These calibrated pattern need to be compared at regular interval with actual antenna pointing estimated over well-established target area like Amazon rainforest.

The compensation of error bias introduced due to antenna pointing is necessary to be considered while using radiometric normalization whether via lab estimated pattern or statistical pattern derived from the raw data. This paper uses a novel approach for radiometric correction in elevation by using lab estimated approach by considering the geometry used for image acquisition. Antenna pointing bias is also incorporated while extraction of actual antenna profile used for imaging by sensor. The results are found to be encouraging. Results of the same are compared with radiometric normalization done by using statistical approach for different terrain types.

Novel Spatial and Spectral Quality Metrics for Pan-sharpened Multispectral Remote Sensing Images

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Nowadays, very high resolution remote sensing satellites acquire data with two payloads together viz. High Spatial Resolution Panchromatic (PAN) Image and Low Spatial Resolution Multi-Spectral (MS) Image on the same platform. Data processing (DP) System software module is designed for automatically generating products ranging from precision to value added products. The automatic value added pan-sharpen product generation in DP is need of the hour for quick and efficient data utilisation. The pan-sharpen image is high resolution multispectral product created by using high resolution PAN and low resolution MS, by preserving the spectral content from MS and spatial content from PAN. The general idea behind pan-sharpening product in DP is to provide user the high resolution multi spectral image for data exploitation and analysis in quick turnaround time. The pan-sharpened image is an important product for numerous remote sensing applications such as classification, segmentation, object detection etc. Various Pan- sharpening algorithms are available in the literature to merge PAN and MS imagery data. Moreover, different pan-sharpening algorithms leads to different pan-sharpening quality. Pan-sharpening image quality refers to both the spatial and spectral qualities of images. The spatial-spectral quality assessment of pan-sharpened image is of utmost significance for different applications. If product is required for Land Use Land Cover (LULC), photo interpretation and classification applications spectral fidelity is given preference while for object identification and AIML based applications, spatial details products are preferred. The data analysis, exploits the available pan-sharpen product in DP and extracts the meaningful information from it, which is further converted into intelligence. For this, spatial quality of the pan-sharpen imagery is more crucial. Most of the existing pan-sharpening quality assessment methods gives more emphasis on spectral quality and limited on spatial quality. Spatial quality of pan-sharpened images is decisive and vital in exploiting the capability of images for end user applications as object extraction, identification, or reconstruction of (man-made) objects, large scale mapping in urban areas etc. There are numerous quality parameters defined in the literature and that makes it difficult to analyse all of them together. So, there is a need for segregating the significant quality metrices. In this paper, critical as well as novel quality parameters for object related application, are proposed and implemented. For spatial quantitative assessment four novel indices namely: Q4 Spatial, High Spatial Pan Division Index, Entropy Division Index and Gradient Division Index for assessing the preservation of texture, edges and sharpness in the pan-sharpen output images are proposed. A unique metric Pan-sharpen Image Quality Index considering both spatial distortion and spectral distortion is proposed. For accounting both spectral and spatial quality two indices based on quaternions are defined using hyper-complex numbers. The required benchmark datasets are created with data acquired by IRS sensors on different terrain viz. hills, rural, urban, desert etc. and different LULC. The quality metrics are applied on the benchmark datasets for evaluating the effectiveness of the qualities of interest. The results of various pan-sharpening algorithms and proposed quality metric estimation on pan-sharpened products are presented in this paper.

A postprocessor for characterization and correction of Scalloping and Banding in Scan-SAR imagery

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In this article, we present an efficient method for characterization and correction of scalloping and banding arising in space-borne SAR imagery acquired in multi-beam scanning mode, called Scan-SAR. Scan-SAR is very useful in several applications due to wide-swath and reduced revisit time. However, due to its design and way of recording signals using alternate beams, Doppler histories can not be continuously sampled, due to which a phenomenon called Scalloping occurs. Essentially, scalloping is manifested in the image as a low-frequency wavelike modulation of intensity in along track direction. Banding is phenomenon observed in multi beam SAR images arising mainly due to the radiometric imbalance across various beams and their noise characteristics. Several studies available in the literature suggest that the complete removal of scalloping and banding is not possible through post-processing techniques.

In this paper, first we establish an approach for efficient estimation and characterization of scalloping and banding function, a kind of measure for quantification of scalloping and banding, respectively, in Scan-SAR. Subsequently, using these measures, we mitigate banding and scalloping through the use of image-processing techniques for spatial and

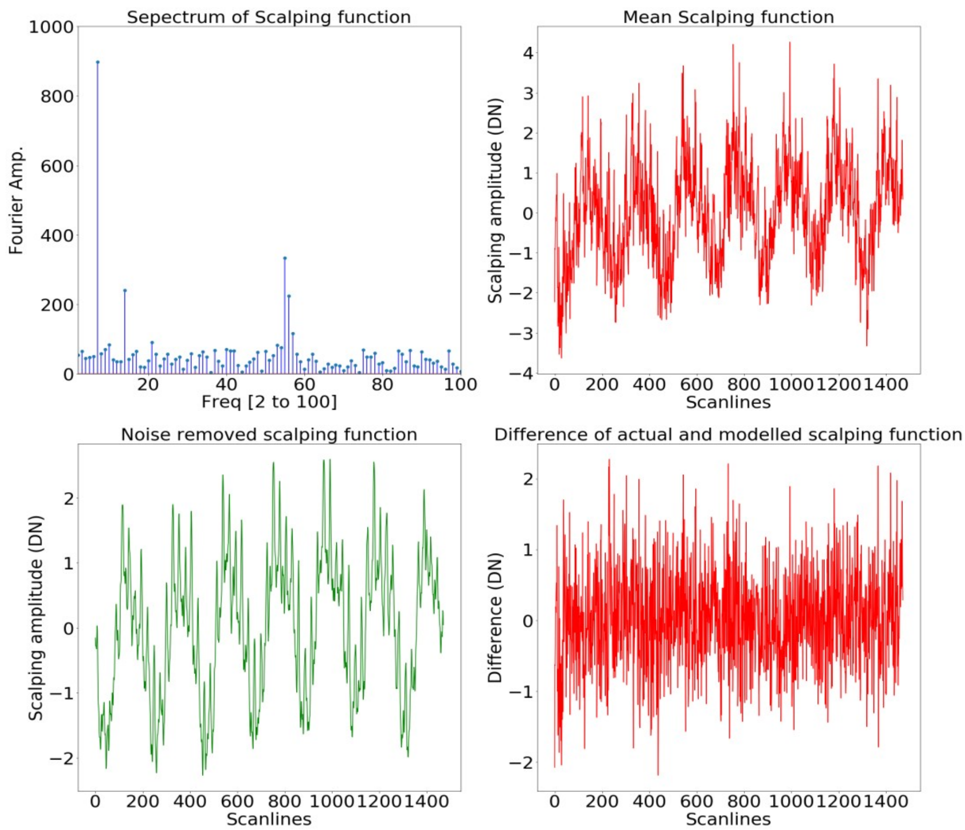


Fig.1 – Mean Scalloping function and noise-removed scalloping function profile

frequency domain, both. Using the scalloping function, first we identify few fundamental harmonics contributing towards scalloping and efficiently filter them from the spectrum via soft thresolding. Banding function is estimated using the homogeneous region from image and using this function the image is made radiometrically balanced. Further, on these de-scalloped and banding-free images, we apply an impulse detector based noise removal algorithm to obtain the final denoised image.

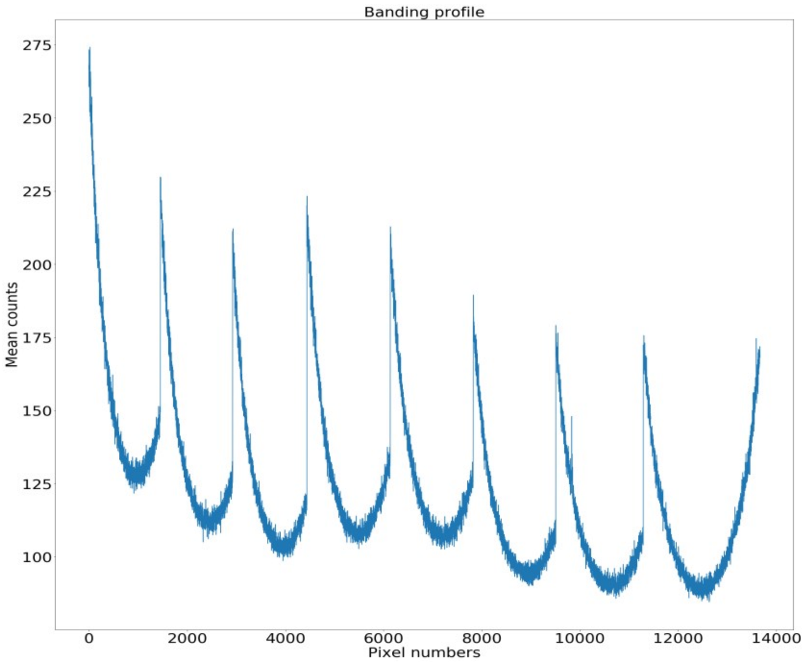
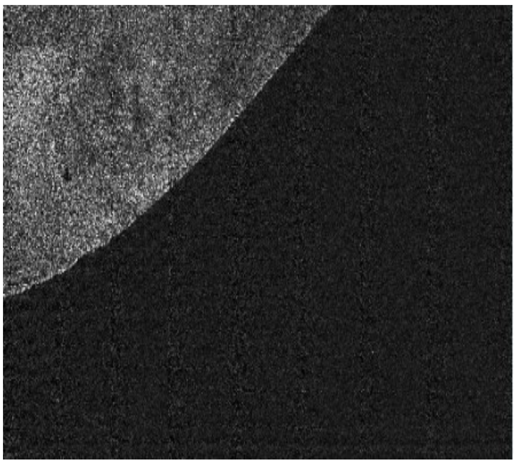


Fig. 2: Profile of Banding function



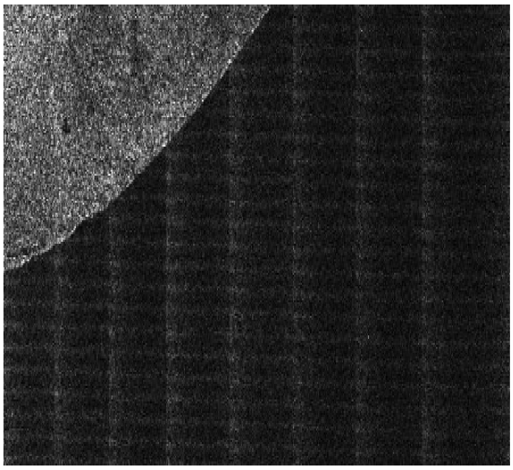


Fig.3 (a) Original Image (b) Descalloped and Banding removed image

Improved discrimination of plantation crops in multi-tier agroforestry systems using UAV Images and Deep Learning

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The horticulture sector has emerged as one of the main agricultural enterprise which is accelerating the Indian economy during last decade. Among the horticultural crops, coconut and areacanut are important plantation crops and India has now emerged as the largest producer in the world. Geospatial technology has been used for mapping and monitoring of major horticultural crops under the national initiative on “Coordinated programme on Horticulture Assessment & MAnagement using GeoiNformatics (CHAMAN)” launched by Department of Agriculture & Farmers Welfare in collaboration with Indian Space Research Organization. High resolution (HR) Resourcesat and Cartosat-1 merged data of 2.5m has been used for mapping major plantations like mango, citrus and coconut using Object Based Image Analysis (OBIA). The HRS data of 2.5m was found to be suitable for regions with homogeneous crops but could not account in heterogeneous and multi-tier cropping systems with scattered plantations. Although, OBIA technique has shown promising results for classification of HRS imagery, the post classification refinement was very tedious and time-consuming for improving the accuracy. In order to overcome these limitations, deep learning approaches have been evaluated for classification of coconut plantations from very high-resolution Cartosat-2 multispectral images with quite encouraging results (Sujith et al, 2021). However, Cartosat-2 images of 1.6m resolutions could not resolve complex agroforestry systems especially in the mixed and multi-tier cropping systems with scattered plantations. In the present study, utility of very high-resolution images acquired from Un-manned Aerial Vehicles (UAV) was explored for inventory of coconut and plantations under multi-tier cropping systems using deep learning.

The study area consisted of Belagumba village, Tumkur District, Karnataka. UAV images in RGB (4cm) and Multispectral (15 cm) modes were acquired during February 28-30, 2021. Field visits were carried out synchronous with UAV flying period for collection of ground truth information and geotagged photos using mobile app. The visual inspection of the image indicated that the coconut plantations were manifested in larger star shaped patterns on the UAV images due to canopy geometry and large crown which is quite district from arecanut plantations. The spectral and spatial patterns of individual coconut trees within the multi-tier cropping system were also clearly visible. It was observed that these spatial patterns of these plantations were clearer in RGB image as compared to MX images mainly due to better spatial resolution (Figure-1). Multi-class training samples covering eight classes viz., coconut, arecanut, other trees, flowers, scrub, open lands, buildings and road were created using interactive visual interpretation for labelling of training samples. About 208 images chips and corresponding labelled training samples (512 x 512 pixels) were extracted in raster format for development of deep learning model. Semantic segmentation with U-Net architecture was implemented in ERDAS Imagine Spatial Modeler. The hyperparameters such as no. of epochs, learning rate, weight decay etc. for the DL model were optimized, iteratively. The DL based classification has been implemented in two steps a) training & validation and b) inferencing. About 80 % of the training samples were used for development of DL model while 20% used for model validation.

The results indicated that the validation accuracy of the trained DL model was about 86.2%. The trained DL model was applied to the entire image covering the study area for classification. The accuracy of classified output was performed by generation of confusion matrix using independent samples. The classification accuracy revealed that the overall accuracy as well individual class accuracy was consistently higher in RGB image as compared to MX image (Table-1). The classification accuracy was better than 80% for the two dominant plantations of the study area viz., coconut and arecanut. The results showed that individual trees have also been captured from the RGB image. The study revealed the requirement of very high-resolution data for inventory of plantation crops in the complex agroforestry systems practiced in the study area and thus, UAV imaging techniques offer an attractive option for mapping of plantation types in multi-tier cropping systems. Further research is focused on analysis of spectral and spatial characteristics of different components of agroforestry systems using a combination of very high-resolution satellite and UAV images.

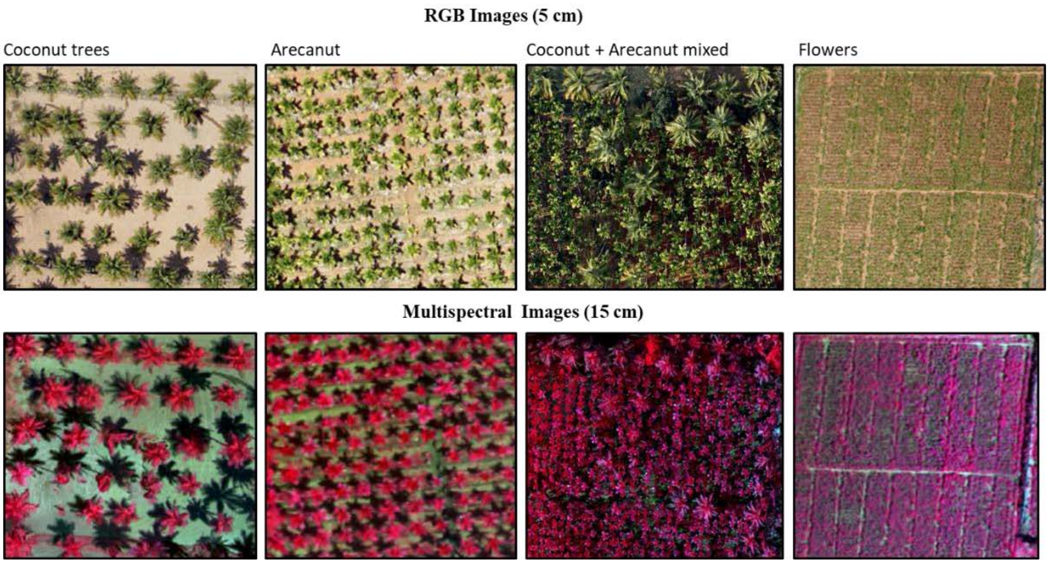

Figure-1: Spectral and spatial patterns of different horticulture crops in RGB & MX modes

Table-1: Classification accuracy of different classes in RGB and MX modes

Modes	Coconut	Arecanut	Flowers	Trees	Field Crops	Scrub	Building	Roads	Fallow
RGB	80.3	85.6	82.9	82.1	75.0	72.1	96.5	76.5	92.2
MX	55.4	80.5	78.8	75.6	65.6	71.1	76.4	70.5	78.8

RGB: Overall Accuracy = 85.5%, Kappa =0.81; MX: Overall Accuracy: 70.5%, Kappa = 0.71

Extraction and Mapping of Coconut Trees in an urban area from UAV Imagery using Object Based Image Analysis

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Remote sensing is crucial for effectively assessing and monitoring vegetation and tree canopies inside most urban areas. Detecting and counting trees in high-resolution remote sensing images is essential for biomass estimation, environment monitoring, yield prediction and so on. The coconut tree (Cocos Nucifera L.) is one of the most important tree species for high economic and ecological values, which belongs to the palm family. The term "coconut" can refer to the whole coconut palm, the seed, or the fruit, which botanically is a drupe, not a nut. Coconut is a large palm plant that can grow up to 80-100 feet with a lean yet slender trunk. The tree is said to have originated in the southeastern parts of Asia. It is also famous as ‘Kalpavriksha,’ which translates to the tree of heaven. As almost all the tree parts have some or other uses, the fruit has many uses in industries ranging from food to cosmetics.

Accurate extraction of coconut trees is necessary for efficient planning and management of ecosystems and resources, due to the significance of the coconut tree as a provider of natural products in urban areas. In recent years, automatically detecting tree crowns from high- resolution remotely sensed images is one of the most popular ways for tree detection and counting. Although numerous studies on feature extraction using deep learning have been executed, the massive data and processing power requirements as well as the longer training times are crucial issues that must be tackled in a better way. With unmanned aerial vehicle (UAV) becoming more accessible, remote sensing using UAVs have garnered a lot of attention. UAVs have applications in traffic management, weather monitoring, precision agriculture, orchard management, etc. Now, it is possible to detect and monitor trees from their canopy with the availability of high spatial resolution images acquired from cameras mounted on UAV. Tree canopy detection and counting has been important in orchard management, forest surveys and inventory, monitoring tree health, tree counting, and so on. However, creating training samples of masks by annotation is an extremely challenging task for two important reasons. Firstly, due to the sheer volume of data required for deep neural networks and the effort required for creating labelled masks through bounding boxes can be manifold. Secondly, resolution of the UAV images and irregular shapes of the tree canopies make it a difficult process to hand draw the masks around the canopies.

An attempt has been made in this study to propose an approach to detect, extract and map the coconut trees in the urban area using very high spatial resolution (VHSR) UAV imagery. 229 images were captured by UAV DJI Phantom pro on 17 October 2020 for a residential colony in Salem, Tamilnadu, India. Each image size was 5472 x 3648 in Red,Green and Blue (RGB) with an average Ground sampling distance of 0.02 m with a 70% overlap for an area measuring 0.72 Sq.km. The VHSR UAV images were processed photogrammetrically using Pix4d software to obtain an Orthomosaic, a Digital Surface Model (DSM) and a bare earth

Digital Terrain Model (DTM). As is known that the traditional pixel-based classification approach has its limitations, such as spectral heterogeneity in collecting vegetation information, an Object Based Image Analysis (OBIA) approach was used Given that the OBIA combines segmentation and classification, the image was divided into several objects using the multi- resolution segmentation (MRS) approach by determining the appropriate parameters. The segmented image was then classified for separating out the vegetation and non-vegetated areas. Rules were then formulated to distinguish between coconut trees and other green vegetation using the geometrical and textural features . The proposed tree extraction procedure was applied to UAV RGB Orthoimage (Data Set 1), DSM that were generated from UAV images (Data Set 2) and combining both DSM and RGB Orthoimage together (Data Set 3). Accuracy assessment was carried out that evaluate the tree extraction results according to the counts, areas and locations.

The study investigates UAV remote sensing derived RGB orthoimage for coconut tree detection, delineation and mapping. The height of the tree is one of the essential characteristics collected by conventional field surveys which is time consuming. Segmenting the DSM Image (Dataset2) and classification on geometrical shape parameters resulted in faster coconut tree extraction. OBIA approach on Dataset 3 resulted in efficient and accurate classification of the UAV Imagery.

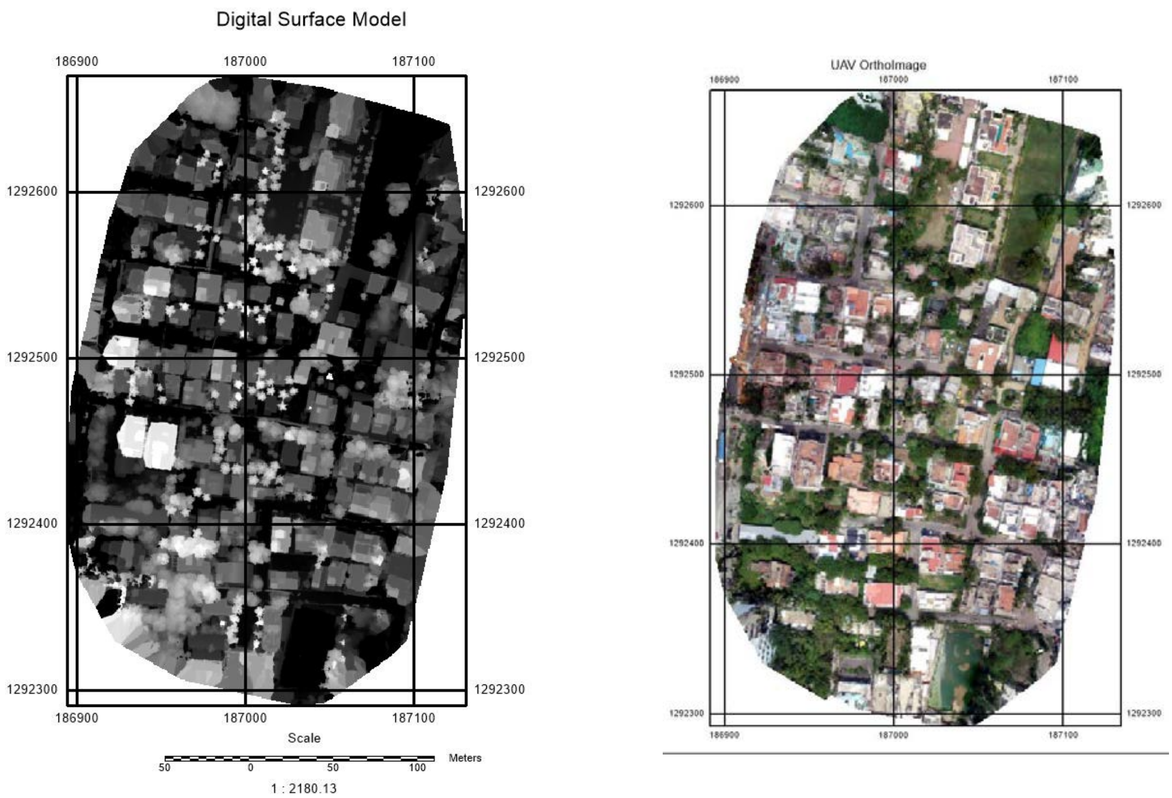

Figure 1: Resulting UAV Orthoimage and Digital Surface Model after Photogrammetric processing

(a) (b) (c) (d)

Figure 2: (a) Ortho RGB subset (b) Segmented Image (c) Extracted Green Vegetation (d) Extracted Coconut Trees

Characterization of EOS-04 Hybrid Polarimetric Data using Standard Radar Targets

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In view of increasing demand of remote sensing applications, Synthetic Aperture Radar (SAR) with its outstanding capabilities in penetrating through cloud, day and night imaging has instigated higher demand to exploit numerous applications which can benefit civil and strategic departments. As user community is perennially waiting for augments in remote sensing technology to suit their requirements in performing 'close to reality' analysis, this demands a payload which has high level of modification on on-board sub-system architecture, novel imaging techniques and accuracies in the data product. To bridge the gap, ISRO's has come up with EOS-04, a follow-on SAR mission for RISAT-1.

EOS-04 is a C-band SAR sensor which works on the basis of active phase array antenna technology and provides electronic agility for achieving multimode imaging capability, similar to RISAT-1. It was launched successfully in February 2022 to open up new vistas for operational utilization of SAR data for management of disaster and natural resources. Fine Resolution Strip map FRS-1, FRS-2, Medium Resolution ScanSAR-MRS, Coarse Resolution ScanSAR- CRS and High Resolution Spotlight - HRS are the modes of SAR operation. In these modes, resolutions from 1m-50 m can be achieved with swath ranging from 10 km – 223 km. Beams can be changed as per different modes to acquire images within 100 km to 650 km off nadir distance. Apart from having traditional imaging capabilities and levels of data products, it has introduced Full Polarimetric mode in Strip map and ScanSAR imaging modes. It's varied value- added polarimetric data products in total aids in improved target classifications. Moreover, ISRO is the first space agency to introduce EO based Compact Polarimetric imaging in the world space arena. Therefore, EOS-04 has also been equipped with its heritage of Hybrid Polarimetry. To complement, a fully calibrated hybrid polarimetric data product can closely compete with the capabilities of Full Polarimetric data in theme-specific image classifications.

Some of the thematic applications demand for either long-term or short term calibration. In view of this, for sustainable operational utilization of EOS-04 data for various applications, calibration exercises are conducted in campaign mode across various ISRO Pan India CR network to perform radiometric, geometric and polarimetric calibration and validation of SAR data. For the calibration and validation of EOS-04 Hybrid polarimetric data products, Trihedral and Dihedral corner reflectors are deployed at NRSC-IMGEOS Cal-Val site and SAC Cal sites apart from Amarapur temporary Cal site during the Initial phase Operations of the mission. The data has been planned and acquired over these calibration sites in Stripmap and ScanSAR modes. The scattering properties of the targets in hybrid polarimetric data are well studied and established with respect to standard radar targets like corner reflectors. The dimensions and structure of standard radar calibration targets in terms of Trihedral and Dihedral Corner Reflectors (CR) plays a vital role in characterizing the scattering mechanism associated with Hybrid polarimetric signals with the target. The critical polarimetric parameters as a function of physical parameters of the target are estimated on radar calibration targets in which the polarization information and phase diversity present in the signal are measured using Degree of Polarization(DoP), Relative Phase and Ellipticity parameters etc., These hybrid polarimetric parameters including Degree of Linear Polarization (DoLp), degree of circularity, Circular Polarization Ratio (CPR), scattering angle(alpha) etc., helps in deciphering the scattering modalities involved for various coherent point targets.

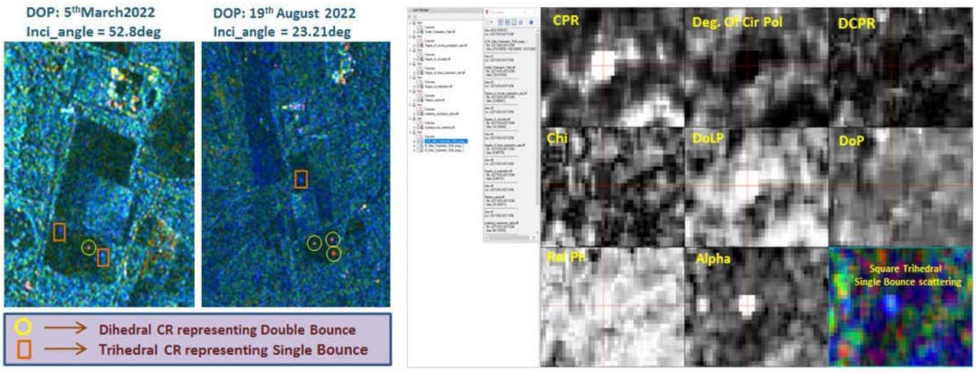

Figure 1: Identified Dihedral and Trihedral Corner Reflectors deployed over IMGEOS Cal-Val Site acquired in FRS-1 (left) and various hybrid pol parameters derived for corner reflectors.

The methodology implemented in characterizing EOS-04 Hybrid polarimetric data involved derivation of Stokes and child Stokes parameters (Raney et al) from Fine Resolution Stripmap (FRS-1) Level-1 Single Look Complex data acquired over Corner Reflectors. As circular polarized transmission have an automatic and inherent capability to differentiate between “Single bounce” verses “ Double Bounce” back scattered constituents which are an essential attribute for polarimetric image classification, polarimetric parameters response for trihedral and dihedral helped in differentiating the scattering response and hence its interaction phenomenon as shown in Figure 1. The preliminary point target and Hybrid polarimetric analysis for EOS-04 has been performed using in-house developed software. To have first cut qualification of data products, the characterization has been done for both uncalibrated and calibrated hybrid polarimetric data. Uncalibrated data of EOS-04 has been considered for which child stokes parameters are derived on coherent targets. Similar analysis also has been performed on calibrated data product which indicated significant improvement of polarimetric parameters. Between calibrated and uncalibrated hybrid polarimetric data, there is a variation of ± 4 to 6 deg difference in relative phase parameter and 2 to 3 deg variation in degree of circularity. The validation of these hybrid pol parameters aids in the better characterization of value added products of EOS-04 like Level-3A m- delta and m-chi polarimetric decomposed products.

This paper presents the detailed analysis performed on standard targets in terms of derived Stokes parameters to promote qualification and quantification of EOS-04 Hybrid polarimetric data utilization in the fields of Agriculture, Soils, Forestry, Earth Sciences, Snow, Hydrology, Oceanography and Disaster Applications.

SDAT: A Python based Tool for Processing and Analysing Spectroradiometer Data

Anand S Sahadevan, Rosly Boy Lyngdoh, Pradyuman Singh Rathore, Deepak Putrevu, Arundhati Misra

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Hyperspectral Remote Sensing (HRS) is a powerful and fastest growing technology in the field of remote sensing. In HRS, an imaging spectrometer acquires the electromagnetic energy reflected from the earth's surface in contiguous spectral channels and forms hyperspectral (Hx) images. Similarly, field-spectroradiometer is designed explicitly for ground-based remote sensing to acquire visible near-infrared (VNIR) and short-wave infrared (SWIR) spectra that is useful in many application areas requiring the measurement of reflectance, transmittance, radiance, or irradiance. Scientific fields of application for reflectance spectroscopy include geology and mineral exploration, soil mapping, monitoring of marine, coastal and inland waters and wetlands, agriculture and ecology. For all these applications, spectral measurements collected in the field or laboratory are critical for understanding spectral characteristics and developing strategies for HRS data analysis. The development of a graphical user interface (GUI) is common in remote sensing for more rapid use of the algorithms. Several python-based software were developed to pre-process, visualize and analyse spectral data. However, these tools cannot provide functionalities such as top-of-atmosphere simulation, PROSAIL simulations, spectral mixing, temporal spectral analysis, band sensitivity analysis, multivariate regression etc. Therefore, SDAT has been developed to perform fundamental and advanced analysis of field-spectral data without requiring programming expertise. Spectroradiometer Data Analysis and Simulation Tool (SDAT) is a Python-3-based free and open-source tool designed to process, analyze and simulate field spectroradiometer data. The Overarching aim of SDAT is to provide free-of-charge and user-friendly access to advanced approaches for spectroradiometer data processing for both beginners and advanced users. Basic as well as advanced functionalities such as spectroradiometer-data management, spectral visualization, spectral transformation, spectral resampling, multivariate regression, temporal spectral visualization, band sensitivity analysis, spectral simulation (6S and PROSAIL), spectral mixing analysis and spectral library utilities (USGS and ECOSTRESS libraries) are available in SDAT. The complete package has been bundled for standalone application in windows-based desktop computers. The tool provides a flexible framework powered by widely used python packages such as NumPy, Pandas, Scikit-learn, and Py6S, enabling scientists to process and analyse spectral data using machine learning methods, which can significantly reduce the time required for processing and analysing lab/field-based spectroradiometer data. The SDAT tool is developed in Python 3.x and coupled to a GUI, which exemplifies rapid code development. SDAT code is 3.x compliant because broad Python 2.x support is slated for deprecation by the core Python team. Several widely used Python libraries are used in SDAT: (1) NumPy (Numerical Python) and (2) SciPy (Scientific Python), which provide a suite of numerical analysis and statistical modules (3) Pandas for data frame representation and exceptional processing performance, (4) Matplotlib and Seaborn for data visualization, (5) scikit-learn for machine learning and multivariate analysis algorithms. (6) Py6S for 6S simulations, (7) OpenCV and scikit-image for image processing, and (8) spectral-python for generating a database for the spectral library. Together these libraries form a highly effective GUI suite for spectral data exploration, visualization, analysis and simulations. Except for the data management module, all other modules can load the spectral data and metadata in comma-separated-values (csv) format. SDAT requires a specific structure for reading the spectral data and the metadata (e.g. target property, target class etc.) stored in separate 'csv' files. There are three layers of abstraction available in SDAT: (1) modules that can read and visualize different spectroradiometer data and perform spectral processing tasks (spectral data management, resampling, spectral transformation, spectral indices, dimensionality reduction, wavelet features); (2) a set of modules for spectral data analysis (univariate and multivariate regression, ML-classification, spectral sensitivity analysis, time-series spectral analysis, spectral data statistics, fractional-green-cover-estimation and spectral library matching); (3) modules for simulating the spectra (PROSAIL, 6S and spectral mixing). In terms of functionality, a standalone GUI has been developed for more rapid use of the analysis tools, which may improve the productivity of the researchers. The software does not attempt to supersede existing libraries; instead presents an innovative way of integrating them, enhancing their functionalities and making them user-friendly.

Effective Use of Drone Imagery for Crop and Pasture Monitoring in the Advancement of Precision Agriculture

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The use of drones for precision agriculture is a developing technology with the ability to play a vital role in crop and pasture monitoring. High-quality data obtained from UAVs through RGB, hyperspectral and thermal sensors are largely used for crop phenotyping, time-series analysis, and biophysical and biochemical plant trait retrieval. To maintain sustainability, maximize crop productivity and optimize land spaces, various aspects of advanced farming techniques need to be incorporated with agriculture which paves the way for precision agriculture.

This project aims to use autonomous low-level flights' imagery to gather information and make analysis on soil and crop fields, providing farmers with time and site- specific information regarding crop health, infections, growth bottlenecks, and other water level parameters. Drone images collected by a multi-rotor UAV flying over a rice paddy field are preprocessed using a semi-auto annotation method and then the capsule networks model (CapsNet) is used for detecting and classifying the rice seedling and arable land with high accuracy. With these RGB image data, various crop parameters like the Leaf Area Index, moisture level, and many vegetation indices are found using Deep Learning algorithms. IoT is further used to organize the findings where connected devices send the data to cloud-based storage. These findings and observations, along with the recommendations for effective crop production are produced as a report to the farmers to promote precision agriculture and increase their yields with reduced costs.

Semantic Segmentation of shelf extents for Amery Ice Shelf using space borne Sentinel-1 and Deep Learning Techniques

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Abstract: Amery Ice Shelf (AIS) is one of the largest glacier drainage basins in the world with area of around 60,000 sq km. The expansion of the boundary extents was observed in recent studies.

Forecasting the expansion rate helps in understanding the ocean and atmospheric dynamic in a better way. Intensive surface snowmelt could accelerate ice loss and endanger the ice shelves under climate warming. Calving of many big icebergs with area as big as 1636 sq km (D-28) has been in recent years, which makes analysis of Amery iceshelf very critical for climate change. Availability of various remote sensing instruments data with high temporal resolution like scatterometer, radiometer, synthetic aperture radar improves the scope for continuous monitoring of the AIS. But handling the large volumes of data samples always demands automatic methods to exploit best out of the availability data, and analyse the temporal variations for a large period.

In this paper an attempt is made to use Deep Learning (DL) techniques for handling the large chunk of data and analyse the calving of icebergs. Sentinel-1 SAR data is used for best exploitation of microwave data for the efficient interpretation of feature changes. In this study data from 2018 to 2022 is used to analyse the temporal and spatial variability of Amery ice shelf. The operations are performed in cloud on Microsoft's PlanetaryComputer HUB, where the datasets are fetched, and Deep Learning Modules, based on Tensorflow are invocated to get the segmented outputs. During segmentation we employ a two-stage Bayesian UNET model on the datasets, trained on first three years of analysis, while the latest datasets are reserved for validation and testing. These resultsare then used to generate subsets of the shelf extents, which are then used for analysis.The predictions generated by the algorithm shows around 87% accuracy with Intersection-Over-Union (IOU) of 0.78. These estimates can be used in studies of the climatic effects of the seasonal and inter-annual melting, and also the spatial variability of the Amery ice shelf.

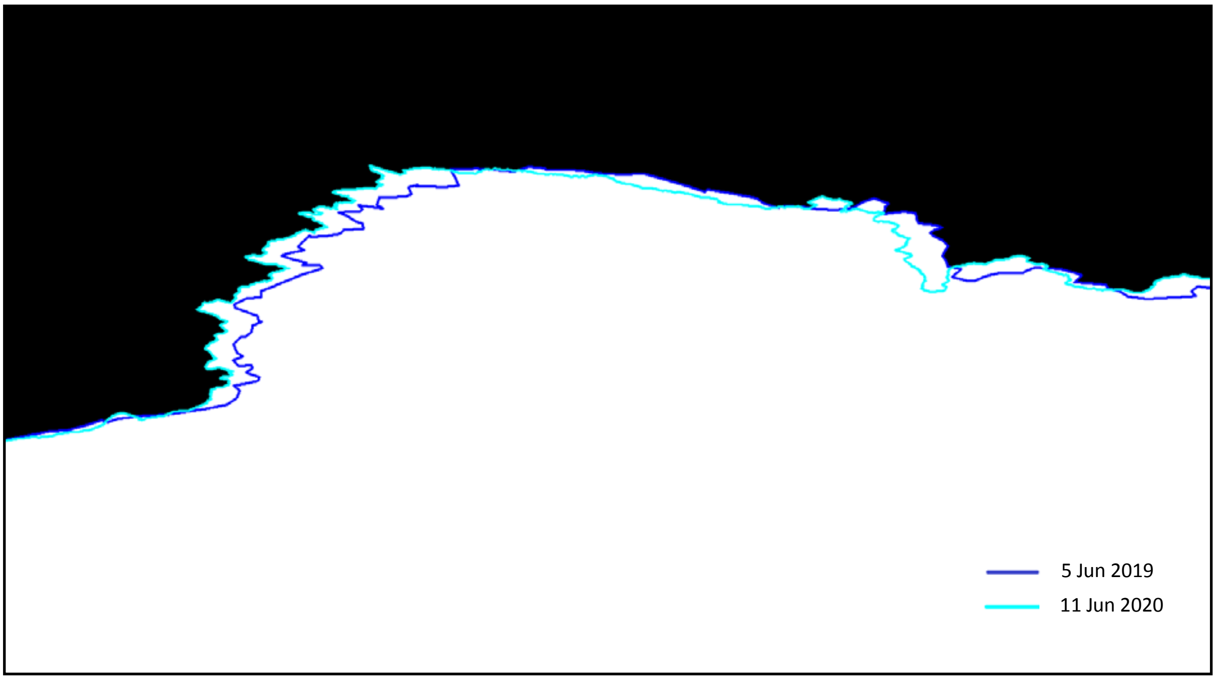

Fig 1. Variability of Amery shelf extents in a year. Black portion represents sea, while white area depicts snow

Leveraging Drone Technology for Large Scale Mapping

COl Rajat Sharma
Survey Of India

Since the launch of the National Land Records Modernization Program Digital India Land Records Modernization Program (NLRMP, now DILRMP (Digital India Land Records Modernization Program) by the Government of India in August 2008, land and property records have gained a lot of attention and have been a part of important administrative discussions. Numerous State governments are struggling in land-related matters because of the unavailability of accurate land records. In general, State governments possess land records, but these are mostly limited to agricultural areas. Built-up areas have often been left as composite large plots in the rural records, and the details of the buildings or individual plots within the inhabited area do not exist.

Selecting a suitable survey technique is a key component of conducting surveys in a campaign mode. At present, the range of available survey techniques is as follows

(a) Ground method using Electronic Total Station (ETS) and Differential Global Positioning System (DGPS)

(b) Hybrid methodology using High Resolution Satellite Imagery (HRSI) and ground truthing by ETS and DGPS

(c) Aerial photography/ drone (UAV-Unmanned Aerial Vehicle) and ground truthing by ETS and DGPS

(d) LIDAR and DGPS.

Parameters For Comparison	Ground Survey Ets/Gps	Aerial Survey (Optical Sensor)	Satellite Survey (Stereo)	Drone Survey (Optical Sensor)
Accuracy Planimetry	5-10 Cm	9-30 Cm	50-100 Cm	5-10 Cm
Accuracy Height(Dtm)	10-20 Cm	40-100 Cm	150-300 Cm	10-20 Cm
Speed	0.1-0.2 Sq.Km/Day	100s Sq.Km/Day	1000s Sq.Km/Day	8-10 Sq.Km/Day
Reliability Of Data	Good (Ground Verified)	Good	Less Reliable	Very Good
Cost Effectiveness	Very Expensive	Expensive	Expensive	Economical
Suitability For Small Area	Yes	No	No	Yes

Drone Technology

An unmanned aerial vehicle (UAV), commonly known as a drone, is an aircraft without a human pilot aboard. Drones are a component of an Unmanned aircraft system, which include a UAV, a ground-based controller, and a system of communications between the two. Drone captures highly precise data quickly, without the need for surveying staff to walk

over dangerous terrain or height to collect the information. The two common types of drone mapping methods are photogrammetry and LiDAR.
(a) Photogrammetry involves capturing high-resolution images that are later processed and stitched using sophisticated software to recreate a survey area in the form of measurable 2D maps or 3D models.
(b) LiDAR sends pulses of light to the earth's surface to detect small objects during drone mapping.
The different maps or deliverables obtained from drone surveying are orthomosaic maps, Digital Surface Model (DSM), Digital Terrain Model (DTM), and contour line maps.

Considering the above-mentioned parameters, it is established that UAVs provides high accuracy and fast capturing in a economical way and a valuable alternative to other technique. Therefore, the use of UAVs is an opportunity large scale mapping.

Scope of Drone Technolgy Into Various Fields
1. Land Surveying & Cartography- Drone surveying generates high-resolution orthomosaic maps and 3D models of areas to create accurate cadastral maps. SVAMITVA (Survey of Villages Abadi and Mapping with Improvised Technology in Village Areas) is one of its kind project launched by Govt of India on the occasion of National Panchayati Raj Day on 24th April 2021. Its aim is to provide an integrated property validation solution for rural India.

Brief of Svamitva

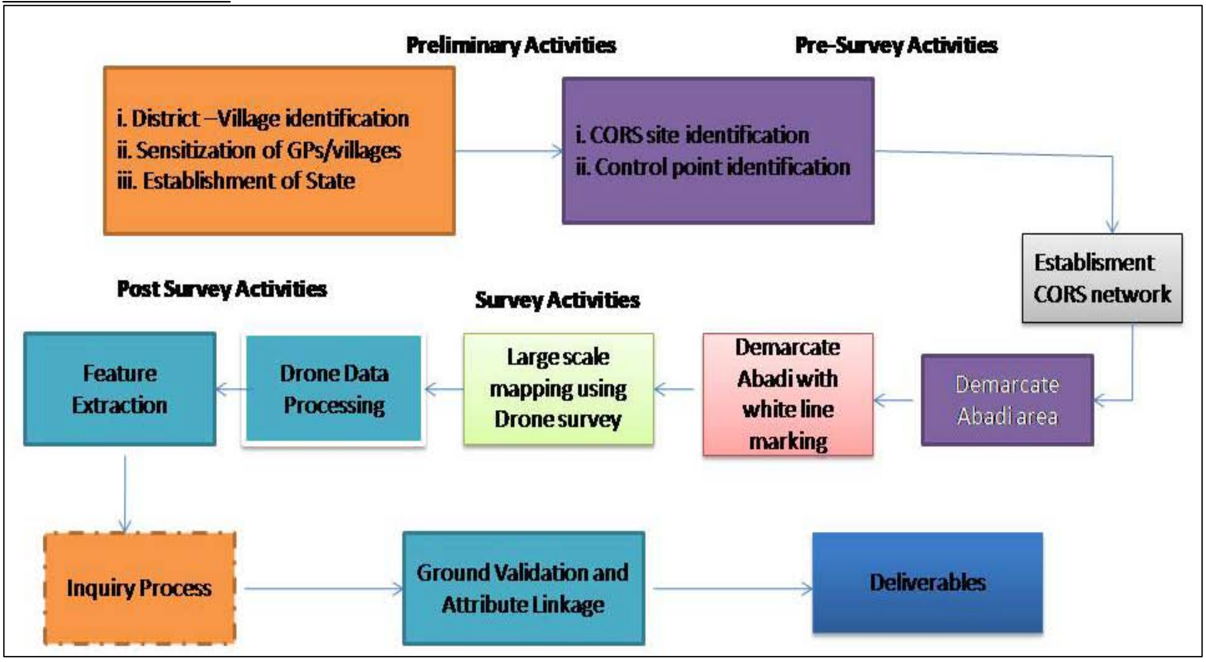

Figure Svamitva Work Flow

Important Aspects of Svamitva:
(a) The demarcation of rural inhabited areas would be done using Drone survey and CORS (Continuously Operating Reference Stations) Networks which provides mapping accuracy of 5 cms.
(b) This would provide the 'record of rights' to village household owners possessing houses in inhabited rural areas in villages.

(c) It will cover around 6.62 Lakh villages of the entire country during 2021-2025.
(d) Survey of India is a Technology Implementation Agency.
2. Urban Planning And Mapping- Drone surveys help urban planners collect up-to-date data of a complex urban area quickly using less staff to study the existing social and environmental conditions of the sites. This makes the planning stage of the development of an urban area easier.
3. National disaster planning- help to assess and plan eventualities according to the disaster.
4. Forest- forest cultivation and maintenance, redeeming wildlife and vegetation, while also monitoring risks to prevent the felling of trees.
5. Waste Management- With drone surveying, verification of slopes of landfill have been built to ensure regulatory compliance and maximum use of airspace. Quick and accurate calculations of compaction densities and remaining airspace can be performed.

Challenges

1. Need to improve the infrastructure related to manufacturing, R& D of Drones and its components.
2. Limitation to work in high altitude and extreme weather conditions.
3. Drone survey can be an efficient survey technique for small and sparsely developed areas to get high accuracy and resolution data.
4. High cost of LiDAR technology: Strategic use of LIDAR technology can help the government to balance the cost of the project while selecting the specific high built-up pockets and survey in one go and not in a piecemeal manner. According to estimates, LIDARs costs same as aerial photography i.e. around Rs. 20,000 to 25,000 per sqkm
5. Delay in mandatory permission and approvals.
6. Training and capacity building of government officials in modern survey techniques such as drone, LIDAR etc. is needed for real time updation of property records.

Conclusion

Drones can be an efficient and useful technique for small and medium dense areas. The high level of maneuverability makes it easy to update the map, unlike ground-based survey, and it also gives easy accessibility to unapproachable areas with less manpower. The advantage of UAV systems lies in their high flexibility and efficiency in capturing the surface of an area from a low flight altitude. In addition, further information such as orthoimages, elevation models and 3D objects can easily be gained from UAV images. The required level of accuracy that is of 5cm for cadastral surveying particularly in SVAMITVA project is being achieved.

Application of UAV Data in Mapping and Visualization of Heritage site: A case study of Manjarabad Fort, Karnataka

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Introduction

Terrain mapping is an essential component of physical geography, field geology, biogeography, archaeology, and a variety of other disciplines, which investigates the structure and dynamics of the Earth's surface. Until recently, Unmanned aerial vehicles (UAVs) have become the main source of very high resolution or high resolution (VHR/HR) datasets for mapping Heritage sites. These heritage sites are significant to history, architecture, archaeology and cultural science and thus need to preserve for the future. Geospatial science provides decisive and effective tools for tracking, spotting, and evaluating the architectural health of any heritage site for the preparation of a framework to conserve the site. In this study, a historical fort situated on a hill and its surrounding area are mapped for its further applications.

Study Area

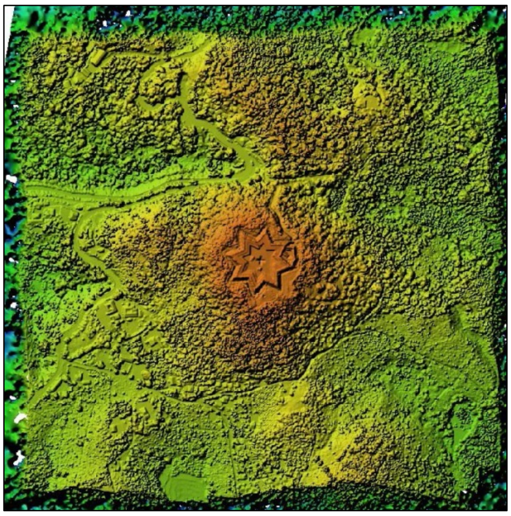
The UAV survey was done for the historic site of Manjarabad Fort, situated in Sakleshpura, Hassan district, Karnataka. This fort was built by Tipu Sultan in 1792. The stellate fort overlooks the vast expanse of plains on one side and the Ghats of Malnad on the other. The fort is made of big granite stones and mud which are enclosed by a wide moat on all sides. The fort's plan is in the shape of an eight-pointed star consisting of canon mounts, cross-shaped stepped tanks for rainwater collection and arched cells serving as resting places for the guards.

Materials and Methods

The UAV datasets were acquired by installing 815 camera stations spanning a 1.09 km2 area around the fort and were flown at a height of 149m, from the point of take-off on the fort using a Phantom 4 Pro V2.0. The whole mission took 1.5 flying hours to complete. Drone deploy, which is used here for flight planning is a cloud-based platform for autonomous mission planning and is particularly used for complex sites. The chunk was processed in the software through a series of steps which includes tie point, point cloud, depth maps, mesh reconstruction, building orthomosaic and finally DEM generation. The one-inch CMOS sensor with an effective 20 megapixel camera sensor resulted in a ground sampling distance (GSD) of 3.75 cm. The GPS onboard the UAV was used to process the chunk in WGS 84 coordinate system, generating high resolution digital elevation model (DEM) and orthoimages for the site along with a 3D visualization.

Results and Discussions

The orthomosaic map was made by blending the original pictures projected on the object's surface and transforming them to the desired projection which resulted in a 3.75 cm point posting. The digital elevation model (DEM) is a 2.5D model of a surface expressed as a regular grid, with height values saved for each grid cell, rasterized from depth maps resulting in 4.05 cm per pixel size. The resulting error consisting of reprojection, camera orientation and position was 0.93 pixels.



(a)

(b)

Figure 1: (a) DEM of the Manjarabad Fort depicting the stellate shape in the centre (b) 3-D perspective view of the site.

The resulting 3-Dimensional model is textured using colour image datasets for better visualization of the terrain. The results of this experimental UAV survey can be used by professionals from diverse backgrounds like archaeologists, conservation engineers, tourism and scholars (history). UAV gives users the benefit of fast, accurate work at a lower cost when it comes to documentation. Furthermore, the products obtained can be used as preliminary data for the conservation of the structure which would significantly help them in analysing and estimating the work.

Simultaneous multi-field spectral response measurement of wide FoV Electro-optical imaging sensors

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Spectral response measurements (SRM) of space-borne Electro-Optical (EO) imaging sensors is an important pre-flight calibration exercise, which helps in post launch retrieval of spectral characteristics of ground targets imaged by the sensor. Often, SRM is performed in sequential manner over few representative field points in the entire FOV of the sensor mainly due to the limitation in ground calibration test setups, resulting in significant test time. This paper proposes an alternative approach for simultaneous measurements of instrument spectral response over multiple field points of the sensor. In the proposed method, the existing monochromator setup has been modified by introducing an auxiliary optical chain, which helps in optical rotation of the exit slit & reorientation of input beam thereby increasing the measurement field points. The approach has been test validated on a wide field narrow band camera and a proto-type multi-spectral camera. SRM results are compared with that of conventional approach and a close match has been demonstrated. The proposed approach enables simultaneous SRM of the instrument at multiple field points of the senor resulting in significant reduction in test time.

Spectral and Special Quality Evaluation of High-resolution Pan-sharpened Data for Information Extraction in Urban Area

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Urban space is known for high heterogeneity of its component structure, shape and materials. Urban/Peri-urban areas in developing countries are prone to rapid land transformation caused by infrastructure and industrial development. High resolution temporal pan-sharpened data generated from visible and near infrared bands can fulfill the need of providing details in such heterogeneous complex and fast changing areas. As spectral distortion in pan-sharpened images restrict the uses of information extraction digitally through automatic process, visual interpretation is adopted for many urban applications. A comparative performance analysis is carried out using high resolution pan-sharpened images generated by different pixel-based methods. The spectral quality and spatial details are assessed through qualitative and quantitative measures. The test datasets belong to areas with varying density of urban/manmade structures. Different statistical measures, like CC, PSNR, ERGAS, RASE, UIQI, SSIM and edge components are used to evaluate the preservation of spectral integrity and spatial details introduced by different pan-sharpening methods. The algorithms for image quality analysis are developed in-house as a ‘Data Quality plug-in module’ with QGIS Software. Some insights are also gained about the performance of pan-sharpening methods and relevance of statistical parameters for developing data driven algorithms.

Endmember Variability Based Spectral-Spatial Weighted Sparse Unmixing for Abundance Estimation of Red and Black Soil over Sparsely Vegetated Areas Using AVIRIS-NG Image

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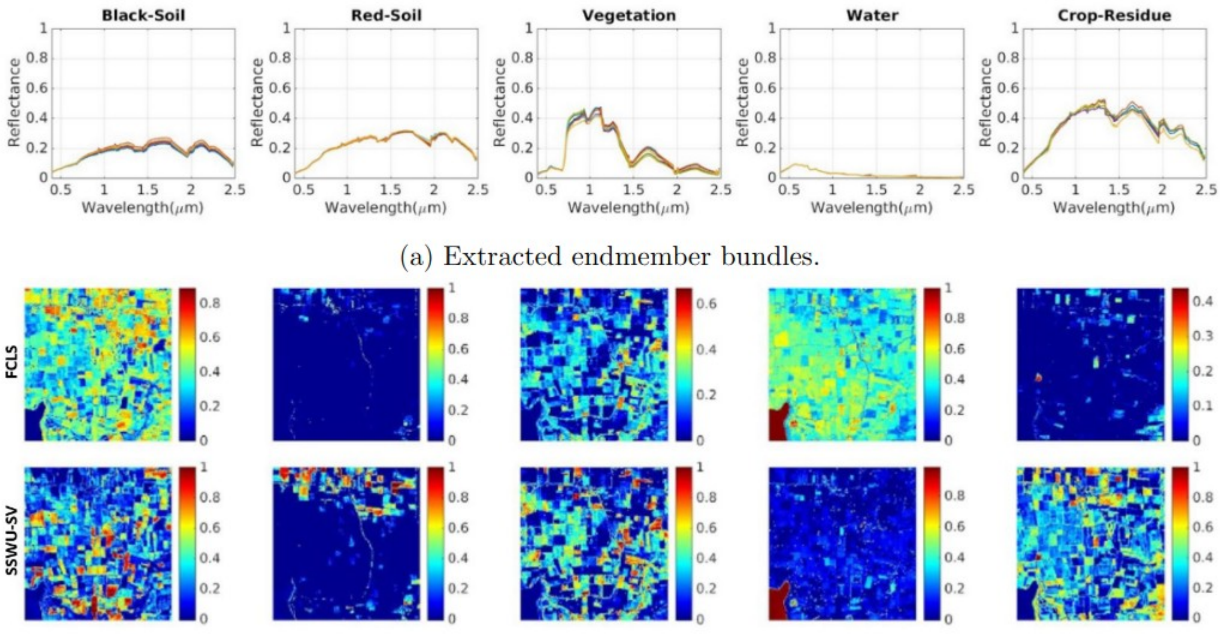
Modern spaceborne or airborne hyperspectral sensors have proven essential in agriculture systems due to their high spectral-spatial sensitivity in the visible-near-infrared and short-wave infrared (VNIR/SWIR) regions of the electromagnetic spectrum. The mapping of bare soil types using hyperspectral imagery (HSI) is crucial compared to traditional pixel-based classification methods due to the spectral mixing between the significant agricultural features such as vegetation, soil, and crop residue. Most spectral unmixing methods focus on analysing the HSI by considering endmembers as independent entities and fail to produce accurate results. However, in agricultural fields, the endmembers are spatially and temporally varied. Moreover, incorporating spectral variability within the endmember class generates ill-posed inverse unmixing problems. In this context, sparse unmixing methods have been practical to incorporate spectral variability by introducing spectral-spatial weighting factors in the sparse regression process, which enhance the sparsity in the abundance estimation and produce more stable results. In this study, an endmember variability-based spectral-spatial weighted sparse regression model (SSWU-SV) is developed for hyperspectral unmixing analysis, which is demonstrated using AVIRIS-NG imagery in the agriculture field over Berambadi Catchment, Karnataka region. Spectral variability within the endmember class, such as red/black soil, crop residue, vegetation, etc., was incorporated for estimating the fractional abundance of red and black soil over sparsely vegetated areas. The proposed methodology produces promising results as compared to the traditional least square-based methods (fully constrained least square method). Accuracy assessments were carried out using spectral angle distance (SAD) and root-mean-square error (RMSE). Extracted endmember bundles for each class and corresponding estimated abundance maps using FCLS and SSWU-SV are depicted in Figure 1(a), Figure 1 (b) (1st row), and Figure 1(b) (2nd row), respectively. Accuracy assessment of FCLS and SSWU-SV using RMSE and SAD is displayed in Figure 2 (1st row) and Figure 2 (2nd row).



(a) Extracted endmember bundles.

(b) Estimated Abundance maps.

Figure 1: (a) Extracted endmember bundles of black soil, red soil, vegetation, water and crop residue, (b) corresponding estimated fractional abundance using FCLS (Top) and SSWU-SV approaches (Bottom).

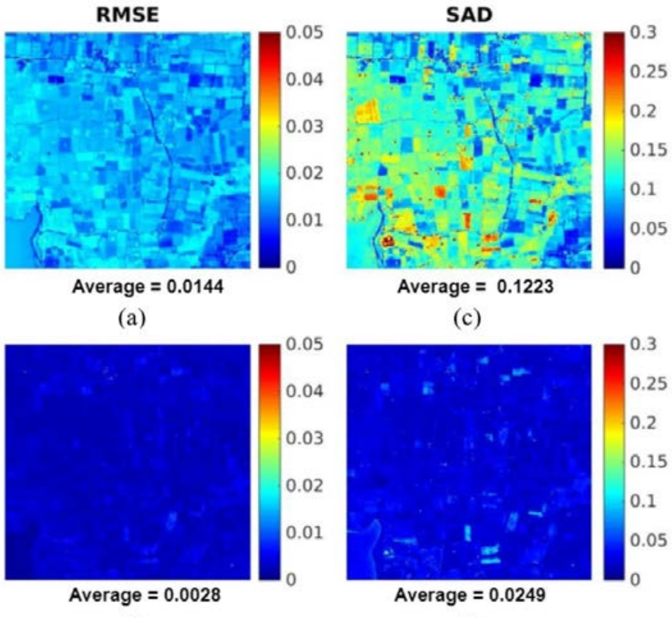


Figure 2: (a) and (c) show the error map of RMSE and SAD and their average values obtained from FCLS. (b) and (d) show the error map of RMSE and SAD and their average values obtained from SSWU-SV.

Volume Estimation of Municipal Solid Waste using UAV Remote Sensing – A case study of Vijayawada Municipality, Andhra Pradesh, India

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Survey technology is towering to new heights with the addition of Unmanned Aerial Vehicles (UAV) or DRONE as more commonly known. UAVs allow for the effective mapping of large areas of land and existing infrastructure, within a few hours, a favourable characteristic, especially at cases where urgent intervention is required. In the areas of land survey, UAV adds an entirely new dimension with their ability to provide aerial photogrammetry, 3D site modelling, photo comparisons, and aerial video. In the present study, an attempt was made to estimate volume of a Municipal Solid Waste (MSW) dump yard using UAV based Ortho images, located at Ajith Singh Nagar, Vijayawada Municipality, Andhra Pradesh, India. A total area of about 0.859 km^2 was surveyed using UAV coupled with GCP Marking and DGPS survey. Around 513 nos. of images were collected using RGB Sensor with 4.13 cm GSD and were processed using Pix4D mapper platform. The DGPS surveyed readings were used for correcting the ortho images and Digital Surface Model (DSM) was generated to estimate the volume of each section of the MSW. The density of solid waste (mass per unit volume, kg/m^3) in India is typically around 450–500 kg/m^3 for converting to metric ton (mt) as per the Manual of the Municipal Solid Waste Management published by Central Public Health and Environmental Engineering Organisation (CPHEEO), Ministry of Urban Development, Government of India. One foot down fill from the Ground Level / 3D Plane was used for calculating the volume of each section of the MSW dump yard. The total estimated volume of all the nine sections of the MSW is about 55,830.31m^3. All the sections were verified using physical measurement through DGPS for a quality check of the estimated volume and were found to be correct with a 96 % of accuracy. It is found that the UAV based survey techniques are better than the traditional survey technology as it is more accurate, time saving and provides synoptic view of the project areas for better understanding and decision making.

Inter Drone Cooperation using robust video analytics for tracking moving objects on ground

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Smart devices in the miniature form like drones are being used by various agencies in numerous scenarios. A person or object being viewed and tracked by a drone are prone to be missed due to limited movement of drones in a highly dense and high rise building urban city. We need an inter drone cooperation of dynamic nature for detecting, identifying, tracking the objects. The seamless handover of tracked object features from one drone to another drone can be done and objects can be continuously monitored. To achieve above objectives a robust feature extraction and tracking method using video analytics is developed for drone platforms. We have proposed a novel method to detect and track objects of interest and handover to nearest drone for taking over. Our method is an AI based intelligent tracking algorithm which can be ported to small form factor GPUs like NVIDIA Xavier or Intel Movidus is developed. We propose a solution by using on-board video analytics, feature extraction and sharing mechanism between drones for a coordinated object tracking.

UAV data decision support system and content summarization

Ravi Kumar Singh
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The commercialization and advancement of unmanned aerial vehicles (UAVs) have increased in the past decades for surveillance. UAVs are resource-constrained devices that are composed of limited storage, battery power, band width and computing capacity. Thus, the UAV's data must be extracted, analyzed, and stored efficiently.

UAV data decision support system is an efficient methodology that deals with foreground objects in time and domain space, thus creating a condensed video for analysis and storage. The summarized video forms the basis for making decisions. The reduced representation saves time, power and frees downlink band width. We proposed a content summarization based solution. As the UAV platform is subject to vibrations and other attitude variations, conventional object summarization techniques fail. A novel approach has been proposed to summarize and visualize extensive airborne videos to cope with this issue. The proposed technique begins with a feature-based learning keyframe stabilization technique to reduce trembling camera effects in the video feed. It is further enhanced by abnormal object detection using a customized detector which extracts only the meaningful data from summarized video. Keyframes and binary decision data is transmitted to ground for further analysis.

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Agriculture, Water and Other Natural Resources Management

Current and future challenges for water resource management and future directions for research

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Our planet stands out from every other one we are aware of due to the presence of water. While there is more than enough freshwater available on a global scale to meet all present and future water demands, its spatial and temporal distributions are not uniform. Water is the biggest normal asset yet just 3% of it is fresh water, of which only 1/3 is open for use in agribusiness and urban communities. The rest is solidified in ice sheets or shrouded excessively profound underground. Our freshwater supplies are insufficient in many areas to satisfy domestic, economic growth, and environmental needs. In such areas, the lack of sufficient clean water to meet human demands for drinking water and sanitation is in fact a barrier to economic development, human health, and the preservation of a clean environment and healthy ecosystems. We must all work together to discover solutions to these limitations. We have many obstacles to overcome in order to accomplish that, particularly in light of the unknown and changing nature of the future climate as well as the fast expanding population that is accelerating social and economic development, globalisation, and urbanisation. Research in all facets of water management is necessary to determine how to best handle these issues. Since 1965, the journal Water Resources Research has contributed significantly to the reporting and dissemination of recent findings about the management of this resource's quantity, quality, and cost. In the future, researchers from many fields can collaborate. They would do well to take inspiration from the American Society of Civil Engineers' mission statement, which reads as follows:

"Civil engineers serve competently, cooperatively, and ethically as master planners, designers, builders, and operators of society's economic and social engine—the built environment; stewards of the natural environment and its resources; innovators and integrators of ideas and technology across the public, private, and academic sectors; managers of risk and uncertainty caused by changing conditions in the environment, among other roles.

Landscape characterisation of Cauvery basin using geomorphic indices derived from digital elevation model

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The competition between internal and external forces within and over the earth produces different kinds of landscapes. These landscapes can be modelled using digital elevation data by evaluating different kinds of geomorphic indices and drainage network of a particular terrain. In the present study, different geomorphic indices viz. hypsometric integral (HI), Hack (Stream-length gradient or SL) and channel steepness (ksn) index were calculated for the landscape characterisation of Cauvery basin, India using Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) having resolution of 30m in Geographical Information System (GIS) environment. Hypsometric integral values, which defined as the area-elevation relationship of the basin, tells the landscape development (old, mature and young topography) and history of cycle of erosion by depicting the climatic, geological and tectonic control over the basin. Computed Hack and steepness index, gives Knick-points (slope anomaly) along drainage channels, which governs erosional condition as well as lithological control over the entire basin. The formed drainage pattern tells about the dominance of structural or lithological control over the basin. In the present study, hypsometric analysis coupled with landform features were carried out. For this, landform maps were generated using integrated analysis of topographic position index (TPI) and slope position classification.

Six sub-basins were generated with pour points along the main channel of Cauvery river using spatial analyst tools (hydrology) in ArcGIS environment and geomorphic indices were estimated over these basins. The obtained HI values were found in the range of 0.11 to 0.27. Computed hypsometric integral and hypsometric curve analysis was used for interpretation of landscape development (old, mature and young topography) over different sub basin of Cauvery river. Analysis revealed that mostly low values (0.11) of hypsometric integral and concave shape of hypsometric curve was observed, which indicates old and eroded stage of topography. The observed value of Hack (SL) and steepness index was computed with in the gap of 30 m elevation. The value of SL index was found very high (up to 160884 m) at certain places, which indicates the presence of the fall along the drainage results into waterfall and dams. These waterfalls and dams were created by erosional processes governed by changes in lithology that determined the landscape evolution and depicts the cycle of erosion. The value of channel steepness index was also found high along the Knick-points, which have high Hack (SL) index value. It was observed that plain features occupy the highest aerial coverage in all the six basins among all the ten landform classes. It was also observed that low value of Hack and steepness index indicates featureless flat topography. The drainage pattern (dendritic and rectangular) were observed and analyzed in context of geological vs. structural prospective and it was found that, dendritic patterns were dominated except in upper part of the basin, where dominance of rectangular pattern was observed. The rectangular pattern indicates that it is tectonically active in past. The outcome of the study shows that the basin is in its old stage and very little amount of erosion and sediment loss will occur in future, which will beneficial for the agricultural and settlement practices.

Hyperspectral remote sensing-based neural network model for early disease detection in commercially important crops

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Plant stress due to fungal pathogens is wreaking havoc on commercial crops all over the world. An accurate and prompt diagnosis of such plant disease is highly required to avoid yield and quality loss. It will be worth if the diseases are detected before appearance of their symptoms as it will help in prevention of spread of disease as compared to the detection of disease after its infection which may lead to total crop loss. Hyperspectral remote sensing techniques along with machine learning algorithms are nowadays playing a vital role in plant disease detection, pest management and stress detection. It also has potential of early detection of infection by trapping the physiological changes in their leaves reflected as their unique spectral signatures. Therefore, we are working on developing models to early detect the disease and its various severity stages in plants using the state-of-the-art technique of hyperspectral remote sensing and artificial intelligence. We are using hyperspectral remote sensing instruments such as handheld ASD (Analytical Spectral Device) Spectroradiometer (325-1075 nm with FOV 3.5 degree) and HySpex imaging system (400-2500 nm). We have developed a library of spectral signatures representing various disease stages in crops including healthy, pre-symptomatic, symptomatic, and fully infected for medicinal and commercial crops tea, potato, stevia, etc. The noisy spectra from the recorded spectral data were removed using statistical approach. Feature selection techniques were used to identify the informative bands for model calibration. Finally, the identified bands were employed in Artificial Neural Network (ANN) architecture to train the early disease detection model. The developed model has accounted for the overall accuracy of between 83% to 92%. Thus, the machine learning algorithms integrated with high-resolution hyperspectral data have provided a novel technique for identifying healthy, pre-symptomatic, symptomatic and completely damaged plants with high detection accuracy. It will help in the prevention of crop yield and quality loss. The model will be further extrapolated to a regional scale with the help of UAVs. We also intend to develop some portable instruments which can facilitate on-the-spot disease stage detection in our targeted crops.

Integrated study in different micro-watersheds of Panchkula district, Haryana

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ABSTRACT

Micro-watershed planning has been conceived and adopted for holistic development of rain fed farming in recent years. The watershed profile divides the terrain into unequal segments with diverse terrain characteristics, varied endowment of nature and distinctly different susceptibility to the natural environment constraints viz. flood, water logging, riverine erosion, drought and soil erosion. The livelihoods of local population mainly rural depend on these natural resources. Quality of water has gained equal importance with quantity. RS data and GIS or GPS techniques have capability to assess the available natural resources and its use. In the present study Integrated study in different micro-watersheds viz. Bhanu, Bila, Kot, Mankiya of Panchkula district, Haryana was carried out. Satellite data of LISS-IV sensor for both rabi and kharif seasons was used to interpret their present land use/land cover and to locate the water sampling sites. Total 34 water sample is collected and analyzed to study the chemical properties. Water quality found good in the study area and 54 soil and water harvesting structures were observed in the study area. The location information of these structures is collected by GPS in Latitude or Longitude. It was found that major area in all the micro-watershed falls under Double crop 1301.26 ha. and land with dense scrub 787 ha. followed by plantation.

Identification of Groundwater Potential Zone in Konar Basin using Geospatial Techniques

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Groundwater is the main source of water in rural as well as in the urban areas. At present we are using it to the extend that it's nearly drain out in a province. And as the population is directly proportional to need and inversely proportional to water resource. Hence the utilization and sustainable use of groundwater is important and as there is a void gap of information to extend we can exploit groundwater resource.

A scientific approach was made using AHP (Analytic Hierarchy Process) technique in Remote Sensing (RS) & Geographic Information System (GIS). For this 9 Parameter viz., Lithology, Rainfall, Geomorphology, Soil, Slope, Lineament Density, Drainage Density, Land Use / Land Cover, and TWI (Topographic Wetness Index) were used and transformed into thematic layer using Arc GIS software. From the aforementioned 9 parameter controlled by the Geology, Rainfall, Soil, Slope and Land Use / Land Cover which was defined by the priority and the rank of the parameter obtained by the relative intensity of importance of different thematic layer weightage to obtaining GWPZ. Using this a GWPZ (Groundwater Potential Zone) map is prepared by overlay weightage analysis by spatial tool in Arc GIS software.

The map was categorised in four sub-categories i.e., Poor, Fair, Good, Excellent. The map shows that the Konar Basin is dominated by The Good potential zone as a whole area covering approximately 951.08 sq.km of the agricultural and forest land in higher altitude. Fair potential zone covering approximately about 296.33 sq.km in the area of increasing drainage order. The excellent potential zone is dominated in zone of discharge of Konar River.

Assessment of Hydrological Behavior of Jhelum Basin using the Modelling and Geo-spatial Approach

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The study focuses in evaluating the behavior of hydrological parameters in the Jhelum Basin using the modelling and geo-spatial approach. It is observed that the annual precipitation over the basin shows decreasing trend. The hydrological behavior of the basin is simulated using Variable Infiltration Capacity (VIC) hydrological model forced with the ERA-Interim hydro-meteorological datasets. The vegetative layer and topographical representations of the basin, in the VIC model, were derived using remote sensing data and products. The simulation period considered for this study is from 1979 to 2019 and model calibration and validation is done for the time period 2005 to 2013 at Asham and Sangam stations. The observed river discharge data is utilized to estimate the dependable discharge (Q75) for the basin at Asham and based upon this Q75, the changes in water availability on different months is analyzed using the hydrological simulations. It was observed that the March, April, November and December months show improvements in the water availability and the months of July, August, September and October indicates decrease in the water availability vis-Ã -vis Q75. The value of flood peaks of different return intervals is estimated by applying Gumbelâ€™s flood frequency analysis method over observed discharge data. It was observed that the frequency of 5-Year return floods have decreased in the recent decades. As major part of the basin receives heavy snowfall during winters and in summers the snow melt majorly contributes to the river discharge, the snowmelt partitioning was also performed for the basin. It was observed that the rate of snow melt has shown increase in the months of March â€“ April due to this massive decrease in snowmelt contribution is observed in the months of May and June. The study as a whole has also strengthen the fact the modelling approach is quite suitable and convenient for observing the behavior of hydrological components in the complex basins like Jhelum Basin . Keywords: Hydrological Parameters, dependable discharge, Variable Infiltration Capacity (VIC), snowmelt partitioning, hydrological components

Sun Induced Fluorescence (SIF) as stress indicator in Wheat crop and its relation with key photosynthetic parameters

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Sun Induced Fluorescence (SIF) serves as useful means for detecting the condition of vegetation as it has a close correlation with photosynthesis, thus it is used to derive Gross Primary Product (GPP). SIF could be a good estimator of net photosynthesis levels in crops affected by water deficit and nutritional stress. The field collected spectral signatures of wheat crop are used of different growth stages under control and stress treatments. SIF retrieval for wheat crop is done from spectral reflectance signatures using Spectral Fitting Method (SFM). Relations between SIF signals and key photosynthetic parameters from combined gas exchange and chlorophyll fluorescence at leaf level based on Farquhar–von Caemmerer–Berry leaf photosynthesis model fitting and others. Sensitivity analysis is done using simulated data from Soil-Canopy Observation of Photosynthesis and Energy fluxes (SCOPE) model to find the varying contribution of various parameters in SIF. Error analysis is done for observed patterns of relationships and thus contributes to the understanding of usefulness of SIF as crucial for remote sensing application.

Hyperspectral Image classification and un-mixing of classes from AVIRIS-NG image of Ahmedabad

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Remote Sensing applications are widely used for Urban planning and mapping. Hyperspectral Remote sensing of urban area can helping in identifying various surface and material types in urban infrastructure. A hyperspectral image AVIRIS-NG sensor from airborne plaform flown over Ahmedabad city, India in 2018 is used. The mixed pixel of hyperspectral image constitute more than one object or surface types. The pure pixels are possible to be estimated using dimensionality determination of image scene. Two methods of Dimensionality estimation were used: Intrinsic Dimensionality and Virtual Dimensionality. The extraction of pure pixel or Endmember spectral signatures is done over the scene using information from Dimensionality determination. The multiclass classification used constraint classification as a generalization that captures many flavors of multiclass. Sensitivity of thresholding value for a class for a classification algorithm is tested in this context. The effects of constraint classification together with thresholding is compared abundance maps using three unmixing algorithms: Unconstrained Classification Least Squares (UCLS), Non-Negative Least Squares (NNLS) and Fully Constrained Least Squares (FCLS).

Machine Learning Approach on Multitemporal Remote Sensing Data for Identification of Rabi Crop in Tehri Garhwal Uttarakhand

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Accurate estimation of active agricultural cropland is essential for a number of management and policy decisions. Remote sensing technology has provided ample opportunity to map active agriculture area at varying spatial scales. In this study, temporal Sentinel-2 multispectral data have been used for mapping active agriculture area during rabi season 2019-20 for Tehri Garhwal District (Uttarakhand, India) using a Random Forest classifier on Google Earth Engine (GEE) cloud platform. This geographical region is facing the challenges of decreasing active agriculture crop land over during the last 2 decades. The monthly mean and max NDVI composites temporal images were generated in GEE. The study revealed that the NDVI temporal stack consisting of mean NDVI composites generated using the full Rabi season data performed the best results with an overall accuracy and kappa of 95.56% and 0.8939 respectively. A total of ~19,833 hectares area was estimated to be under active agriculture land during Rabi season and found to be in agreement with the reports from the agriculture department. Thus, a decreasing trend of active agriculture was confirmed in this study. Keywords: Cropland, Google Earth Engine, Sentinel-2, Random Forest, NDVI.

Understanding the behaviour of basaltic layers in groundwater recharge with integrated modelling of remote sensing, 3D stratigraphic and electrical resistivity tomography data

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Conceptually groundwater recharge (GWR) is a very complex phenomenon, it varies both spatially and temporally due to its dynamic nature (Saha et al. 2022). GWR is an integrated effect of hydrogeological surface and sub-surface variables. However, in basaltic aquifers of Deccan traps, sub-surface conditions are more critical than their surface counter parts (Ansari et al. 2016). Basaltic aquifer comprises of a complex arrangement of top weathered/ altered surface, variable basaltic layers, and phases of intermittent weathering zone. The top layer represents a higher magnitude of anisotropy and heterogeneity in its geo-physical, geo- chemical and hydrogeological properties due to differential weathering. The deeper parts characteristics are mainly controlled by differential flow patterns of basalt along with intermittent hiatus of weathering. Groundwater in these provinces occurs in a very limited quantity with very low prospects. The deeper portion of these aquifer systems is constituted by lava flows, which comprise massive basaltic units which are occasionally accompanied by fractures. The surface signatures of fractures in these aquifers on many occasions are false informative. Therefore, the non-fractured massive portion of aquifer identification needs a deeper level of understanding with comprehensive subsurface knowledge of aquifer systems for groundwater exploration. Thus, understanding the aquifer geometry, extension, flow pattern, and different flow layer formation are of equal or more importance than surface variables for site suitability of artificial groundwater recharge (AGWR).

RS-GIS has evolved as a major tool for the complex analysis of data collected from various sources, for groundwater studies (Saha et al. 2021). However, the Spatio-temporal variability along with complex flow patterns of basalt fractures false surface manifestation, complicated hydrogeological setting, and surface camouflage makes it very difficult to understand the groundwater regime only by RS techniques. 3D aquifer stratigraphic model based on well observations is very useful for conceptualization and visualization of groundwater recharge regimes in critical basaltic provinces (Raiber et al. 2015). These models provide a scientific and predictive tool for determining appropriate solutions to groundwater regimes. Electrical resistivity tomography (ERT) is a powerful technique for imaging the sub-surface in 2D, for accurate delineation of sub-surface aquifer conditions for understanding the recharge characteristics (Kumar et al. 2020).

Bhalki micro watershed, Bidar district, Karnataka in Deccan basaltic province has been witnessing a severe water crisis for the past few years (Charan et al. 2020). The lack of reliable comprehensive information on the aquifer characteristics has further worsened this situation. With an aim to create a balance of groundwater resources, this study is carried out with integrated modeling of remote sensing (RS), 3D stratigraphic, and electrical resistivity tomography data.

The model delineated four zones of AGWR namely, unsuitable, moderately-suitable, suitable, and highly-suitable according to their recharge characteristics. Spatial coverage reveals ~ 12% area is highly suitable, ~30 % is suitable, ~40% is moderately suitable whereas ~18% in unsuitable for AGWR. The delineated recharge zone of the study area is found to be in agreement with the groundwater depths and dynamicity. This technique has provided immense benefit in the identification of fractures/weak zone, and differential flow patterns of basaltic formation for groundwater recharge, which is otherwise impossible to identify and delineate. This research methodology can assist the planners/policy makers for groundwater development and recharge strategies to create sustainable groundwater development scenarios.

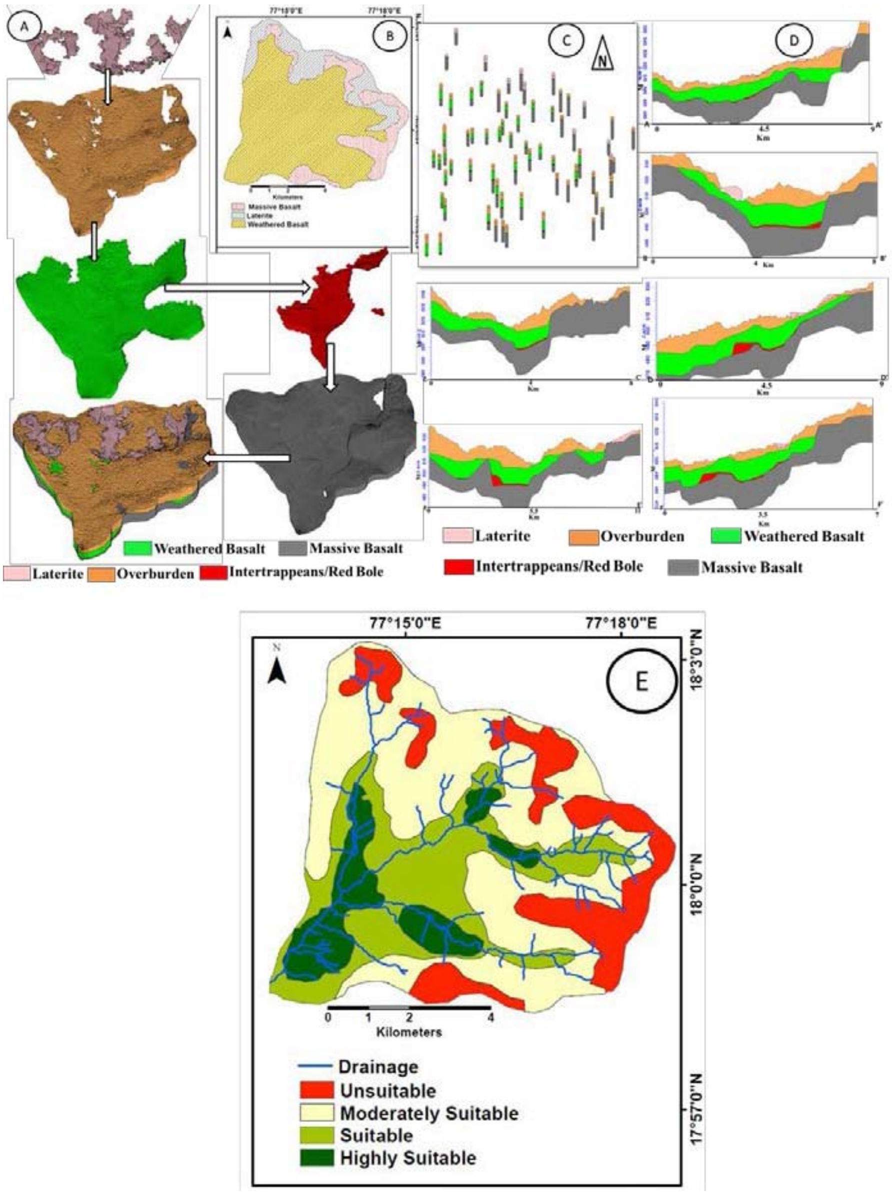

Figure A: Different basaltic layers and the 3D stratigraphic formation of the aquifer; B: Lithology map, C: Well logs locations, having differential stratigraphic information; D: Cross-section profiles of the aquifers obtained along different direction, E: Site suitability zonation of the study area, showing four different categories of recharge zones

Identification of mango varieties and estimation of leaf chlorophyll and nitrogen content using Hyperspectral data

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Identifying crop varieties would significantly help in assessment of yield variability within horticulture crop like mango. Hyperspectral remote sensing, because of its large number of contiguous bands has potential in varietal identification. Chlorophyll is one of the main constituents determining leaf reflectance in the visible region which is vital for photosynthesis in plants. Nitrogen is key element in chlorophyll and its deficiency results in sub optimal photosynthesis. Determining the chlorophyll content and its relation with nitrogen content through remote sensing will help in realizing efficient management of nutrient status of plants, resulting in improved productivity. Current study was carried out at Indian Institute of Horticultural Research (IIHR) farm, Hessaraghatta, Bengaluru. The study aims at selecting the optimum bands to identify two mango varieties *i.e.,* Alphonso and Totapuri and estimate leaf chlorophyll and leaf nutrient content from ground based hyperspectral measurements, chlorophyll content index (CCI) using chlorophyll concentration meter. Sample size was 25 for each variety measured in three replications and each observation was an average of 5 spectral measurements. The chlorophyll and nutrient analysis were carried out in laboratory for the leaf samples from which spectral measurements were made during three critical stages viz., dormancy period, flowering and fruit set period of mango crop. The collected spectra were used to generate different hyperspectral vegetation indices for establishing relationship with laboratory estimated nutrient content.

The stepwise discriminant analysis (SDA) was carried out and separability measures, such as Wilks' lambda and F-Value were used as criteria for identifying the narrow bands for varietal discrimination. Based on the hyperspectral reflectance patterns, the spectrum has been divided into seven parts namely 400-490nm, 490- 590nm, 590-690nm, 690-800nm and 800-1050nm and 1050-1350nm and 1425-1800nm averaged to 5 nm range for subsequent analysis (Manjunath *et al.*, 2011, Sahoo *et al.*, 2015) The region between 490-590 nm (green) is where reflectance is higher compared to the adjacent values while 690-800 nm is an important region showed significant rise in the reflectance values in the red edge based on which many indices are developed for various application. These regions are significantly different from the others in SDA. The stepwise mode selects the best band based on the selected condition and additional bands will be added sequentially while accounting for already added bands. Hence, there is a need to do partition similar spectral regions in order to get all the important features. Backward and stepwise methods were used in SDA to get the most important bands in each of the 7 regions. The analysis showed that, the best bands for varietal discrimination are centered mostly in between 400-700 nanometer. These selected bands can thus be used to classify the hyperspectral images to derive canopy parameters at regional scales.

Amongst the indices analyzed, it was found that Transformed Chlorophyll absorption in Reflectance Index (TCARI), crop chlorophyll content and Modified Chlorophyll Absorption Ratio Index (MCARI) showed strong correlation with the measured total chlorophyll with highest r^2 of 0.82, 0.76 and 0.79, respectively. CCI showed strong correlation with lab measured leaf chlorophyll content during dormancy as well as fruit set stage with r^2 of 0.63 and 0.57, respectively. CCI was then compared with chlorophyll indices derived from the leaf spectra, the first derivative based BmSR index was the best performing index with r^2 = 0.72 and 0.93 during dormancy and flowering to fruit set stage, respectively. The analysis revealed that the chlorophyll was strongly correlated in the visible region and nitrogen is correlated with chlorophyll content with an r^2 of 0.6 to 0.9 from dormancy to fruit set period. Leaf Nitrogen showed positive correlation (0.5- 0.75) in the Short-wave infrared region centered around 1480nm and green region centered around 400- 500nm. It was found that NDSI index was strongly correlated with measured leaf nitrogen (r^2 = 0.65). The results reveal that nitrogen is highly correlated with chlorophyll content in leaves which can reasonably be estimated from narrow band indices.

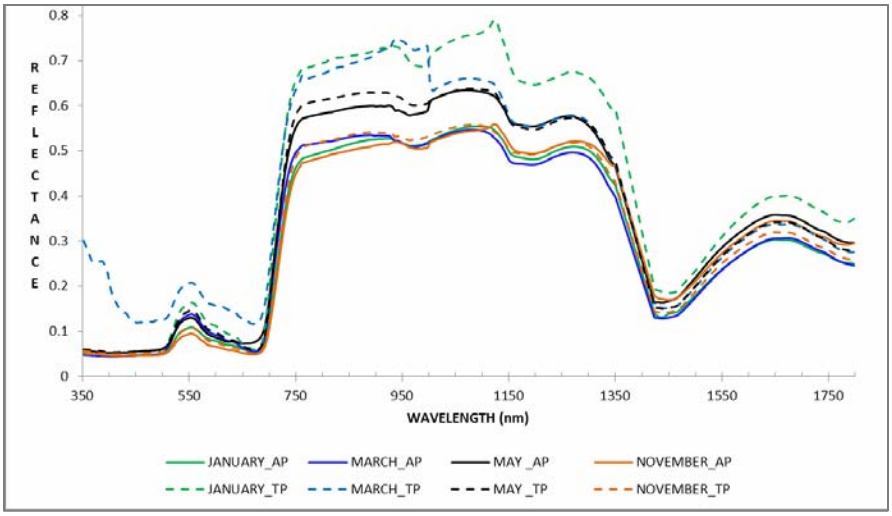

Figure-1: Temporal Hyperspectral profile of mango Leaves of Alphonso (AP) and Totapuri (TP) varieties measured from ground based spectroradiometer

Estimation of Major Soil Nutrient in Humid Tropical Regions of India: A Non-Destructive Approach using hyperspectral data and Machine Learning Models

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Soil is one of the important resources for maintaining a sustainable future of Indian agriculture for ensuring food security. More than 121 million agricultural fields across India, needs to be tested and the capacity of the soil testing laboratories lags behind the requirement. Precise mapping of soil using conventional analysis is laborious and time consuming. Advanced remote sensing techniques hyperspectral domain can be used to address this challenge by developing soil spectral libraries. Soil spectral signatures of specific soil types that can be linked to a range of soil properties and nutrient recommendations. Over the past few decades, remote sensing approaches have been tested for providing solutions for rapid soil assessment. These approaches are fast, non-destructive and have large spatial coverage. There are four factors that influence the remote sensing of soils such as mineral composition, organic matter, soil moisture and texture. In the prersnet study, use of ground based hyperspectral radiometer has been explored for the development of spectral signature repository of humid tropical soils of Kerala for assessment of soil nutirents.

Soil samples were collected from micro watershed in Palakkad district of Kerala using grid sampling. Field and lab level spectral signatures were collected using a portable spectroradiometer with a spectral range of 350-2500 nm (Fig.1). The collected spectra were pre-processed using different transformation techniques like smoothing, binning, absorbance, de-trend, continuum removal, Savitzky-Golay derivatives (SGD), standard normal variate (SNV), multiplicative scatter correction (MSC), and normalizations were carried out. Simultaneously soil samples were processed and analyzed for the physico chemical properties along with Major Nutrients (NPK) using standard procedures. The lab analyzed values were compared with the spectral data using advanced statistical techniques such as Multiple Linear Regression (MLR), Partial least Squares Regression (PLR), Support Vector Machines (SVM), Random Forest (RF), and Gaussian Process Regression (GPR) for selection of best bands to predict the soil properties and major nutrients like nitrogen, phosphorous and potassium. The statistical and machine learning techniques was adopted with eight different preprocessing techniques for major nutrients prediction. The accuracy measures like coefficient of determination (R^2) and root Mean Squared Error (RMSE) used for model calibration.

Support vector machine with Savitzky-Golay Derivatives transformation showed higher Coefficient of determination value (R^2) and minimum Root mean square value (RMSE) in both training (R^2=0.96, RMSE=8.94) and testing (R^2=0.49, RMSE=20.10) for Nitrogen. Gaussian Process Regression without retransformation showed significant relation in both training (R^2=0.94, RMSE=8.79) and testing (R^2=0.58, RMSE=12.62) for phosphorus. Similarly support vector machine with De-trend transformation showed better relationship in both training (R^2=0.99, RMSE=6.43) and testing set (R^2=0.66, RMSE=100.54) for potash. The analysis revealed that the best bands for prediction of N, P and K are 482 to 510 for N; 1342-1350 for P and 850- 909 for K, respectively. Among the models tested, Support vector machine (SVM) with Savitzky-Golay Derivatives (SGD) transformation performed better for predicting soil nitrogen; Gaussian Process Regression (GPR) without retransformation, for predicting soil phosphorus and SVM with detrend transformation for soil potassium, since they correlated well between field spectral data and lab chemical analysis. Development of soil spectral signature can help in rapid analysis of large no. of samples in quick time which would help in the nutrient recommendations for improving the crop productivity. In this regard, furtrher research is focussed on establishing relationships between narrow spectral bands with different nutrient contents for benchmark soils using ground / UAV / satellite based hyperspectral imaging techniques.

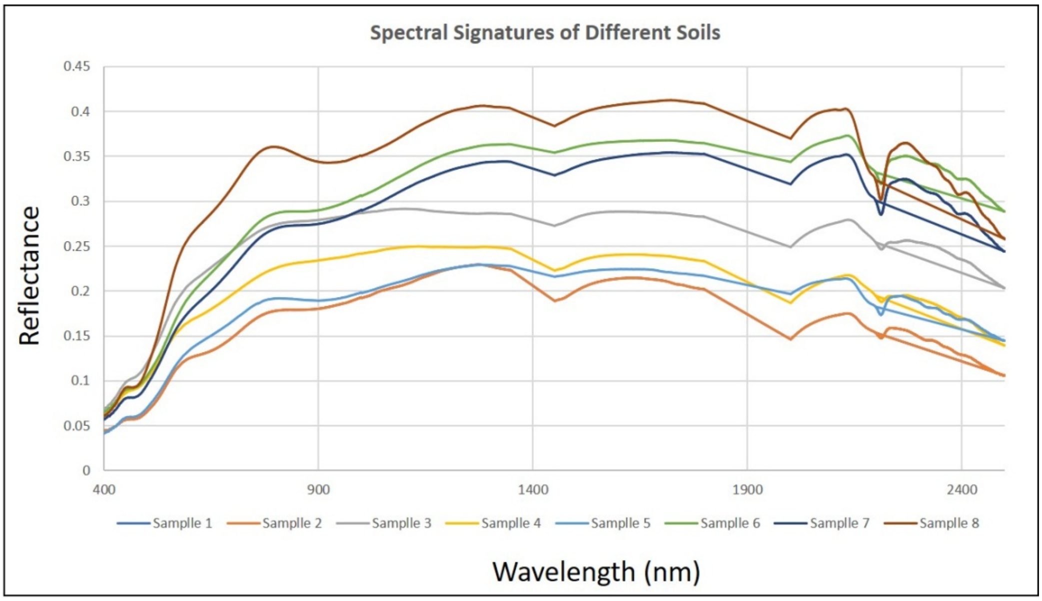

Fig-1: Comparison of hyperspectral profiles of different samples for surface soils

Assessing spatio-temporal variations in crop water requirement of wheat crop in semi arid region of Punjab

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Increasing population is a major global concern which will lead to a proportional rise in food and water requirements. To meet the rising food requirements, the crop productivity has to be increased with the limited resources available. Recent studies show that there is a notable amount of water being lost in the form of excessive irrigation, ground water depletion, runoff losses and evapotranspiration (ET). To conserve water, increasing the water use efficiency (WUE) is one of the most effective means. Irrigation scheduling can play a crucial role in achieving higher WUE. To schedule irrigation, estimation of ET is considered a vital step. This study aims to estimate ET, irrigation water requirements of wheat crop in Ludhiana district using geo-spatial technologies and representing the spatio-temporal variations. ET of wheat crop during three rabi seasons (2019-2020 to 2021-2022) were estimated using satellite and meteorological data. Sentinel 2A and MODIS 16 data was used in this study. The obtained satellite images were processed using ERDAS Imagine software. After processing the image, the district map was used and unsupervised classification was carried out to generate wheat crop mask. MODIS 16 data was used to find ET product. Climatic variations, crop water requirements and differences in yield in different blocks of the district over the years were studied and factors affecting these changes were analysed. Comparing the climate during different growth seasons, it has been observed that, maximum and minimum temperatures increased over years, and the rainfall was highest during 2019-20 (212 mm), followed by 2021-22 (146 mm) and 2020-21 (113 mm). Within the growing season of wheat, ET increased with the vegetative growth from November to February and decreased as the crop reached maturity stage during March and April. Total ET reduced gradually over years. Yield of the crop showed a sharp decline during 2021-22 as a result of heat wave that occurred during the grain formation stage. Yield was affected by various factors like climate, crop variety, sowing date and duration of the crop and management practices including evapotranspiration. ET maps were generated in ArcGIS using the monthly evapotranspiration obtained from MODIS 16 data. The monthly ET maps were combined to form a seasonal ET map. Mapping of the evapotranspiration and irrigation water requirements can help in understanding the spatial as well as temporal variations within the study area. This information can potentially be helpful for the end users (farmers, policy makers etc.) to easily identify the water requirement of the crop in specific localities and plan an irrigation schedule accordingly.

Hydrodynamics Assessment of Rapti River in Balrampur and Gorakhpur District by Geospatial Techniques

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The Rapti River originates as a River that drains the Chitwan valley of Nepal and flows west to join the Narayani River a short distance north of the Indian border. After coming into the plains the major districts through which the River flows are Bahraich, Shravasti, Balrampur, Siddharth Nagar, Sant Kabir Nagar, Gorakhpur, and Deoria districts of Eastern Uttar Pradesh. The River basically changes its coarse and flow pattern during monsoon season in Balrampur, and Gorakhpur district and creates the accountable disaster in terms of human settlement and agricultural land. The shifting of River is governed by numerous factors like sinuosity, agricultural practices around the banks, rainfall pattern and intensity, types of soil, and geography of the area. Generally, the River changes its course, flow directions, and pattern in 10-20 years. But Rapti River changes its coarse and flow direction within a short interval of time which ranges from 2 to 3 years respectively. Due to continuous and unprecedented changes in the flow direction of the Rapti River in the Balrampur, and Gorakhpur districts, the loss of the agricultural, flow pattern, properties, and human settlement is very accountable.

This research paper focuses on drastic changes in the flow pattern, the effect on urbanization, changes in Agricultural practices, and sedimentation patterns at selected locations from years 2013 to 2021 respectively at an interval of 2-3 years using Geospatial data. With the help of Remote Sensing & GIS Techniques, we can continuously observe and monitor the temporal changes in the flow pattern of the Rapti River.

Remote sensing and GIS for the analysis of crop diversification patterns in Nalgonda district, Telangana state, India

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Remote sensing and GIS are very crucial for agricultural studies. The delineation of land use and land cover of distinct groups, natural resources including water, flora, agriculture, fallow land, barren terrain and habitation through the help of remote sensing and digital image classification provides a knowledge-based data to study the possibilities of crops diversification in the Nalgonda District. There is a huge potential for crop diversification in the district for several reasons; availability of irrigational infrastructure, farmers' interests, and agro-business development. However, most farmers are not ready to take risks and choose crop diversification patterns. The current research makes the case that remote sensing will provide a clear picture of the ground with the help of spatial data and the possibilities of crop diversification in the Nalgonda district. In this sense, crop diversification can serve as an excellent illustration of sustainable agriculture that meets present and future requirements. Based on field surveys, observation, and an extensive literature review, the current study makes the case that crop diversification and the combination are feasible throughout the district. The study findings will benefit academics, policymakers, geographers, and agricultural researchers.

Concept of River Recovery in Anthropogenically Disturbed River Systems: Integration of Google Earth Engine and Fluvial Dataset

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The Mahanadi-Brahmani river system is anthropogenically disturbed by large dams, changes in land use land cover and gradual alteration of geomorphic units. The concept of river recovery and river health assessment holds significant importance in the present time as, slowly, Indian river systems are responding to fluvial disturbances. The disturbances are in terms of changes in process (flow-sediment), morphological units and ecological entities. River recovery is defined by the inherent adjustment capability of fluvial systems to the alteration in boundary conditions. In the present study, Google Earth Engine cloud computing techniques (GEE), along with a long-term fluvial dataset, will be integrated to assess the river health and future trajectories. The process-based indicators have been formulated, which will assess the system state disorderness, self-organisation of instream vegetated landforms and resilience to fluvial disturbances. The results show that the Mahanadi-Brahmani is observed to offer a dominant fixed control in terms of nodal sections and macro-channel banks. In addition, the GEE clod-computing results show the prevalence of both threshold-modulated and filter-dominated systems for the Mahanadi-Brahmani Rivers. The present knowledge on river recovery is further integrated with different Indian river systems that show large heterogeneity in fluvial controls.

Intra and inter-annual groundwater storage assessment using gravity based terrestrial water storage from grace and grace-fo data in ganga-brahmaputra river buffer

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Groundwater is essential source for the sustainable development and its management is very important. Spatio-temporal analysis of groundwater storage changes is a prerequisite to sustainable water-resource management over river basins. In this study, Ganga-Brahmaputra River buffer (100 km) i.e. Ganga River starting from Rudraprayag and Brahmaputra from Siang, Arunachal Pradesh to Bay of Bengal has been taken for the analysis. The younger alluvium is exposed along the present course of Brahmaputra River and Ganga river buffer; marked by sand, silt and clay of relatively more recent age possesses secondary porosity, which is the main cause of groundwater migration in these areas. Also most of the study area comes under agricultural area where the groundwater variations will be prominent. Monitoring of the changes in the groundwater storages spatially in this mountainous and highly varied aquifer systems is very difficult and time consuming from in-situ spars measurements: Here the opportunity for adopting the Remote sensing techniques to accurately quantify the ground water storage changes. GRACE and GRACE-FO (Gravity Recovery and Climate Experiment) are such missions having twin satellite launched by the NASA, and the German Aerospace Centre combined in March 2002 for tracking down the mass redistribution of the earth by monitoring changes in gravitational force, the observed monthly changes in gravity are caused by monthly changes in mass. In this study we have used GRACE CSR RL06 Mascon’s for TWSA (Terrestrial water storage anomaly) of 0.25 degree resolution which represents change in Terrestrial Hydrological mass, along with this other hydrological parameters such as Soil moisture at different depths, Canopy water storage and Storm surface water anomalies (2004-2009) from GLDAS NOAH Land surface model were used to extract the groundwater as a residual from the water-budget equation. The intra and inter- annual analysis has been carried out in three different time periods such as 2005-08, 2013-17 and 2018-21. The overall observations from this study revealed that there is sufficiently decrease in the Groundwater storage from 2005 to 2021 in the downhill side of chosen river buffer. We observed that in 2006 it’s a dry year and the groundwater storages are very less i.e -9.19 to 16.160 mm/year throughout the study region and is maximum in the 2016-17 accounting as -0.218 to 75.088mm/year and -1.58 to 76.24 mm/year respectively. Interestingly,In the year 2005, Dehradun region is showing a highest groundwater storage depletions i.e it is experiencing negative anomalies varying from-34.56 to -0.012 mm/year , but its gradually increasing over a period of time and in 2021 groundwater storages are improved to the extent of 65-70 mm/year. Data for Dehradun and part of Assam were also been validated with well data obtained from CGWB ,showing the greater correlation coefficients around 0.75 in Selakui and 0.71 in Selenghat,Assam with the same trend. Uncertainity in the GRACE TWSA is not accounted during the validation.

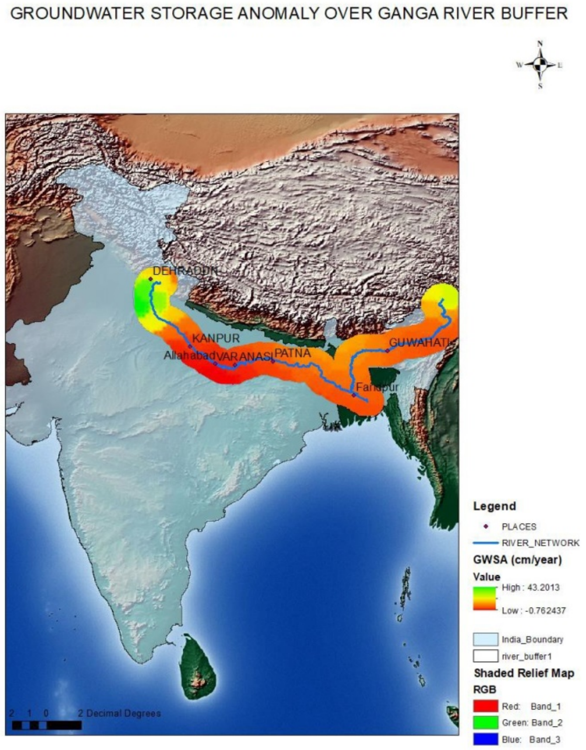

Figure 1: Groundwater storage anomaly map

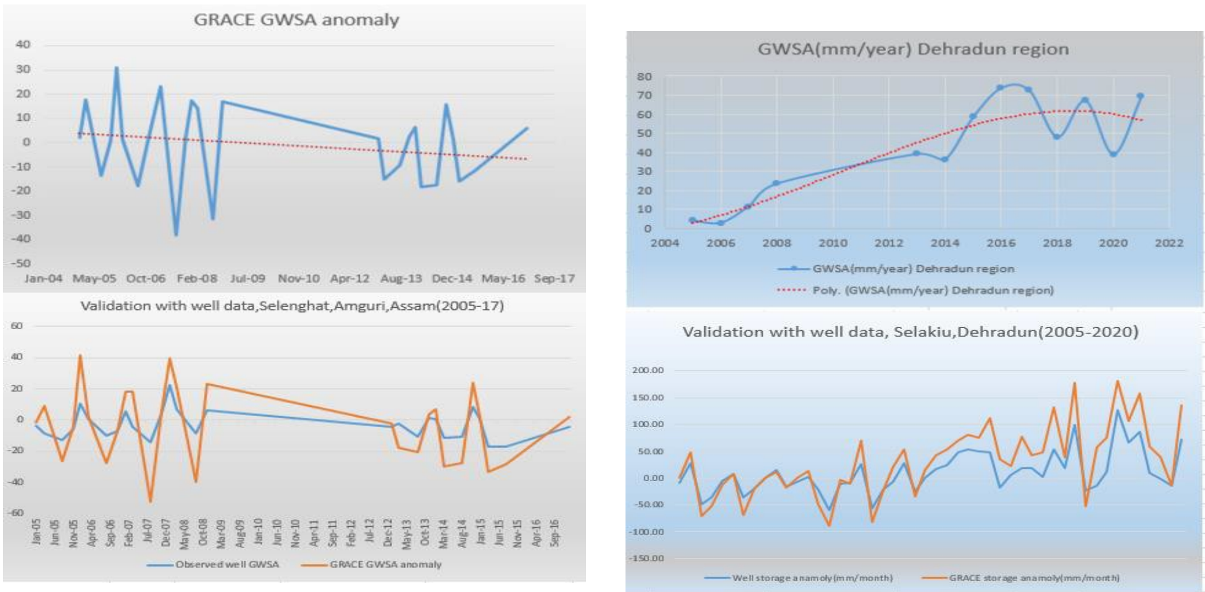

Chart 1: Trend and Validation of GRACE GWSA with Well data

Mapping of Mustard Crop with Planet Scope High-Resolution Dataset using Machine Learning Algorithms

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Agriculture, is considered as one of the important sector for any country like India which contributes a high percentage of share in economy. So, managing the crops and monitoring its growth become an important task. Crop type data are an important piece of information for many applications in agriculture and even useful for different agencies such as insurance agencies, geoportal, regional and national agricultural boards to take important decision. Therefore, accurate crop mapping is required which is a simple yet critical issue in agriculture for mapping a different crop. Manually, mapping of crops is a tedious task and does not provide an accurate result so Remote Sensing techniques are deployed here. In the past few decades, Remote sensing has played an important role in acquiring necessary data for extracting crops at global as well as at local scale. The satellite remote sensing has been also undergone huge transformation in collecting data at different spatial resolution. In past, usually coarse as well as medium resolution images were used for mapping the crops as the cost of high resolution satellite images are always a hindrance. But now, free availability of the Planet Scope dataset with a daily revisit cycle and spatial resolution of 3m has generated new opportunities for mapping small land holding. The objective of the study is to map a Mustard field in Haridwar district, as it is considered as one of the important crop in the study area. Mustard crop being a catch crop and contributes a high percentage in oilseeds production after soybean and palm oil. In past, brown mustard was cultivated in most of the area, while now its cultivation is decreased and replaced by Indian Mustard. This study utilizes 6-time series Planet Scope images acquired during the growth period of the Mustard crop from November to March for 2021-22. Random Forest (RF) and Classification and Regression Tree (CART) algorithms of machine learning have been in this study. Further, spectral indices images of NDVI, GCVI, ND2 and EVI2 were generated from the original data set. These datasets provide better and specific spectral information regarding green vegetation and crops. The study has divided into two scenarios, wherein the first scenario, only the best 3 band combination of the original spectral bands having maximum Transformed Divergence (TD) seperability are taken as input for classification while, in the second scenario some commonly used vegetation indices as such, NDVI, GCVI, ND2, EVI2 have been considered along with the original spectral bands for classification. The ground truth data were collected using Sokkia handled Global Positioning System (GPS) to frame the training as well as validation datasets (70% training and 30% validation, respectively) for mapping and accuracy assessment. On the basis of the training data, in first scenario the best 3-band combination using original data were found to Band 6 (Red), Band 7 (Red edge) and Band 8 (NIR), while for second scenario, the best 3-band combination are Band 7 (Red-Edge), EVI2 & GCVI. The classification results show that RF is able to classify the Mustard crop with an accuracy of 87.5% with an F1 score of 82% in the first scenario and 90.2% accuracy with

F1 score of 86% in the second scenario, while CART is able to classify Mustard crop with an accuracy of 79.94% with F1 score as 75% in the first scenario and 81.74 % accuracy with F1 score as 82.34% in the second scenario respectively. From the given study, it is found that Random Forest using the combination original data and spectral indices provides best results. This allows for a better extraction of mustard crop using Planet Scope.

Impact of Upstream Water Storage Structure in Streamflow Modeling – A Case study of Ujjani Reservoir

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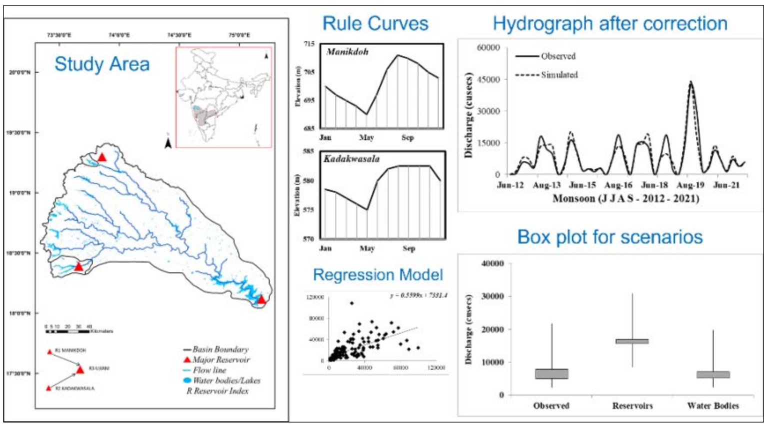
Hydrological models are often considered an efficient tool for simulating hydrological processes. The simulated water balance components are compared with their observed counterpart in terms of discharge, soil moisture and evapotranspiration and sensitive parameters are tweaked till the best match is obtained. Calibrating model parameters alone is insufficient to arrive at the simulation near observed variables; one such important factor identified in this study is the importance of upstream water storage structures. When water impoundment structures are not defined in the modelling environment, routed discharge is devoid of upstream abstractions which leads to the incorrect simulation of (1) river discharge, (2) inflow into the reservoirs, and (3) water resources availability assessment.
Representing upstream water storage structures in hydrological models helps to improve the performance of the hydrological model towards the simulation of river discharge and reservoir inflow estimation. In this study, a semi-distributed, macro scale, Variable Infiltration Capacity (VIC) model is used for simulating daily water balance components. The gridded model framework was prepared using the geospatial dataset from the NBSSLUP soil map of India, NRC - Land Use and Land Cover, MODIS LAI, SRTM - Digital Elevation Model (DEM), and meteorological dataset from India Meteorological Department. The model simulated surface runoff and base flow were routed through the stream network using the linearised 1-D St. Venant routing formulation. The model simulated state variables such as soil moisture and evapotranspiration were validated against the soil moisture in-situ measurement and latent heat flux measurement from eddy covariance flux tower data as well as MODIS – ET product respectively.

The established modelling framework was utilised to simulate reservoir inflow for the Ujjani reservoir situated in Krishna Basin which is abstracted by two major reservoirs namely Manikdoh and Khadakwasala and other small to medium water storage structures. The reservoir water balancing is performed for each reservoir by defining reservoir hydraulic particulars such as minimum drawdown level, full reservoir level, spillway level & its designed discharge and operational rule curves to simulate reservoir releases.



To account for the storage in lakes and water bodies, a methodology is developed to relate the cumulative Year-to-Date (YTD) rainfall in the catchment and Inflow into the reservoir in terms of volume. The cumulative rainfall over the catchment denotes the moisture condition of the catchment in terms of dry/damp/wet conditions. A 1st-order regression relationship is established between rainfall and observed inflow to the catchment moisture condition; the intercept from the regression equation is taken as the storage correction factors for simulated discharge obtained from the reservoir module.

The performance is measured for the simulated inflow after incorporating major reservoirs and applying a storage correction factor to account for other abstractions in terms of R^2, NSE, KGE and PBIAS. A significant improvement in R^2, NSE, KGE, and P-Bias is obtained from 0.45 to 0.75, -0.8 to 0.73, -1.1 to 0.84, and -119 to 1 respectively before and after the application of storage correction factors. This study emphasizes the role of the incorporation of water structures in the hydrological modelling framework for accurate and reliable estimation of stream flow and inflow estimation which is merely not possible alone with the model calibration

Utilization of airborne hyperspectral AVIRIS-NG data in identification and mapping of hydrothermal alteration zones for gold deposits in Gadag Schist Belt, Karnataka

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In this study, we have utilized the Airborne Visible/Infrared Imaging Spectrometer-Next Generation (AVIRIS-NG) hyperspectral dataset to map hydrothermal alteration zones in the Gadag Schist Belt (GSB), Karnataka. This region is part of the Western Dharwar Craton, and is known to have a significant amount of gold mineralization. Hydrothermal alteration zones are considered as crucial landmarks for mineral exploration and may also represent a prospective mineralization zone. The visible-near infrared (VNIR) and shortwave infrared (SWIR) regions in electromagnetic spectrum reveal diagnostic absorption features in the minerals found in alteration zones.

In this regards, few image analysis products are derived from spectral mapping techniques using VNIR and SWIR bands of the AVIRIS-NG data to map the alteration minerals. These alteration minerals are muscovite, kaolinite, chlorite, iron oxide gossan, which are highlighting the phyllic, argillic, and porpyllic alteration zones. These image products were integrated with conventional ratio images, relative band depth images, and eigenvector-based principle component (PC) images of AVIRIS-NG data to improve the alteration minerals zones in this study. We perceived that the image spectra derived from these improved alteration zones are analogous to the laboratory spectra of those altered minerals. We have also used tilt derivative products derived from ground gravity data and AVIRIS-NG enhanced images to delineate the geological structures governing the hydrothermal process for gold deposits. Most of the identified alteration zones are associated with geological lineaments. These findings are further validated with the existing geological map, locations of gold mineralization provided by GSI-Bhukosh, and the potential anomalies derived from ground geophysical data. This study concludes that airborne AVIRIS-NG data can be effectively utilized for alteration mapping of economic minerals.

Hybrid Retrieval of Leaf Area Index and Chlorophyll Content of Rice Crop using PRISMA Hyperspectral Data

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Non-destructive remote sensing-based estimation of crop biophysical and biochemical variables over different space and time is essential for various applications such as variable rate applications, crop monitoring, crop stress detection, yield modelling, environment monitoring etc. One sided green leaf area index (LAI) is most important biophysical variable which controls the carbon, water and energy exchanges between the land and atmosphere and is one of the essential climatic variables. While chlorophyll content (CC) of the canopy determines the absorption of solar radiation for photosynthesis. Hyperspectral reflectance of crop canopy in visible, near infrared and shortwave infrared region of the electromagnetic is influenced by the chlorophyll content, canopy architecture, etc. and many previous researches has been carried out to relate spectra to these properties which provides a base LAI and CC retrieval using hyperspectral data. Two common approaches for retrieval are physical process based radiative transfer model (RTM) and statistical machine learning regression algorithm (MLRA). RTM describes crop reflectance as function of canopy, leaf and soil background while data driven MLRA models the non-linear relationship between reflectance and crop parameters. Hybrid retrieval approaches are being adopted very recently through combining the RTM and MLRA. It helps in solving the ill-posed relationship between reflectance and crop traits i.e, several combinations of crop properties have similar effect on crop reflectance. The new generation PRecursore IperSpettrale della Missione Applicativa (PRISMA) satellite of Italian Space Agency provides hyperspectral cubes on a 30 km swath, 30 m spatial resolution and 29 days temporal repetivity and it has paved a way for formulating and testing several retrieval models for its operational applications. This study was undertaken to test and validate various hybrid retrieval techniques for LAI and CC using PRISMA data.

The study has been conducted in the part of Bargarh district of Odisha which is an identified JECAM site for developing various approaches for rice mapping, monitoring and yield estimation and is characterized by rice-rice ecosystem under irrigated condition. Field campaign were performed during active vegetative growth stage of the crop during 22-28 Feb 2021. Spectral measurements, LAI, CC, crop height, transplanting dates were collected during the campaign. The coefficient of variations of collected LAI and CC were 32.5 % and 19.4 % respectively. Staggered transplanting, variable fertilizer application etc. were the source of variation in LAI and CC in the study area. Archived Level-2 PRISMA data of 24th Feb 2021 were acquired, noisy bands were removed and resampled to 10 nm FWHM. Spectra derived from in-situ spectroradiometer and PRISMA for the ground sampled location were generated and further used in the study.

Radiative transfer models PROSPECT4 (leaf) and 4SAIL (canopy) were parametrized using ground measured data to simulate sufficiently large number of spectra (~1000 nos). These spectra were incorporated for training and validation of various machine learning regression algorithms i.e, Random Forest (TreeBagger), Kernel ridge Regression, K-nearest neighbors regression, Gaussian Processes Regression, Least squares linear regression, Partial least squares regression, Support Vector Regression and principal component regression. The accuracy of each model was evaluated based on the coefficient of determination (R^2) and root

mean square error (RMSE) by comparing the observed and modelled parameters. Random forest regression was best performing method for LAI retrieval with RMSE of 0.28 $m^{-2}m^{-2}$ and R^2 of 0.86 while kernel ridge regression performed best for CC with RMSE of 2.37 µg cm^{-2} and R^2 of 0.88. The respective best performing models were deployed on PRISMA to generate a spatial map of LAI and CC.

These retrieval approaches were also tested with the multispectral (13-bands) Sentinel-2 data acquired for the study area for the same date. Results showed a significant higher retrieval accuracy in PRISMA compared with Sentinel-2. Hence the study demonstrated the potential of spaceborne PRISMA hyperspectral data for retrieval of LAI and CC of the rice crop.

Deep Neural Network for soybean crop yield estimation at disaggregated level using multi temporal weather and earth observation dataset.

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Crop yield prediction at local level is of great significance for various agriculture applications like crop market planning, crop insurance, harvest management etc. Conventionally, crop yield estimation is done by conducting destructive Crop Cutting Experiment (CCE) which tends to be laborious, time consuming and cost ineffective. Moreover, at times, CCE data is also subjected to moral hazards. The government of India is making efforts to reduce the dependencies on CCE and there has been a growing demand for technology based crop yield estimation at disaggregated level in the county. Earth observation (EO) dataset, due to its large area coverage and ability to monitor crop condition regularly throughout the agriculture season offers a good set of matrix to model crop yield. In recent years, Machine Learning (ML) models, owing to their ability to approximate non linear relations, have gained momentum for crop yield estimation. ML models like Deep Neural Network (DNN), Convolution Neural Network (CNN), Random Forest (RF) can be easily integrated with EO datasets and can be used for classification and regression analysis. In Indian context, many studies have reported the effectiveness of EO dataset and ML models for yield estimation of major crops like rice and wheat but such studies are limited for other important crops like soybean.

In this study, a DNN based approach is envisaged for soybean yield estimation at local level (circle) by considering multi temporal weather and satellite (optical and microwave) datasets. The study was conducted during *kharif* 2019 in major soybean growing districts of Maharashtra i.e. Akola and Washim. Initially, soybean mask of the study area was generated using Sentinel-1 (S-1) and Sentinel- 2 (S-2) datasets and multiple parameters attributing to crop yield were extracted for soybean cropped area at circle level. The feature set used in this study includes: season maximum composite of NDVI and LSWI derived from S-2, temporal dataset of cross polarized backscatter (σVH) derived from S-1, Profile Available Water Content (PAWC), cumulative monthly rainfall and rainy days during June to October computed from Automatic Weather Station (AWS), and circle level soybean crop yield data received from Department of Agriculture, Maharashtra.

Stratified random sampling was adopted for segregation of soybean crop yield into training and validation dataset at the ratio of 70:30. DNN was initialized with *He* initialization and trained with a batch size of 8. Among the tested network configurations; the best model performance was obtained with 3 hidden layers (256-128-32) with Leaky ReLU activation function and dropout coefficient of 0.3. Mean Square Error (MSE) was used as the loss function and Adam was used as an optimizer during the back propagation due to its unique ability to take into account the feature density during the learning process.

In the study area, a good distinction between high and low yielding circle was observed in the temporal profile of σVH. Subsequently, the performance of DNN was studied under two different scenarios. (a) *pooled feature scenario*, where entire season σVH was used in yield estimation along with other feature set and (b) *feature engineering scenario,* where 3 phonological indicator were extracted from σVH temporal profile i.e. (i) maximum season composite of σVH , (ii) dynamic range of σVH from the date of sowing till maximum vegetative stage and (iii) area under the σVH curve. These phonological indicator were then ingested in DNN along with other feature set for yield estimation. We found that feature engineering improved the DNN validation accuracy by about 17% from Root Mean Square Error (RMSE) of 135 Kg/Ha in the case of pooled feature scenario to RMSE of 112 Kg/Ha in the case of feature engineering scenario.

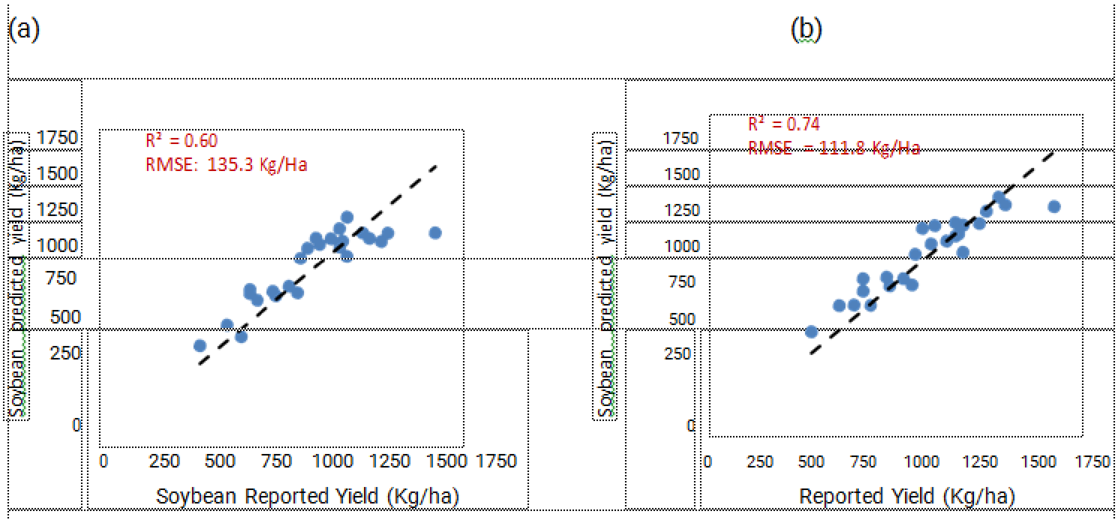

Fig: The relationship between soybean reported yield and DNN predicted yield for validation dataset in the case of (a) pooled data approach and, (b) feature engineering approach.

Development and validation of spectral models for prediction of soil properties in soils of Maharashtra

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A total of 568 sampling points were identified by ICAR-NBSS&LUP and sampling was done by Neoperk field team across the 6 districts of Maharashtra – Sangli (101), Amravati (102), Chandrapur (102), Pune (94), Raigad (105) and Jalgaon (64) from 30 cm depth using a post-hole earth auger. The collected samples were air-dried and further processed by grinding using a wooden mortar-pestle and sieving through a 2mm (and 150μm) brass sieve. Standard procedures were followed for determination of soil pH, EC and soil organic carbon (SOC). Soil diffuse reflectance spectra were recorded for each soil sample using a FieldSpec Pro FR spectroradiometer (Analytical Spectral Devices Inc., Boulder, Colorado) at wavelengths from 350 to 2500 nm with a spectral sampling interval of 1 nm. The original spectra consisting of relative reflectance values of 2151 points (at 1 nm interval) between 350 and 2500 nm were averaged at every tenth-nanometer wavelength interval from 360 to 2490 nm by integration technique. This procedure resulted in a new dataset, with reflectance values specified for 214 wavelengths for all samples, which were further processed with Moving average filter and Savitzky-Golay filter for noise removal. These resulting spectra were transformed to 1^{st}, 2^{nd} derivative spectra by applying 1^{st}, 2^{nd} or 3^{rd} order polynomial and 3, 5, 7, 9 no. of smoothing points which resulted in 54 derivative spectra from each sample. Outlier from soil properties were removed using Interquartile Range method (IQR), where, value below Q1(first quartile) minus 1.5*IQR and value above Q3 (third quartile) plus 1.5*IQR are considered as outliers and removed from data set to generate final data set.

For spectral data modelling, the whole dataset for each soil properties were divided into two subsets viz. calibration (70%) and validation (30%) datasets by applying Kennard Stone data partition method. The prediction approach involves cross-validation with all samples in the calibration dataset, and subsequently tests the prediction accuracy using independent validation dataset. The accuracy and stability of different regression models were assessed based on coefficient of determination (r^2) and root mean square error (RMSEP).

Soil properties of the calibration datasets were calibrated to soil reflectance data (54 derivative spectra), using PLSR (Partial Least Square Regression) technique and the best calibration model were selected based on coefficient of determination (r^2) and root mean square error (RMSEP) and validated on the independent validation datasets. Relatively good spectral models were obtained in calibration for pH (r^2=0.81, RMSE=0.42), sqrt-EC[mS/m] (r^2=0.49, RMSE=0.80) and Ln-SOC[%] (r^2=0.64, RMSE= 0.31), which also resulted in good prediction ofthese properties in the validation datasets for pH (r^2=0.78, RMSE=0.43), sqrt-EC[mS/m] (r^2=0.41, RMSE=0.76) and Ln-SOC[%] (r^2=0.53, RMSE=0.32). The scatter plots of measuredand predicted values for pH and SOC in validation data set are given in Fig. 1.

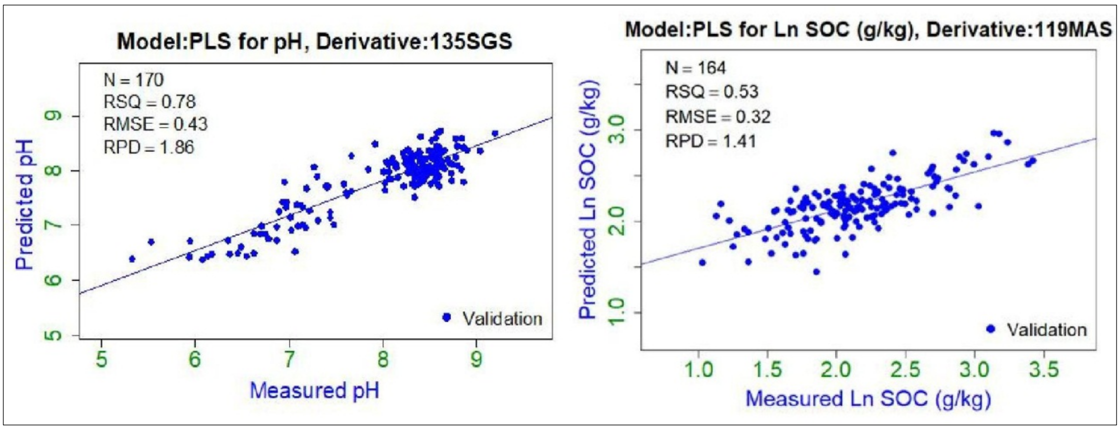

Fig. 1 scatter plots of measured and predicted values for pH and SOC in validation data

SWOT Hydrology Simulator set up for River Discharge estimation over Narmada River Basin

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River discharge is one of the important hydrological variables for many scientific and operational water resources and flood risk management. With decreasing numbers of in situ gauges globally, it is vital to develop new approaches using remote sensing and hydrological modelling for determining river discharge. Satellite altimetry provides the useful information about river stages and along with optical/microwave imagery can be used as a pseudo database to measure river discharge. However, existing altimeters only provide range information along a narrow swath and further friction parameters and cross-sectional area are the two important variables that are difficult to estimate using remote sensing dataset. Estimating river discharge from observed surface water elevations, river width and slope is central to the upcoming Surface Water and Ocean Topography (SWOT) mission. In this study, we have proposed to set up a SWOT hydrology toolbox at 20 locations along the stretch of nearly 600 km of Narmada River. The virtual stations (VS) were selected based on the availability of water level information from Central Water Commission (CWC) dataset or over the tracks of Sentinel-3A (9-VS) and Sentinel-3B (10-VS) radar altimeters. For each VS, the river reach was defined as a length of river approximately 10 km over which a time variant single value of water level and extent was assigned. Google earth engine was used to generate ~2900 water mask images using OTSU thresholding algorithm (Sentinel-1A/1B) during the period 2016-2022.

The SWOT hydrology toolbox was set up with the water level, extent information over the river reaches. In the first step, orbit information along with a data frame was used for the computation of the swath and date of the pass. The waterbody of the study region covered by the SWOT was used to generate pixel clouds, in which every pixel location was simulated in terms of the range and azimuth. The pixel elevation was simulated as elevation information derived from the SWOT interferogram. The elevation in the pixel cloud was estimated using water level with inclusion of the height error. The pixel cloud was processed using a global river reach database and further used for the estimation of the parameter such as river slope, water level, river width, dark pixel and other related parameters for each pixel associated with the simulated interferograms. The simulated products were generated for every river node for the reach of 200 m length. The altimetry retrieved water level over the virtual station after Sardar sarovar reservoir was found to be fluctuating between 10.6 -18.27 meter during the period 2018-2022. Open-source data provided by CWC for unclassified basins on the India- Wris website during the period 1990-2017 was used to build the discharge and water level database. The long-term fluctuations in stage and discharge series were examined for trend analysis and rating curve generation. Extreme downstream gauge station (close to Gaurdeshwar) was selected to analyse the volume of water discharging into the ocean. Monthly and yearly discharge time series was analysed and a drastic reduction in discharge was observed in recent years. Maximum annual discharge was recorded in 1994, i.e. 74674 MCM whereas the average discharge during the study period was 24707 MCM. Quantification of seasonal and inter-annual variability of freshwater discharge will represent unprecedented information for the climate research community. It will also address the science question of the role of freshwater discharge in changing ocean salinity and its impact in ocean circulation models.

Inter-comparison of Long-Term Trends of Rainfall for Hydrological studies over Meteorological zone and major River Basin of India

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Climate change has substantially affected global precipitation patterns which has led to the intensification of the hydrological cycle and frequent occurrence of floods and droughts. Precipitation is generally regarded as the fundamental component of the hydrological cycle as it is not only associated with atmospheric circulation and weather phenomena but also has direct and indirect socio-economic implications in terms of water and food security. Hence, Availability of accurate precipitation estimates helps our understanding of global and regional climate variability and is crucial in managing the available freshwater resources already under threat due to the impacts of climate change. The present study statistically evaluates long-term (1901-2020) trends in average annual rainfall at river basin and meteorological zone scale using IMD 0.25x0.25 daily gridded rainfall data. River basin and meteorological zones (met zone) were selected to evaluate trends at different climatic zones and to determine any co-linearity of rainfall trends with topographic variability. The widely employed Mann-Kendall test was used to determine the presence of any significant trend in rainfall over a particular zone or basin. Sen's slope estimator was used to compute the magnitude of change in rainfall for the particular period. In Northern India, the Indus basin witnessed an overall increase in rainfall in the last 120 years. Average annual rainfall in the Indus basin was 554.39 mm for the first 40 years (1901-1940) which increased to 633.71 mm during 1941-1980 and further increased to 715.60 mm for the period 1981-2020. *However, a decreasing trend in average annual rainfall was observed in the last 40 years (1980-2020).* The Ganga basin witnessed a decline in overall mean rainfall from1089.94 mm during 1901-1940 to 1029.28 mm between 1981-2020 with a significant decreasing trend ($\alpha = 0.1$) during 1981-2020 respectively. Significant increasing trend ($\alpha = 0.1$) was observed for the Godavari basin from 1901-1940 but a decreasing trend (although insignificant) was observed for the next 40 years. Similar observations were obtained for Krishna and Cauvery basin with a magnitude of change of -4.14 mm/year and -4.23 mm/year respectively. Mahanadi river basin along the eastern stretches of India witnessed a significant increasing trend for the first period (1901-1940) with a z value 2.39. However, the trend declined significantly in the next 40 years from 1941-1980 with a z value of -2.62 and a magnitude of change -7.69 mm/year. An increase in average annual rainfall was obtained for major river basins of western India (Mahi, Sabarmati and Tapi) over the last 120 years (1901-2020) while overall rainfall over Narmada basin declined from 1125.97 mm (1901-1940) to 1057.96 mm (1981-2020). Except Mahi basin, all the major basins of western India witnessed a significant increasing trend for the first period (1901-1940) while insignificant trend was observed for the other two time periods.

Overall rainfall declined over the Brahmaputra basin from 2581.78 mm/year (1901-1940) to 2380 mm/year (1981-2020). A significant increasing trend (z=3.25) was found for the year 1901- 1940 while a statistically significant declining trend (-1.89, $\alpha = 0.1$) was observed during 1981- 2020 over the basin respectively.

Analysis at a river basin scale is not a true representation of long-term trends in rainfall and its dependence on climate and topography. Hence, long-term trends were also evaluated at meteorological zone scale (met zone) to understand the changes in rainfall patterns and its correlation with regional climatic and topographic factors. Significant increasing trend (α = 0.05) was found in Arunachal Pradesh (Z=4.02), Chhattisgarh (Z=2.2) West Madhya Pradesh (z=2.55) and East Madhya Pradesh (z=2.1) between 1901-1940 respectively. All the met zones witnessed an increasing trend during 1901-1940 except South Interior (SI) Karnataka (z=-0.2), Uttarakhand (z=0.5), Haryana Chandigarh and Delhi (z=-0.4) and Gangetic West Bengal (z=-0.524). Most of the met zones witnessed a decline in rainfall from 1941-1980. Statistically significant decreasing trend at α = 0.05 was observed over Kerela with z value of -2.24 and magnitude of change -10.73 mm/year. Himachal Pradesh and Odisha also experienced significant decline in rainfall with z value of -2.55 with a rate of change -8.8 mm/year and -6.04 mm/year respectively. Maximum positive rate of change for the period 1941-1980 was obtained for Coastal Karnataka (z=1.22) and a rate of change 8.26 mm/year respectively. Further, only SI Karnataka, Jammu and Kashmir, West Rajasthan and Saurashtra zones witnessed an increasing trend in rainfall (insignificant) for the period. A significant increasing trend at α = 0.05 was only observed for SI Karnataka zone with z value of 2.8 and magnitude of change 5.65mm/year. Out of the 34 met zones analyzed, 17 zones witnessed and insignificant increasing trend while other zones experienced a decline in average annual rainfall from 1981-2020. East Uttar Pradesh witnessed the highest negative value of z-statistics (z=-3.11) and magnitude of change -6.85 mm/year.

Arunachal Pradesh, Jammu and Kashmir and West Uttar Pradesh also witnessed a significant decline in rainfall with a magnitude of change -18.14mm/year, -11.18 mm/year and - 5.12mm/year respectively.

The present study illustrates the importance of rainfall analysis at a river basin or a zonal scale. In general, rainfall has declined along the eastern parts of India and major basins of Indian floodplains - Ganga and Brahmaputra basin which could significantly impact the water and food security of the region. However, it was observed that rainfall has increased, particularly in the last 40 years along western basins of India and met zones of west India. Proper water management policies should be implemented to tap the rainfall in the arid regions to overcome the problems of water security in Gujarat, Rajasthan and parts of Maharashtra. Further, the study outlines that there is no clear long-term trend in rainfall for all the basins and zones during the last 120 years as trend has shifted or changed for many basins at an interval of 40 years.

Flow Regime Assessment of River Basins in Himachal Pradesh

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The effects of climate change on the world's water resources have always been crucial. The impact of climate change might be quite significant in a nation like India where there are many climatic conditions. The pattern of snowfall and snowmelt, as well as significant seasonal changes in stream flow and water levels, are all impacted by glaciers, which are thought to be an indication of climate change. Some major factors affecting the change in flow regime include heavy rainfall, cloud bursts, Glacier Lake Outburst Floods (GLOFs), droughts, snowfall, snowmelt, etc. Himachal Pradesh's glaciers are also impacted by rising temperatures. Major glaciers in Himachal Pradesh are melting at an alarming rate, and bad effects can be seen on the hydrology of the region's main rivers like the Beas, Sutlej, Chenab, Ravi, and Yamuna. Snowmelt brought on by an increase in temperature first causes floods and later causes river basins to dry out. Therefore, hydrological process modelling is essential for planning water resources and for integrated watershed management. To predict the stream flow using the precipitation data, hydrological models have been constructed. Using the Soil Water Assessment Tool (SWAT), this study's main goal is to evaluate the effects of climate change on the river regimes in severely glaciated regions of Himachal Pradesh over the course of the preceding few decades. Daily stream flow data collected from hydrological stations in HP are used to verify the model. Also obtained from remote sensing data-based indices, such as NDSI, is decadal ice volume change.

Identification and Mapping of Bamboo growing in selected site of North Eastern region of India areas using PRISMA satellite data

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Bamboo is known to be fastest growing plant on land and it has wide range of values and uses, directly or indirectly. Bamboos are indicator of high biodiversity and play a significant role in the ecosystem structure and functioning. Bamboo is important for the biomass production and act as carbon sink. In India, government had launched several projects to improve bamboo productivity and to increase the economy. The eastern India is major source of bamboo production in country and accounts for more than 50% of total productivity in the country. Being a useful and important element of nature, bamboo resource monitoring is of utmost importance. Present study is focused on the estimation of bamboo growing areas in the part of Meghalaya state which is rich in bamboo resources. The study area includes part of Nongkhyllem reserve forest situated in Ri Bhoi district of Meghalaya. There are various studies carried out to identify the bamboo species and its utilization however there is lack of information of its spatial distribution at regular time interval. The current study is aimed to discriminate and map bamboo growing areas in the study area. PRISMA (Precursore IperSpettrale della Missione Applicativa) hyperspectral data was utilized for the discrimination of bamboo from the mixed deciduous forest composition in the study area. The level 2D product of the data was used, which is radiometrically and geometrically corrected. Ground truth data was collected for the identification of bamboo locations at ground. The ground information was used to identify the pure pixel in the hyperspectral data. Based on the ground data, spectral separability (Jeffries-Matusita distance) was performed to distinguish bamboo from other vegetation classes. The distance between bamboo and moist deciduous forest ranged from 1.3 to 1.7. Further hyperspectral data was used for the classification of bamboo growing areas where machine learning based random forest classifier was used. Various spectral and texture based input layers generated from hyperspectral data were used as input for the classification. Spectral layers include reflectance, principle components, and vegetation indices. Since PRISMA also comes with the panchromatic band at 5m spatial resolution, it was used for texture analysis. Output from Grey Level Co-occurrence Matrix (GLCM) was used as texture layers. Out of total geographical area, around 13% area was classified under the bamboo growing area. The classified output was used for the accuracy assessment which was found to be 72%. PRISMA data was found to be useful for the discrimination of bamboo from other tree species present in the study area. The spatial distribution map of bamboo growing area created in the study can be utilized for the sustainable management, conservation and development activities. Various stakeholders can also utilize the information for policy making and livelihood purposes.

Digital mapping of soil properties of Vidarbha region with legacy data and minimum sampling

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Precise information on the potential and constraints of soil resources is a prerequisite for their long-term management besides aiding the formulation of relevant policies. The present study attempts to generate high resolution digital maps of soil properties of Vidarbha region using legacy data and minimum profile sampling in data sparse areas. The conditioned Latin hypercube sampling (cLHS) approach was followed for identification of optimum number of appropriate sites for detailed soil profile studies. This approach identifies optimum number of samples and their locations that covers the entire variabilities of the region in terms of soil forming factors. The soil forming factors supplied to the model included various terrain parameters derived from 30 m SRTM DEM, various vegetation parameters derived from temporal Landsat 8 OLI & TRIS data (30 m) and MODIS (250m) NDVI data, and various satellite-based climate parameters (Worldclim). A total of 1400 legacy and 233 fresh samples were used to prepare digital maps of soil depth and different soil properties (soil reaction, electrical conductivity, soil organic carbon, calcium carbonate and clay, sand and silt fractions) at six standard depths. Various machine learning techniques such as random forest (RF), support vector machine (SVM), partial least square regression (PLSR), elastic net (EN), and cubist were assessed for modeling each property at each depth using various validation indices. Models were validated using cross validation and independent validation, both. RF outperformed in all cases with R-squared of 0.5 to 0.8 for various properties. Soil pH ranged from slightly acidic to alkaline with clear distinction between the eastern and western parts of the region. The eastern part covering the districts Gadhchiroli, Chandrapur, Bhandara and Gondia and some parts of Nagpur district were slightly acidic. The soils in the Purna valley were identified with high EC, particularly in the subsurface (upto 80 dS/m in 15-30 cm layer). Soils were low to medium in organic carbon. The soils of the eastern part of the region were also found distinct from that of the western one in terms of lighter texture and lower calcium carbonate.

Development of an integrated system for effective planning and monitoring of Crop Cutting Experiments (CCE) for the state of Meghalaya

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Timely and accurate yield estimation holds key to critical decision making leading to food security of a country. Crop Cutting Experiment (CCE) is the traditional method of yield assessment where selection of sample locations is based on random sampling and standard statistical estimation procedure. The recent developments in geospatial technology combined with IT and Mobile technology has brought ample scope for improvements in the yield estimation procedure making the system more robust and transparent. We have developed a new approach to optimize the CCE sample plots for rice yield estimation based on spatial stratification considering the agro-climatic condition, soil type and elevation in the state of Meghalaya. Nine agro-climatic zones, eleven soil types and three ranges of elevation were derived from appropriate satellite data products. Gain in precision due to the spatial stratification over the conventional CCE sampling approach adopted by Directorate of Economics and statistics, Govt. of Meghalaya has been calculated with the cost function $C = C_0 + \sum_{i=1}^{k} c_i n_i$. A GAGAN enabled android based mobile application has been developed for collection of the CCE field data and a dashboard system has been developed for visualization and timely monitoring of CCE exercise in the state. The integrated approach developed for the state of Meghalaya is expected to increase accuracy in yield estimation of rice crop and will also bring transparency in planning and monitoring of the CCE exercise.

Mapping of spatial distribution of Tropical Tasar primary host plants in Jharkhand using advanced geospatial techniques

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Sal, Arjun and Asan are the three primary host plants of Tropical Tasar silkworm (Antheraea mylitta). Spatial distribution of these species using geospatial technology has not been appropriately explored. Advanced geospatial tools and techniques offer cost and time effective solution with better accuracy in comparison to traditional survey methods. This study was carried out for mapping of spatial distribution of Tropical Tasar primary host plants in Ranchi and West Singhbhum districts of Jharkhand state using Sentinel-1 and Sentinel-2 multi-sensor satellite imageries. Selected vegetation indices, texture features and topographic features were derived to serve as the inputs for three classification algorithms; viz., Random Forest, Gradient Tree Boost and CART. Feature selection methods were employed to select the feature subset that would give the best classification results. It was found that Random Forest has emerged as the best classifier in terms of accuracies achieved. The feature selected subset gave better accuracies than the dataset containing all the features initially considered. The overall accuracies achieved for mapping of the host plants in Ranchi and West Singhbhum were 89.26 % and 70.41 % respectively.

Predicting Yields of Rabi Wheat Crop Using Daily NDVI Data for Insurance Applications

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Accurate estimation of crop yields is vital for the valuation of crop insurance. The traditional area index method is cumbersome and costly. This paper puts forward remote sensing data as a solution to the need for quality and cost-effective data. The study is conducted over 24 districts in the states of Punjab and Haryana. The districts selected are majorly wheat-producing (90% or more) during the rabi season.

MODIS Terra daily NDVI (MODIS/MOD09GA_006_NDVI) time series data is used for the purpose because of its longevity. We apply Bhuvan land use thematic maps to mask cultivated areas in the 24 districts during the last two decades (2000-2021) to understand the temporal climatic effect on the crop at the district level.

We propose a model concept to improve the computation of crop insurance premiums that show encouraging early results. The predicted yields can potentially be used for pricing the crop insurance after further improvements. The proposed methodology improves the crop insurance valuation compared to the traditional rate, thereby improving the market equilibrium in the sector.

Estimation of groundwater storage change at small basin scale using GRACE time series data: a case study of the Subarnarekha River Basin, India

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Groundwater is a crucial element of the global water cycle which helps in sustaining agricultural, domestic, and industrial activities worldwide, especially in the most populous countries like India. Overexploitation of groundwater with respect to population growth and climate change has caused substantial depletion globally. It may further exaggerate other adverse impacts including seawater intrusion, drying up of wetlands and rivers, and deterioration of the aquatic ecosystem. India is amongst the largest user of groundwater where most of the irrigated agriculture is solely dependent on groundwater. This continuous abstraction may further deteriorate the situation. Hence it needs to be continuously monitored.

The study aims to assess the spatio-temporal groundwater storage change and its trend in the Subarnarekha River basin, India. Here several time series data were integrated for the period January 2003 to December 2016 (14 years). Centre for Space Research land solution-Gravity Recovery and Climate Experiment (CSR-GRACE) gravimetric measurements Mascon solution was used to derive Terrestrial Water Storage Anomaly (TWSA). The additional components for the estimation of net Groundwater Storage Anomaly (GWSA) include Soil Moisture (SM) and Surface Runoff (SR) which were derived from the Global Land Data Assimilation System (GLDAS-Noah model (NOAH)). Rainfall from Tropical Rainfall Measuring Mission (TRMM) was used to understand its influence on the temporal variation of TWSA and GWSA. TWSA from GRACE integrated all forms of water above and beneath the surface of the Earth. Hence, the mass balance approach was used for the estimation of groundwater storage change. Mann- Kendall (MK) trend test has been applied to understand the interannual and seasonal trends of TWSA and GWSA.

The results show that there is a negative trend in the TWSA and GWSA. Whereas there is an insignificant positive trend in rainfall. The TWSA shows a significant decreasing trend (95% Confidence Interval (CI)) at the annual scale. It further shows a significant decreasing trend with 9.08 mm year^{-1} in the post-monsoon. The GWSA shows an insignificant decreasing trend in the annual and pre-monsoon. Moreover, a significant decreasing trend (at 95% CI) with 4.72 mm year^{-1} was observed in the post-monsoon. This decreasing trend may be attributed to extreme agricultural activities and urbanization. The temporal variation of GRACE-derived TWSA shows a very good association with rainfall in different years. Thus, the study indicates that GRACE-derived gravity solutions are suitable for the estimation of groundwater storage change variations in large as well as small-scale basins and helpful for understanding the regional water cycle. This may further help in sustainable water management and water conservation.

Temporal trend analysis and runoff sensitivity to rainfall and air temperature of Tawi catchment, Western Himalayas

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The goal of the current study is to examine the temporal trends in the air temperature, rainfall and river discharge in parts of Tawi catchment, Western Himalayas. Using Pearson's product-moment correlation at a 95% confidence level, the link between rainfall, air temperature, and river discharge was also investigated. Additionally, a sensitivity analysis of river discharge to rainfall and air temperature was carried out. Mann-Kendall test, a non-parametric approach, has been used to analyze the trends in rainfall, air temperature, and river discharge. Significant findings have made as a result of the assessment for two meteorological stations, namely Udhampur and Jammu. For the years 2000 to 2020, statistically decreasing trends in the maximum, minimum, and mean air temperatures and river discharge except in a few months are seen at Jammu station whereas statistically increasing trends in the maximum, minimum, and mean air temperatures and rainfall are seen at Udhampur station. Further significant decreasing trends in minimum temperature of winter season and decreasing trends of river discharge for all the seasons except post monsoon noticed at Jammu station. Also significant increasing trend in minimum temperature of pre monsoon and significant increasing trend in rainfall of monsoon season noticed at Udhampur station. Sensitivity analysis of river discharge to rainfall and evapotranspiration exhibited very low values of sensitivity coefficient in most of the months, indicating less sensitivity of river discharge to rainfall and evapotranspiration. However, the sensitivity coefficient of river discharge to air temperature having much higher values, indicating that river discharge is more sensitive to air temperature at Jammu station.

Satellite-Based Crop Evapotranspiration Estimation by using Basal Crop Coefficient and Potential Evapotranspiration Approach

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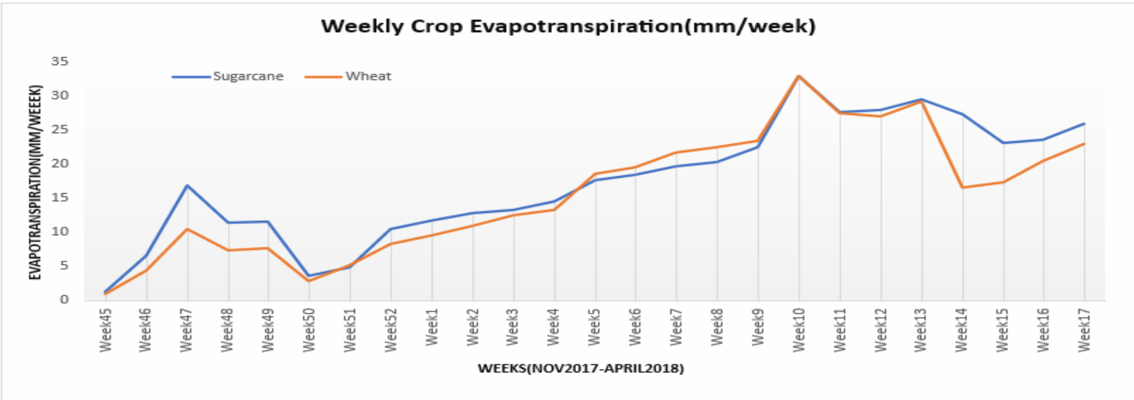
Agriculture sector is the world's largest consumer of water and there is an increasing need for efficient and ethical use of water throughout society. India experiences an average annual rainfall of 1,190 mm, which is more than the combined 700 mm of all land areas on the planet. In spite of that, water stress conditions are still present in different regions of India. In addition to the growing mismatch between crop demand and water availability, the situation has been made worse by the remarkable mismanagement of irrigation water resources. Therefore, increasing crop yield per unit of water used is a need of time. Crop evapotranspiration (ET) represents crop water demand and is governed by weather and crop conditions. Crop coefficient (Kc) is a crucial variable for water allocation and irrigation scheduling. The main objective of study was to assess the basal crop coefficient using seasonal NDVI and to estimate the seasonal crop evapotranspiration. The study was conducted in humid subtropical climate region over an area of Delhi, Meerut and Baghapat district. The rabbi season of November 2017 to April 2018 was selected. Standard metrological weeks were considered for weekly estimation of crop ET. It contains 25 weeks' starting from week 45th (November 2017) to the week 17th (April 2018). Data processing part was done on Google Earth Engine platform which provides Sentinel-2- time series NDVI from that, weekly Basal Crop Coefficient maps were generated over a period of time. The Kc depends on vegetation grown in that area. It varies from crop to crop over region.It depends on each week NDVI value. Basal crop coefficenet was calcuulated by NDVI value of each pixel for that week, when subtracted by same minimum NDVI value of for whole sesaon divided by maximum NDVI value of season subtracted by minimum NDVI value of whole season.So, for each week different Kc value images were generated.Total 25 different Kc values for each week were generated. Daily Potential Evapotranspiration (PET) data was derived from University of Bristol, United Kingdom. They provide hourly and daily evapotranspiration data for whole globe of 0.1-degree spatial resolution. The PET data uses Penman-Monteith formulation developed by the FAO and hourly climate data from ERA5- Land, the product is an hourly estimate of potential evapotranspiration. Calculated Basal Crop Coefficient (Kc) and Potential Evapotranspiration (PET) were multiplied to get actual evapotranspiration rate. Crop mask over an area include sugarcane and wheat mask was found out by supervised classification with an overall accuracy of 84.48% and kappa coefficient with 0.72. Wheat and sugarcane mask filter was used to mask out crop areas in study area. The results showed that Kc values was varying from 0.12(45th Week, 2017) to

1.0074(15th Week,2018). Correlation between NDVI and Kc value was around 0.87. This shows that Kc values were dependent on NDVI values. PET rate becomes almost double in 15th Week (36.24 mm/week) as compared to 45th week (17.97 mm/week). Since this PET depends on climatic variables like temperature, relative humidity etc. the impact of this directly affects crop growth. Weekly wheat crop ET values were gradually increased from sowing stage to the harvesting stage. Weekly crop evapotranspiration showed at initial stage of wheat crop at a time of sowing was around 2.87mm/week in weeks50-51(Mid-December, 2017). Later it was increases up to 30-33mm/week in 15th week (Apri, 2018) when the crops were fully mature. Total evapotranspiration rate of wheat crop and sugarcane crop during period of November 2017 to April 2018 was found to be equal to 393.85 mm/season and 436.35mm respectively. Seasonal crop evapotranspiration map showed spatial distribution of wheat and sugarcane crops in study area highlighting areas with low to high water requirement. The study provides information about use of water for irrigation and can be helpful for farmers, field managers and policy makers.

Results:



Impact of land-use systems on soil organic carbon and its projection in North-Western India

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Land use has a significant impact on soil organic carbon (SOC) dynamics and evaluation of the impact of land use on SOC is required to understand the long-term productivity and possible sustainability of a land use system. The effect of land use on SOC was studied in the Shaheed Bhagat Singh Nagar district of Punjab (India). The land use map of the area was prepared using Resourcesat-1 satellite data (LISS-III sensor, spatial resolution 23.5 m). Surface (0-15 cm) soil samples were collected under different land uses (cropland, forest, scrubland, and plantation) using stratified random sampling. Soil samples were analysed for soil texture, bulk density, pH, electrical conductivity, organic carbon, Olsen P (available P), NH4OAcâ€“extractable K (available K), and CaCl2 extractable S (available S) using standard methods. Ordinary kriging was used to study the distribution of soil properties in different land-uses area. Soil organic carbon under future climate was simulated using Rothamsted Carbon (RothC) model with current land-use and management practices. Organic carbon in surface and subsurface soils was in the order: Forest > Scrubland > Plantation >Cropland. Soil organic carbon was significantly.

Detection of late blight of potato by integrating epidemiological, proximal and remotely sensed data

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Late blight caused by oomycete Phytophthora infestans is the most important impediment to potato cultivation globally and has been considered a threat to global food security. Even after more than 175 years of Irish famine, it continues to be the most devastating disease of potato worldwide In India, losses caused by late blight ranges from 5-90% depending upon the climatic conditions with an average of 15% across the country. Field scouting and continuous preventive pesticide applications have been adopted to prevent yield losses, but these strategies are either time-consuming or expensive. One of the alternative is to use proximal and remote sensing data having the appropriate spatial, spectral and temporal scale to detect the disease at early stages by sensing the changes in chemical and physical properties of the crop The major potato growing areas in Punjab are Hoshiarpur, Kapurthala and Jalandhar districts. In order to map the potato cultivated areas in these districts of Punjab using satellite remote sensing, Sentinel-2 images of October to February 2020-21 and 2021-22 were downloaded. These images were classified using unsupervised classification method. Late blight of potato was detected from Sentinel-2 imageries (multispectral satellite imageries) and hyperspectral data. A field survey was carried out from December 2020 to February 2021 and also from December 2021 to February 2022 near synchronous with the satellite pass for ground truthing of the classified potato and also identifying the locations of late blight of potato in Hoshiarpur, Kapurthala and Jalandhar districts. The potato was classified in these districts with an accuracy of >90%. In order to detect the late blight of potato using Sentinel-2 imageries (multispectral satellite imageries), Vegetation indices (VIs) derived from the VISâ€“NIR-SWIR region of the images were evaluated for their capability to detect the disease. Seven spectral indices were evaluated: NDVI (Normalized Difference Vegetation Index), NDRE (Normalized Difference Red-Edge Index), GNDVI (Green Normalized Difference Vegetation Index), SAVI (Soil Adjusted Vegetation Index), Clgreen (Chlorophyll Green Index), Clrededge (Chlorophyll Red Edge Index), DWSI (Disease Water Stress Index). Among all the indices, DWSI provided better discrimination of disease (accuracy of 86.1% with Kappa Coefficient of 0.70) followed by CREI (accuracy of 86% with Kappa Coefficient of 0.68) and NDVI (accuracy of 77.8% with Kappa Coefficient of 0.56) when the diseases severity was â‰¥ 50%. The reflectance combination of green (550nm), red (680nm), NIR (near infrared, 800nm) and SWIR (short wave infrared, 1660nm) used in DWSI plays a major role to discriminate the severity of disease crop. Higher values of DWSI indicate the higher severity of disease. These results suggest that the combination of near-infrared, green, red and SWIR bands of Sentinel- 2 can be used to discriminate the healthy plants from disease infested plants in potato. In order to detect the late blight of potato using hyperspectral data, the reflectance spectra of healthy and diseased were collected from farmerâ€™s field in Hoshiarpur, Kapurthala and Jalandhar districts at regular interval using Spectroradiometer (wavelength interval between 350 - 2500 nm) on clear and cloudless days during February 2021 and 2022. In addition, spectra of healthy and diseased plants were also collected from the field experiments carried out at Punjab Agricultural University Farm, Ludhiana. The field collected spectra were pre-processed after removing the saturated reflectance values due to water absorption and other background noise. The sensitive bands for detecting the disease from field experiments were 583, 603, 1080 and 1301 nm with â‰¥ 20% disease infestation. The reflectance was decreased in the SWIR band (1600-1800 nm) and there was no consistent pattern of plant reflectance from 2000 to 2400 nm. These results require validation using optimization of spectral pre-processing techniques from hyperspectral data. In addition, the predictive ability of spectral indices derived from multispectral images and hyperpspectral data coupled with climate data will be carried out for accurately detecting the disease in potato.

Mapping the Changing Blue Cover of Ahmedabad city of Gujarat, India using satellite data

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The blue cover of the city (river, lakes, ponds and wetlands) are an important part of an urban ecosystem as they perform various significant environmental, social and economic functions. The blue cover acts as a source of drinking water, helps in recharging ground water, supports biodiversity and provides livelihoods. The location and persistence of the blue cover is affected by climate and human activity and affects climate, biological diversity and human well being. Thus it is very important for measuring long-term changes of the blue cover at a high spatial resolution. With this background this study is undertaken for Ahmedabad city of Gujarat which is the 7th largest metropolis of India covering a geographical area of approx. 464 sq km. In this study a comprehensive accounting of the transitions in blue cover of Ahmedabad city has been using Landsat data having a spatial resolution of 30 m for a period of 37 years (1984 â€“ 2020). A total of 10 types of water bodies were classified which are (i) Permanent (ii) New Permanent (iii) Lost Permanent (iv) Seasonal (v) Lost Seasonal (vi) New Seasonal (vii) Permanent to Seasonal (viii) Seasonal to Permanent (ix) Ephemeral Seasonal (x) Ephemeral Permanent. The spatial quantification reveals that the blue cover of the city is around 8,096,745 m2 which is 1.7450 % of its geographical area. Of this blue cover, 2,834,973 m2 (0.6110%) didnâ€™t register any change in its characteristics i.e. permanent water body remained permanent water body (which is 5889 m2 (0.0013%)) while seasonal water body remained seasonal water body (which is 28,29,084 m2 (0.6097%)). The city gained 4,900,806 m2 (1.0562%) of blue cover (74,058 m2 (0.0160%) is now the new permanent surface water body while 48,26,748 m2 (1.0402%) is the new seasonal surface water body) while it lost 2,289,248 m2 (0.4934%) of blue cover (permanent water body 842 m2 (0.0002%), ephemeral permanent water body 5,888 m2 (0.0013%), seasonal water body 4,79,640 m2 (0.1034%) and ephemeral seasonal water body 18,02,878 m2 (0.3886%)). Around 360,966 m2 (0.0778%) of blue cover witnessed a transition - 270,097 m2 (0.0582%) of permanent water body became seasonal water body while 90,869 m2 (0.0196%) of seasonal water body became permanent water body. The major reason of having relatively high area fraction in the category of new seasonal surface water body is the interlinking of the Sabarmati river with the Narmada river while that of ephemeral seasonal water body is because of the change in the path of the Sabarmati river within the city. The study gives a very comprehensive detail of the surface water bodies of the Ahmedabad city which would be of crucial importance for the civic administration for strengthening the â€˜urban bluing activityâ€™ which will have a significant impact on reducing the urban heat island effect and mitigating the urban air pollution.

Analysis of AVIRIS-NG Hyperspectral Remote Sensing Data for Mapping Talc Mineral Types at the Amba Mata Mines, Rajasthan

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This study utilises hyperspectral remote sensing data to map the various mineral grades in the Amba Mata Talc mines (Udaipur-Dungarpur, Rajasthan). The study area is located between the latitudes 23°57'36" and 23°56'4.86103" and the longitudes 73°38'3.02856" and 73°39'10.1704", which is between Khanween and Paldewal on the boundary of the districts of Udaipur and Dungarpur. The rocks of the study area are predominantly metasedimentary sequences of the Aravalli supergroup. The occurrence of talc mineralization primarily as thin bands along the foliation planes of the host rock shows that talc mineralization is the result of the steatitization of dolomite by metamorphogenic fluids created during the metamorphism of these rocks. Talc deposits are abundant in the central portion of the dolomite zone. The region's talc is foliated to massive in appearance, pale green to white in colour, and of "middle to high grade." There are 18 active mines that produce around 300,000 tonnes of talc per year. The deposits are proportionate. Talc is a clay mineral composed of hydrated magnesium silicate with the chemical formula $Mg_3Si_4O_{10}(OH)_2$. It is associated with low to medium grade metamorphic rocks rich in magnesium. Talc is the softest mineral used in anticaking agent, filtering aid, coating agent, lubricating and release agent, surface-finishing agent, texturizing agent, and dusting powder.

This study classified the minerals present in the Amba Mata mine area in the Udaipur district of Rajasthan using airborne data from the Airborne Visible-Infrared Imaging Spectrometer - Next Generation (AVIRIS-NG) with 425 bands covering the wavelength range of 380 nm to 2510 nm with 5 nm sampling, and Ground Sampling Distance (GSD) of 8 m. AVIRIS-NG reflectance data was downloaded from the website of NASA's Jet propulsion laboratory. Due to its improved spectral and spatial resolution, AVIRIS-NG has been shown to be a valuable data set for identifying talc minerals in the SWIR region.

The talc mineral was mapped in the AVIRIS-NG image of the study region using two methods: Spectral Angle Mapper (SAM) and Spectral Feature Fitting Algorithm (SFF). Talc displayed a doublet-shaped spectral pattern with large absorption dips at 2289.75 and 2338.80 nm in the AVIRIS-NG image. The mapped mineral area corresponds to the real rock formation that exists in the Talc Chlorite Schist area. The spectral matching of talc pixels is validated using the US Geological Survey's available spectral library (USGS). The talc discovered in the mining region is of varying grades. Variable slopes of the Talc-classified region were exhibited to illustrate the changing mineral composition of the area. Pure talc exhibited a prominent doublet at a wavelength of 2320nm. In this study, 77.4% of the total talc was accurately mapped.

A Novel Two Stage upscaling Approach for Validation of SMOS Derived Soil Moisture

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Validation of soil moisture derived from space borne passive microwave sensors has been a challenging task owing to the large variability existing in soil moisture within the coarse resolution cell offered by passive sensors. This paper describes the findings on how validation of Soil Moisture and Ocean Salinity mission (SMOS) derived soil moisture information has been carried out by using a novel approach of using SAR as an interface. SMOS provided brightness temperature in L-band (1.4 GHz), at a spatial resolution of 25-50 Km with a global coverage achieved within 3 days. This paper describes the research carried out for the SMOS Cal/Val Category -1 Announcement of opportunity project, ESA SMOS Cal/Val AO Proposal ID 3284, for calibration of SMOS soil moisture product. The objective of the research was to calibrate and validate the SMOS derived soil moisture information using two-stage up scaling approach. In the first stage, up-scaling from field point measurement on ground to spatial scale using multi parametric satellite SAR data to be achieved by incorporating the effect of surface roughness, soil type and presence of crop cover. In the second stage, up-scaling of the SAR derived spatial soil moisture maps at 1km scale to 25x25km grid to be attempted. The soil moisture information thus arrived is a more realistic soil moisture value comparable with the soil moisture information retrieved from SMOS data. The approach involved soil sample collection in synchrony with SAR satellite overpasses. Envisat-1 ASAR Standard beam mode (S1) data in the incidence angle range (190 to 210) as an interface. The next step is to study the difference in thus derived soil moisture and SMOS derived soil moisture. A detailed experiment involving 13 ground campaigns for field level measurement of soil moisture in synchronous to the Envisat-1 ASAR and SMOS passes were conducted. The campaigns were spread over three study areas selected based upon spatio-temporal behaviour of the study areas with respect to soil moisture. Four Envisat-1 ASAR data were acquired but ground campaigns were not carried out during the over pass. Hence in all, 17 spatial/temporal SAR data from Envisat-1 ASAR have been used. Field level measurements of soil moisture information were collected by means of the ground experiments. These field level measurements are used to generate the spatial soil moisture map at 1km resolution by using multi-parametric Envisat ASAR (100kmx100km area). In the second stage the spatial soil moisture maps are scaled to the SMOS grid size giving a realistic representation for comparing the two soil moisture values. It was observed that when soil moisture models are generated by incorporating the effect due to surface roughness and crop cover, the validity of such models holds good for varying ground conditions (rms error between observed and estimated soil moisture is observed to be around 4% m3/m3). At the same time it is observed that when up scaling to a 25 km grid is done, the accuracy of soil moisture maps thus generated exhibits less error due to effect of averaging for surface roughness and crop cover. These soil moisture values can be taken as representing the near true value of soil moisture status. Thus the two stage approach soil moisture leads to a more realistic calibration of the soil moisture values that are arrived at by the SMOS payload. A total of 235 pair of SAR derived and corresponding SMOS derived values have been obtained. The spatial and temporal spread of the 235 25kmx25km grid

cells ensured covering large soil moisture variability expected on the ground. It was observed that soil moisture derived from SMOS is not in agreement with that of two-stage up scaled soil moisture derived using SAR as an interface. It is also observed that the SMOS derived soil moisture were not in agreement with ground measurements, whereas SAR derived soil moisture were in agreement with ground soil moisture. rms difference between SMOS soil moisture and SAR derived soil moisture at 25 km of 235 25x25km grid cells was observed to be as high as 21.9 (%m3/m3). A study of SMOS RFI maps for the dates on which ground and Envisat-1 ASAR derived soil moisture measurements were available, indicated that the errors in SMOS derived soil moisture could be attributed to high RFI contamination of SMOS signal over the study areas.

Astronomy and Planetary Remote Sensing

Evidence of preserved channel splay in Mawrth Valles of Mars, A site for future Mars exploration

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Mars experiences a wide variety of geological processes which can be compared with the Earth. The study of these processes in detail helps in understanding Martian evolution in space and time. Past mission details derived from orbiters and rovers provide compelling evidence of the fluvial, volcanic, glacial and lacustrine landforms and their geomorphic and mineralogical significance (Alemanno et al., 2021; Schmidt et al.,2021). Each geological province has its morphological and mineralogical evidence, which indicates the set of paleo-environments operating on Mars (Aharonson et al., 2002). Future landing missions are being planned with a fundamental scientific objective of evidence for past water that may have supported microbial life.

The Mawrth Vallis region is approximately 22°N, 342°E, where the highlands of Arabia Terra meets the lowlands of Chryse Planitia. The valley is formed by massive flooding in the ancient past between the southern highlands and the Northern lowland. This is widely studied by researchers for its vast deposit of phyllosilicate assemblage (kaolinite, montmorillonite, smectite) and the layered deposit, providing a unique opportunity to evaluate the aqueous activity of early Mars and the possibility of a habitable environment in the early age of Mars (Michalski et al. 2010; McKeown et al. 2009; Wray et al. 2008; Loizeau et al. 2007; Poulet et al. 2008). However, most studies are restricted to the inferred downstream region of the valley, whereas the upstream region remains mostly unexplored. The downslope of the Vallis is well studied and has also been chosen as a candidate landing site by Mars missions like Exomars and MSL, whereas the upslope of the Vallis is not much explored.

The conjugate analysis of optical and hyperspectral data as well as the topographic DEMs from archive Mars mission datasets like Mars Orbiter Laser Altimeter (MOLA), THEMIS IR mosaic image, High-Resolution Stereo Camera (HRSC), High-resolution Imaging Science Experiment (HiRISE) and Compact Reconnaissance Imaging Spectrometer for Mars (CHRISM) in the southern part of Mawrth Valles shows evidence of a channel splay deposit which has reworked an earlier crater impacted basaltic valley floor.

The topographic data from HRSC Digital Terrain Model (DTM) were used for morphological analysis. The DTM derived elevation profiles highlight the changes along the channel boundary, especially at the confluence of the channel and the crater wall. The elevation profiles show a typical channel profile with bank highs and the channel floor depth in the middle. However, in one sectional profile, only the left bank of the channel is visible, with a pronounced elevation change towards the right. The possibility of the arcuate ridge cannot be ruled out, and the slope extends towards the crater floor, where the crater base depth is the same as the river channel base. Thus, it can be assumed that the channel margin is deformed due to ancient breaches that happened during crater formation. Thus, the region shows the overlapping crater and fluvial system, which can be analysed for the mineralogical changes for better understanding. The high-resolution panchromatic image from HiRISE data was used to enhance further the morphological details of the crater formed along the fluvial channel.

The optical data from HRSC and HiRISE substantiates the evidence of an arcuate channel with elevated channel boundaries, which has been breached along the outer bank into a crater floor which contained basaltic deposits of early Noachian age. The splay can be identified as an outward spreading fan-shaped with striated boundaries. Within the flat deposit of the crater floor, the unidirectional striations can be observed after enhancing the contrast of the image. The striations may represent the subsurface aqueous flow direction, indicative of the aqueous history of Mars. These striations were observed towards the centre of the crater floor, whereas along the margins of the crater, ridge-like features are observed, which resemble the TARS (Transverse Aeolian Ridges). The TARS features are the depositional units formed by the Aeolian process (as evident in the archive image of MARS). Thus the area shows the morphological variations of both fluvial and aeolian processes operating in the past.

Additive analysis of hyperspectral data in this region shows mineralogical evidence of a channel splay deposit which has reworked an earlier crater-impacted basaltic valley floor. Information from a preliminary analysis of CHRISM data in the vicinity of the channel shows the presence of clay minerals like Kaolinite with Chlorite in the basaltic valley floor. The presence of such minerals with supporting geomorphologic evidence of reworked channel splay indicates the region may be of rich organic past aided by aqueous history and presents a unique study site for future Martian explorations.

Quantitative evidence that sub-quarks like particles were remotely viewed, a possibility supported by holographic model of the Universe

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Quarks are constituents of protons and neutrons. Attempts are being made to study these particles using large hadron colliders. There are some hypotheses as per which quarks further consists of sub-quarks (Terazawa 1980). We have found some very interesting studies and claims that direct observations of quark and sub-quark like particles is possible through clairvoyance and anima siddhi (Phillips 1995 and 1999) . These claims are around one hundred years old and were made by Annie Besant and her colleagues (Annie Besant et al. originally published in 1908, New publication in 2007). Annie Besant came to India in 1893 and was a student of chemistry, so she tried to learn anima siddhi through which one can become very small in size (probably astral body) so much so that even up to an atom. Her ambition was to see the atoms directly. She learned this siddhi and developed extraordinary strong clairvoyant faculty. She and her colleagues Lead beater and C Jinrajdasa attempted to directly see structures of ninety two elements (hydrogen to Uranium) which were available at that time along with many molecules. They developed a discipline which is now known as Occult chemistry. No body believed in these claims, till Dr. Stephen Phillips (1995, 1999), a ph d in particle physics from London studied their work and argued that this could be possible. However, an opposite opinion was expressed by a study group from Yale University (1999) who completely rejected it. On the other hand, a similar claim is also being made by ancient Jain scriptures where size of smallest particles of matter were estimated through power of clairvoyance (Pokharna 2022). Thus Annie Besant and coworkers claimed to have actually seen constituents of the Hydrogen atom and atoms of several other elements known at that time through clairvoyance (Annie Besant 2007). They found that the Hydrogen atom (Figure 1) consisted of 18 constituents known as Anu-s (name of the smallest physical particle of matter in Hinduism) grouped in six subgroups of three, each distributed into two triangular structures. The circles shown here are actually spheres and are in constant motions of different types, but group of anu-s are interconnected and the groups themselves are having motions of different types. Now this group of six spheres is surrounded and enclosed in a shell, surrounded by some type of matter. Now we know that all stable elements of nature consists of protons and neutrons, which in turn consists of up quarks and down quarks. So to compare the number of anu-s with the current elements of chemistry, we have divided the rest masses of up quarks and down quarks by rest mass of an electron so as to normalize the masses of up quarks and down quarks to find out how heavier they are compared to an electron and made these ratios closest to the integral values. The normalized mass of up quark turned out to be 4 and the corresponding value for down quark turned out to be 9. So it was then argued that up quark and down quarks further consists of smaller quarks which we call them as quanta in analogy with Vernon Neppe and Edward Close (2015) which might correspond to some kind of sub-quarks (Terazawa 1980). To our surprise the resulting number arrived at for proton was 17 for and 18 for Hydrogen atom that is when electron is also considered. Means the two numbers matched perfectly. This was therefore repeated for all ninety two elements. To our utmost surprise, we found an agreement of over ninety percent accuracy with a percent error of 8.64 between the number of anu-s as observed by Annie Besant and number of quanta estimated for corresponding elements for all ninety two elements available at that time (Figure 2). A possible hypothesis has been also developed treating the Universe as a hologram (Talbot 2011). It appears that if Universe is like a hologram then such paranormal processes are possible. It was further observed that a concept of hologram also comes for consciousness in Jainism which imply holographic structure of the Universe. This incidentally has remarkable parallels with Nilpotent Quantum mechanics and universal rewriting system (Peter an Peter, 2017). This is a very preliminary analysis, but it appears that further researches may provide new avenues of thought which can give new dimensions to the technology of remote sensing (Surendra Singh Pokharna 2022) Figure 1. Structure of Hydrogen atom as viewed through clairvoyance Figure 2. Scattered Plot between the number of anu-s observed through clairvoyance and number of quanta estimated for ninety two elements of the periodic table. References: Annie Besant, Charles Webster Lead beater, and Curuppumullage Jinarajadasa Occult Chemistry: Clairvoyance observations on the Chemical Elements, Cosimo Classics, 2007, original published in 1908.

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GNSS Systems and Applications

Investigation of the impact of a strong magnetic storm occurred on 26 August 2018 by using GPS-TEC measurements observed at Agra.

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The ionosphere is a very complex system and it is controlled by solar activity which can affect it largely. In the present work, GPS and GLONASS-based measurements of TEC data at a low latitude station Agra (lat. 27.2° N and long 78° E) have been analyzed related to a strong magnetic storm that occurred on 26 August 2018. The geomagnetic storm parameters such as Dst, ? Kp, Bz, F10.7 solar flux, and Sunspot numbers (SSNs) have also been examined and found significant changes in their variations. The maximum values of Dst, Kp, Bz, and SSNs are -150, 74, -14.7, 74, and 32, respectively. A critical analysis of the initial, peak and final phase of the strong magnetic storm is examined with the TEC variations and significant variations are recorded on the day of the magnetic storm and a few days after its occurrence due to the delayed effect on the magnetic storm at low latitudes. These results are consistent with the findings of earlier workers. Keywords: Magnetic storm, GPS, GLONASS, TEC, etc.

Correction of Tropospheric Delay in IRNSS Data

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Satellite Navigation System is a constellation of satellites that transmits signals from space to help users determine their position with time. The Indian Space Research Organization created the regional navigation satellite system, the Indian Regional Navigation Satellite System (IRNSS). High positioning accuracy is needed to integrate the usage of IRNSS over various positioning systems, which necessitates modelling each bias. This research aims to model the tropospheric bias that retards the IRNSS transmissions. Weather-related variables can be used to model this systemic bias. However, the physical characteristics and climate of the Indian continent set it apart from other parts of the world. Thus, to incorporate local climatic conditions regional tropospheric model is highly essential. We have used the saastamoinen model to model tropospheric delay and then compared it to the receiver-generated delay. The results show that the tropospheric delay ranges from 2 to 8 m based on the zenith angle and other meteorological parameters. It shows a similar tendency to the receiver-generated delay. Further, a high correlation between the zenith angle and tropospheric delay indicates that the delay can be molded as a function of the zenith angle. The correlation is the same for all geosynchronous satellites and can be described as a function of a two-degree polynomial (R^2 > 0.99). However, the tropospheric delay of geostationary satellites I03 and I06 correlate less with the zenith angle.

Utilization of GNNS Receivers in Regional Geophysical Gravity Surveys

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In geophysical mapping, the state-of-the-art-technology Global Navigational Satellite System (GNSS) utilizing for determining three-component position information (latitude, longitude and elevation) of gravity and magnetic field observations in regional gravity surveys. Using the signals transmitted by GPS satellites. The ground-based receivers can be used to calculate the high precision data on the Earth's surface. Due to the high challenges faced in regional geophysical surveys, Post-Processing Kinematic (PPK) mode of Differential Global Positioning System (DGPS) receivers deployed to achieve the objective with a very precise/accurate positioning of in horizontal and vertical. Further, these surveys are deployed in dense forest covered areas where the satellite positioning ambiguity canâ€™t be solved, where the conventional survey methods are deployed to measure the reduced level of the gravity observations. The study provided accurate position and elevation along with minimum closing error. However, the geophysical data processing requires accurate positioning for calculating the gravity anomalies. The satellite-based navigation system GNNS receivers provides more accurate horizontal and vertical position and accurate elevation for processing of gravity data.

Health GIS

GIS for Control of Communicable Diseases

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Geospatial information system (GIS) is one of the effective tool to mitigate and control the spread of vector borne, water borne and airborne diseases. It cannot only provide a platform for preparation of geospatial mode but by using other mathematical models, can be used for development of predictive model using various climatic and environmental factors. Various airborne, water borne and vector borne diseases can be predicted in advance which can help policy makers to effectively plan out strategies for control of spread of diseases especially in case of Vector borne diseases. Such modellings and tools can be used to access the possible breeding grounds and sources of infection. WHO™s concept of T3 i.e. Test, Treat and Track fits well with the use of Geospatial concept and through its analytical model as well as predictive model, burden of disease can be reduced and mortality can be decreased substantially. The data can be used to guide the control strategies more efficiently. GIS Mapping of diseases can led to rapid application of sophisticated analytics to track the geographical distribution of diseases. Tracking of transmission of disease can be mapped out that gives a brief insight about the index case and pattern of further spread of disease. More precise disease tracking can also illuminate causes and spark opportunities for prevention

Integrated Hyperspectral Remote Sensing and Artificial Neural Network (ANN) algorithm for non-invasive age determination of Himalayan medicinal plants

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The Indian Himalayan region abode a wide range of medicinal plants. Approximately, 1700 such medicinal plants have been reported to possess medicinal properties. Many of them have become threatened due to their over-exploitation to meet industry demand for herbal raw materials. The *Valeriana jatamansi* and *Saussurea costus* are such medicinal plants which are also threatened and are on the verge of extinction. The oil content in their roots is used in pharmaceutical and perfumery industries and its amount varies with the age of these plants. The dry roots of *V. jatamansi* are used to cure cardiac problems, dry cough, asthma, seminal weakness, skin diseases, etc. While *S. costus* have anticancer, anti-ulcer, and anti-inflammatory medicinal properties. Thus, the plants harvested at optimum age will yield appropriate oil content. Ironically, these plants are uprooted in unscientific manners based on their morphological characteristics and flowering time. The wrong judgement of age leads to wastage of plant material and which is the major cause of their threatened status. Therefore, it is necessary to determine the age stages of plants to harvest them at the right time. In this backdrop, we have developed a technique for rapid and non-invasive plant age determination using Hyperspectral remote sensing, which can detect the phenophases of plants using their reflectance behaviour (signature) in a large number of continuous and contiguous wavelength regions. We have used hand-held spectroradiometers (make Analytical Spectral Devices) to record the spectral information of *V. jatamansi* and *S. costus*. These data were analysed using machine learning (ML) techniques as this is widely used to analyse Hyperspectral remote sensing big data using a complex modelling approach leading to more accuracy as compared to conventional statistical algorithms. Two ML algorithms were used the first Principal Component Analysis (PCA) was used for feature selection and the second Artificial Neural Network (ANN) helped in the classification of age stages. Using PCA, we have identified sensitive wavebands for differentiation of age stages such as red-edge (747 to 756 nm) and Near-infrared (860, 870 to 874, 876 to 885 nm). Then, utilizing these identified bands, we employed the ANN classification model on 65 samples of *V. jatamansi* that were grown in a controlled environment and the result showed very high classification accuracy (Overall accuracy = 100% and Kappa coefficient = 1). The developed model was then validated in the farmer's field of *V. jatamansi* (n=60) with an accuracy of 88% (k=0.84). We have also validated the model in the farmer's field of *S. costus* (n=87) with a classification accuracy of 82.76% (k= 0.71). Thus, the developed technology offers a unique approach to harvesting these threatened medicinal plants at their optimum age. It will help the sustained use of medicinal plants with maximum yield.

Assessment of Mobility and Health Condition on COVID-19 Morbidities and Mortalities - A Case Study of Tamil Nadu, India

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The rates of infection and mortality relating to COVID-19 has many influencing factors associated with it. Though awareness on COVID-19 infection has been made throughout the country, mobility of people between places cannot be avoided to sustain their livelihood. Thereby, mobility of people increases the infection rate. Rate of infection has a positive correlation with the rate of mortality since the infected population include people who have vulnerable medical condition which influences the rate mortality. The present study aims to find how mobility, amid the phased lockdowns, relates to rate of infection and to find how health characteristics relates to rate of infection and mortality. The study is planned to carry out for entire Tamil Nadu at district level. Data on mobility during the pandemic is provided in the Google mobility report which contains data on mobility of the people with the purpose of it and health characteristics data are obtained from National Family Health Survey (NFHS-5), a country wide primary survey report conducted by the International Institute for Population Sciences (IIPS); from the report, sugar level, blood pressure, consumption of tobacco and alcohol data are taken for the study. The data are collected for the years 2020 and 2021, which includes the two major waves of COVID-19 in India. Tamil Nadu has managed well in both the waves owing to its numerous health care units, infrastructure, and facilities. Tamil Nadu is one of the leading states in India in spending on health care services and schemes; this enabled the state to produce a greater number of doctors and to hold higher ratio between doctor and people.

Data and Methodology

The study has been conducted using the data available as in COVID-19 report, Google mobility report, and NFHS-5 report. These reports contain huge volume of data based on date and location. The data are segregated and grouped for the selected period of study for the entire Tamil Nadu state. During the initial periods of the study there were only 32 district administrative units; few districts were formed in the later periods of the study. However, the report generated by Google and NFHS-5 have included only the 32 districts, hence the study has included only the initial districts. These data are available on daily basis, which are compiled to monthly formats.

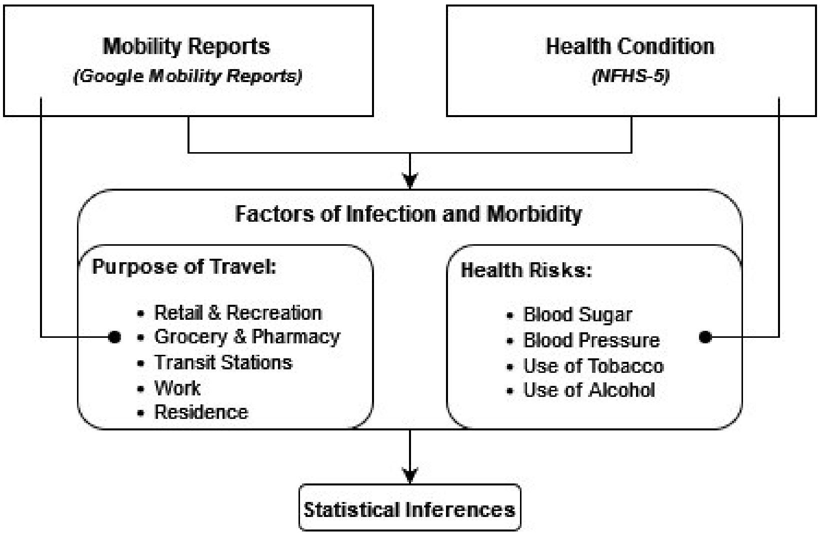

Figure. 1 Methodology flow chart of the study.

The study has been carried out with statistical methods to reveal the correlation between various factors of infection and mortalities using Pearson correlation method, and to model the relationship between these factors with the use of regression technique (figure 1). Pearson correlation is a widely accepted method to assess the relationships between variables. The method has been applied between daily COVID-19 infection and the mobility values. Firstly, Mobility has been treated as one of the most influential factors in relation to infection rate across the globe. Changes in the mobility and corresponding changes in the infection rate could reveal the underlying facts about infection and necessary actions can be taken to control the spread. Also, the mobility patterns among the countries are not uniform so as to draw universal plans and policies to put at action. Secondly, mortality due to COVID-19 and prevailing health condition of the infected people could reveal the dominating factors of mortality and its geographical distribution.

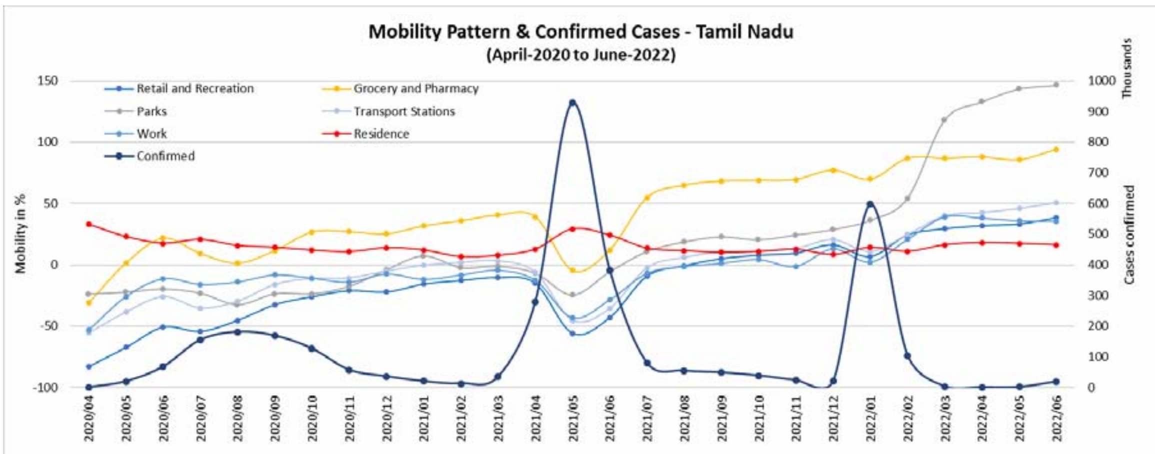

Figure 2. Month wise pattern of mobility and confirmed cases. (Mobility is on the primary axis and confirmed cases on the secondary axis).

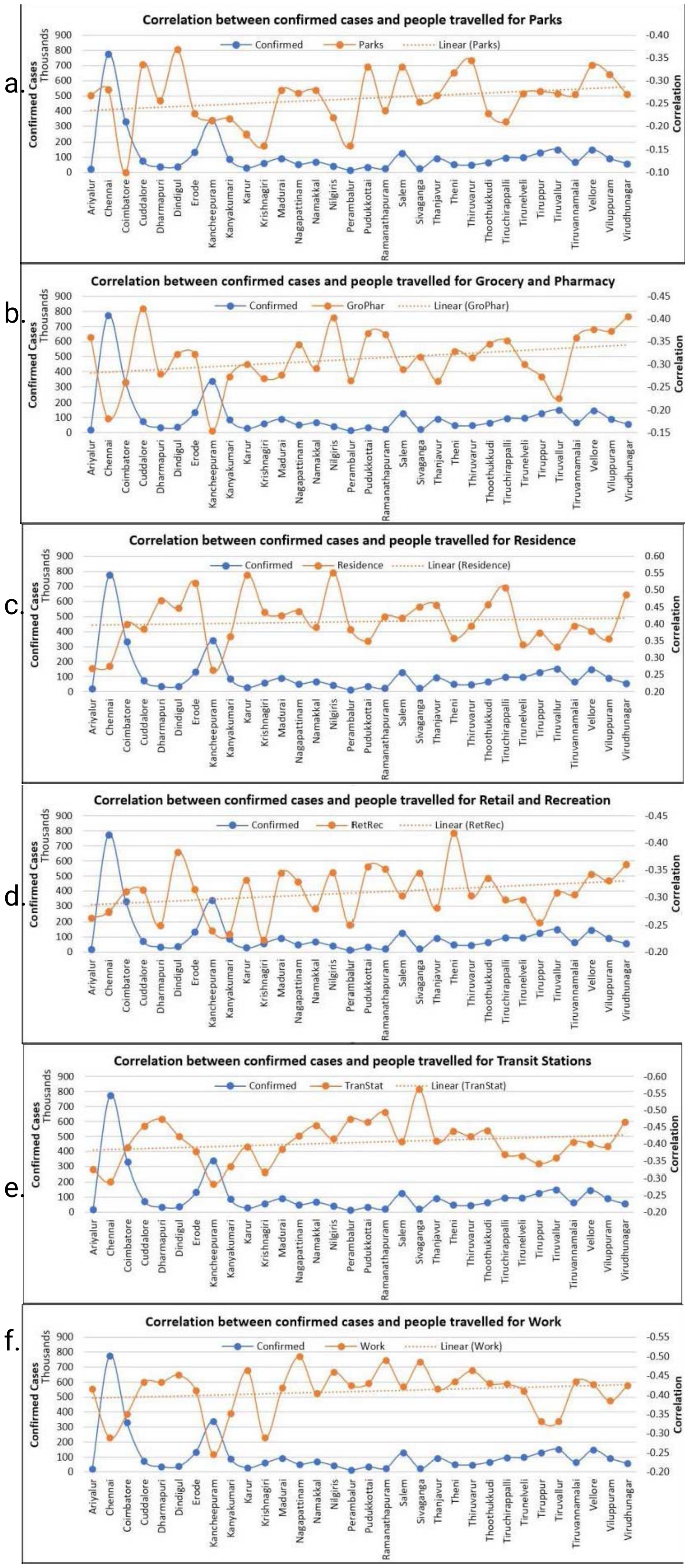

Figure 3. Shows the district wise correlation graph between confirmed cases and people travelled to select Points of Interests (POIs).

The study has utilized vast amount of daily data related to mobility and COVID-19 cases for a period of about 27 months for 32 districts in the state. These reports are compiled to month-wise data and further analysis were carried out. Simultaneously, health data were fetched from NFHS-5 reports. In the analysis, we used Pearson's correlation method to find the relationship between the select variables. Mobility during the COVID-19 period has dropped till the beginning of the third wave, which covers almost 16 months. Only in the July 2021 the mobility values have reached the baseline value that is observed during January and February of 2020. In our study, we found that there is a strong positive correlation between mobility and infection across the districts. However, the rate of spread across the districts was not uniform due to various factors like, population density, adherence to mobility restrictions, and health condition of the people. In addition to that, we observed the level of urbanization and socio-morphological characters of the city are also the crucial factors in determining the rate of infection.

Consumable supply systems like public markets, is the chief area, we believe, where people might have infected and transferred the virus in large numbers. Since many of the private shops were shut due to the problems in procurement and to avoid public gatherings as directed in the curfew; additionally, the shops were run only during the permitted hours. Another important aspect we analysed in our study is the statistical calculation of the correlation between pre-existing medical conditions and deaths reported due to COVID-19. The results display strong positive correlation between blood sugar and COVID-19 related deaths. As we discussed earlier, high blood sugar level makes it difficult to combat the infection and increases the death rates. Districts that reported high blood sugar level does not necessarily report high COVID-19 related deaths because the people in each district will have heterogeneous factors like lifestyle, medication, food, finance, health care systems, geographical conditions etc. that determines the death rate. During the periods like COVID-19, to combat the spread of infection in countries like India, supply system must be strengthened to control the infection and health care units must be arranged with adequate infrastructure at micro levels in order to efficiently provide health care services to the infected peoples.

Healthcare Clinic Asset Mapping using Machine Learning Techniques

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As a developing world, there are significant challenges to collect the data for analysing development of rural area, urban areas, water bodies, land cover and land use, soil classification etc. Through the use of cheap and straightforward software, locally relevant training materials, and the provision of data collecting techniques to verify the trustworthiness of the data. The techniques like surveying, digital globe, Volunteered Geographic Information (VGI), Location-Based Services (LBS), Geovisualisation are some of the specialized data collection application. There are more specialized and scientific data collection through by creating the road map with chosen specified topic is most important for variety of decision-making, marketing, planning and development activities.

A new wave of technological innovation is allowing us to capture, store, process and display an unprecedented amount of information about our planet and a wide variety of environmental and cultural phenomena called Geographical Information System (GIS). There are other data collections in remote sensing, like Global Position System (GPS), Hyperspectral Images (HSI) are used to collect the data. The data collection through remote sensing is very easy and analysis of this data is also easy and cost effective.

Data collection method includes data capture which constitute primary and secondary data. Map projections are a systematic rendering of points from the curved earth surface onto a flat map surface. The world is seen as discrete objects which represent vector data and as a continuous surface which reflects raster data as shown in figure 1. Vector uses points, lines, polygons and raster use a cell or grid structure. Geo-processing is any GIS operation used to manipulate data such as clip or buffer. Automation is the ability to perform repetitive tasks. Geodatabase is a database designed to store, query and manipulate geographic information and spatial data. Data quality is the degree of data excellency categorized as precision and accuracy.

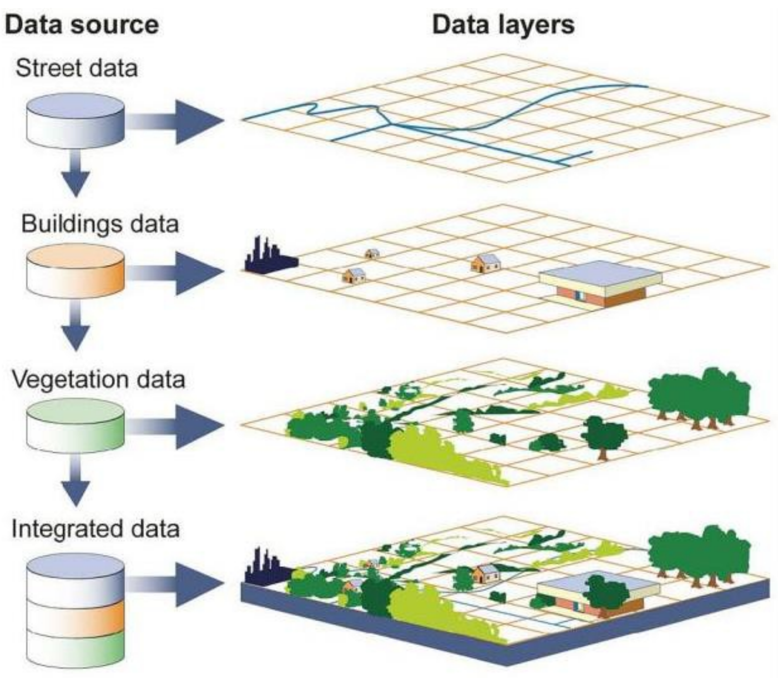

Figure 1: Raster Reflects Data of Geographical Information System (Google Courtesy).

Then for storing and analysing the collected GIS data Artificial Intelligence, Big Data, Internet of Things, Cloud, Wireless and Broadband are used as environment to store the collected data and the data analysis is helpful to the citizens, business and government. The collection of data and storing of data derivation is as shown in figure 2.

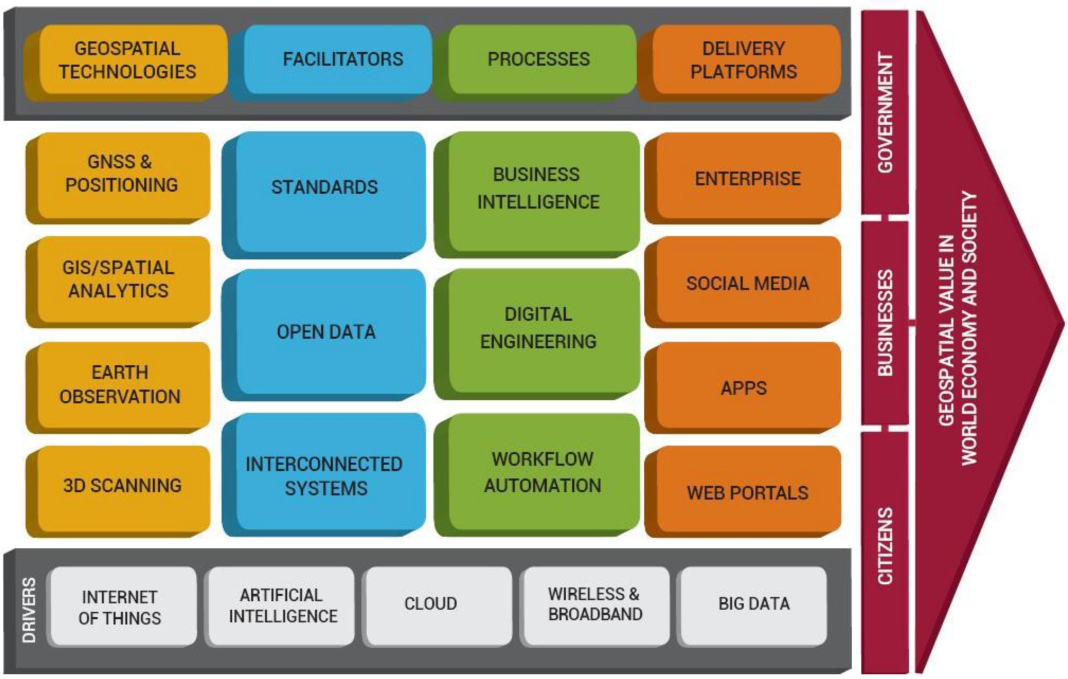

Figure 2: Representation of Data Collection process with Storing types and applications

Hence, GIS is a valuable and affordable tool for the decentralisation of health data analysis to low resource settings. This study aimed to test the appropriateness of new, inexpensive and simple GIS tools in poorly resourced areas of a developing country. GIS applications were trialled in pilot studies based on mapping of health resources and health indicators at the clinic and district level in the predominantly rural and urban province of Tirupati and Chittoor Districts.

The pilot applications were aim at developing health policy and services that address geographical and social inequalities in health, therefore it is benefited from evidence-based approaches that can used to investigate spatial aspects of health policy and practice, and evaluate geographical equity (or inequity) in health service provision with (i) rapid field collection of health infrastructure data using a GIS and GPS (ii) storing the data in the cloud based environment of easy access (iii) mapping health indicator by constructing a model using machine learning technique and (iv) Predict whether the Clinic location area nearer and far to the patient (v) Predict whether to build emergency Clinic at accumulated distance. The construction model is visualised as shown in figure 3.

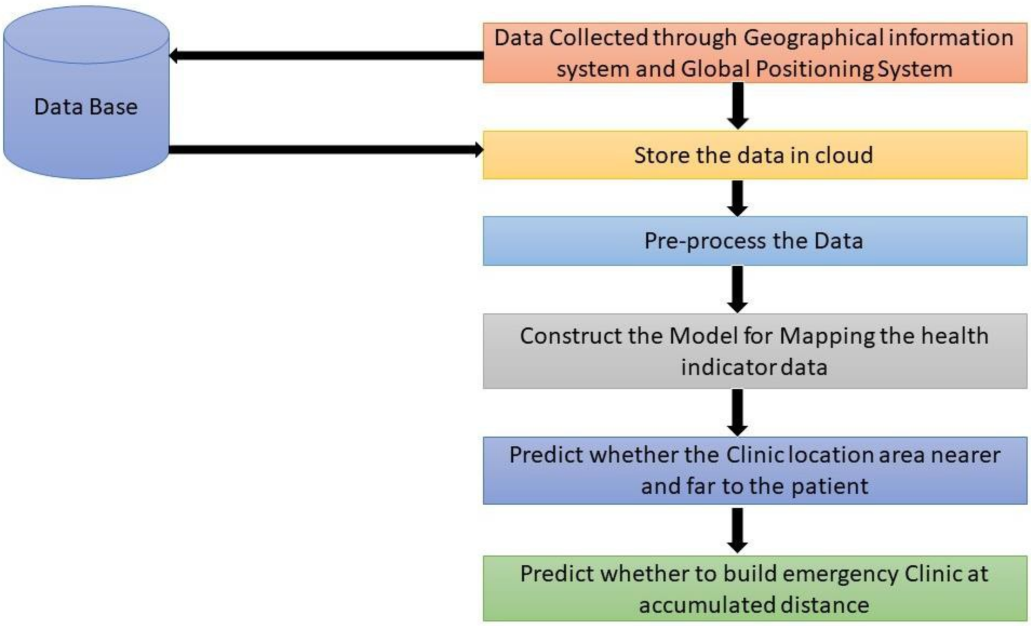

Figure 3: Construction Model for developing Clinic analysis using GIS

Spatio-Temporal Diffusion Pattern and Hotspot Detection of Dengue: A case study of Delhi region

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Dengue is one of the major global public health concerns, according to World Health Organisation. Being a subtropical country, India has been prone to a frequent increasing trend of dengue outbreaks in highly urbanized and densely populated regions. Delhi is one of the fastest-growing cities in the world and is most prone to dengue outbreaks. Geospatial technologies have been greatly applied in epidemiological studies and provide various tools and techniques required for addressing epidemiological problems, determination of contributing factors, and identifying critical areas. The spatio-temporal distribution at the ward level provides significant insights into the diffusion pattern of dengue which might not be significant at greater scales. This study presents a GIS approach to analyze the spatial and temporal dynamics of dengue epidemics at the ward level. The objective of this study was to examine spatial diffusion patterns and hotspot identification for reported dengue cases. Geospatial diffusion pattern of the dengue outbreaks during the period 2015- 2021 has been investigated using epidemiological data from the Department of Public Health, Delhi. To determine the space-time dynamics and pattern of dengue outbreaks during 2015-2021, all cases were firstly geocoded at the block level using google earth. Thereafter, a general statistical analysis (based on gender and age group) was done to examine the vulnerable population. Subsequently, this data has been analyzed for determining spatial patterns, cluster analysis, and spatio-temporal patterns of hotspots during the study period. The spatial pattern has been determined by analyzing point patterns. Kulldorff's space-time scan statistic was used to identify spatio-temporal dengue clusters. The Getis-Ord Gi* and Anselin Local Moran's I statistics were used for further characterization of statistically significant dengue hotspots and cold spots. A total of 4111 cases were reported from 64 wards across three districts of Delhi. Annual incidences of dengue varied from zero to 111.20 per 100,000 people. The results revealed that spatial diffusion patterns during the years 2015-2021 represent spatially clustered patterns with significant differences at the ward level. The Space-time analysis revealed that the outbreak movement and spread patterns might be related to entomologic and epidemiologic factors such as vector density, the proximity of water, dumping sites, mobility of people, endemicity of region, seroprevalence, mode of circulation, etc. The hotspot analysis shows the spatial trend of dengue diffusion as significant clusters in highly dense urban areas. These hotspots were found to be consistent with those identified by Kulldorff's space-time scan statistic. These clusters may be prioritized for resource allocation for more efficient prevention and control of dengue. The methodology is based on basic GIS techniques for space-time analysis and may be applied to other infectious disease surveillance. This study provides useful information regarding the outbreak patterns of infectious disease in time and space, which may help public health departments to plan strategies to control the spread of disease.

Standoff detection of Novel Corona Virus by Laser induced Fluorescence (LIF) Method

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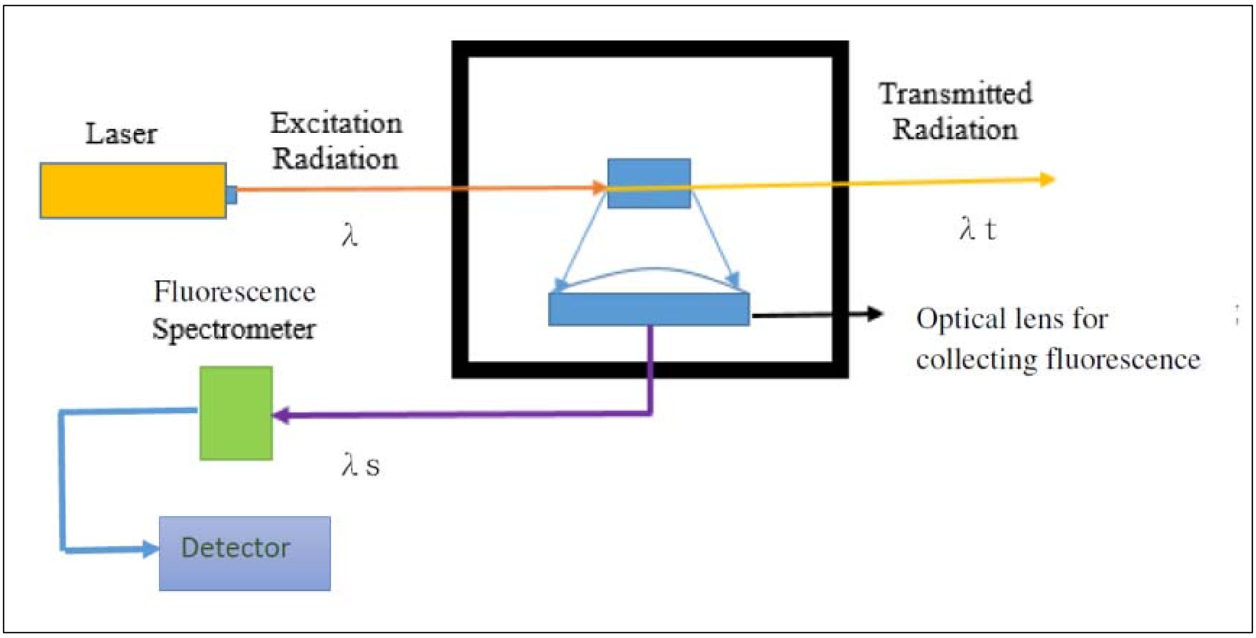
Biological hazards like some types of fungi, bacteria and viruses are big threat to human life. Biological agent incidents in general are unpredictable and will effect seriously. Effects and human loss from such kind of biological attacks can be minimized by an early and fast detection of the event.

Laser induced fluorescence (LIF) methods are being used extensively in the classification of bacteria by many researchers over the years. This method could be a proper approach to develop a system suitable for analyzing and categorizing viruses also. Because of the molecular composition, different viruses emit different spectra as a fingerprint. This phenomenon can be made use of classifying the virus.

This paper is aiming at usage of LIF method for detection and analysis of the novel coronavirus. If successful, development of a fast virological analysis may revolutionize this field, allowing fast responses to epidemiologic events and reducing risks. Moreover, the cost reduction may lead to an increase in the monitoring frequency, which may likely to help prevention and spreading of the pandemic.

The laser-induced fluorescence technique is based on the fluorophore excitation by laser. The radiation near-UV or UV light induces the fluorescence, whereas the fluorescence radiation is in the visible region. A 266 nm Q-switched diode pumped solid-state laser is used for emitting the required laser energy. Typically, the pulse repletion frequency of the laser is 5 kHz with an average power of about 25mW is needed. The laser radiation passes through a cuvette where the suspected novel corona virus sample is placed. The cuvette should be made out of quartz as it will be transparent to UV and visible radiation. A fiber optic cable is to be placed near the cuvette at 90° with respect to the laser beam. The optical fiber will collect the fluorescence signal along with the scattering radiation and directs the collected light onto the spectrometer. The exposure time of the spectrometer ranges from 1ms to 65s. The cuvette and the collecting system will be placed inside a closed chamber, allowing the exclusion of external radiation to reduce the background signal like sun, lamps, etc. Two holes to be made to permit the laser beam to pass through the box and irradiate the sample. No optical filters are needed to exclude scattering radiation. In fact, the first and the fourth harmonics are not recorded by the spectrometer, whereas the scattering of the second harmonic is sufficiently small to be filtered numerically. Experimental schematic diagram is shown below.

Experimental schematic diagram



Healthcare Facilities & Its Accessibility in the Tribal Dominated Dahod District of Gujarat, India

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Sabarmathi University, Ahmedabad

At least half of the world's people still lack full coverage of essential health services. The Alma Ata Declaration in 1978 expanded the approach to "improving health for all people" from the focus on doctors, hospitals, and biomedical advances to include human rights, concern for equity, and community participation. According to Niti Ayog assigned based on criteria in Gujarat state Dahod district is one of the Aspirational districts in country India. Over all ranking Dahod stands at 17 ranks, the Population growth rate of tribal communities of Dahod district is higher than other tribal communities of Gujarat, The District has registered 33.7% decadal growth of the Scheduled Tribe population from 2001 to 2011.

The study aims to reduce disparities in coverage and formulate a strategy to assess the vulnerability of the villages to primary health facilities and improve access to public health facilities. The methodology adopted for the study was to maintain a digital database using spatial and non-spatial data. Spatial data includes all the topographic and thematic maps. GIS-based methodology, Existing health care facilities include CHCs, PHCs, and Sub-centers using GPS measure of latitudes and longitudes; updated list of all existing health facilities and other amenities facilities. The collected Latitude and Longitude through a ground survey of every health facility were transferred into ArcGIS software and mapping of health facilities of Dahod in the state of Gujarat, India was done for the year 2020, administrative and socio-economic layers, its visualization, analysis, and preparation of map has been carried out. In the Dahod district total of 21 Community Health Centers, 97 Public health Centers, and, 637 Sub Centers (Health and Wellness Center) operating has been mapped. Site suitability analysis for identifying ideal locations for new CHCs has been done and Different tools and techniques like proximity analysis for facility catchment of average aerial distance coverage method, service area for facility Catchment of actual road distance coverage, and vulnerability scenarios as a parameter to analyze the situation, has been used to calculate the indices.

All the healthcare facilities at different levels have been analyzed and come up with that how much of the population is getting benefits of services. In India, GIS can also support the effective implementation of massive healthcare programs such as The Ayushman Bharat Digital Health mission to support the integrated digital health infrastructure of the country. And Pradhan Mantri Jan Arogya Yojna Abhiyan (PM-JAY) that are being rolled out by the government.

GIS Applications during Covid Management - Telangana Experience

G Shva Kiran,

Commissioner and Director Municipal Administration CDMA- Telangana, MAUD Campus, AC Guards, Hyderabad

When the lock down was announced on 24 March 2020, the state of Telangana, more so the city of Hyderabad faced a piquant situation. Restricted movement, 20 lakh household, how to make them stay at home was the million rupee question. One of the main reasons why people ventured out was to purchase vegetables and groceries. The departments of Agriculture, Horticulture and marketing were facing a challenge of procuring vegetables from traditional vegetable cultivating areas of Telangana, arranging labour, coordinating with the farmers and transporting it to Hyderabad. On reaching Hyderabad, the vegetables had to be routed through the 12 Rythu Bazars, which through the Mobile Rythu Bazars (MRBs) were to cater to the vegetable and fruit needs of the denizens of the city. A committee to oversee the availability and regulate essential commodities was constituted by the Government with the Principal Secretary, Agriculture as its Chairman. The Committee included senior officers from the Agriculture, Horticulture and Marketing as well as Police, Postal, Transport and civil society representatives. It was during the initial meeting the proposal to use GIS (Geographic Information System) and mapping was suggested. About 200 vehicles, 20 lakh households, 625 sq kms, 6000 quintals of vegetables to be delivered, was a daunting challenge. It was at this stage that the help of National Remote Sensing Centre (NRSC), located at Hyderabad was requisitioned. NRSC mandate includes providing geospatial services for good governance. Over a few conversations, emails and following social and virtual distancing, the Department of Agriculture and NRSC agreed to collaborate. The methodology was NRSC would provide a link for the MRB drivers to register their mobiles. The information about the vehicles required was, name of the driver, vehicle number, mobile number of driver and group name. NRSC created a special group for the Mobile Rythu Bazar fleet. A brief help document was created and the senior officers of the department were instructed to get the MRBs registered. At the back end, a senior NRSC scientist and yours truly were watching the registrations and approving the same. It was possible to locate the MRBs on Bhuvan Portal and track their movements. This enabled to check the number of vehicles plying, which routes, halting time and distance covered in Kms. The pattern of MRBs was analysed and routes for subsequent day were made. With the intervention of the department officials routes were identified to cover all the areas in the city to help implementation of the â€œStay Homeâ€� regulation. With the location sharing feature, being a part of mobile it was possible to connect the requirements from various RWAs, communities, gated colonies very easily as the Bhuvan portal is a georeferenced mapping tool. While this tool ensured that the vehicles were monitored closely it shows how technology when correctly used can deliver even if the devil is corona.

Ecosystem Accounting, Resilience and Restoration

Wetland Health report card using Remote sensing Inputs

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Space Applications Centre, ISRO

Wetlands are unique ecosystem that provide several ecological and economic services. Wetlands have been negatively impacted by climate change and anthropogenic disturbances which affect the wetland health and function. This includes loss of vegetation, salinization, excessive inundation, water pollution, emergence of invasive species, excessive development and infrastructure development. In a wetland ecosystem, water plays an important role in controlling environment and associated life forms. A healthy wetland system shows persistence of native species, absence of contaminants, water quality parameters as per acceptable standards and sustainable ecological processes. About 75 wetlands of international importance (Ramsar sites) exist in India. These are ecologically productive sites and most of them are home to migratory bird species. Degradation in the health of these wetlands directly affect the growth and sustenance of flora and fauna around the wetlands. Thus development of a near real time health monitoring system is needed to aid in proper planning and mitigation. Remote sensing helps in collecting information over large spatial scale with regular monitoring on systematic basis. This paper aims to develop a wetland health report card to monitor different parameters indicating ecological character using satellite observations. Monitoring parameter includes governance (percentage wetland Converted to Non wetland use), hydrology (percentage wetland covered under water, water connectivity, Shoreline development index), Water characteristics (productivity, turbidity, color and temperature), Biodiversity (% wetland covered by invasive macrophytes, Natural Habitat) and Catchment characteristics. Each parameter are scored with actual values close to acceptable standards. An overall wetland score is calculated to specify wetland health. This score will help in regular monitoring and assessment of wetland health. This wetland health report card is available in google earth engine for analysis and visualization. This is a first such effort to develop a remote sensing based wetland health monitoring system.

Near Real Time Thermal Based Ecological Monitoring Using Google Earth ENGINE

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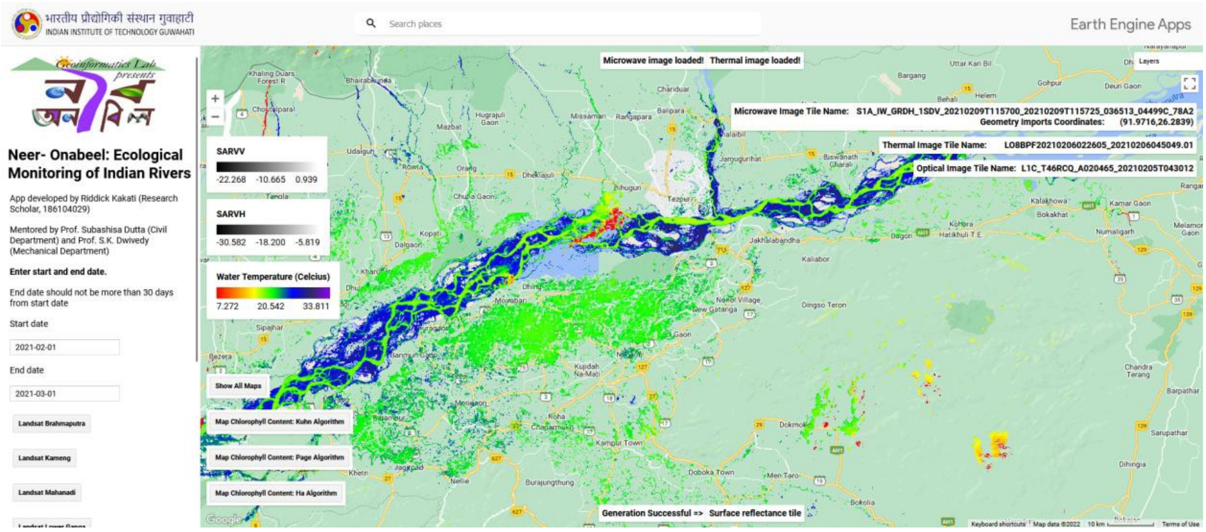
According to ecological theory, the environment influences all living things. Previous research has demonstrated the significance of thermal fronts to fish distributions in aquatic bodies. To date, the majority of fish studies in India have relied on ship-based acoustic data collection, which is limited by the ship's maximum speed. In addition, environmental data are often collected in situ through sampling at widely separated sites. Today, satellite-based remote sensing techniques have advanced rapidly, and data with finer spatial and temporal resolution are now publicly accessible. Numerous research utilising the thermal band of Landsat have already produced temperature maps of seas and oceans. However, there are few studies on rivers. In addition, cloud computing services such as Google Earth Engine expedite data processing without requiring client resources. An automated thermal data processing algorithm will aid in near-real-time river monitoring, hence preserving environmental balance.

This study automates thermal and optical data processing by development of a Google Earth Engine app to map thermal fronts and water quality parameters in the Indian rivers Brahmaputra, Ganga, Kameng, and Mahanadi. Radiative transfer equation has been used for thermal imageries to handle raw satellite thermal data, since it has been claimed in the literature to be superior than the Mono Window Algorithm (MWA) and Single-Channel Algorithm (SCA) for oceans and seas. On the other hand, Dark Object Subtraction technique has been automated to obtain surface reflectance from raw optical satellite data. On an average in 2021, the algorithm for automatic thermal processing predicted a temperature range of 15-33°C for the River Brahmaputra, 10-20°C for the River Kameng, 18-30°C for the River Mahanadi, and 8-20°C for the River Ganga. The obtained temperature ranges were within the range of values measured in the field for the River Brahmaputra. On superimposing the thermal maps with maps of chlorophyll- a concentration maps using optical data (NDCI), which is an indicator of water quality, it has been observed that for Brahmaputra and Kameng rivers, it was less than7.5 mg/m^3, for Mahanadi it was in the range of 7.5- 16 mg/m^3 and for Ganga, it was 25-33mg/m^3. It has been observed that a higher variability of water temperature leads to higher primary productivity, and further increase might lead to eutrophication. For River Ganga, a higher concentration of chlorophyll- a and a temperature variation has been observed in this study. The increase in greenness of river has also been reported by news articles. Thus, the algorithm for automated thermal mapping combined with chlorophyll- a monitoring can then be used for environmental monitoring, decision making, and research.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Geoinformatics Lab presents
Neer- Onabeel: Ecological Monitoring of Indian Rivers
App developed by Riddick Kakati (Research Scholar, 186104029)
Mentored by Prof. Subashisa Dutta (Civil Department) and Prof. S.K. Dwivedy (Mechanical Department)
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End date should not be more than 30 days from start date
Start date
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End date
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Landsat Brahmaputra
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Landsat Mahanadi
SARVV
-22.268 -10.665 0.939
SARVH
-30.582 -18.200 -5.819
Water Temperature (Celcius)
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Generation Successful => Surface reflectance tile
Layers

Forest Health Index: Developing a framework towards efficient monitoring of forest ecosystem

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Forests are one of the crucial ecosystems in the world covering about 31% of the global terrestrial area. More than 1.6 billion people worldwide are dependent on various forest resources and about 350 million people rely directly on them for their livelihoods. This implies that forests need to be managed and monitored responsibly, encompassing the three pillars of health – economic, social and environmental. The monitoring of forests on these broad indicators is becoming increasingly important. India is one of the mega diverse developing economies which is ranked 10th in the list of countries having the largest forest area comprising 1.8% of the world's forests. They constitute 21.71% of the land area. It has millions of rural and tribal population who are dependent on the various forest resources for their sustenance. This huge dependence accompanied by rapid industrialization and increasing agricultural expansion to fulfil the demands of the growing human population has created a stress on the existing forest wealth of India. The Forest Survey of India (FSI) is the nodal organization responsible for the mapping and reporting of the nation's forest cover and evaluation of forest resources. The biennial report highlights the state of forests of the nation on the basis of parameters like forest cover, forest density, forest canopy cover and assessment of the forest resources. But the FSI report published only assesses and monitors a few of the ecological indicators thereby neglecting the economic and social aspects of forests. This undermines the complete potential of the Indian forests and hence its enhanced contribution to the national planning and development. There is unavailability of detailed reporting on the economic indicators like trade of timber and NTFPs, per capita income of the people dependent on forest based activities, the employment generation of people, per capita supply and consumption of NTFPs and timber, rate of total livelihoods and the total expenditure in forestry sector. Social indicators like people's participation in management and benefit sharing process, promoting of indigenous knowledge and skills, strength of man power in forestry sector, occupational health and safety, people's involvement in forest conservation and educational activities, tenurial rights of local communities, recreational and cultural benefits need to be included in the present framework to augment social well-being. Hence, it is essential to develop a composite forest monitoring system on the basis of relevant indicators which will help to bring out the true contribution of forests. Such a comprehensive indicator-based framework is currently lacking in the national monitoring system. It is developed by compiling different individual indicators into a single index based on an underlying model. In this regard, developing composite forest health index is of paramount interest and relevance for designing future strategies for conservation. Thus, there is a need for a comprehensive forest health index on the basis of potential ecological, economic and social indicators that will help in efficient monitoring and sustainable management of forest ecosystems.

A systematic review of current knowledge on the impact of climate change on India's biodiversity: trends, and gaps

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Climate change is a global threat to biodiversity and has been recognised as the primary cause of species extinction in the coming decades. Climate has a significant impact on species distributions and the overall Spatio-temporal patterns of biodiversity. Species are at risk if the climate conditions to which they have adapted and the habitats to which they have adapted disappear in the future. Species Distribution Models (SDMs) have been used to predict a species' current and future geographic range and environmental niche. A growing number of studies report global changes in species distribution under various future climatic scenarios. Global studies, on the other hand, commonly do not conform to regional relevance. As a result, in this study, we examine the existing literature to determine the current state of. Thus, in this study, we review the existing literature to understand the impact of climate change on India's biodiversity, as well as research trends and knowledge gaps.

We conducted a review of the literature to determine the impact of climate change on Indian biodiversity across all biogeographic zones. To reflect the most recent trends in the field, we used the publish or perish software and focused on papers published in the last 22 years (2000-2022). This research strategy yielded 375 papers. Papers with the terms "Species Distribution Models," "Climate Change," or "India" in the title, keywords, or abstract published between 2000 and 2022 were included. A set of data was gathered from each paper to conduct the analysis. Our search excluded any grey literature. The screening of abstracts was the first step in selecting papers for our review. Articles were excluded if they were: (i) purely conceptual and did not include a real case study; or (ii) only reported modelling SDMs for the current scenario (i.e., review, perspective, and comment papers). As a result, only papers with climate change impacts on Indian biodiversity were retained for the second step of the analysis. New papers were included by cross-referencing the downloaded paper. Finally, 102 publications were chosen for quantitative analysis.

We found the number of papers published on SDM, and climate change increased significantly after 2015. The studies were mostly conducted in the Himalayan regions (n=50), followed by the Western Ghats (n=19). The majority of studies focused on plants (n=46) (Figure 1) compared to other taxon groups. Most of the studies were published in ecological, multidisciplinary, or biodiversity conservation journals. Most of the studies failed to report the amount of uncertainty resulting from data gaps and model parameters. We propose that in the future, the quality of SDM-related studies be critically reviewed to ensure that they are reproducible. Furthermore, based on the reviewed literature, we recommend that future SDMs account for uncertainty levels as part of the modelling process and more studies should be focused on lesser-studied taxa.

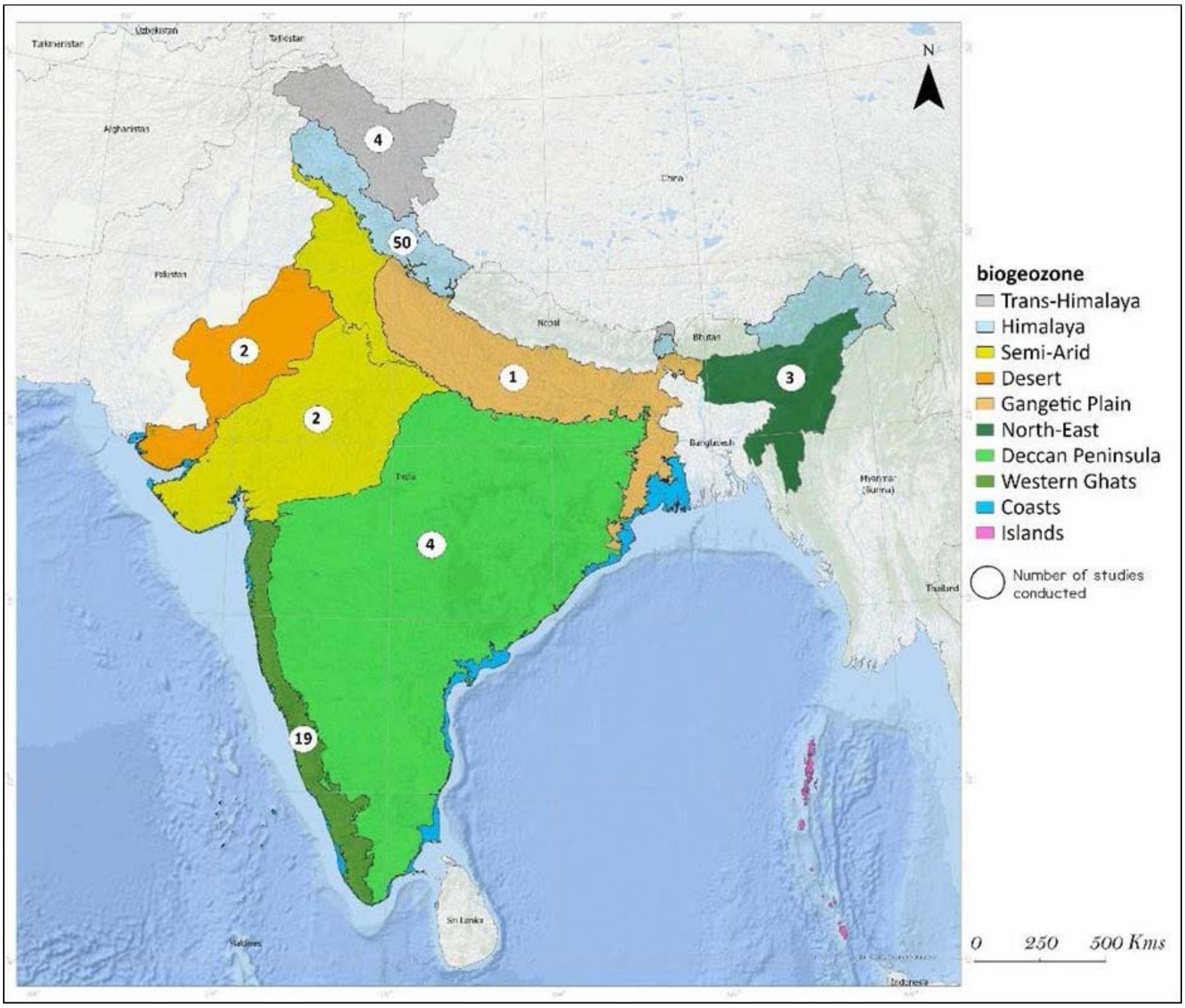

Figure 1 Number of studies conducted in different biogeographic zones

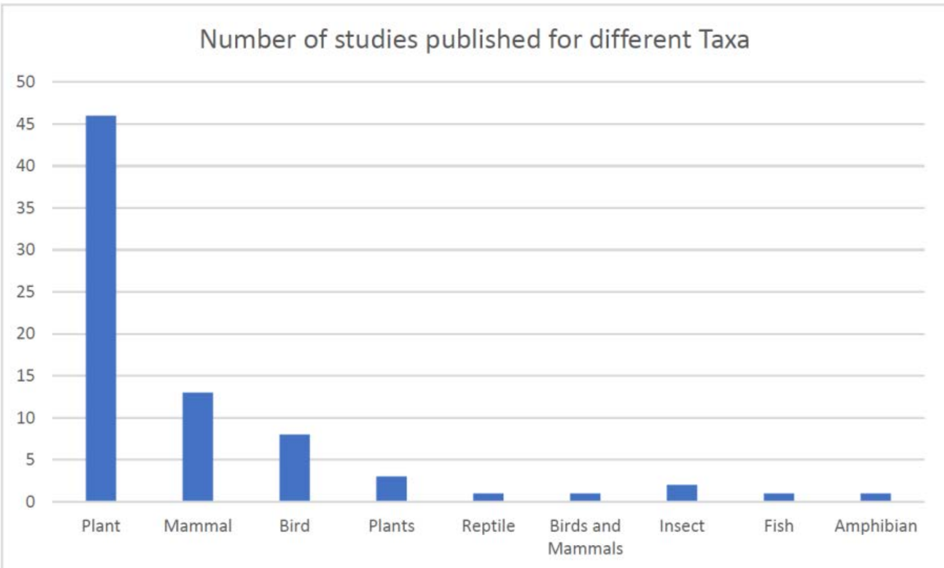

Figure 2: Number of studies published for different Taxa

Machine learning techniques to map mangroves in the Coringa wildlife sanctuary Andhra Pradesh, India

P Pranav[1]., Nandini Menon N[2]., Ummey Shameem[3]., Grinson George[1]
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[2] Nansen Environmental Research Centre (India), Kochi, India, 682506 [3]Department of Zoology, Andhra University, Visakhapatnam-530003

Mangroves are critical coastal resources in tropical and subtropical regions of the world as they offer significant ecological and economic services and coastal protection. Mangroves are being damaged all over the world, and efficient mangrove delineation aids in the conservation of the shrinking coastal flora. For mangrove mapping, multispectral and hyperspectral images are being used, and in this instance, Sentinel-2 satellite images hosted by the European Space Agency were utilized. Machine learning techniques were applied for classification using Remote Sensing and GIS software library (RSGISLib), a set of python packages and the command line-based software packages developed by Earth Observation and Ecosystem Dynamics Group, Aberystwyth University. Mangroves at the Coringa wildlife sanctuary (CWS) in Andhra Pradesh, India, were mapped and subsequently validated by a comprehensive field survey carried out in the region. The classification accuracy was tested where the classification train score was 99.97%, and the test score was 93.25%. Mangroves at CWS are adversely impacted by extensive aquaculture and agricultural activities and are important ecologically as they sustain species of flora and fauna that are highly endangered. The demarcation of the spatial extent of local mangroves helps in their conservation and safeguards the coast and its resources.

Satellite Meteorology

Role of Planetary Boundary Layer on the surface absorbing aerosols over a hilly remote station of North-East India

Arundhati Kundu, Shyam S. Kundu, Som Kumar Sharma, Manasi Gogoi, Arup Borgohain, Rahul Mahanta, Rekha Bharali Gogoi.
North Eastern Space Applications Centre

Pollutant concentration at the surface can be influenced by several factors, such as boundary layer growth, entrainment of free atmospheric air, surface meteorology, and emission scenarios. This study addresses the possible links between Planetary Boundary Layer (PBL), Black Carbon surface mass concentration (BC), and lower tropospheric meteorological conditions over Umiam (25.67Â°N, 91.91Â°E, 1040 m AMSL), a high-altitude station of the Shillong Plateau. In recent times, absorbing aerosols like BC grabbed serious attention from the scientific community for their significant but moderately understood role in changing climates. For this study, BC mass concentration is obtained from a seven-channel Aethaloemeter (Make: Magee Scientific, Model: AE33) and Boundary-Layer height (BLH) is collected from a ground-based automatic LIDAR Ceilometer (Make: Vaisala, Model: CL31) from February 2021 to January 2022. Other meteorological parameters such as Temperature, Relative Humidity, Wind Speed, and Wind Direction have been taken from a collocated Automatic Weather Station and accessed from the Meteorological and Oceanographic Satellite Data Archival Centre (MOSDAC) website. Temporal characteristics of Black Carbon surface mass concentration (BC) and Boundary Layer Height (BLH) show an out-of-phase relationship in most of the seasons. However, during winter a secondary peak of BC concentration around 8 a.m. suggests that PBL is not the sole influencer in driving this. A wind direction shift is usually observed at that time which is driven by Mountain-Valley wind circulation and brings pollutants from the valley region which increases BC loading in the atmosphere at that time. Further, BC concentration showed a manifold increase over a short period of time during Post-monsoon. A thorough inspection with the help of the HYSPLIT trajectory model and Ceilometer backscattered profiles implied the dominant role of long-range transport during that season. This study is crucial to understand BC variabilities that can lead to the serious implication of the changing precipitation patterns and glacial melting over the Himalayan Region. Further, a ceilometer is found beneficial to understand dispersion conditions and the evolution of upper-level aerosols.

Northern Europe Heat Wave July 2022: Cause, Effects and the Future of the Earth

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The heat Wave in Northern Europe and North East Africa is not a natural phenomenon. Due to global rise in temperature (because of Global Warming), the changes in the route of Northern Jet Stream towards north pole, Human made activities has made a crystal like path to the birth of heat Wave. The sudden rise in day temperature at the beginning of Summer 2022 in most of Southern Europe (like: Entire Italy, Spain, Greece, All France except north part, South Part of United Kingdom, South and South East Germany,) and others have made deep impact on the lives of Europeans as well as on biodiversity.). Europe has witnessed the extreme challenges of draughts, flash flood, Bushfire and other natural disasters in last 20 years. Most of the countries of Europe are under the direct shadow of natural disaster. The changes in the Ecosystem has made a permanent mark on the future of the earth. The paper explicates several causes of Heat wave in Northern Europe in July 2022 and the effects on Climate, Geo-Biodiversity, Human Life of earth. The Future of the Heat Wave on our planet and our steps/actions to solve this problem.

Long-term Trend of the Planetary Boundary Layer and its Relationship with Atmospheric Pollutants over North East India

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The interaction of the Planetary Boundary Layer (PBL) with the atmosphere and the surface consequences in the transfer of heat, moisture, pollutants etc. both horizontally and vertically in the atmosphere, which makes it one of the crucial parameters essential for weather and climate models as well as pollutant dispersion. In this study, we have analyzed 42 years (January 1980 â€“ December 2021) of boundary layer height (BLH) using three reanalysis datasets viz., ECMWF (European Centre for Medium - Range Weather Forecasts) Reanalysis Version 5 (ERA5), Indian Monsoon Data Assimilation and Analysis (IMDAA) and Modern-Era Retrospective analysis for Research and Applications-2 (MERRA2). A well-established non parametric Mann Kendall test with 95% confidence level and Senâ€™s slope estimator has been used to study the long-term trend and significance of the PBL trend over North East India (NEI) and its neighbouring areas. Further, its relationship with surface aerosols and trace gases like Black Carbon (BC), Organic Carbon (OC), Dust PM2.5, Sulphate aerosol (SO4), Carbon Monoxide (CO) and Ozone (O3) has been studied for the same period using MERRA2 reanalysis data. Dependency of the PBL on the surface heat budget demands further detailed studies on aerosols and trace gases, as aerosols directly affect the radiation budget of the earthâ€™s surface. Substantial increase in the green house gases can be seen with the rapid growth in industrialization in the recent years. The PBL is most influenced by the absorbing aerosols consisting primarily of OC, BC and brown carbon. Aerosol-PBL interaction results in heating of the upper PBL stabilizing the PBL, suppressing the turbulence mixing and forming a shallow boundary layer leading to high concentration of air pollutants near to the surface. One of the important parameter viz. ventillation coefficient (VC) has also been calculated for 42 years to determine the pollution potential over the study region. We have observed that during the winter, pre monsoon, monsoon and post monsoon seasons; almost all the North Eastern (NE) states of India show significant negative trend except for some parts Arunachal Pradesh during winter, monsoon and post monsoon seasons where it showed positive trend of BLH. However, during post monsoon most of the parts of the NE states do not show any significant trend. Myanmar and towards west of NEI especially Bangladesh showed significant decreasing trend during all the seasons. As measured by MERRA2, maximum negative trend was mostly observed during pre - monsoon season over Arunachal (~ -1.8 m/year), Assam (~ -7.9 m/year), Manipur (~ -4.3 m/year), Meghalaya (~ -8.5 m/year), Nagaland (~ -5.3 m/year) and Sikkim (~ -2.0 m/year); except for Mizoram (~ -6.07 m/year) and Tripura (~ -6.6 m/year) where higher negative trend was observed during the seasons of winter and post monsoon respectively. It has been observed that the areas of decreasing BLH trend showed increasing trend of BC, OC, Dust, SO4, CO and O3 surface concentrations as measured by MERRA2 i.e. a strong negative correlation can be seen between the PBL and atmospheric pollutants over NEI and its adjoining areas. However, OC and SO4 concentrations during the monsoon season over the NEI do not show any positive or negative trend. Moreover, highest decreasing trend of VC was also observed during pre monsoon season over Arunachal (~ -4.7 m2s-1/year), Assam (~ -35.2 m2s-

1/year), Manipur (~ -24.6 m2s-1/year), Meghalaya (~ -48.4 m2s-1/year), Mizoram (~ -21.0 m2s-1/year), Nagaland (~ -23.9 m2s-1/year), Sikkim (~ -16.7 m2s-1/year) and Tripura (~ -38.8 m2s-1/year) which implies less dispersion potential of pollutants and high concentration of aerosols and trace gases over the region during the season.

A Mathematical Modelling Approach for Deriving Land Surface Temperature Diurnal Model Parameters over India Using INSAT-3D Imager Data

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Land surface temperature (LST) is a critical surface parameter at the land?atmosphere interface, which has an important role in the interaction of energy exchange between land surface and atmosphere. All the surfaces possess a definite LST diurnal (LSTD) cycle and the knowledge about the LSTD is quite important for many meteorological, climatological, hydrological, and ecological applications. LSTD cycle can be characterized by a set of mathematical model parameters, which describes thermal behaviour of the land surfaces. Geostationary satellite payloads such as INSAT-3D Imager with a high temporal resolution have the ability to fully characterize the diurnal cycle of LST. A theoretical study was carried out in the present paper with an objective to derive the LSTD parameters over India using INSAT-3D LST products. The INSAT-3D Imager provides LST products at 4km spatial resolution and 30-minutes temporal resolution. A mathematical model consisting of a harmonic and an exponential term is fitted to the LSTD, describing the effect of the Sun?s radiation during day and the decrease of the surface temperature at night, respectively. The results of the modelled LST through LSTD fitting evidently showed that modelled LST images have more pixels present because of filling of LST pixels in place of missing data values in the raw LST images. Various LSTD cycle model parameters such as, residual temperature, temperature amplitude and time of maximum were also obtained for diurnal LST observations. The LSTD parameters fitting errors in terms of root mean square error and coefficient of determination ranged between 0.5-2.5K and 0.90-0.99, respectively for majority of the pixels over India. The difference between INSAT-3D LST and modelled LST at 30-minutes interval at corresponding local solar time showed a good agreement with the largest absolute difference occurring during the sunrise (less than 2K). While for the remaining part of the day both agree well with LST error remaining less than 1K. The advantage of present study is, by fitting the LSTD model summarizes the thermal behaviour of the land surface and yields more representative and informative thermal surface parameters. Cloud cover usually becomes a hindrance for the generation of LST over large area, however proposed method yields approximate cloud free LSTD in place of the discontinuous data series, if cloud cover exists for a brief duration of less than 4 hours. The proposed approach also offers a unique way to derive new set of thermophysical parameters over Indian landmass, which would be useful in keeping watch on surface and environment from space.

Machine Learning based Estimation of Total Precipitable Water from INSAT-3D Imager Observations

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Total precipitable water (TPW) is a key parameter for monitoring the development of the various weather phenomenon, viz., deep convective systems, thunderstorms, etc. It also plays a major role in various nowcasting applications, like heavy rainfall alerts, cloudbursts, etc. Hence, the accurate estimation of TPW is very crucial. The radiosonde based conventional measurements lack in providing the high spatio-temporal coverage of TPW as they are sparsely distributed in space and are acquired mostly twice in a day. Since nowcasting applications require continuous TPW at high spatial and temporal resolution, it can be achieved with the satellite-based observations. Therefore, the present study deals with the estimation of TPW from observations in the water vapour and thermal infrared (TIR) channels of INSAT-3D Imager using machine-learning technique. The deep neural network (DNN) technique is utilized here to estimate TPW from INSAT-3D Imager observations. DNN is a supervised machine-learning algorithm that predicts the output by establishing the relationship between the input vector and an output. Herein, water vapour and TIR channel observations of INSAT-3D Imager for three years from 2018 to 2020 are collocated with TPW from European Center for Medium range Weather Forecast (ECMWF) reanalysis (ERA5) available at 0.25 degree uniform spatial resolution to prepare a matchup dataset. The inputs vector consists of Julian day, geolocation, brightness temperature of water vapour and TIR channels of INSAT-3D Imager, emissivity of all three channels and the satellite zenith angles. The ERA5 TPW is the output of the DNN. For the training of the DNN, 70% of the total collocated matchups are selected randomly. The rest 30% are used for the testing of the DNN. The independent testing is also performed on INSAT-3D observations of the entire year 2021. The assessment of the developed DNN is carried out by computing the standard statistical quality indicators like bias and root-mean-squared error (RMSE) in the predicted TPW with respect to the ERA5 TPW. The DNN is developed for land and ocean surface separately due to larger variation in the emissivity over land. The assessment of the developed DNN over both surfaces show the similar statistics. The quality evaluation of the training and testing datasets shows the negligible biases and similar RMSE of ~3mm in the predicted TPW when compared with ERA5 TPW. However, for the independent testing when the developed DNN is applied on the observations of INSAT-3D for 2021, the bias (RMSE) in the predicted TPW as compared to ERA5 TPW over land is observed -0.29 (4.37) mm, whereas over ocean the observed bias (RMSE) is 0.36 (4.81) mm. Moreover, as per literature, the RMSE of

Deciphering the signatures of convective rain cells using simultaneous observations from C-band Synthetic Aperture Radar onboard EOS-4 satellite and GPM measurements

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The space-borne Synthetic Aperture Radar (SAR) is commonly used for imaging of Earth's surface under all weather conditions. Recently, the Indian Space Research Organisation (ISRO) launched Earth Observation Satellite (EOS)-04 on 14 February 2022, and it carries a C-band SAR for Agriculture, Forestry, Hydrology and Flood mapping applications. It is well known that the signature of rain cells can be detected on SAR images at all radar frequencies. It becomes more complex, especially at the C-band wavelength, where it lies in the transition region of Bragg scattering. In this paper, we have used C-band SAR images and near-simultaneous observations from the Global Precipitation Measurements (GPM) Microwave Imager (GPM-GMI) to study the signatures of multiple convective rain cells. The dark and bright rain signatures in the three cases discussed the advantages and limitations of C-band SAR imagery. The bright patches are found on C-band SAR imagery, which depicts the information of hydrometeors such as graupels or hails in the melting layer. The EOS-4 image depicted in Figure 1(a) shows a C-band SAR image over the Australian Sea coast region and the zoomed picture of that is shown in Figure 1(c) in ascending orbit with HV polarization mode. HV denotes that the signal is emitted at horizontal polarization and received at vertical polarization. The image is acquired from the Bhoonidhi platform (https://bhoonidhi.nrsc.gov.in/vista/index.html). The C-band radar image consists of bright area, which is caused by the reflection of raindrops in the convective precipitating system (e.g., Aleprs et al., 2016) on 30th May 2022. From this picture, it is evident that the C-band SAR image shows multiple convective rain cells. Alpers et al (2016) attributed the localized enhancement in the radar backscattering signal to the reflection of hydrometeors in the melting layer, which consists of water-coated falling ice particles and undergoes a phase transition from solid to liquid. Figure 1(c) shows an example of hydrometeor (such as grauples, hails, ice, water coated ice) contribution in the melting layer region. The example shown here is in HV polarization, which seems to be strongly associated with SAR backscattered signal from hydrometeors in the melting layer than that in HH mode (figure not shown). Brown and Robinson (1952) investigated the radar cross-polarized backscattered signal was found with more contribution from the melting layer compared to that of a single-polarized one.

Further, we have compared quasi-simultaneous observations from GMI and Ku-band precipitation radar onboard the GPM satellite to confirm our observations. Figure 1(b) & (d) shows the rain rate derived from GPM-GMI observations. The maximum rain rate observed in this case was above 30 mm/hr, which is a heavy rain rate condition. Figure 2(a) shows the spatial distribution of reflectivity from GPM Ku-band radar observations at 2km height, which is evident that the presence of packets of high reflectivity areas. These high reflectivity areas are associated with multiple convective rain cells, which was observed in the C-band SAR image (Figure 1(b)). The vertical structure of reflectivity is shown in Figure 2(b). From this picture, it is observed that the convective rain cell vertical extent was 16.5 km, and its diameter was about 50 km. Unambiguously from GPM Ku-band radar observations, the melting layer was found to be around 4.8 km in height and the maxim melting layer width was ~1.2 km. The quails-simultaneous measurements from C- band SAR and GPM depict the variability of SAR backscattered signal during low-, medium-, and heavy-rain rate conditions. In future, we will decipher between convective and stratiform rain signatures on C-band SAR imagery and the possibility between C-band backscattered signals with lighting events. Thus, the present study demonstrates the potential of C-band SAR for the signatures of convective rain cells.

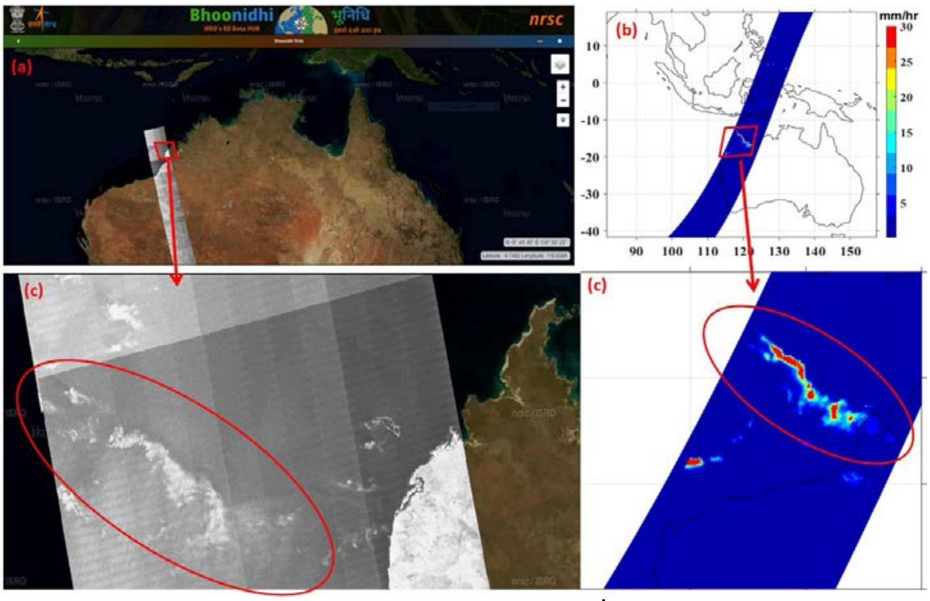

Figure 1: (a) EOS-4 C-band SAR image on 30th May 2022 and (c) zoomed, (b)&(d)GPM-GMIrainratedistribution.

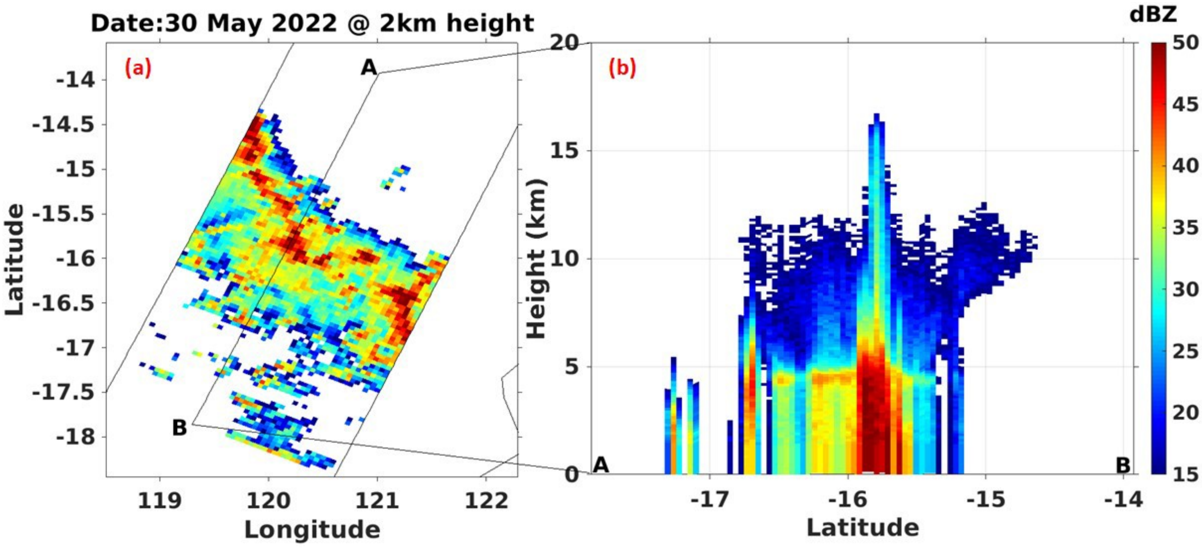

Figure 2: (a) GPM-Ku-band radar reflectivity at 2-km height, (b) vertical structure of reflectivitycorrespondinglinedrawnin(a).

Impact of COVID-19 lockdown observed on various atmospheric processes obtained using ground based, space borne and model simulations

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The lockdown measures that were taken to combat the COVID-19 pandemic minimized anthropogenic activities and created natural laboratory conditions across the globe for investigating several atmospheric processes. More than 200 papers were published across the world but mainly restricted to surface pollution and air quality. Its impact is not only seen on the surface air pollution but extended to dynamic and thermodynamic processes. In order to see effect on these processes, quality observations from the surface, ground-based and space borne remote sensing observations are utilised. Since these observations do not provide all the atmospheric parameters, WRF model simulations are also performed. Before using these simulations, they are validated/compared with ground based and satellite measurements. Both observations and WRF-Chem simulations show a 20â€“50% reduction (compared to pre-lockdown and same period of previous year) in the concentrations of most aerosols and trace gases over Northwest India, the Indo Gangetic Plain (IGP), and the Northeast Indian regions. It is observed that this was mainly due to a 70â€“80% increase in the height of the boundary layer besides the low emissions during lockdown. However, a 60â€“70% increase in the pollutants was observed over Central and South India including Arabian sea and Bay of Bengal during this period, which is attributed to natural processes. Elevated (dust) aerosol layers are transported from the Middle East and Africa via long-range transport, and a decrease in the wind speed (20-40%) causes these aerosols to stagnate, enhancing the aerosol levels over Central and Southern India. A 40â€“60% increase in relative humidity further amplified aerosol concentrations. Effect of the lockdown is also seen on the convective processes. Our results suggest that besides emissions, natural processes such as background meteorology and dynamics play a crucial role in the pollution concentrations over the Indian sub-continent. COVID-19 provided an opportunity to test this hypothesis by ceasing all major anthropogenic activities, providing the background for a large-scale natural laboratory experiment.

An analysis of LIS lightning data on-board TRMM vis-à-vis deep convective clouds detected from SAPHIR on-board Megha-Tropiques

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Human and economic loss due to lightning events all over the globe in general and over India in particular is putting more emphasis on focused studies of lightning. Lightning is one of the important climate variable (ECV) and a meteorological event that is now being categorized as serious meteorological natural hazards similar to thunderstorms, cloud bursts, flash flood etc. Like any other meteorological phenomenon lightning too require the measurements of meteorological parameters along with the accurate and efficient detection of lightning events at very high spatial and temporal resolution. Lightning event usually happens around the globe with an approximate frequency of 50 occurrences per second. Above all, its occurrence is highly localized in time domain with varied intensity. These challenges put a serious limitation on detecting lightning at regular spatial and temporal scale with a ground network. Satellites are ideal platforms and are used to detect lightning using various sensors, e.g. Lightning Imaging Sensor (LIS), Microwave Imaging Sensors, and Infrared imagers. Among all these sensors, LIS is the most accurate and sensitive for detection of lightning events. Since lightning is often associated with strong convective system therefore, the occurrence of lightning and the strength of convection in terms of cloud height required to be studied. The variation in height of deep convective system could be very well captured by microwave humidity sounders. The present study aims to analyze the lightning events detected by LIS with respect to the cloud height estimated from deep convective clouds detected by SAPHIR observations.

Lightning Imaging Sensor has been utilized to detect the lightning events (intra-cloud (IC) and cloud-to-ground (CG)) in both day and nighttime (Christian et al., 1992). The TRMM LIS monitors the 777.4 nm atomic oxygen multiplet, detecting optical pulses produced by lightning above a background levels. LIS can measure the amount, rate and radiant energy of the event with ~4 km resolution, millisecond timing with ahigh detection efficiency (Blakeslee et al., 2014) without having any land-ocean bias (Christian et al., 1992). LIS also has capability to observe the storm systems for longer periods (~ 2 minutes) to measure the lightning flash rates (Christian et al., 1992). International Space Station (ISS; drifting orbit of 407 km, 51.6° inclination) also carries a LIS onboard from 2017 onboard. The LIS has a detection efficiency of 69% and 88% during day and night, respectively (Cecil et al., 2014) Indo-French satellite Megha-Tropiques (MT) was launched in October 2011. It carried an instrument called SAPHIR (Sondeur Atmospherique du Profil d'Humidite Intertropicale par Radiometrie) that provided high temporal/spatial resolution in microwave region around 183.31 GHz. It is a cross-track radiometer. It observes the earth with a maximum scan angle of 42.96˚, a 1700 km wide swath with a footprint resolution of 10 km at nadir that elongates into a 14 km X 22 km ellipse at the edges of the swath (Clain et al., 2015). SAPHIR channels are carefully chosen, so that they are sensitive to humidity in different layers in the troposphere using six channels centered around 183.31 GHz (Kumar et al, 2018).

In the present work, LIS lightning events for May2019 are spatially and temporally collocated with SAPHIR observations in S1 (183.31±0.2 GHz), S2 (183.31±1.1 GHz), S3 (183.31±2.8 GHz), S4 (183.31±4.2 GHz) and S5 (183.31±6.8 GHz) bands. Five categories (no convection, no significant convection, convection with low height, convection with medium height, high convection, very deep convection) are generated from the collocated observations using different thresholds. The thresholds are taken from (Nizy Mathew et al. et al. 2016). The lightning events are further analyzed in terms of these categories. It has been found that most of the lightning events (~45%) belongs to very deep convection, whereas, a very small fractions of events (< 1%) belongs to no convection events. Another significant class of lightning belongs to class no significant convection (~50%). The spatial distribution of various categories is also carried out.

Surface Energy Fluxes over Ahmedabad city, India: An investigation using MERRA-2 Satellite Data and WRF-Chem Model

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Energy fluxes are considered an Essential Climate Variable. Any changes in the surface solar irradiance, resulting from the presence of reflecting and absorbing aerosols, may be balanced by changes in the surface energy fluxes. Surface Energy Fluxes are estimated in terms of Ground Heat Flux (GHF), Upward heat flux at the surface (UHF), and Latent Heat Flux (LHF) which varies spatially, diurnally as well as seasonally. Surface Energy Flux affects by multiple factors like Land Use, Land Cover, Air Pollution, and Meteorology. This study focuses on mapping surface energy fluxes with respect to anthropogenic air pollution over Ahmedabad, the fastest-growing largest city in Gujarat, India. In recent years, cause of rapid population growth; citywide resource consumption has increased resulting in high ambient air emissions dominantly Particulate Matter (PM). Power Plants, Industries, and Vehicles are major PM emissions sources of air pollution. We have simulated the Energy fluxes in the WRF-Chem model using a city-level Particulate Matter (PM) baseline inventory (2 × 2 Km grids) in a combination of the ECMWF ERA-Interim meteorological scheme for the period of May 16 to 29 and December 16 to 29, 2018. City-level Particulate Matter Inventory was developed considering the Residential, Commercial, Vehicular, Industrial, Power Plant, and Crematories as sources of air pollution. Surface Fluxes in terms of Latent Energy Flux and Sensible Heat Flux are also mapped using MERRA-2 Satellite data (M2T1NXFLX). MERRA-2 is the latest atmospheric reanalysis of the modern satellite era produced by NASA's Global Modeling and Assimilation Office (GMAO).

Using baseline PM emission as a model emission input, Diurnal variation observed that from morning to noon simulated UHF and LHF increased and reached maximum till noon. Energy fluxes follow a reducing trend till evening and almost remain constant till early morning. Simulated GHF follows the exact reverse diurnal pattern for May and December month. GHF and UHF were observed highest over the "walled city" which is located in the center of the city where the peripheral wards observed comparatively low energy fluxes. Spatial variation of the LHF follows a reverse trend than the GHF and UHF. Higher flux values were observed during the summer season than in the winter season. Energy fluxes in terms of Latent and Sensible Energy Flux were also mapped using MERRA satellites over the same period. It is observed that energy fluxes follow the same diurnal pattern as observed in model-simulated fluxes. But model overestimated the energy flux as compared to the satellite-derived fluxes. High energy fluxes were observed over heavily urban built-up areas and densely populated areas. The study results would be of great use for strengthening the heat island mitigative strategies as well as for improving the air action plan.

Estimation of land surface temperature to study urban heat island and its effect using remote sensing

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Cities often experience a distinguished climate termed the “Urban Climate”. Urban climates are characterized by differences in climatic variables (air temperature, humidity, wind speed and direction, and amount of precipitation) from those of less built-up areas. The major factors contributing to the differences are the Land use and Land cover transformations. These land use changes often includes replacement of natural surfaces with highly reflective parking lots, concrete masses, asphalt roads etc. affecting the thermal environment in cities. The urban air temperature is gradually rising in all cities in the world. One of the possible causes is the drastic reduction in the greenery area in cities. Researches show that urban places are warmer than surrounding rural environments and generally termed as “URBAN HEAT ISLAND”. Salem city of Tamil Nadu is experiencing rapid urbanization that has resulted in remarkable UHI. Understanding the distribution of Land Surface Temperature (LST) and its spatial variation will be helpful to decipher its mechanism and find out possible solution. This study tries to investigate and identify land use types which have the most influence to the increase of ambient temperature in Salem city. For the present study Landsat 8 images of 2014 was obtained from USGS for the study area. Using bands 1-9 of the pre-processed images the land use / cover pattern was mapped. The thermal band of Landsat 8 is used in identify the specific location of micro urban heat islands within the city.

Gridded Ensemble Precipitation Estimates for India

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Understanding the regional hydrological balance requires knowledge of the spatial and temporal variations in rainfall. The distribution of precipitation is vital for managing water in agriculture, producing electricity, and tracking droughts. For India's economy, rainfall during the southwest monsoon season is essential. Real-time monitoring of rainfall distribution is needed to evaluate monsoon progress and control drought or flood situations. Regional studies on the hydrological cycle, climatic variability, and model validation require high-resolution gridded rainfall data. In recent years, there has been a great deal of interest in the development of high-resolution gridded rainfall databases. Over the years, numerous algorithms and interpolation approaches have been developed to create datasets with an appropriate distribution. Existing gridded products in India include a multi-stage quality assessment and techniques such as Shepard's Interpolation method and probabilistic interpolation. Unfortunately, in data sparse regions, the skill of these techniques becomes extremely restricted or non-existent, and uncertainty information is usually unavailable. In this study we will be using an ensemble-based precipitation datasets for the Indian region along with uncertainty. The distribution of precipitation has studied using 30 different ensemble members of precipitation with 0.25-degree resolution at a daily level. We evaluate the spatial distribution of precipitation across the Indian region using estimates of the mean, median, and standard deviation of the ensembles. Here we show that the ensemble members can give a better spread of the precipitation throughout the study area and thereby we can reduce the errors in hydrological applications. The ensemble members can utilize the gauge station information as well as terrain information. Each ensemble members depict distinct information individually and are discrete in nature. Our research is expected to serve as a foundation for more complex ensemble-based products for meteorological variables over India. The produced dataset can also be used in a wide range of hydrological and meteorological applications.

Inter Sensor comparison of continental scale Land Surface Albedo derived from INSAT-3D and MODIS Sensors

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Land surface albedo (LSA) is one of the crucial parameters in general circulation models, hydrology models, numerical weather models, and surface-radiation-budget studies. It is defined as the fraction of incident solar radiation (0.3 – 4.0 µm) reflected by land surfaces (Dickinson, 1995; Liang, 2004). LSA is a key geophysical parameter that controls the energy budget in land-atmosphere interactions (Dickinson, 1983). Based on solar illumination conditions, rainfall, soil moisture, vegetation growth, snow accumulation /melting, and anthropogenic activities, LSA varies spatially and seasonally. We compared inter-sensor- derived albedo using INSAT-3D and MODIS in this study. INSAT- 3D albedo can be derived from visible and shortwave infrared channels using narrow to broadband albedo (Pandya 2022). This product allows for a clear comparison with Moderate Resolution Imaging Spectro radio meter (MODIS) bi-hemispherical albedo (white-sky albedo) MCD43C3 as a 16- day 5km gridded combined product generated from Terra and Aqua MODIS data. Over a one- year period, the analysis has to be carried out for various land cover types including vegetation, urban, water, forest, etc. The analysis shows that INSAT-3D LSA is having a good correlation with MODIS LSA over dessert with R^2 of 0.85 to 0.98. Comparison of LSA from INSAT 3D and MODIS have RMSE of 10-12%. Both products show seasonal variation and follow similar trend. However more detail study has to carry out on agricultural and forest region because of diversity of vegetation over a small region.

Study of Atmospheric Clouds using a Lidar Satellite and Reanalysis datasets over Udaipur

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Clouds are a vital component of the hydrological cycle that manifests global weather conditions. The cloud height, different layers, and cloud fraction in the atmosphere play a critical role in precipitation and regulating the Earth's energy budget. Due to scanty ground- truth observations, clouds have remained a major source of uncertainty in regional and global climate models. In this study, we investigated the cloud characteristics over a Western-Indian semi-arid region (Udaipur) using a ground-based Lidar (ceilometer) and reanalysis datasets. The ceilometer located at the Udaipur Solar Observatory (USO) main campus (24.61° N, 73.67° E) is a low-power lidar that gives cloud base heights of up to three layers simultaneously with high temporal resolution (3 seconds). It uses an InGaAs diode laser operating at centre wavelength 910 nm in pulse mode to scan cloud base heights up to about 8 km. One year's observations (2021 – 2022) are used to investigate cloud occurrence, cloud base height (CBH) statistics for different cloud layers, and variations during different seasons. A significant difference (about 800 meters and more) has been found in the cloud base height observed by Lidar and calculated from satellite-observed cloud top height (CTH). Seasonally more difference is found during monsoon when a multilayer of clouds is observed. It is found that reanalysis datasets overestimate the CBH in most of the month. These ground-based observations of cloud characteristics will be useful to validate and improve regional climate models by bridging the reliable data gaps that cause divergence in model output.

Detection of Heat wave using Land Surface Temperature products of INSAT-3D, MODIS and Meteorological Air Temperature Data over Gujarat during March 2022

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Heat wave has devastating effect on human health, economic impact, crop degradation, Forest fires and bio diversity. Increment over the years in anthropogenic activities leads to becomes heat waves which are more intense, protracted, and frequent. So, the study of heat waves is very significant and useful for development of understanding of the phenomena which causes the imbalance of earth's radiation budget and in turn contribute to the global warming and other effects. In the present study, satellite observations and air temperature data were used to identify heat wave over Gujarat region, which occurred during 15th to 17th March 2022. The Land Surface Temperature (LST) data from Indian National SATellite (INSAT-3D) imager were used for the normal days and the days of heat wave. Color Enhancement images of INSAT-3D over Gujarat region for normal and heat wave years is used to represent temperature difference [A-D]. During the heat wave, LST rose up to 322K, which resulted in severe condition in some parts of Gujarat. According to the LST analysis of various land cover types for the years 2019-2022, most of the land covers showed higher LST intensity during a heat wave. Additionally, we also conducted a qualitative analysis of the relationship between air temperature and Moderate Resolution Imaging Spectrometer (MODIS) satellite LST by fitting a linear trend line to the data for the past 15 years. It shows that there was a rise in LST in 2022. Particularly, urban region shows higher LST value of about 11 K in contrast with normal year [2]. It also describes how land covers have dynamically changed over time as well as offers helpful details regarding several aspects like urban sprawl, urban heat island effect, and anthropogenic activities in the regions which lead to changes in the energy balance of the region. A rise in daytime air temperature during the heat wave is shown by comparing the air temperature of normal years and heat wave years. We observed that the peak temperature is greater than 7K on the day of the heat wave [3]. This study highlighted the potential of satellite remote sensing as a reliable method for the analysis and detection of heat waves from the synoptic perspective as well as for understanding heat wave patterns.

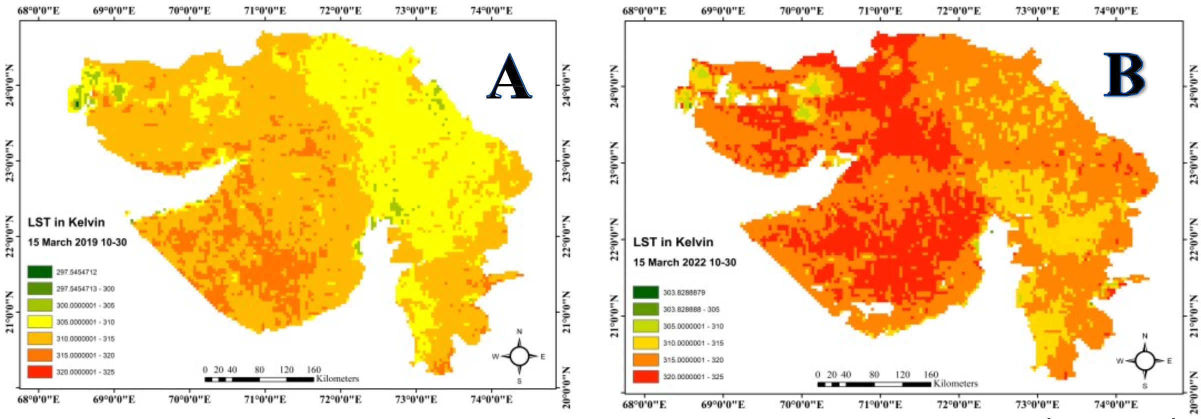

Figure 1. INSAT-3D LST for the normal (A, C) and heat wave year (B, D) of 15th and 17th March 2019 and 2022 at10:30 IST over Gujarat region.

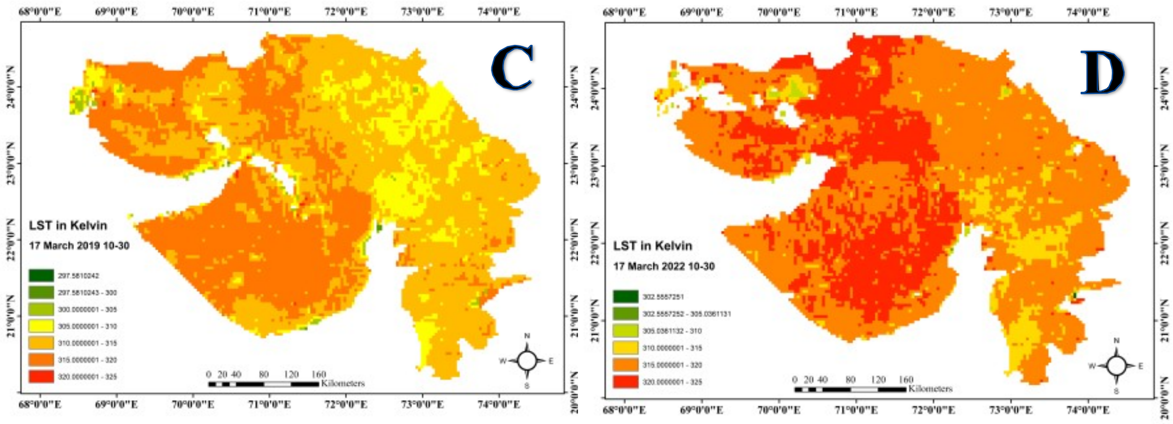

Figure 2. Time series analysis of MODIS maximum LST and average Air temperature for urban area over the central region of Gujarat for 15th March.

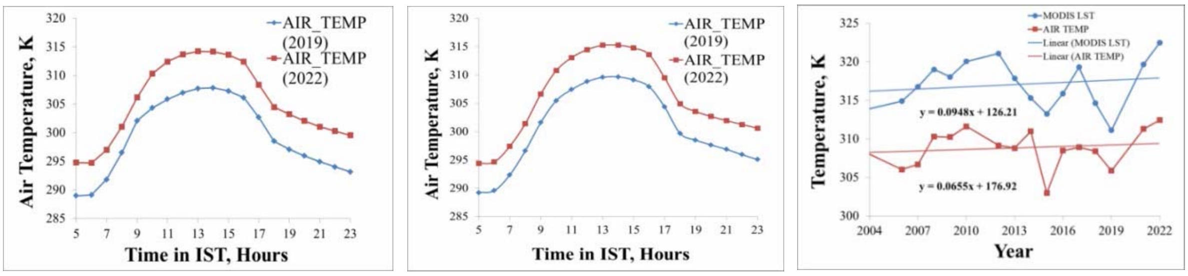

Figure3. Comparison of hourly average Air temperature of normal and heat wave years for 15th and 17th March over Ahmedabad area.

Satellite Oceanography and Blue Economy

A study on improving the accuracy of SCATSAT-1 retrieved winds using SST-dependent correction

Rajesh Sikhakolli, Prakash Chauhan
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Conventionally, Ocean surface wind vector information is retrieved from scatterometer observations assuming that the centimetre scale roughness measured by these instruments is only governed by the local winds. Accordingly, the Geophysical Model Functions are developed by relating the scatterometer system parameters, and backscatter observations with the collocated wind information. off-late, from recent studies it is observed that the scatterometer observed surface roughness is also affected by other geophysical parameters such as Sea Surface Temperature (SST). Moreover, physics-based radar backscatter model simulations have shown that the Ku-band radar backscatter measurements are more affected by the SST variations than the C-band measurements due to the fact that the dynamic viscosity of water decreases with SST, and, because viscous dissipation influences the distribution of gravity-capillary waves on the ocean surface. The SST-induced changes of short waves are predicted to be quite small at C-band, but substantial at Ku-band. In line with this, the observed SST effects are negligible at C-band, but considerable for Ku-band radar measurements. As the SCATSAT-1 scatterometer is operating in Ku-band, there is a need to check this hypothesis for any observed systematic biases due to the SST effect and to improve the quality of winds retrieved from SCATSAT-1 by applying a new correction method to overcome these SST-dependent systematic biases to make this data more suitable for long-term climate studies along with other scatterometer data sets such as QuikSCAT, ASCAT, and CFOSAT etc., Earlier analysis to understand the role of SST in the underestimation of ocean surface winds, from the SCATSAT-1 shows that significant systematic negative biases up to 0.6 m/s, especially in the southern hemisphere around 60 degrees south latitude, were observed in the SCATSAT-1 retrieved wind speed under low SST conditions and especially for wind speeds less than 8 m/s. This confirms that under low SST conditions, if the wind speed is also lower, that leads to the underestimation of backscatter and in turn leads to the underestimation of wind speed by the SCATSAT-1 scatterometer. To overcome this issue, in the present study, an attempt has been made to develop a new method for correcting the SST-dependent systematic biases using collocated SCATSAT-1 and ECMWF analysis fields. Using, one full year of SCATSAT-1 L2B wind data for 2018, a collocated database with ECMWF analysis wind speed and SST data has been prepared. Using this collocated database the wind speed bias (SCATSAT â€“ ECMWF) has been modelled as a function of SCATSAT-1 retrieved wind speed and SST bins and a look-up table (LUT) has been prepared to correct this SST dependent biases. Results from the present study clearly demonstrate that this new SST-dependent correction method is able to overcome the issue of systematic underestimation of SCASAT-1 retrieved winds under low SST regions (Systematic bias got reduced from -0.62 m/s to -0.07 m/s in the southern hemisphere) and also improves the overall accuracy of SCATSAT winds. This study also assumes importance in light of the upcoming OCENSAT-3 mission planned for launch in November 2022. As this mission is going to provide simultaneous observations of winds and SST from its SCAT-3 and SSTM payloads. Hence, we propose to use the new SST-dependent correction method developed in the present study to generate climate quality wind data from the simultaneous observations of winds and SST from OCEANSAT-3 data and in future we are also planning to reprocess the entire OSCAT and SCATSAT-1 data to generate long-term consistent climate quality wind vector information.

Evaluation of A High-Resolution Wave Modeling System for The Indian Ocean Using In-Situ and Satellite Data

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An extensive and accurate understanding of the ocean state and its prior information is very crucial for planning maritime activities and safeguarding the lives and properties of the coastal population and seafarers, who depend on the ocean for their livelihood, especially in a maritime country such as India. Development, calibration and evaluation of a reliable wave model is of utmost importance in this aspect. The main reasons for that are 1) the observational network alone cannot cater to the huge demand for ocean wave data 2) accurate short-term ocean forecasts could only be generated using deterministic models. Aiming for such an objective, a fine-resolution Indian ocean wave forecasting system was developed using the latest version of the state-of-the-art wave model WAVEWATCH III 6.07. The model was forced with 0.125-degree X 0.125-degree resolution GFS winds. The modelling system was evaluated in terms of statistical quantitative error estimates such as correlation coefficient, bias, RMS error, and scatter index using in-situ and satellite data during normal as well as cyclonic conditions. The analyses were carried out after segregating the oceanic regime into the coastal and open oceans. The results suggest that the significant wave height simulated by the model is in good agreement with the in-situ and satellite observations with a correlation coefficient above 0.9, and scatter index less than 20% at all the deep-sea locations considered. The results for the shallow water locations are also encouraging, with an error well below the reasonable limits prescribed for planning maritime operations.

Coastal Water Characteristics along Eastern Coast of Tamil Nadu, India during Northeast Monsoon Period

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PV. Nagamani, Rajashree V Bothale, Prakash Chauhan**
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National Remote Sensing Centre, Hyderabad**

A study was carried out to characterize the coastal waters along Tamil Nadu during the monsoon period of 2020 using in-situ observations. In this study, chlorophyll-a was investigated along Eastern coast of Tamilnadu at three different locations covering the Tamilnadu coast include Ennore, Cooum and Kovalam. It is observed that major number of stations fall under the category of an ultra-oligotrophic state and the remaining were oligotrophic. Similarly, the concentration of nutrients like ammonia, nitrate, nitrite, phosphate and silicate were obtained along the study area. It is inferred that the variations in chlorophyll and nutrients concentrations along the sampling stations were may be due to enrichment caused by littoral drift, domestic discharge, discharge of back waters and increased level of pollution, etc.

Detection of Floating Plastic Wastes in Coastal Water bodies using Multispectral Sentinel-2 Satellite Imagery

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1- Dr. M.G.R Educational & Research Institute, Chennai

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Plastic pollution is a severe environmental hazard to biodiversity and the marine ecosystem. Many past studies have focused on the high-level accumulation of plastics near coastal waters. The main aim of the study is to detect floating plastic wastes in coastal water bodies using sentinel-2 satellite remote sensing images. Two unsupervised (K-means and fuzzy c-means (FCM)) and two supervised (support vector regression (SVR) and semi-supervised fuzzy c- means (SFCM)) classification algorithms were used to identify floating plastics. The remote sensing data is considered as the input for unsupervised classification algorithms, whereas supervised classification techniques require in situ information on the presence/absence of floating plastics in selected Sentinel-2 grids for modeling. Data from the study area are considered to calibrate the supervised models and estimate model efficiency. Two indices (NDVI and FDI) and a combination of six bands of reflectance data (blue, green, red, red edge 2, near-infrared, and short wave infrared 1) from multiple bands of Sentinel-2 data are selected to develop the models, as they are found to be the most efficient for detecting floating plastics.

Shallow-water Bathymetry Mapping with Space-borne LiDAR

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Indian Institute of Technology, Indore

Preparation of bathymetry maps over large regions is a challenging and tedious task. The amount of in-situ data required for building models that provide acceptable accuracy is impractical to collect. But in order to aid navigation, coastal trade as well as research in the field of marine sciences and study of sub-aquatic life, bathymetry maps are a must. With the availability of open-source multi-sensor data, remote sensing provides a solution to this problem with advantages like spatially continuous data availability and multi-wavelength data acquisition.

In this work, ICESat-2 LiDAR data (532 nm), which has water penetration capability is used along with Landsat 8 optical data. Here, the relationship between LiDAR derived depth and optical reflectance is used for the preparation of bathymetry map for the Andaman and Nicobar area in India. LiDAR data is used for bathymetry photon extraction where all the points extracted are logged in a database along with their respective geo-locations. To get precise geo-locations, refraction correction is carried out to compensate for the deviation in path and miscalculation that takes place while estimating the geographical coordinates of the photon return because of the refraction at the air-water interface. The sea surface and sea bed height are calculated by binning the points extracted and applying a percentile threshold. These heights are further used for estimating the depth. The depths calculated for different geo-locations are then split into two parts for training and validation of the machine learning model.

The optical data from Landsat 8 is pre-processed which includes several steps such as re-projecting to the same coordinate system and datum for uniformity, application of land and cloud mask so as to retain only sea area, and radiometric calibration to obtain reflectance for red, green, and blue bands. After the pre-processing, a stacked database of the reflectance values is prepared. The reflectance values corresponding to the photon depths are extracted using the geographical coordinates. A training database is prepared consisting of optical reflectance and depths and is used to train an extra-trees regressor model for depth calculation on Landsat-8 data. The model training is carried out using the optical reflectance values and bathymetry photon depths.

The trained model is then used for filling in the voids since LiDAR data is discontinuous and preparation of bathymetry maps require continuous information. This model learns the relationship between reflectance and depth and predicts the depth based on optical reflectance. The results thus obtained are validated using the testing data and it is observed that the prediction is performed with minimal noise and outliers. The residuals obtained i.e. the difference between the actual and predicted values of depths, are observed to be very less. The predicted depths are used to generate a map for the study area. Hence it is concluded that this method can be employed to generate bathymetry maps for navigation as it provides continuous information over the water with considerably less error than the open source modelled maps available.

Characteristics of Ocean Internal Waves detected from EOS-04 (RISAT-1A) data

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Earth, Ocean, Atmosphere, Planetary Sciences & Applications Area
Space Applications Centre (ISRO), Ahmedabad – 380015 04 October 2022

In this study, several EOS-04 scenes which shows prominent wave features are selected and analyzed to obtain its characteristics. Primary objective of this work is to determine the wave's origin that is, whether it is an Ocean Internal Wave (OIW) or an Atmospheric Gravity Wave (AGW). Initially, EOS-04 GeoTIFF MRS datasets are processed and noise filtered using an in- house developed python-based tool. The output is then stored in NetCDF formatted files which contains backscatter coefficient, local incidence angle and azimuth angle. Subsequently, characteristics of OIWs present in the EOS-04 scenes are computed and also inter-compared with the available Sentinel-1 scenes. The wavelength of internal waves observed over Andaman Sea is found to be around 2.2 km with direction travelling towards the east coast of India at -14° angle. In order to distinguish the OIWs from AGWs, the cloud and wind pattern over the region is also analyzed using INSAT-3D/3DR images and NCMRWF analysis winds respectively. Further, we also investigate the impact of OIWs on Ocean vertical density structure and mixed layer depth using numerical model simulations. This work presents limited analysis and in future with more data availability detailed study and also the modeling of internal waves will be performed.

Monitoring biological productivity over coastal Arabian Sea as a consequence of climate change

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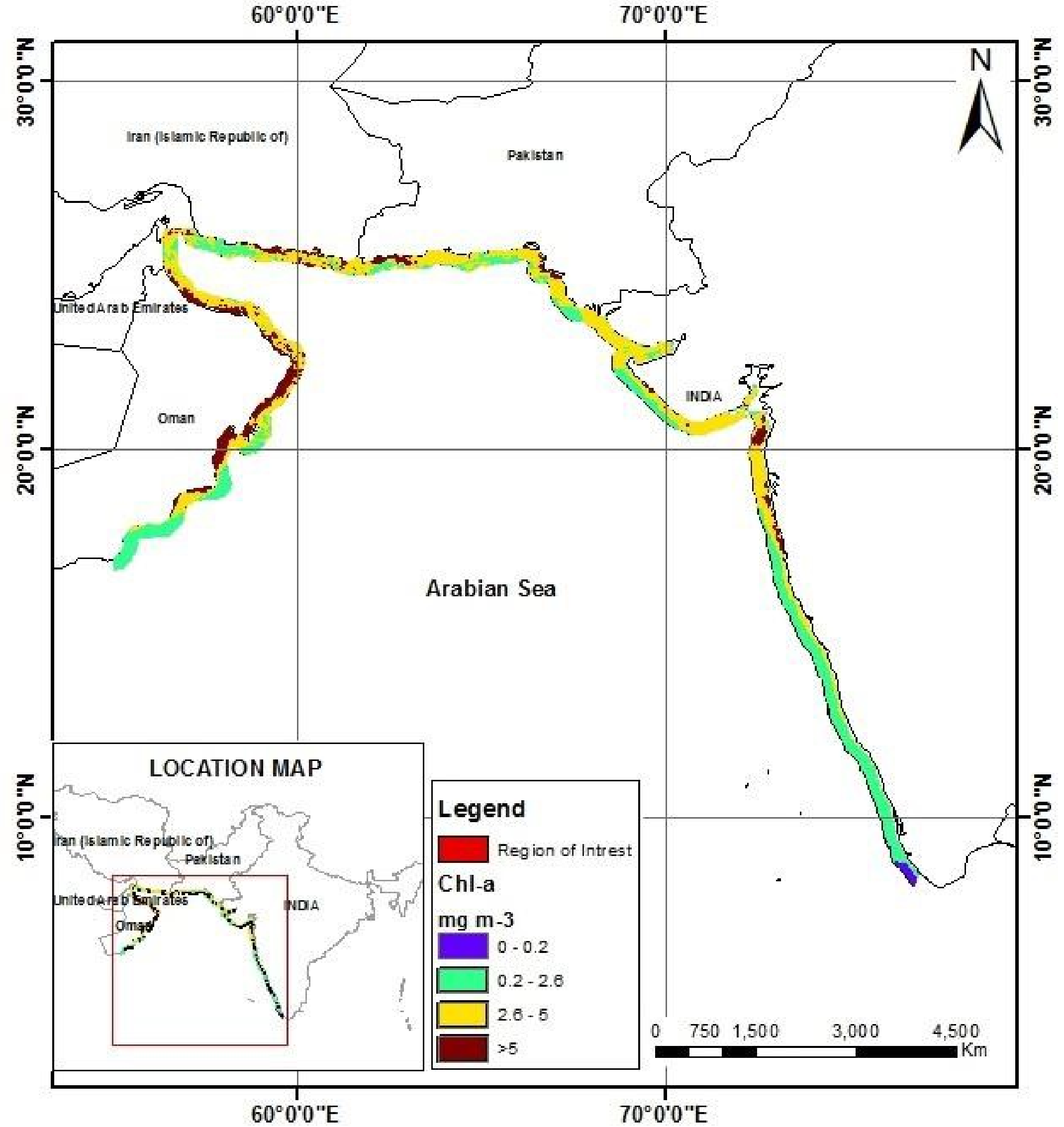
Oceans make up nearly 70% of the Earth's surface. This implies their closely packed correlation with the climate and weather of the globe. At present, climate change is one of the greatest threats to the humanity. It is not only hazardous for the environment and various ecosystems on a global level but its effects are now already being witnessed. It influences change in the breeding patterns of the flora and fauna, migration of different species, overgrowth of some species endangering others etc. The organic matter produced by phytoplankton in the ocean waters is a major component of the ocean's productivity, and plays a vital role in the carbon sequestration. However, climate change has posed a threat over it. It has been widely reported in the literature that an increase in sea surface temperature (SST) decreases oceanic productivity. Since, coastal oceans are strongly impacted by the fluxes from the land through river run-off as well as industrial discharge in addition to the changing SST, the biological productivity of coastal oceans is expected to change over the years. As a result, this study was planned to monitor the biological productivity in the coastal region of Arabian Sea over two decades (2003-2021). Here, monthly data was monitored for chlorophyll-a (Chl-a), Sea Surface Temperature (SST), diffuse attenuation coefficient at 490 nm wavelength (Kd or Kd_490) with respect to the bathymetry of the region. Chl-a data was used as a proxy to oceanic biological productivity and is intensively monitored for two seasons-winter and summer. Data products under study are from MODIS on-board Aqua. For bathymetry, General Bathymetric Chart of the Oceans (GEBCO) was used. The analysis revealed large deviation observed in the concentration of Chl-a at different locations. The linear regression is generated to evaluate the relationship between Chl-a and Kd_490. The positive relationship has been observed between Chl-a and Kd_490 with the mean value of $r^2 = 0.95$, whereas $r^2 = 0.27$ for regression between SST and Chl-a. The productivity pattern in the Arabian Sea has changed over the past 19 years, according to time series analysis of ocean color data. This change appears to be linked to the warming trends occurring across the Asian peninsula. Also, consistently high productivity of Chl-a has been observed over the Gulf of Oman.


60°0'0"E
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Iran (Islamic Republic of)
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Arabian Sea
LOCATION MAP
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Chl-a
mg m-3
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>5
0 750 1,500 3,000 4,500
Km


WINTER SEASON


SUMMER SEASON

Monitoring of Marine Microplastic using Satellite data

Abhinav Gummalla[1], Reema Mathew[1], Ramana M.V[1], P.V. Nagamani[1], Prakash Chauhan[2]

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2 National Remote Sensing Centre, Indian Space Research Organization (ISRO), Hyderabad.

Micro Plastics are plastic particles with a size of less than 5 mm. Every year humanity produces ~360 million metric tons of plastic. With Inadequate waste management, most of the plastic ends up in rivers, which will get distributed to entire global oceans. Because of wave actions & Solar UV radiation, plastic objects break down into small particles, microplastics. Plastics take anywhere between hundreds of years to thousands of years for degradation. They exist for long times in the ocean once they enter. Since, microplastics are of the same size as plankton, many marine living organisms consume microplastics, thinking of plankton. These microplastics travel through the marine food chain and also end up in human beings. The presence of microplastics in human food is already reported. The presence of these things can cause unintended and fatal consequences. So it is essential to study and monitor marine microplastics.

Traditionally microplastics are measured using plankton net trawling. However, these measurements are very time-consuming, limited in time & space and come with their shortcomings. Microplastic can travel 100 Km/day under persistent moderate wind conditions, and their concentration varies up to three orders magnitude within small regions. So it is imperative to monitor microplastics under a synoptic scale with high temporal resolution.

Space-borne active radiometers like CYGNSS measure ocean surface wind speed using Mean Square Slope (MSS), which represents ocean roughness. Microplastic present on the ocean surface acts as surface tension retardants and decreases its roughness. So for the same wind speed, roughness measured by CYGNSS is different for different microplastic concentration present. This anomaly in surface roughness measured by the satellite (MSS) is correlated to microplastic concentrations to derive marine microplastic maps.

Data used.

- GDAS NCEP reanalysis surface winds.
- CYGNSS satellite measures surface winds and MSS.
- Microplastic distributions model (Van Sebille Model)

In this study we will show the algorithm development for retrieval of marine micro plastic and preliminary results for Indian & Global regions.

Impact of Marine Heat Wave on Fish Catch along the Indian Coast

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The Marine Heat Wave (MHW) is a discrete prolonged anomalously warm water event more than 90 percentile of local climatology which persists for five days or more in specific regions (Hobday et al., 2016). In the recent decade, the frequency of extreme events has increased with the high intensity of cyclones, heavy rainfall, etc. due to climate change. The inter-annual variability of MHW led to an impact on Marine Ecology. The present study attempted to calculate the average Intensity and spread of MHW over the Arabian Sea and Bay of Bengal Basin from 2016 to 2021. In this regard, the climatological threshold (90 percentile) was estimated from the Optimum Interpolation Sea Surface Temperature (OISST) of the past 30 years. Further, the fish catch reported along at the landing centres along the west and east coast of India collected by CMFRI were used in this study to understand the impact of MHW on fisheries. The correlation between marine fish landing and the spread of MHW was established. The results revealed the negative Impact of MHW on the lead years of marine fish catch. Further, it was recorded that strong negative correlation between the percentage of MHW spread area with marine fish catch data along both east and west coast of India. This study gives us insights into possible fish catch scenarios in subsequent years in case of prolonged MHW over the basin level. The impact of MHW on the depletion of nutrients, primary productivity, Ocean eddies and thermal fronts needs to be investigated for a better understanding of the fish catch variability. However, high-frequency fish catch data is needed for further analysis and to quantify the lead period decline of fish availability after MHW events.

1

Assessment of Optical Characteristics and Trophic State of Tropical Waters Using Moderate Resolution Optical Remote Sensing Techniques

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The western coast of India is densely populated and is largely influenced by greater anthropogenic activities such as fishing, tourism, sea routes, etc. which make it prone to imbalances in water quality and eutrophication. With the increased anthropogenic activities in the recent years, eutrophication has become a serious threat to coastal waters and has expanded to open waters of Arabian sea as well. Eutrophication is nutrient enrichment in the water due to the human activities that leads to the deterioration of the coastal environment (Case 2 water) and sometimes the open ocean environment (Case 1 water). Hence, the regular spatial and temporal monitoring is required to maintain control on the water quality, for which satellite remote sensing is the widely known affordable technique. The parameters used for assessment of eutrophication for the case 1 and case 2 waters are chlorophyll (Chl-a) concentration, trophic state index (TSI) and total suspended sediments (TSS). The present study utilized the level 2 products from MODIS aqua satellite (ocencolor .gsfc.nasa.gov) to derive the Chl-a and TSS concentration. The products were obtained for the period of 10 years (2011-2021) during pre-monsoon and post-monsoon seasons. Assessment of various water quality parameters were obtained using power function equations applied on the remote sensing reflectance (rrs). Chl-a concentration along the study area was obtained from the power function algorithm using rrs(443) [Chl-a= $10^{(0.6994-2.0384X-0.456X2\ \ +0.437X2-X)}$]. For the estimation of trophic state index, Chl-a concentration dependent equation [$TSI = 2 \times ([10 \times \log(Chl\text{-}a) + 1] + 10) + 18$] was used. Remote sensing reflectance at 667 nm was used to derive turbidity as suspended sediments have highest reflectance in this wavelength. TSS concentration was calculated using turbidity with the equation, [$TSS = 1.09 \times (Turbidity)^{1.0774}$].

The analytical results showed that Chl-a concentration was high (> 4 mgm^{-3}) in both case-1 and case-2 waters during the study period with a significant increase of Chl-a in open ocean waters. This evidently shows that there is a spatial extension of high Chl-a concentration to open waters. During both the seasons, the TSI ranged between 70-75 (except during 2019), indicating the eutrophic and hypereutrophic state of the coastal area as well open ocean water. The TSS concentration was found between 1-3.5 mg/L. The higher TSS concentration was reported in case-2 water than the case-1 water, showing the impact of anthropogenic activities in the coastal areas. Conclusively, it is evident from the study that, there is a prominent seasonal variability in chlorophyll-a concentration, trophic state index and total suspended sediments at both coastal waters and open waters. Variability in wind pattern, monsoon, terrestrial runoff, circulation pattern, sediment deposition in coasts, anthropogenic activities like aquaculture are the plausible factors resulted in the observed variability in Chl-a, TSI and TSS at different spatial and temporal scales. The assessment showed that both case 1 and case 2 (coastal and open sea) waters of the selected study region are in hypereutrophic stage, making water potentially unfit for fishing and recreation purposes, with limiting light penetration, increase in algae, decrease in oxygen concentration

and reducing water quality. Further, time series studies using high-resolution spatial datasets are inevitable to understand the spatio-temporal variability of these parameters in detail, so that flawless sustainable coastal management plans can be derived.

Bio-Optical Properties and Phytoplankton Size Classes of Cochin Estuary during Southwest Monsoon

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The performance of the global ocean colour for phytoplankton size cells (PSCs) is a research problem due to the lack of ground truth data and complexity in Indian coastal and inland waters. The goal of the current research is to study how optically active substances (OAS) and PSCs modify the spectral remote-sensing reflectance (RRS) in Cochin Back waters during SW monsoon. High spatial variability was observed in the chlorophyll a (Chl-a) concentration and showed typical case 2 characteristics with a larger influence of Coloured Dissolved Organic matter (CDOM) and TSM in the underwater light field. The micro size fraction of the plankton was dominant during the period with a good relation with total Chl-a (R^2=0.79) and it influenced the spectral characteristics of the Rrs. For the improvement of the retrieval algorithm of PSCs in the Cochin backwaters, the influence of size fraction on reflectance needs to be further investigated.

1. Introduction

Phytoplankton is microscopic single-celled plankton that can perform photosynthesis and is present in freshwater, oceans, and lakes. Since estuaries get a steady supply of nutrients from rivers and other land-based discharges, serve as the nursery grounds for phytoplankton growth (Neill, 2005). In addition to phytoplankton and its by-products, other optically active substances, (Moore et al., 2014, Barnes et al., 2014, Sun et al., 2014) such as particles in suspension and Coloured Dissolved Organic matter (CDOM) also have an impact on coastal waters biogeochemistry and light availability (Blondeau-patissier et al., 2017, Menon et al., 2011, Tilstone et al., 2012, Brezonik et al., 2015). Also, phytoplankton's size class (PSC) has a significant impact on underwater light field, trophic levels interactions and biogeochemical cycling. The remote estimation of the size fraction in the estuarine system is still a scientific question to be addressed. A study was conducted in the Cochin estuary with the objectives (1) to understand the influence of CDOM and TSM in the Rrs components (2) to study the variability of size-fractionated phytoplankton biomass and its influence of Rrs.

2. Methedology

Samples from Cochin estuary were collected from 12 locations in Cochin Back Water (CBW) during south west monsoon season (August 2022). Dissolved oxygen (DO) and nutrients (ammonia, nitrate, nitrite, phosphate and silicate) were analysed using standard protocols (Grasshoff, 1983). Phytoplankton size class (PSC) pigments (Chl a) divided into macro phytoplankton, micro phytoplankton, nanophytoplankton, and picophytoplankton were determined by sequential filtering (Luke Auman Basset,2015) and the pigment concentration was determined using a fluorometer (Fluorometer, Turner 10 AU). Remote sensing reflectance (Rrs) were measured using Satlantic Hyperspectral Radiometer.

3. Result and discussion

The regular mixing of freshwater and seawater in estuaries results in a variety of physio-chemical changes that affect the water quality of the Cochin estuarine systems. Surface water temperature varied from 25.5 to 28.8°C during the study period. The pH and salinity of the water samples varied from 6.54 to 7.32, 0.052 to 6.87psu respectively. The surface salinity during monsoon was very low in CBW due to the high volume of fresh water received from 6 rivers (George, B. et.al, 2012). Ammonia, Phosphate, Nitrate and Nitrite varied from 8.68 to 51.14 µmol/L, 0.64 to 10.5 µmol/L, 4.87 to 34.63 µmol/L and 0.02 to 1.19µmol/L respectively.

The concentration of surface Chl-a varied from 0.46 to 4.11 mg/m^3 in CBW during monsoon. Maximum concentration of chlorophyll a (4.11ug/l) was recorded in the Njarakkal whereas the minimum (0.069 ug/l) was observed in the Murinjapuzha. The concentration of surface CDOM varied from 3.99 to 13.60QSDE with an average value of 9.06±2.58 QSDE. The concentration of TSM varies from 3. 0 to 74.67 mg/L with an average of 21.11±22.61 mg/L. TSM of stations near to barmouth regions showed a good correlation with Chl-a (R^2=0.82, N=4) and salinity (R^2=0.73, N=4) respectively. Among the near coastal stations, CDOM showed a negative corelation with salinity (R^2=0.6, N=4) and positive corelation with Chl-a (R^2= 0.52, N=12). This showed freshwater brings terrestrial CDOM and phytoplankton derived CDOM were dominant in the cochin estuary (Vishnu et al 2018). Micro phytoplankton dominated during monsoon in the CBWs. Kalamukku station had highest abundance of microplankton (3.30 mg/m^3). Macro, Micro and Nano fractions of phytoplankton showed good correlation with Chl- a (R^2=0.790, 0.757 0.609, N=12 respectively). The picophytoplankton abundance was low during the monsoon period (0.004±0.013 mg/m^3). The Rrs spectra showed a peak in the blue (466 nm) and green regions (588 nm). The effect of Optically Active Substances on spectral remote-sensing reflectance (Rrs), was observed and the bigger plankton showed an influence in the blue region of the reflectance.

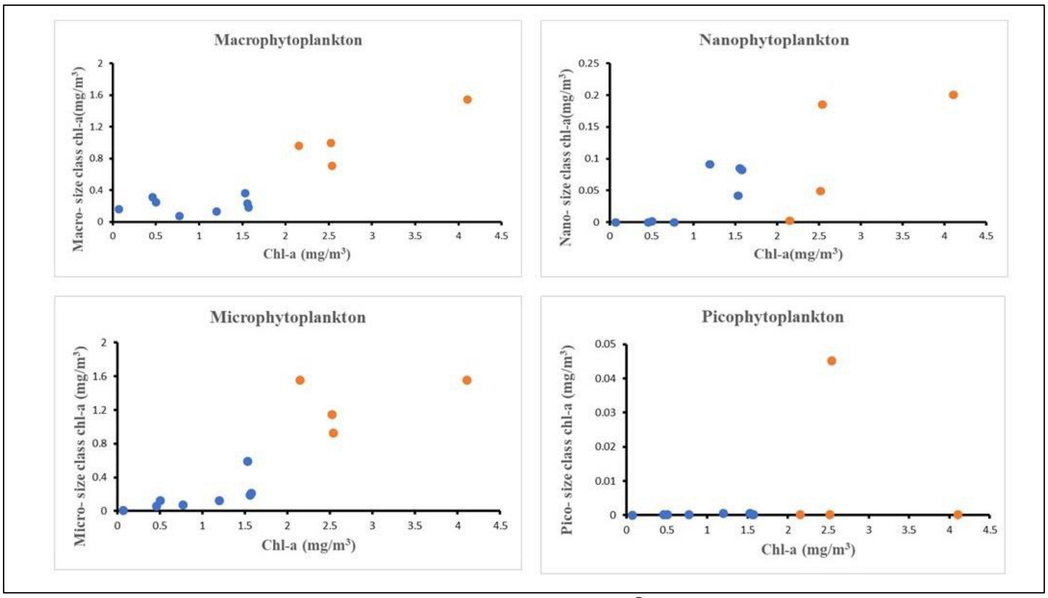

Fig.1. Distribution of biomass (Chlorophyll-a mg/m^3) of various phytoplankton size class(Macro-, Micro-, Nano-, Pico-) in the Cochin Estuary during SW monsoon.

4. Conclusion

OAS fluctuation in the study area was linked to freshwater discharge and sea water intrusion, particularly during the southwest monsoon. Chl-a was the main element in the OAS and the phytoplankton size class (PSC) fractions have an important role in the spectral characteristic of Rrs. The effect of PSC fraction on the reflectance has to studied further for the accurate retrieval algorithms in the CBW.

Review of Shallow Water Bathymetry Estimation using different Techniques from Optical Sensor Data off the Visakhapatnam

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The accurate information about the depth of the water (bathymetry) in shallow coastal region is very much important for marine navigation, coastal engineering and marine ecosystem conservation. Since the traditional way of echo sounder based bathymetric survey has very high operational cost and is subject to navigation safety, remote sensing based methods are a viable option. In the current study, two different techniques for estimation of shallow water bathymetry from optical data of Sentinel-2 MSI are applied and the results are evaluated using in situ bathymetry data collected off the coast of Visakhapatnam, Andhra Pradesh. The first technique is using the Stumpfâ€™s linear regression algorithm, which is based on the difference in shallow water bottom reflectance of two different wavelength bands depending on the depth and benthic type (Stumpf Model).The second technique is utilising the linear wave dispersion theory, which says that in the near coast domain where the water depth is less than half of the swell wavelength, as the swell wave reaches the shallower water, the wavelength and wave celerity decreases as a result of decrease in bottom depth (Shoaling Effect). The Stumpf model, which require in situ depth measurements to tune the algorithm, gives the bathymetric map in the native resolution of the satellite data. Whereas the bathymetric map generated utilising the Shoaling effect is of coarser resolution, but it does not require any in situ measurements.

Estimating Temporal and Spatial Variations of Partial pressure of Carbon dioxide from Remotely Sensed Biogeochemical and Bio-optical Parameters

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The partial pressure of carbon dioxide (pCO^2) in estuarine systems is strongly influenced by biogeochemical inputs from the land, physical variables and bio-optical parameters. Remotely sensed variables are often used in pCO^2 estimation. Remotely sensed Chlorophyll-a concentration is an indicator of biological activities in water, temperature has a role in determining the solubility of CO^2 and has been frequently used to estimate pCO^2 from remote sensing images. In addition to this, bacterial respiration produces CO^2 by the process of decomposing dissolved organic matter (DOM). Thus, absorption by coloured dissolved organic matter (aCDOM) retrieved from satellite remote sensing images also contributes in estimating pCO2. In addition to these, physical parameters such as salinity and pH also plays major role. Although open oceans act as the major sink for atmospheric CO^2, the role of estuaries need to be explored. Studies on seasonal variations in pCO^2 were performed in some of the Indian estuaries such as Hoogli, Mandovi, Mahanadi etc. All these studies conclude that variations in pCO^2 are wider in Indian estuaries. This in turn marks the importance of conducting continuous scientific studies in order to explicate their role in atmospheric carbon dioxide emission. Cochin backwaters is situated between the latitudes$\sim$ 9.50^0N–10.10^0N and longitudes 76.10^0E–76.50^0E, along the southwest coast of India, extending parallel to the coast from Munambam in the north to Alappuzha in the south, in the state of Kerala. Previous studies showed that the freshwater stations in the estuary have lower pCO^2 levels except during south west monsoon, with corresponding high pH values, compared with the outermost stations. It also portrayed the strong spatial heterogeneity and patchy distribution of the aquatic carbon parameters within the Cochin backwaters. The current study aims at estimating the temporal and spatial variations of pCO^2 from remotely sensed biogeochemical and bio-optical parameters. The knowledge about these spatially and temporally varying variables influencing the pCO^2 estimation can also shed light on the heterogeneities in the biogeochemical and physical processes steering the carbon cycling in the Cochin estuary and can serve as a strong basis for future pCO^2 estimation in the area using remote sensing techniques.

Role of Geophysical Parameters in Influencing the Activity of Atlantic Ocean Hurricanes

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Hurricanes are one of the most extreme weather events, posing great threat to life and society of the coastal regions. There has been a steep rise in the activity of hurricanes in the global ocean basins during the last 30 years, either in terms of genesis frequency or intensification trends. The North Atlantic Ocean (NAO) basin has experienced an enhanced number of hurricanes since 1991, where a hurricane season spans a period from April to November. Two out of the three most active Atlantic hurricane seasons (AHS) are during this period. With 30 named storms, the recent 2020 AHS was the most active season on record. This season experienced 14 hurricanes of categories 1 and 2, and 7 hurricanes of categories 3, 4 and 5. The present study investigated the local meteorological and oceanographic conditions of the North Atlantic main development region (MDR) during the 2020 AHS to probe into the state of the environment conducive to cyclogenesis. Results showed the MDR environment to be highly favourable for cyclogenesis, which resulted in the simultaneous existence of five storms in the basin during September 2020. The study further analysed the impact of several major meteorological and oceanographic parameters on modulating the hurricane activity in the basin for the 1991-2020 period using statistical methods such as multiple linear regression and wavelet local multiple correlation. Sea surface temperature difference between the MDR region and the global tropical oceans, termed as differential SST, was found to be the major parameter influencing hurricane frequency in the basin. However, with a closer look at the intra-seasonal variability, low-level relative vorticity was observed to have more influence during Septembers for the period 1991-2020. Vertical wind shear was found to have the least influence on modulating the hurricane activity in the basin. Further work is being carried out to isolate the inherent variability in major met-ocean parameters influencing hurricane activity in the NAO basin and its evolution and risk assessment in the future climate change scenarios.

Seasonal Dynamics of Chlorophyll Concentration in the North Indian Ocean based on Satellite Observations and Numerical Model

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Phytoplankton is a microscopic autotrophic organism that lives in the upper sunlit layer of the oceans which contains green pigments, Chlorophyll that allows absorbing sunlight mostly in blue and green bands for photosynthesis. They are primary producers responsible for maintaining the food web in the aquatic ecosystem and play a significant role in the uptake of the atmospheric carbon dioxide (CO_2) in the oceans. Satellite-measured data have been the primary source of information for the characterization of Chl-a seasonal and inter-annual variability over the regional and global oceans. The present study aims to investigate seasonal dynamics of Chlorophyll-a concentration (Chl-a) in different biogeographic regions of the north Indian Ocean (NIO) based on satellite observation and simulated ocean state from Regional Ocean Modeling System coupled with the biogeochemical flux module (ROMS-BGC). Satellite observations were taken from the Moderate-resolution Imaging Spectroradiometer (MODIS) and Ocean Color Monitor 2 during 2010-2020. However, the satellite observations are subjected to the limitations of spatial and temporal data gaps and differences in radiometric uncertainty and sensing capability; they show reasonable agreements between them in describing known seasonal variability in the study domain. The number density of non-missing data points available for this study primarily varied in the range of 40-80% for OCM2 compared to a relatively higher number density (>60%) for MODIS. Although the frequency distribution of OCM2 Chl-a exhibits left-skewed Gaussian distribution similar to the MODIS across coastal and open ocean domains, they differ significantly from each other with a relatively higher mean and standard deviation for OCM2 than that of the MODIS. On the other hand, all the data sets are highly coherent in terms of the spatial patterns of annual and semi-annual harmonics and their climatological mean. These coherent features with constant high and low values and physical and chemical properties describe different ecological provinces in the regional domains of the study region. The mean climatology of Chl-a describes distinct regions of maxima and minima with large amplitude in the north and western parts of the Arabian Sea, northern Bay of Bengal, and continental shelf domains around India, open ocean domain adjacent to the Somali coast, south of Sri Lanka, and Lakshadweep Sea. In contrast, the open ocean domains of the Arabian Sea and Bay of Bengal and the Equatorial Oceanic domain have reduced Chl-a concentration. The regions of high climatological mean Chl-a show intense seasonal and inter- annual variability. The seasonal cycle of Chl-a has strong spatial coherence with abundant nutrients. Analysis of the simulated ocean state from the ROMS suggests that the coastal upwelling is the primary cause of the seasonal dynamic of micro-nutrient in the highly productive zones such as the regional oceans off the coast of Kerala, Tamil Nadu, and Sri Lana and the south-western Arabian Sea around Somalia. It plays a secondary role in the northwest Arabian Sea. On the other hand, monsoon-driven coastal and estuarine circulation and associated terrestrial-originated nutrient influxes into the ocean play a significant role in the control of seasonality of Chl-a in the north-eastern Arabian Sea towards the Gulf of Khambhat and Kutch and the northern Bay of Bengal. Further a few controlled experiments with the ROMS-BGC have been performed to understand the relationship among ocean circulation, nutrient dynamics and phytoplankton evolution towards the variability of Chl-a.

Performance of the MODIS nFLH algorithm in Coastal and Open Ocean waters from period 2012-2018: A Case Study

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Although satellite technology promises great usefulness for the consistent monitoring of chlorophyll-*a* concentration in coastal and open ocean waters, the complex optical properties commonly found in these types of waters seriously challenge the application of this technology. Blue–green ratio algorithms are susceptible to interference from water constituents, different from phytoplankton, which dominate the remote-sensing signal. Alternatively, modelling and laboratory studies have shown a non decisive posi- tion on the use of near-infrared (NIR) algorithms based on the sun-induced chlorophyll fluorescence signal. In an analysis of a *in situ* monitoring data set from 2012 to 2018 at Coastal and openwaters as a case, this study assesses the relation- ship between the normalized fluorescence line height (nFLH) from the Moderate Resolution Imaging Spectrometer (MODIS) and chlorophyll-*a*. The determination coefficient (r^2) at individual sites, highest 0.83 (n = 20, $p < 0.01$) at Kakinada coastal waters in 2018. Overall, there was low relationship between *in situ* chlorophyll-*a* and nFLH ($r^2 = 0.30$, $n = 15$) at Fraserganj coastal waters in 2016. Nevertheless, the low determination coefficient obtained was still three times higher than that between *in situ* chlorophyll-*a* and OC3M, the standard product traditionally used to estimate chlorophyll-*a* in ocean waters, which is based on the blue–green section of the spectrum. A better relationship of $r^2 = 0.73$ ($n = 20$) was obtained at Arabain Sea open waters. Although these results from coastal and open waters did not demonstrate a consistent spatial applicability of MODIS nFLH, a few good determination coefficients found in particular sites (*r*2 = 0.52, 0.51; n = 32, 100) show that good relationships can be achieved.

Identification of the Southwestern Bay of Bengal Coastal Upwelling Zone using Clustering

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IIT Bhubaneswar

Potential fishing zones (PFZs) are traditionally identified on the basis of sea surface temperature (SST) and surface chlorophyll (Chl) concentration data. More specifically, regions with large horizontal gradients of SST, along with higher chlorophyll concentrations, are known to be associated with comparatively higher fish catch. However, the nearly year-round presence of clouds limits the availability of Chl and accurate SST observations over the Bay of Bengal (BoB) region. This problem is most prominent during the southwest monsoon (SWM,) which also happens to be the peak coastal upwelling season along the western BoB. Coastal upwelling is known to produce ideal conditions for supporting PFZs (coastal SST gradients and high Chl concentrations) with the major coastal upwelling systems (Eastern boundary upwelling systems) associated with tremendous amounts of productivity. Synergistic approaches relying on different satellite observed data (including sea level anomaly and ocean surface winds, in addition to SST and Chl) and numerical models have been utilized to overcome the limitations mentioned previously. In the present analysis, we aim to develop a similar approach (based on multiple reanalysis datasets) to identify the offshore extent of the coastal upwelling region in the southwestern BoB using a clustering method. In turn, the identification of the extent of coastal upwelling will enable the determination of the precise location of the coastal upwelling front and temporal variations in its intensity.

Site suitability modeling for coral recruits with reference to calcareous algae in selected locations in Palk Bay region

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Recruitment is an important factor controlling the population dynamics of corals and plays a major role in promoting the recovery of degraded coral reefs and maintaining healthy coral populations within ecosystem. The study carried out to identify the suitable sites for coral recruitments using *in-situ* and remote sensing data. Six stations namely Vedhalai (S1-VDL), Mandapam (S2-MND), Vilunditheertham (S3-VLT), Ariyankundu (S4-ARY), Vadakadu (S5-VDK), and Olaikuda (S6-OLK) in Palk Bay were selected for the study based on the live coral cover. Major coral reef forms were recorded using standard protocol with physico-chemical parameters such as pH, salinity, dissolved oxygen, and depth for the model creation. Sea surface temperature, PAR and chlorophyll were obtained from ocean color web portal. The recruitment density was high in S6 followed by S5, S3, S4, S2 and S1 (Fig. 1).

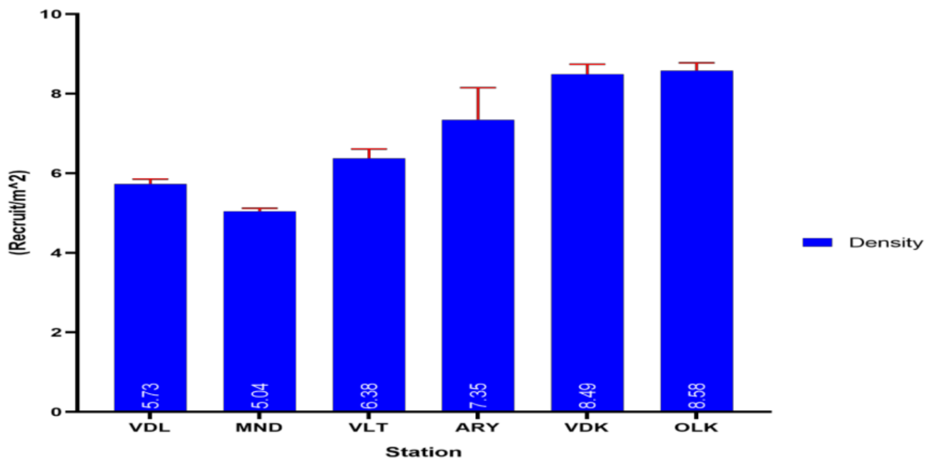

Fig.1 Recruitment density in the selected sites of Palk Bay

The recruitment with reference to substratum and life forms depicts that mostly digitate, tabular and acropora branching forms were dominant and the similarity of 57.67% found in S6 and S5. Substratum preference by the coral recruits varies with the availability of coralline crustose algae. The model was developed using the weighted overlay analysis (Fig. 2) and input parameter weightage was derived from PCA.

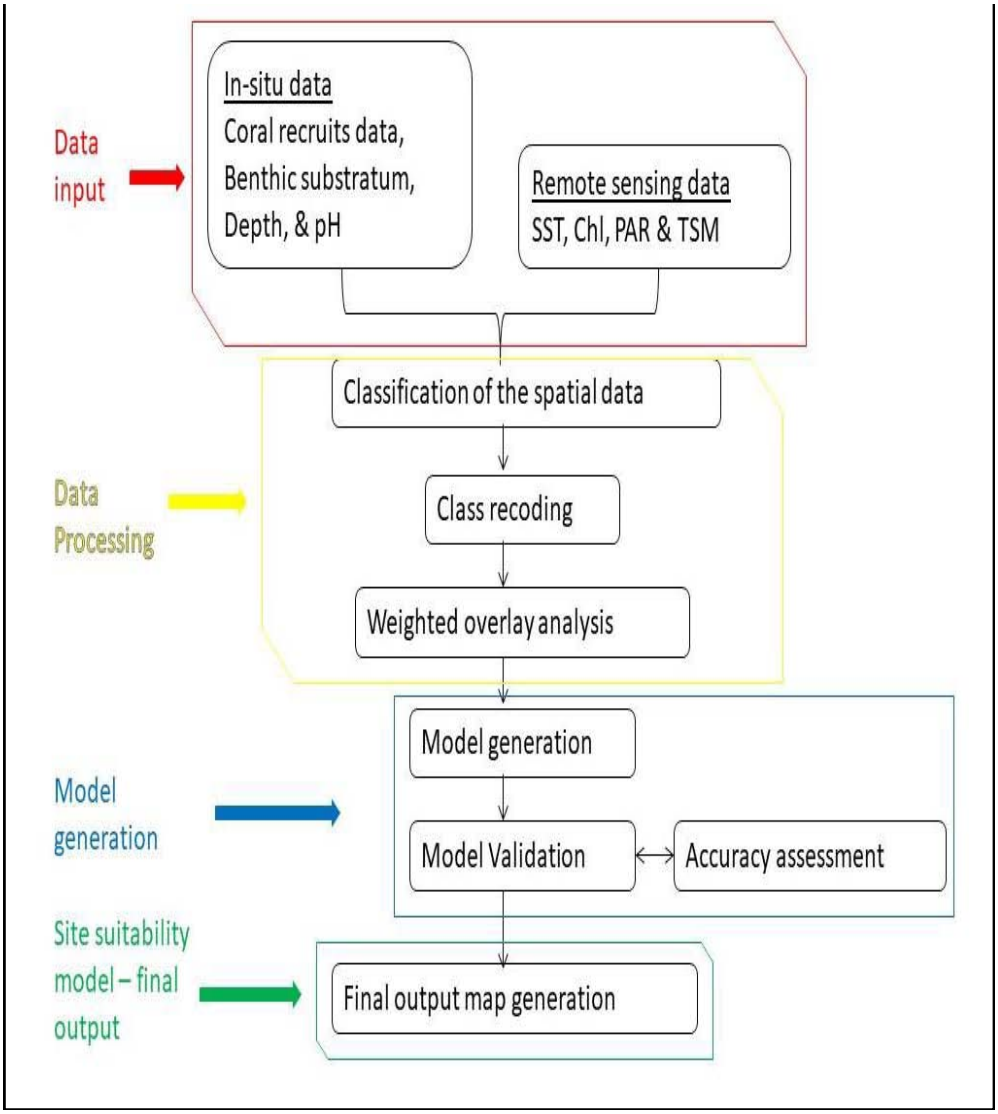

Fig 2. Flow chart of the method

The result indicates S6 and S5 were highly suitable for coral recruits than other stations. The model has validated with ground truth assessment. Continuous monitoring is required to ensure the model accuracy for conservation and restoration. This model can be used for regional authorities for coral reef management.

Touching the Untouched: Implications of geospatial tools in mapping the reservoirs for fisheries development

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Reservoirs have tremendous fisheries potential amongst the inland water resources and aptly referred as â€˜sleeping giantsâ€™, as the fish yield potential of these resources are yet to be tapped. Existing gaps in the availability of absolute information and data on the inland water resources hinder the applicability and implementation of various fisheries development programmes, which in turn impact inland fisheries production. The present study was carried out on the reservoirs, viz., Sri Ram Sagar, Kaddam, and Swarna from the Godavari Basin, covering the period 2016-2021, as a case study to demonstrate the use of remote sensed data in fisheries stock enhancement planning. The perennial and seasonal water spread area of reservoirs under study was estimated through composite water maps prepared using Sentinel 2A data ranged between 8 to 19% and 4 to 29%, respectively. Further, the potential area for enclosure fish culture (both cage and pen culture) in these reservoirs were found to range between 14.89% (Sir Ram Sagar) to 48.54% (Kaddam). The field validated results revealed less than 0.1% of the perennial water spread area mapped in these reservoirs is under use for cage culture This highlights under-utilization of these reservoirs and demonstrates scope for developing the enclosure fish culture or other culture-based fisheries for enhancing the fish production. The study also demonstrates the use of geospatial tools in development planning for expanding enclosure fish culture in the reservoirs and in turn enhancing fisheries production from the reservoirs in India.

Advanced Future Technologies for EO Missions

Secured Communication between Satellite Network Links

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The rapid growth of online communication has increased the demand for secure communication. Most government entities, healthcare providers, the legal sector, ï¬nancial and banking, and other industries are vulnerable to information security issues. Text steganography is one way to secure communication by hiding secret messages in the cover text. Hiding a large amount of secret information without raising the attackerâ€™s suspicion is the main challenge in steganography. Due to the presence of the wireless medium, SATCOMs are more prone to impersonation attacks. To mitigate this problem, various authentication protocols have been proposed in this project. Most communications between government, companies, ministries, and individuals are being transformed from physical to online. Secure communication is an imperative to protect sensitive information transmitted through the Internet. The emergence of new manufacturing processes and radio technologies promises to reduce service costs while guaranteeing outstanding communication latency, available bandwidth, flexibility, and coverage range. On the other hand, cyber security techniques and solutions applied in SATCOM links should be updated to reflect the substantial advancements in attacker capabilities characterizing the last two decades. However, business urgency and opportunities are leading operators towards challenging system trade-offs, resulting in an increased attack surface and a general relaxation of the available security services. I. Security of the Satellite to Satellite Communication Links Due to the wireless nature of such communications, attacks on these links are both possible and potentially dreadful, as they can disrupt the availability of a SATCOM by just affecting the operation of a single link. II. Information Hiding: Information hiding refers to hiding secret messages in a digital medium such as video, audio, image, and text. Watermarking and steganography are considered to be information hiding techniques. Watermarking is the method of hiding a single or dual watermark in a cover text in the form of a tag, label, or digital signal. III. Text steganography: Text steganography provides a secure communication channel by hiding the secret message in text to be delivered safely through the public channel. But still the security can be increased against statistical attacks by creating a strong STEGO key. This project fetches the information from the user by using normal computer keyboard. The userâ€™s input is then encrypted as cipher text and transmitted to LoRa. The data received by LoRa is then decrypted as plain text. The plain text is been saved as a STEGO key and transmitted to satellite (internet).

NISAR: Mission Updates and Science Plan

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The NASA–ISRO L & S band Synthetic Aperture Radar (NISAR) mission is a partnership between NASA and ISRO, currently scheduled to launch in January 2024 and to have a minimum mission lifetime of three years. The mission is optimized with high resolution imaging (3-10 meters), wide swath (240 km), high precision pointing and orbit control and short revisit period (12days) with polarimetry and interferometry for studying hazards and global environmental change, specifically in support of its core science disciplines: Ecosystems, Cryosphere, Land Deformation and Coastal Ocean. Some of the important mission and instrument parameters are shown in Figure 1. The satellite is designed to provide a detailed view of the Earth to observe and measure some of the planet's most complex processes, including ecosystem disturbances, glaciers and ice-sheet dynamics, seismic induced land deformations, coastal process dynamics and natural hazards. In addition to its science requirements, the mission has a requirement to be capable of supporting disaster response through expedited event-driven downlinking, processing, and delivery of relevant data.

NISAR data products will be structured as Level-0, 1, 2, 3 and 4. Raw radar signal data is assigned as level-0 product. Single Look Complex (SLC), Multi-Look Detected (MLD), phase unwrapped (UNW) and wrapped nearest-time interferograms (IFG), and polarimetric covariance images (COV) are defined as level-1 products, Geocoded products as level-2 products and large area mosaics of radiometric terrain corrected images as level-3 products. In addition to these basic products, number of science products in physical units will also be developed and provided to the users as level-4 products. NISAR has an open data policy where all data products will be provided freely to the public through ISRO (NRSC Bhoonidhi) and NASA (ASF DAAC) and portals.

Parameters	S-band	L-band
Orbit	747 km with 98° inclination (Polar Sun-synchronous)	
Repeat Cycle	12 days	
Time of Nodal Crossing	6 AM / 6 PM (dawn-to-dusk orbit)	
Frequency	3.2 GHz ± 37.5 MHz	1.257 GHz ± 40 MHz
Wavelength	9 cm	24 cm
Polarimetric Modes	Single, Dual, Quasi-Quad, hybrid Circular Pol (in S-band only), and Quad Pol (in L-band only)	
Range Bandwidths	10, 25, 37.5, 75 MHz	5, 20+5, 40+5, 80 MHz
Swath Width	> 240 Km (except for S-band QQP Mode and L-band 80 MHz BW mode)	
Spatial Resolution	6.5m (Az); 2m-15m (Slant-Ra)	7m (Az); 2m-30m (Slant-Ra)
Incidence Angle Range	33 – 47 deg	33 – 47 deg
Noise Equivalent σ^o	Better than -25 dB	
Pointing	Left (South), capability exists for left/right pointing	
Pointing Control	< 273 arc seconds	
Orbit Control	< 500 meters	
Data Policy	Free & open access	
Mission Duration	3 years science operations (5 years consumables)	

Figure 1. NISAR: Major mission and instrument characteristics

The NISAR science observation plan is designed to tackle the science questions posed by persistent and consistent imaging of Earth's land and ice surfaces throughout the life of the mission, delivering time series of approximately 30 images per year from both ascending and descending vantage points. NISAR will be operated with a predefined observation plan and the plan will be revisited every 6 months to review the successes of the observations to date and adjust as necessary to optimize. A typical observation scenario of NISAR over a 12-day observation cycle is shown in Figure 2. At present, the project is considering a left-only mode of operation to better optimize science return by uninterrupted coverage of Antarctica up to 87.5°S latitude and sacrificing the coverage of Arctic beyond 77.5°N latitude, with the expectation that other international missions will continue to provide science observations in the Arctic regions. While L-band data are planned over all land regions over the globe, S-band data are planned over the South Asia, Antarctica, regions in the Arctic such as Greenland and Beaufort sea and a few global cal/val sites.

Modes coverage Legend	
S(VV+VH) 10 MHz	
S(CP) 25 MHz	
S (HH) 37.5MHz	
S (HH+HV) 25MHz	
L(HH+HV) 20+5 MHz	
L(QQ) 20+5 MHz	
L(VV) 80 MHz Half swath	
L(HH) 40+5 MHz	
L(HH) 20+5 MHz	
L(VV) 5 MHz	
L(HH+VV) 5 MHz	
L(VV+VH) 20+5 MHz	
L(HH+HV) 40+5 MHz	
L(QQ) 40+5 MHz	
L(QP) 40+5 MHz	
L(VV+VH) 5 MHz	
L(HH+HV) 20+5 MHz; S (HH+HV) 37.5 MHz	
L(VV+VH) 20+5 MHz; S (CP) 25 MHz	
L(HH+HV) 40+5 MHz; S (CP) 37.5 MHz	
L(QP) 40+5 MHz; S (CP) 25 MHz	
L(VV+VH) 5 MHz; S (CP) 25 MHz	
L(VV+VH) 5 MHz; S (VV+VH) 10 MHz	
L(HH) 40+5 MHz; S (CP) 25 MHz	
L(VV) 5 MHz; S (CP) 25 MHz	
L(VV+VH) 20+5 MHz; S (CP) 37.5 MHz	
L(HH+HV) 40+5 MHz; S (HH) 75 MHz	
L(QQ) 20+5 MHz; S (HH+HV) 25 MHz	
L(HH) 20+5 MHz; S (HH+HV) 25 MHz	
L(HH+HV) 40+5 MHz; S (HH+HV) 25 MHz	
L(QQ) 40+5 MHz; S (HH+HV) 25MHz	
L(QP) 20+5 MHz; S (HH+HV) 25MHz	
L(HH) 77 MHz; S (HH) 37.5 MHz	
L(HH) 40+5 MHz; S (HH) 37.5 MHz	
L(HH+HV) 40+5 MHz; S (VV+VH) 10 MHz	

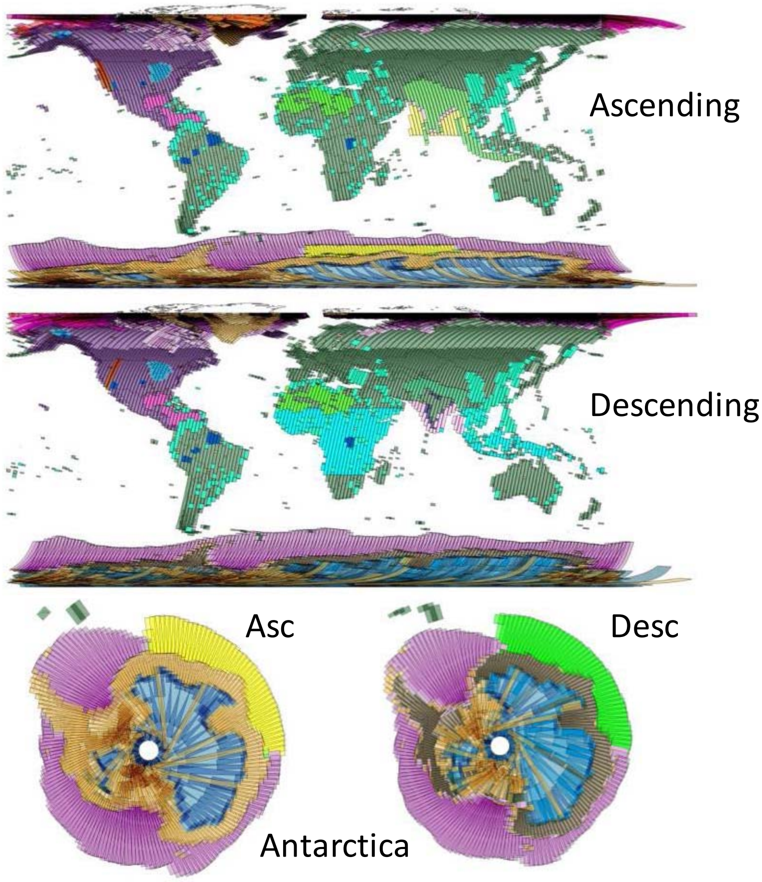

Figure 2. Typical observation scenario over a 12-day observation cycle over Indian and global targets in left-looking NISAR ascending (Asc) and descending (Desc) orbits. Coverage over Antarctica is shown separately in polar stereographic projection at the bottom. The colour codes depicting various imaging modes are shown in the left.

From the Indian perspective, NISAR is considered a science mission with the potential to augment SAR-based applications in India and the countries in the South Asia, feeding data to several operational project activities. In addition, the blanket L-band coverage globally will support science and applications everywhere. The primary science objectives of NISAR are: 1) Characterize the global distribution and changes of vegetation above-ground biomass and ecosystem structure related to the global carbon cycle, climate and biodiversity; 2) Determine the likelihood of earthquakes, volcanic eruptions, and landslides through surface deformation monitoring; and 3) Predict the response of ice masses to climate change and impact on sea level. In addition, the NISAR mission plans observations to improve monitoring of crops, surface water bodies, root-zone soil moisture, oceans off the coasts of India and the US, shore- line dynamics in the coastal regions, groundwater, hydrocarbon, and sequestered CO_2 reservoirs.

Both ISRO and NASA have developed comprehensive plans for the utilization of NISAR data with common objectives. The NISAR Utilization Plan intends to engage the stakeholder community and increase the utility and accessibility of NISAR data by a) demonstrating the value of the NISAR mission within a broad societal context; b) supporting activities that engage a diverse user community; c) educating a broader community on the utility of SAR data; d) working with interested end users to develop information products, and e) contributing to an observation plan and data delivery schedule that facilitates both science and applications within mission constraints. ISRO has made great efforts and will continue to engage the Indian academia and research community for the utilization of NISAR data through organization of NISAR science workshops, applications theme specific user's workshops, training and outreach programs and announcement of opportunity programs with NISAR prototype airborne L&S band SAR data.

Earth Observation Satellites Ground Station

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India's first indigenously designed and developed experimental satellite the Aryabhata on April 19, 1975.Starting from Bhaskara-I, the First Experimental Earth Observation Remote Sensing Satellite built in India in 1979 and the operational first generation Earth Observation remote Sensing satellites IRS-1A and IRS-1B were launched in 1988 and 1991, respectively. The second generation, operational, multi-sensor satellites IRS-1C and IRS-1D were launched in 1995 and 1997. Cartosat series satellites focusing on the Earth Observation and its atmosphere. Cartographic applications were the need is for small-target detection and mapping of features in mixed-clusters, to the latest Cartosat series satellite a variety of sensors are operating in visible, infrared, thermal and microwave spectral regions, including hyper-spectral sensors to acquire digital data at spatial resolutions ranging from 1 km to a meter have been built as Earth Observation Satellites. National Remote sensing Centre has established Ground Station, Antenna Systems with dual shaped reflectors in Cassegrain configuration at Integrated Multi-Mission Ground Segment for Earth Observation Satellites (IMGEOS) facility.

Data Reception System development

The Ground Station (Figure-1) provides a G/T of 31.5 dB/deg K in X-band and 14 dB/deg K in S-band. The Antenna systems are operational and the Payload data from all IRS & Non – IRS Missions is being received regularly from these Antenna Systems. The dual polarized S/X –band feed configuration of the antenna system supports Multi Mission data reception through RHCP and LHCP carriers simultaneously. EOS-4 (RISAT-1A) payload data is transmitted in dual polarization at 640Mbps data rate and hence Antenna Systems are required few developmental systems to receive EOS-4 (RISAT-1A) data. That way IMGEOS station is now capable of tracking and receiving Earth Observation Satellite data. This paper will brings out, how this NRSC Ground station is evaluated from IRS 1A on wards to EOS series satellites sensor data.

Remote sensing Data Reception in Ka-band systems has to be developed in RF, Servo and Antenna Mechanical systems. RF Systems: RF Systems comprises of Feed electronics, Down converters, Tracking system, Up converters, Fiber Optic trans-receivers, Demodulators. Digital Servo Control System: Digital Servo Control System consists of servo control, drive and encoder assembly subsystems and associated software for precise and accurate control of Azimuth, Elevation and Train axes of the Antenna. Antenna Mechanical systems: The mechanical system consists of 3 Axis Tracking mount, Reflector, Sub reflector, feed assembly. This paper will tell about Past, Present and Future Ground station of CartoSat Data reception at NRSC Ground Station

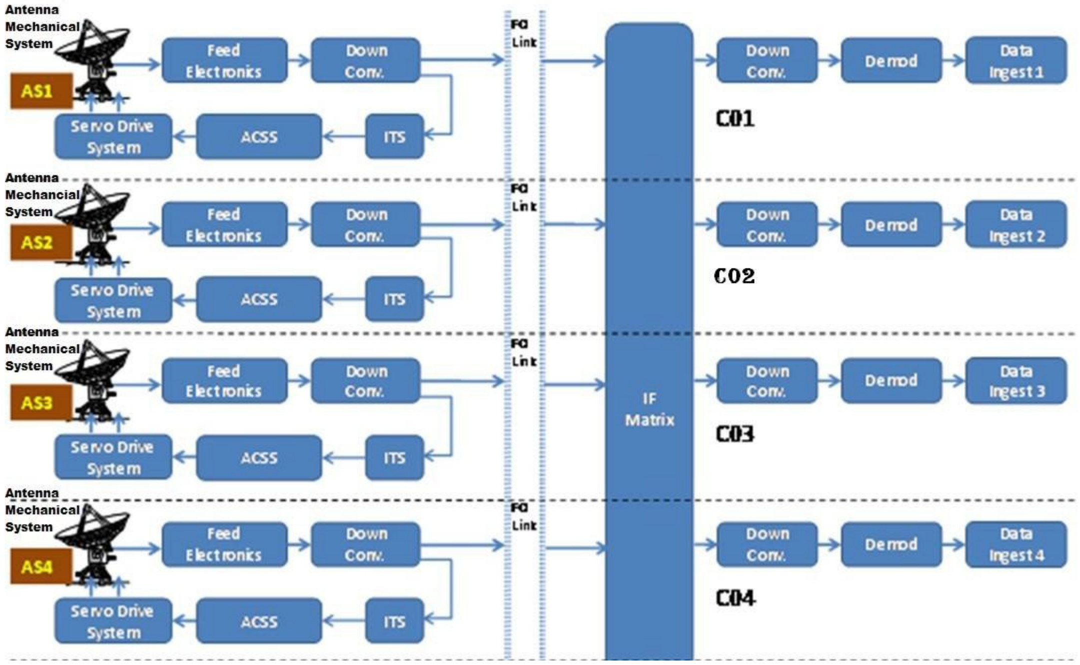

Figure 1: Configuration of data reception system at IMGEOS

Geo Smart Science Education its Software Development and its Role of Importance in World Utility

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If we study Geo Smart Science education (earth science) how old is the planet of the golden future? From where does gold originate? Where are the sources of gas and oil? Human survival cannot advance without it. Where do the iron bars that are used to make the tools, buses, and railroads that we use come from? What causes earthquakes and tsunamis? The world has been around for 4,500 years or 4.5 billion years in total. You should read Geology Group in Degree or PG? if you want to get the answers to these questions. The framework for Earth science literacy must be an evolving text that changes with our understanding of the planet. Water has coexisted at Earth's surface in three states (solid, liquid, and gas) for billions of years, making Earth unique in our solar system. When lava cools, sediments collect and solidify, and older rocks are altered by heat, pressure, and fluids, new rocks are created. Igneous, sedimentary, and metamorphic rocks are created by these three processes. Tsunamis are natural disasters that happen on Earth earthquakes. eruptions of volcanoes and earthquakes Noticed Nepal has recently experienced earthquakes. Let the earthquakes do us in. structures and buildings that kill us. only when it is covered by them. Similarly, there were two ways to find raw gold. One is a primary way, while the other is a secondary approach. The primary method can be found in the earth's source rocks as well as in the aggregate with water and sand after rivers. Earth is hour home where diamonds are discovered, and as a byproduct, metals like Pb, Cu, and Zn, etc., are discovered. There are two different kinds of earthquakes that occur on earth, namely major and small plate moment of earthquakes. When shook or radiated, earthquakes and tsunamis happen both on land and in the ocean. This topic is a fantastic tree. Both one subject and another subject benefit from it. For example, geology, mathâ€™s, chemistry, physics, astrology, botany, zoology, statistics, and economics. At its core, geoscience is an interdisciplinary field that studies the earth system using computer modelling, mathematics, biology, chemistry, and physics. There is a plenty of Geosoftware available now days without this cannot run world for example ESRI-GIS, Remote Sensing, GeoMage, Photogrammetry, Lidar, Surpac, ERDAS, Gemcom, Minex, Vulcan, Auto-Cad, Auto-Cad map etc, As per UNFC classification we can estimate reserves and resources metals and non-metals from using this software and administrate purposes education, business, government sectors, defense army, urban and town planning, environmental assessment, forest and wild life tracking, waste land development, Hydrogeology groundwater resource management, Mineral exploration, land use thematic mapping, epidemiology, tourism, Archeology and Agricultural application.
Keywords: Geo Smart Science Education, Geo Software, Awareness and Utility.

Image Denoising using Machine Learning for individual and huge data with its metric analysis

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Google

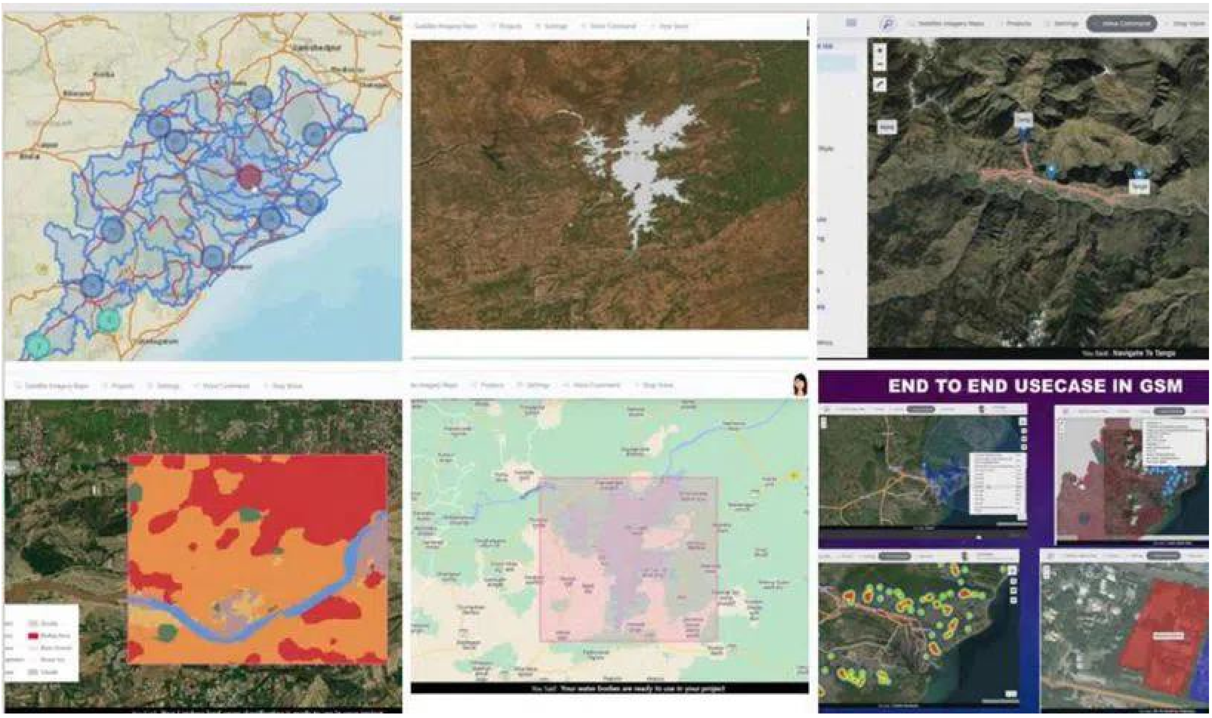
In this paper, we introduce a new denoising approach. Image denoising is one of the fundamental challenges in image processing and computer vision. The main goal of this project is to acquire completely noise-free images with high accuracy and in a short time. Therefore, in our project, we propose an effective denoising technique using RNN (Recurrent Neural Network) for noisy fixed-pattern images that can reduce the use of a large number of auto encoders. Here, the image is passed to the recurrent neural network as pixel information in the form of a 3D coordinate system. A RNN does not migrate information from one node to another until it meets basic requirements. It uses a single auto encoder, which reduces noise and time complexity. Statistical analysis is performed considering metrics such as SNR (Signal-to-Noise Ratio), PSNR (Peak Signal-to-Noise Ratio), MSE (Mean Squared Error), and Entropy. From this research work, we get a completely noise-free image.

Garudalytics Smart Mapping

Jayanta Poddar
Garudalytics Private Limited

With the voice-activated technology becoming more and more popular in the recent time, Garudalytics has devised a voice-based mapping platform, Garudalytics Smart Mapping (GSM), which is an amalgamation of location intelligence and artificial intelligence. In GSM, the functionalities can be triggered in three ways, i.e., by click event, by command type event or by voice command. It is capable of handling voice commands and perform multiple operations like query, buffer, navigation, nearby analysis, swipe between the layers, export layer among others.

GSM is a light-weight SaaS based product which is device independent, and it can be accessed on a web browser or as a mobile app. It also features a few AI/ML tools for the feature extraction and classification.



Evaluation of methods for computation of Satellite Velocity vector from position vector

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Satellite angular velocity (SAV) is one of the most important orbital parameters used in physical sensor model to perform geometric correction of remote sensing satellite data. Gyroscopes are used to measure this parameter. Recent methods also include Star sensor based optical flow estimations [6]. In case of non-availability of these instruments SAV can be computed using the position information (XYZ). In this paper two models namely Gibbs and Herrick-Gibbs are explored to compute velocity vector information from three time sequential position vectors of the satellite.

Data sets (Image, Orbit and Attitude) are chosen from L-3 Camera of IRS-1C: India's second generation Remote sensing satellite. System level geometric corrected products are generated by using the computed SAV from both the models and achieved geo-location accuracies are inter-compared. The experimental results suggest that the Herrick-Gibbs model is suitable for cases in which angular separation among input position vectors is less than 1^0.

A Theoretical Modelling Study for Selection of Optimal Split-Window Algorithm to Retrieve Land Surface Temperature for ISRO's Upcoming EOS-06 SSTM TIR Sensor

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Land Surface Temperature (LST) is an important parameter for the study of interaction between earth surface and atmosphere regionally and globally. Moreover, it is also, used as an input to the various climatological, ecological, and hydrological studies [1]-[5]. Low-earth orbital Earth Observation Satellite (EOS)-06 or Oceansat-3 is the planned mission of Indian Space Research Organisation (ISRO). It will acquire global land and ocean surface data with high spatial and temporal resolution across the different bands. EOS-06 will carry four different sensors onboard, namely, thirteen band Ocean Colours Monitor (OCM-3), two Thermal InfraRed (TIR) bands on Sea Surface Temperature Monitor (SSTM), Ku-band scatterometer (SCAT-3) and Advanced Research and Global Observation Satellite (ARGOS). Two TIR bands of SSTM, Band-1 (10.75 to 11.25 μm) and Band-2 (11.75 to 12.25 μm) will have 1080 m spatial resolution and Noise Equivalent Delta Temperature (NEΔT) less than 0.15 K, with 1440 km swath and TIR bands saturation temperature is around 340 K. These specifications make SSTM quite suitable for the LST retrieval.

Since last four decades, varieties of LST retrieval methods were developed, which are categorized into three groups: single-channel, multi-channel and multi-angle algorithm [6]-[8]. Split Window (SW) algorithm is widely used to retrieve LST for the use of two adjacent bands in atmospheric window in TIR region. A study has been carried out in this paper to find the most suitable SW algorithm to retrieve LST from SSTM observations. Ten different reported SW algorithms having good veracity is selected in the present study, namely, Sobrino and Raissouni, 2000; Coll and Caselles, 1997; Caselles et al., 1997; Sobrino et al., 1996; Wan and Dozier, 1996; Sobrino et al., 1994; Sobrino et al., 1993; Ulivey et al., 1992; Vidal, 1991; Price, 1984 [9]-[18]. Nearly seven lakh at-sensor radiance simulations were carried out using MODTRAN 5.3 radiative transfer model for various atmospheric and surface geometry. The spectral response function of the SSTM TIR bands has been considered for the computation of SW coefficients, and effective wavelength has also been derived, which are, 11.04 μm (Band1) and 12.09 μm (Band2). SW coefficients of all algorithms have been successfully derived from the simulations. The SW coefficients dependency on aforementioned parameters have been analysed, which have linear or non-linear relations. The analysis included assessment of dependency of SW coefficients on surface emissivity, water vapor and view angle. The selection of optimal SW algorithm is based on theoretical sensitivity analysis of algorithm. The differential classical error theory is used, which computes error in LST due to errors in different terms of algorithm. The classical error theory equation is,

$$e(LST) = \sqrt{\delta_{alg}^2 + \delta_{\mathrm{NE\Delta T}}^2 + \delta_{\varepsilon}^2 + \delta_W^2}$$

Where, δ_{alg} is theoretical standard error of the algorithm, $\delta_{NE\Delta T}$is error due to the sensor's NEΔT, δ_{ε} is the error due to LSE and δ_W is error due to the atmospheric water vapor.

Table 1. Obtained SW coefficients of different SW algorithms for the SSTM sensor. The results of the sensitivity analysis(δ_{alg}, δ_{NEdT}, δ_{ε} and δ_W are in K) and Bayesian test error (in K).

SW algorithms	SW coefficients									R^2	$\sigma_{algorithm}$	$\sigma_{NE\Delta T}$	σ_{LSE}	σ_{WV}	σ_{Total}	Bayesian test error
	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9							
Price, 1984	7.1440	0.9821	1.0432	-0.3308	-0.6501	-	-	-	-	0.959	2.3643	0.2259	2.6170	-	3.5340	0.6363
Vidal, 1991	4.0026	0.9850	1.1297	43.1718	-47.9437	-	-	-	-	0.975	1.8463	0.2398	0.7671	-	2.0136	0.6745
Ulivery et al., 1992	3.8114	0.9850	1.1300	51.3081	-52.2118	-	-	-	-	0.975	1.8449	0.2398	0.8227	-	2.0342	0.6843
Sobrino et al., 1993	-8.2836	1.0314	-0.1706	0.1984	43.6015	-29.5745	-	-	-	0.985	1.4041	0.2443	0.5196	-	1.5169	0.3364
Sobrino et al., 1994	54.5879	0.9850	1.1300	-50.7618	-49.7152	-	-	-	-	0.975	1.8448	0.2398	0.5025	-	1.9269	0.6569
Wan and Dozier, 1996	5.9655	0.9763	0.1689	-0.2341	3.7522	-9.3093	20.6950	-	-	0.978	1.7086	0.2473	0.7940	-	1.9002	0.6866
Sobrino et al., 1996	2.8829	0.9912	0.5882	0.4254	-1.4368	72.4523	-11.2989	-71.0187	13.3189	0.991	1.0780	0.2808	0.8247	0.7462	1.5742	0.5461
Caselles et al., 1997	15.8842	1.9712	-1.0280	-220.9240	-	-	-	-	-	0.970	2.0107	0.2329	0.9611	-	2.2407	0.6875
Coll and Caselles, 1997	-8.2836	1.0314	-0.1706	0.1984	43.6015	-29.5745	-	-	-	0.985	1.4041	0.2419	0.5196	-	1.5166	0.3364
Sobrino and Raissouni, 2000	-1.0494	1.0023	0.3987	0.1543	66.4539	-10.4271	-62.8288	11.5983	-	0.988	1.2604	0.2689	0.7380	0.0620	1.4864	0.6430

The Bayesian optimization test error analysis of all SW algorithms were carried out, which provided the standard error in LST using the difference of the Bayesian optimization model's predicted LST and actual LST. The derived results of sensitivity and Bayesian test error analysis is shown in **Table 1**. It is confirmed that the results obtained by Sobrino et al., 1993; Sobrino et al., 1996; Sobrino and Raissouni, 2000 provide better accuracy as compared to other algorithms.

Development of Elastic Computing Platform to host Geospatial Applications with Dynamic Workloads

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Geospatial applications have become an integral part of day to day life. Most of the Geospatial applications are compute-intense and the distributed processing is the ideal approach to improve the overall performance. These applications are widely used in diverse public interests with application areas like G-Governance, Land Use and Land Cover, Natural resources, Agriculture, Water Bodies, Ground water, Natural disaster management, Navigation and visualization etc. These applications have increased in leaps and bounds in the recent times. The user base is highly dynamic for this sector and few of the applications are used seasonally. Hence, it is beneficial to host these web applications using a virtual infrastructure instead of physical resources. Elasticity is the degree to which a system is able to adapt to workload changes by provisioning and de-provisioning resources in an autonomic manner, such that at each point in time the available resources match the current demand as closely as possible.

This paper brings out a mechanism to develop an elastic computing platform to host the geospatial web and mobile applications that experience highly dynamic workloads. The proposed solution utilizes an open source tool called Open stack to realize this objective.

The proposed solution is an open stack based computing platform to meet the hosting requirements for these Geospatial applications. Open stack is an open source platform that uses pooled virtual resources to build and manage hosting resources. The proposed architecture involves a robust design platform with a three-node architecture. This platform offers benefits like on-demand provisioning of resources by eliminating need to install and configure physical resources. It offers dynamic scaling of the allocated resources to scale based on usage. It enables to fully utilize the hardware resources by improving the efficiency. It provides centralized monitoring of multiple compute nodes through single dashboard by simplifying the ease of management. This platform can deliver a high performance in executing compute intense workloads related to the geospatial application development and deployment. All the services in the platform can be independently integrated and tweaked to or requirements using APIs. It is a cost effective solution by consolidating the requirements to reduce the overall costs to establish the infrastructure.

This platform can provide latest state of art technologies like load balancing, enhanced security and monitoring features through inbuilt services. A sample instance was generated and the performance analysis was discussed in this paper.

Blockchain Technology - Introduction and Perspective for Space Applications with a Geo-spatial Use Case

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Space Applications Centre, ISRO

Blockchain is a revolutionary disruptive technology which has brought ripples in multiple fields ranging from finance to medical sciences. Originally designed to solve the double spending problem in a distributed ledger, several innovative applications have emerged and new ones are being discovered every day. At the heart of Blockchain, lies an immutable distributed ledger which contains a record of all transactions performed on the blockchain. The ledger is immutable in that once records are added into it, they cannot be edited or manipulated thus facilitating tamper-resistance. In a typical blockchain-based system, trust and management responsibilities are distributed among the operators. Unlike traditional systems, blockchain based systems require nodes to perform consensus operations to be able to verify and validate incoming transactions and add the blocks to the blockchain. Many revolutionary full-fledged applications, concepts as well prototype solutions have been developed in different fields such as Finance, Gaming, Banking, Supply chain management, etc. have been developed and working. Concepts such as DeFi, Smart contracts, DApps, as well Distributed Autonomous Organizations (DAOs) are currently being used to transform the way traditional organizations work. However, in this regard, the Space industry has been comparatively slow in adopting the ideas derived from this technology but it is now catching up at a rapid pace. It might be years before truly meaningful automatic applications based on this technology are available through space assets, but the foundations are being laid by different stakeholders in a bit-by-bit manner. The work presented in this paper has two main objectives. First, we identify and briefly discuss the major potential use cases of the Blockchain technology for the Space industry, based on our survey of the field. The main idea is to draw attention to the potential of this technology at a juncture where the Indian as well as Global space sector is undergoing a transformative revolution. Also, as per the Union Budget 2022, digital rupee based on Blockchain technology will be introduced in the fiscal year 2022-23. Several new applications in the area of Space technology such as Space infrastructure contracts, Supply chain management for space parts, Geospatial data tokenization, and Data anti-counterfeiting systems are described. The use of Blockchain technology to conceptualize, design, develop as well as collaborate on Space infrastructure can provide the necessary fabric to the exploding landscape where thousands of organizations are looking for lease of assets as well live data exchange for better collaboration. Use of extended technologies such as Smart contracts and DeFi can also enable timely completion of collaborative multiparty Space infrastructure and Geospatial application projects. Second, we focus specifically upon an innovative solution for Geospatial data availability sharing using Blockchain technology. The use of this technology not only brings benefits of decentralization into picture, it brings robustness from security as well validation point of view. The solution is designed in a scalable manner and can be used for sharing of large amounts of Geospatial data availability information between various national institutes, private agencies, or even individual field contributors. By leveraging the properties of immutability and verifiability, the consistency of the Blockchain can be maintained. Also, new concepts such as reputation based incentives, and techniques for

Proof-of-Location are introduced to improve the tendency towards legitimate data contribution to the Blockchain. The developed solution, which is currently at a prototyping stage, will have potential to change the geo-spatial data exchange landscape as the decentralization can enable the agencies to browse data offline, plan data and studies in more effective way utilizing the existing multimodal data available across the country/participating agencies. Individual users can develop applications, tools and browse systems around the locally available Geospatial data information from all participating nodes in the network, giving them more power compared to a centralized data search system. The use of Blockchain technology can be a big enabler towards Earth Observation (EO) data sharing landscape adding to the scope of the ongoing digital transformation of this field. The identified use cases as well the data sharing solution can enable timely information sharing as well as large scale collaboration amongst the EO community. Finally, we also discuss some limitations of the Blockchain technology and possible future directions for Blockchain research in this field.

Mapping forest canopy height using machine learning algorithm by coupling GEDI and Sentinel-1 data

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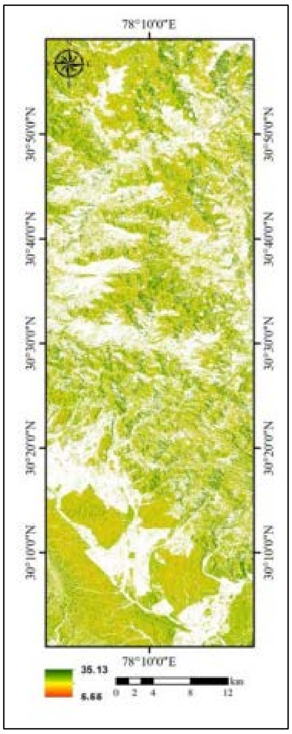
Forests are one of the greatest terrestrial carbon reservoirs that hold approximately 45% of the world's active carbon and sequester approximately 32% of anthropogenic emissions annually, constituting them an important part in the world's carbon cycle. Precise estimates of the distribution and total carbon storage in global forests are outmost important for modelling and monitoring climate change. Particularly, aboveground biomass (AGB), that includes all live vegetation above the ground, is listed by the Intergovernmental Panel on Climate Change as one of the most visible and dynamic terrestrial ecosystem carbon pools involving biomass which represents about 30% of the total terrestrial ecosystem carbon pool. Spatially continuous canopy height is a vital input for modeling forest structures and functioning in many forest types. It is significantly an important indicator of biomass and carbon stock. Moreover, canopy height has become a top influential factor for the diversity evaluation of flora and fauna. Therefore, precisely measuring of canopy height is fundamental for estimations of forest structure and functioning in the Himalayan region. The present study showed an attempt to develop a random forest (RF) approach to map the spatial pattern of the forest canopy height across an elevation gradient in part of North West Himalaya (NWH) by coupling the available canopy height footprint product from Global Ecosystem Dynamics Investigation mission (GEDI) with the Sentinel-1 satellite data. More recently, the GEDI has provided an unprecedented number of forest canopy height samples from 2019. Sentinel-1 VV and VH backscatter values and backscatter derived texture information were used to extrapolate the canopy height. The RF model was run using a set of 18 variables and variable importance, which is based on the increase in node purity (IncNodePurity) was obtained. The minimum RMSE was obtained using variables which include .The predicted forest canopy heights varied from 5.55m to 35.13m across an elevation gradient in NWH region. It was observed that the RF-based model was able to predict forest canopy height with R 2 of 0.95 and %RMSE of 4.20%. Based on the vegetation type map of India (scale 1: 50,000) prepared by Roy et al. 2015, it was observed that in Tropical sal mixed moist deciduous, canopy height ranged from 10.12 to 31.93 m. Similarly, for Pinus spp. the height ranged from 8.3m to 34.84 whereas for Himalayan moist temperate forest height ranged from 8.01 to 29.42m. The C-band from Sentinel-1 data is sensitive to crown characteristics and canopy structure and hence, the backscatter values are indicative of forest structure. The canopy height map can further be used as an input for spatially modelling aboveground biomass in the area.

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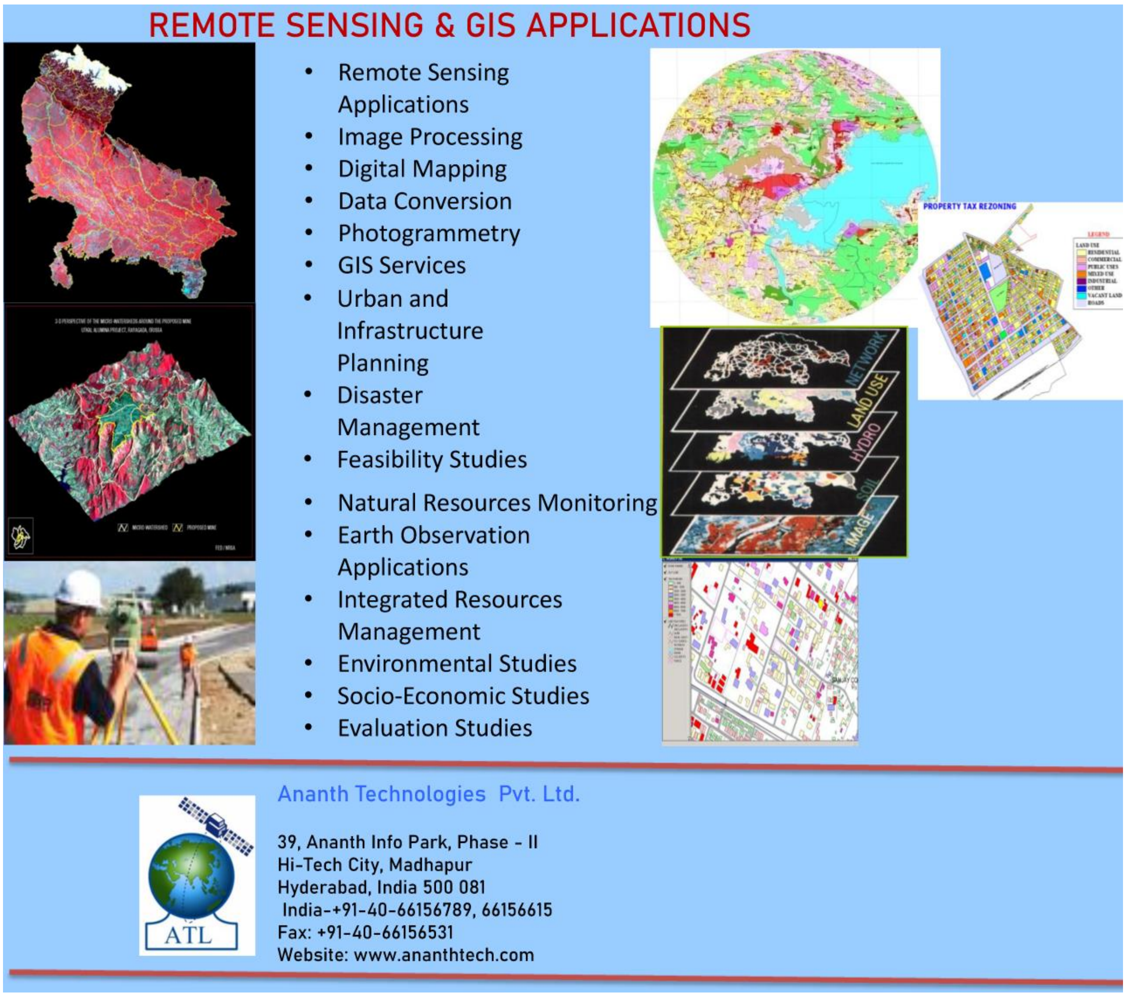

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