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Lulc For Uttarakhand For Year 2000 Using Gee And Machine Learning Algorithm

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Abstract: Temporal remote sensing satellite data is useful for natural resources and environment monitoring. Environmental landscape modelling, urban planning, and historical land cover change studies benefit from an accurate representation of landscape attributes and precise assessment of spatio-temporal changes. Manual methods analysing temporal satellite data, for identifying changes is a time-consuming process. Automated procedures analysing remote sensing satellite data using online platforms can be efficient solution in land use land cover (LULC) studies. Goal of this study is to assess LULC changes using online geospatial processing tools and multi-temporal remote sensing satellite data. Open-source Landsat data for 2000 is used for identifying the changes. Different regions including urban, semi-urban & rural are selected for assessing the performance of the proposed procedures. The region Uttrakhand have been studied to quantify long-term LULC changes and identify the driving reasons behind them. The LULC classification has been implemented on the Google Earth Engine (GEE) platform and results are obtained for Random Forest Algorithm. The RF classifier produced a better result . The quantitative study of LULC maps reveals divergent trends for different classes .

Keywords: Land cover and landuse classification, temporal changes, land cover prediction, QGIS, Google Earth Engine.

Introduction

Global environmental change is a crucial issue driving climate change, biodiversity loss and land degradation. Natural and anthropogenic processes have significantly altered land use land cover (LULC). Understanding spatiotemporal patterns for landscape change is critical for sustainable resource management.

Temporal urban feature mapping provides a historical perspective of urban evolution by integrating multiple data sources into a georeferenced database. Using historical maps, demographic data, and census records, it reconstructs past landscapes and tracks urban growth over time. Analyzing these patterns helps identify the relationships between physiographic and socioeconomic factors influencing urbanization. Historical overviews of urban development offer insights into future trends. Temporal urban maps assist in measuring urban sprawl, monitoring impermeable surfaces, evaluating water pollution and sedimentation, and modeling future growth patterns. These insights are valuable for urban planners, policymakers, Earth scientists, and global change researchers. The consequences of informed growth decisions impact millions in metropolitan areas.

Land use land cover change detection identifies possible environmental impacts of urbanization, forest conversion and agricultural expansion (Drummond and Loveland 2010). Land use change depicts the human footprint, contributing to biodiversity loss and land degradation (Butt et al. 2015). Urbanization is a major global transformation, occurring rapidly, particularly in developing countries (Majumdar and Chatterjee 2021). Extracting precise LULC data from images remotely sensed needs efficient classification approach. These classifiers are broadly categorized as supervised or unsupervised and further classified as parametric or nonparametric, hard or soft (fuzzy), and per-pixel or sub-pixel-based (Jain et al. 2016).

Over the last decade, researchers have regularly studied local and regional climate changes under anthropogenic impact to understand environmental effecting factors (Ohana-Levi et al. 2019). Industrialization and urbanization are key drivers of global climate change (Ackom, Adjei, and Odai 2020). A major issue in urban area is rising surface temperatures due to vegetation loss and the expansion of impervious surfaces (Zhang et al. 2017).

This study aims to: i) Utilize online geoprocessing platforms and multi-temporal satellite data to generate LULC information, ii) Analyze temporal LULC data to map and monitor urbanization patterns, iii) Identify land cover types and their distribution, iv) Assess LULC classification accuracy using supervised classifier (Random Forest), v) Predict LULC changes using historical data integrated with landscape metrics and ecosystem services.

The spatial patterns and temporal trends of urbanization in Uttarakhand were analyzed using satellite imagery from 2000. Landsat 5 datasets were used for the study. Major land use classes—water bodies, built-up, forest, and cropland—were classified using automated procedures. Land use changes over time were assessed to track conversions from cropland, vegetation, and canopy areas to built-up regions, identifying urban expansion. The rise in built up area was analyzed across rural, semi-urban, and urban regions to detect trends.

Landsat 5 stacked datasets, along with machine learning algorithms, were used for land use land cover (LULC) classification. The specific objectives of this study are: i) Classify LULC using supervised machine learning algorithm. ii) Evaluate the suitability and accuracy of supervised classifier for LULC classification. iii) Predict LULC for land cover categories and analyze observed trends.

The paper is organised as follows: "Study Area" describes study region, while "Data Used" explains the datasets utilized. "Methodology" outlines the process employed, and "Results and Discussion" presents experimental findings and performance evaluations. Finally, the study is summarized in the "Conclusion" section.

Study Area

The methodology proposed is implemented and tested over a wide range of area of Uttrakhand.

Uttarakhand: The northern Indian state of Uttarakhand is located between latitudes 28°43' and 31°27' N and longitudes 77°34' and 81°02' E. This state which is mostly hilly, shares boundaries with Nepal in east and China (Tibet) in north, as well as with Himanchal Pradesh in the northwest. With a gross land area of 53,485 square kilometers, 86% of Uttarakhand is made up of mountains and 65% is made up of forests. The state of Uttarakhand is abundant in natural resources, including forests and water, as well as numerous glaciers, rivers, and snow covered high peaks. High mountains and glaciers cover the majority of state's northern region, which is part of larger Himalaya range. The Uttarakhand glaciers are the source of the Ganga and Yamuna river.

Uttarakhand state has a large number of rivers as its northern part is a home of glaciers. Hence, there are many perennial rivers in the state. The state is mostly drained by Ganga, Yamuna, Bhagirathi, Alaknanda, Kosi, Mandakini, Gori-Ganga,Ramganga and Pindar rivers, and other major rivers with their tributaries.

Its study area layout map is shown below in Figure 1.

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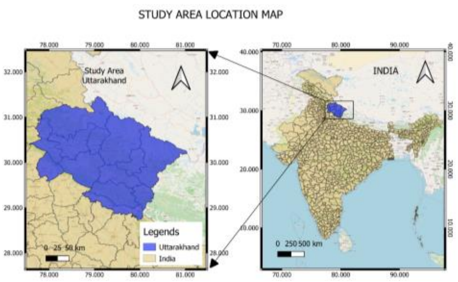

Figure 1: Study area layout of Uttarakhand region

Methodology

Data Used: A thorough review of the literature was conducted, which aided in determining the data needed to meet the study's goal. Google Earth Engine (GEE) helped to retrieve all the required datasets. Google Earth Engine, is an online geoprocessing platform capable of analysing satellite imageries, in addition to GEE, additional software applications including QGIS are used for further investigation of GEE results.

Satellite datasets : Landsat 5 TM Collection 2 Tier 1 calibrated top-of-atmosphere (TOA) reflectance products (United States Geological Survey (USGS)) for the year 2000 and Calibration coefficients needed for processing the satellite data are extracted from the image metadata file.

Online satellite data processing platform

Online satellite data processing platforms facilitate the querying, retrieval, and analysing remote sensing images in an efficient manner. Google Earth Engine (GEE) is widely used framework, that helps in the processing of global-scale satellite imagery both archived and existing. With the help of an explorer web application, high-speed parallel processing and machine learning algorithms utilizing Google's computational infrastructure, and a library of Application Programming Interfaces (APIs) with development environments for programming languages like Python and JavaScript, the Google Cloud Platform (GEE) gives users free aquisition to petabytes of publicly available remote sensing imagery and other by-products.

Google Earth Engine (GEE) provides framework that we utilize to study detailed aspects of LULC and environmental parameters using publicly accessible satellite data. The Google EEP application, which makes use of JavaScript APIs, is employed to efficiently upload and analyze satellite datasets. It offers complex geostatistical and geospatial functions on input datasets in addition to analysis. Landsat imagery hosted on GEE is used via Google EEP for performing the analysis.

Land Use Land Cover (LULC) Classification

Major classes namely forest and agriculture areas with significant tree cover, and cropland are classified using remote sensing satellite images on online satellite data processing platforms over a study period. Features that include water sources such as river systems, streams, canals, lakes, and reservoirs are categorized under the water bodies class. If at least 30% of the impervious surface area of a residential, transportation, industrial, or commercial area is made up of automobiles, asphalt, or other construction materials, the area is classified as urban/built-up , which comprises mixed urban and built-up area. Places with substantial greenery and a tree cover percentage of at least 60%. (areas with dense greenery). Croplands constitute minimum 60% of the area is used for cultivating crops, or cropland and vegetation cover. Mosaics: mixtures of 40–60% small-scale cultivation and uncultivated trees, shrubs, or herbaceous plants.

Further, for each class, reference samples are selected. In this procedure, more than 450 training points have been used, with roughly one-third of the data samples utilized to train the classifier and the remaining two-thirds being utilized to validate the results of the classification.

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We utilize training data set to enhance the supervised classification algorithm, whereas validation datasets were employed to conduct accuracy assessment of generated land cover classification map.

Machine learning techniques for classification

Supervised machine learning-based classification techniques namely Random Forest (RF) are applied to input satellite datasets for LU/LC classification. GEE inbuilt classifiers are used to classify the images for RF. At first class names and their properties needs to be stored as predictors' numeric values for classification. Once the different classes are defined, the user can create their own classifier from scratch or use the inbuilt one for classification. Users can also change the default parameters of the classifiers. The training data was ingested into the model and the classifiers were trained over the training dataset. The training data is a feature collection with properties containing predictor variables and properties containing the class label. The classifiers classify the input satellite images ranging from class 1 to class 5. Validation data is used to estimate the classification error.

Accuracy assessment

Accuracy evaluations are valuable and effective ways of determining how effectively the classification procedure completed the study's task. The validation dataset obtained from one-third of the reference locations was used to validate the generated land cover categorization maps. A confusion matrix of land cover maps was generated based on previous studies to evaluate the accuracy of the findings.

Result

Landsat satellite images over the area of interest for the study period were pre-processed and classified using supervised classifiers on the GEE platform. The input satellite images are trained and classified showcasing 05 major classes namely forest, built-up, agriculture, snow and water body. LU/LC observed by classifying temporal satellite data are explained in the below-mentioned sections.

LU/LC analysis

Satellite datasets for the year of 2000 were analysed using machine learning-based supervised classifiers, LU/LC for Uttarakhand show the trend of urbanisation.

Uttarakhand

For the year 2000, the Uttarakhand region is divided into 5 major classes as Forest, Build-up, Agriculture, Snow and Water bodies.

The accuracy obtained for the RF classifier is more than 93.478%, and Kappa Cofficient is 92.164%.

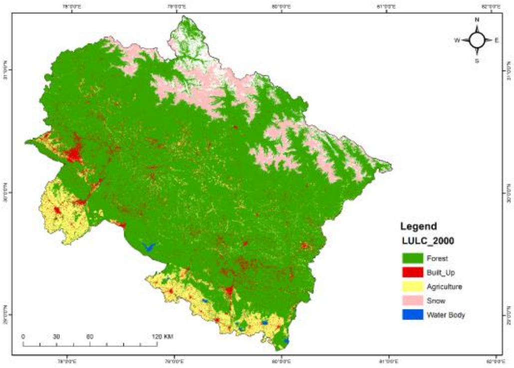

Fig 2:

Discussion

This study concludes that the built-up area has expanded steeply and become the dominant class in Metropolitan and Urban regions while there is a gradual increase in the urban settlements in the semi-rural and rural regions, the cropland/natural vegetation and the Forest area remain the dominant classes. In order to monitor local, regional, and global resources and the environment, data on changes in the earth's surface LU/LC management can be closely monitored. The supervised learning classifiers are used to track the LU/LC change.

The suggested land cover classification approach employs the GEE platform's supervised classification algorithms, which use a wide range of indices and topographic data. The algorithms allow the integration of a variety of data types in the modelling process and accurately identify diverse land cover. Ready to use remote sensing satellite data on GEE provides high speed analysis implementing powerful processing techniques for different regions and is capable of handling huge datasets. GEE's datasets and methods are free to use for non-commercial & research purposes. Scientist have been able to evaluate billions of satellite datasets using parallel processing by GEE.

Conclusion

The availability of Landsat satellite data and geospatial GEE technology, represents significant step forward in terms of automating the monitoring and evaluation of land-use change across different geographic areas. This research effectively identifies various classes and land cover, as well as the spatial and temporal changes in land cover which have occurred because of land use change in Uttrakhand , and evaluates using satellite imagery for year 2000. We also mapped and correlate the observations to realize the trend with the growing urban population. The trends observed through the graphs depict that with the increase in urbanization and population, there is a steep and steady decrease in different land use land cover classes for Metropolitan and Urban regions. With increasing urbanization, there is decline in the total area of cropland/natural vegetation and Canopy area, and the area occupied by water bodies such as reservoirs, ponds, canals, etc.

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