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Geospatial mapping of land use and land cover for watershed management in the Nidnegal micro watershed, Karnataka

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Abstract

Land use and land cover (LULC) information is essential for understanding watershed characteristics and developing effective strategies for sustainable natural resource management. The present study aimed to prepare a high-resolution LULC map of the Nidnegal micro watershed, located in the Hiremorab sub-watershed (4D4D2) of Hirekerur Taluk, Haveri district, Karnataka, using remote sensing and Geographic Information System (GIS) techniques. High-resolution QuickBird satellite imagery (0.61 m spatial resolution) was processed in the Google Earth Engine (GEE) platform, and supervised classification was performed using the Random Forest algorithm. Field observations and GPS-based ground truth data were used to develop training samples and validate the classification results. The classified LULC map identified six major land use classes: agricultural land, scrub forest, plantation, built-up area, water bodies and fallow land. Agricultural land was the dominant land use, covering 488.75 ha (52.95%), followed by scrub forest occupying 372.35 ha (40.34%). Plantation, built-up area, water bodies and fallow land accounted for 2.65%, 2.23%, 1.73% and 0.11% of the watershed area, respectively. Together, agricultural land and scrub forest occupied 93.29% of the total geographical area, indicating the predominance of agricultural activities and natural vegetation within the watershed. The classification achieved an overall accuracy of 91.00% with a Kappa coefficient of 0.89, demonstrating a high level of agreement between the classified map and reference data. The study confirms that the generated high-resolution LULC map provides reliable spatial information for watershed characterization and can serve as a valuable database for soil erosion assessment, carbon stock estimation, agroforestry land suitability analysis and sustainable watershed management planning.

Keywords: Land use land cover, watershed management, remote sensing

Introduction

Watersheds are the fundamental hydrological units that sustain water resources, soil productivity, biodiversity, and agricultural livelihoods. However, rapid population growth, expanding agricultural activities, urbanization, and economic development have exerted increasing pressure on the limited land resources within watersheds, leading to significant changes in land use and land cover (LULC). These changes alter natural hydrological processes, accelerate soil erosion, reduce groundwater recharge, degrade water quality, and threaten the long-term sustainability of watershed ecosystems.

A comprehensive understanding of land use and land cover dynamics is therefore essential for effective watershed planning and management. Land use reflects human activities carried out on the land, whereas land cover represents the physical and biological features present on the Earth's surface. The interaction between these components influences runoff generation, sediment transport, vegetation cover, and the overall ecological health of a watershed. Accurate and up-to-date LULC information provides a scientific basis for assessing watershed conditions, identifying environmentally sensitive areas, and planning appropriate soil and water conservation measures. Remote sensing technologies have a significant potential for mapping and extracting information about forest structure and biomass (Sinha *et al.*, 2015) ^[6].

With advances in remote sensing and Geographic Information Systems (GIS), monitoring spatial

and temporal changes in land use has become more efficient and reliable. The remote sensing data has many applications. One of the important applications is land use land cover classification (Koppad and Tikhile, 2013) [4]. These geospatial technologies facilitate the evaluation of land resource dynamics, support watershed prioritization, and aid in developing sustainable land management strategies. Integrating LULC assessment with watershed management enables informed decision-making for conserving natural resources, enhancing agricultural productivity, reducing land degradation, and ensuring the sustainable use of land and water resources for present and future generations. Considering the importance of accurate land use information for effective watershed planning and management, the present study was carried out to prepare a high-resolution land use and land cover map of the Nidnegal micro watershed using remote sensing and GIS techniques

Materials and Methodology

Study area

The Nidnegal micro watershed is one of the seven micro watersheds delineated within the Hiremorab sub-watershed (4D4D2) of Hirekerur Taluk, Haveri district, Karnataka, India. It was identified as the highest-priority micro watershed based on morphometric analysis due to its greater susceptibility to soil erosion and land degradation. The watershed was selected for the present study to assess land use and land cover dynamics and to support sustainable watershed management through geospatial techniques.

Preparation of Land Use Land Cover (LULC) Map

The Land Use Land Cover (LULC) map of the Nidnegal micro watershed was prepared using the Google Earth Engine (GEE) cloud computing platform through a supervised classification approach employing the Random Forest (RF) algorithm. High-resolution QuickBird satellite imagery (0.61 m spatial resolution) was utilized for the preparation of the Land Use Land Cover (LULC) map of the selected micro watershed.

Initially, cloud-free satellite imagery of the study area was collected and pre-processed in GEE to improve image quality and ensure accurate classification. Pre-processing included image filtering, mosaicking, clipping to the watershed boundary, and generation of spectral indices. Normalized Difference Vegetation Index (NDVI) and False Colour Composite (FCC) images were generated to facilitate the identification and visual interpretation of different land cover types.

Training samples representing six major land use and land cover classes were selected using NDVI, FCC imagery, and field observations. Ground truth data were collected from representative locations across the micro watershed using GPS during field surveys. The combined use of field observations and very high-resolution imagery improved the accuracy and reliability of the training dataset.

The training samples were converted into an `ee.FeatureCollection()` in GEE and used to train the Random Forest classifier. The classifier learned the spectral characteristics of each land cover class from the training dataset and subsequently classified all image pixels into their respective classes. The resulting classified image was exported as the final LULC map of the selected micro watershed.

Land Use Land Cover Classes

Based on spectral characteristics, field verification, and visual interpretation of QuickBird imagery, the study area was classified into six land use and land cover categories.

- a. **Scrub Forest:** Forest areas with canopy density ranging between 10 and 40 percent, consisting mainly of scattered trees, shrubs, and bushes.
- b. **Agricultural/Crop Land:** Areas under seasonal or annual agricultural cultivation, including croplands used for food and commercial crop production.
- c. **Plantation:** Areas occupied by systematically planted perennial tree crops such as arecanut and other horticultural or commercial tree species managed for economic purposes.
- d. **Fallow Land:** Agricultural fields that remain temporarily uncultivated to restore soil fertility and are characterized by sparse or negligible vegetation cover.
- e. **Built-up Area:** Areas occupied by residential buildings, roads, commercial establishments, and other infrastructural developments.
- f. **Water Bodies:** Natural and artificial water features such as rivers, streams, ponds, tanks, and reservoirs containing permanent or seasonal water.

Accuracy Assessment

The accuracy of the classified LULC map was evaluated using an independent set of reference samples derived from field observations and high-resolution QuickBird satellite imagery (0.61 m spatial resolution). The reference samples were compared with the classified output to generate a confusion matrix in Google Earth Engine.

Experimental Results

The Land Use Land Cover (LULC) map of the Nidnegal micro watershed (MWS-5) was prepared using high-resolution satellite imagery (QuickBird - 0.61 m resolution) through visual image interpretation and digitization in a Geographic Information System (GIS) environment. Based on the image interpretation, the study area was classified into different land use land cover categories and the resulting LULC map is presented in Fig. 1. The spatial extent and percentage distribution of each LULC class are summarized in Table 1. The classification resulted in six major LULC classes, namely crop land, scrub forest (hillock), plantation, built-up, fallow land and water bodies.

The results revealed that agriculture was the dominant land use class, covering 488.75 ha, which accounted for 52.95 per cent of the total geographical area of the micro watershed. This was followed by scrub forest, occupying 372.35 ha (40.34%). Plantation covered 24.41 ha (2.65%), while built-up area extended over 20.54 ha (2.23%) of the total area.

Further, water bodies occupied 15.94 ha, representing 1.73 per cent of the micro watershed area. Among all the LULC classes, fallow land occupied the smallest area of 1.03 ha, accounting for only 0.11 per cent of the total area.

Overall, agriculture and scrub forest together constituted 93.29 per cent of the total geographical area of the Nidnegal micro watershed, whereas plantation, built-up area, water bodies and fallow land collectively occupied the remaining 6.71 per cent.

Discussion

The land use and land cover (LULC) analysis of the Nidnegal micro watershed identified six major land cover classes, with agricultural land occupying the largest area (488.75 ha; 52.95%) followed by scrub forest (372.35 ha; 40.34%) while plantation (2.65%), built-up area (2.23%), water bodies (1.73%) and fallow land (0.11%) occupied comparatively smaller proportions of the watershed. The dominance of agricultural land indicates that the watershed is primarily agrarian whereas scrub forests are largely confined to hillock regions with relatively steeper slopes and

shallow soils. Similar land use patterns were reported by Ravikumar, (2020) ^[1] in the Koranahalli sub-watershed, where cultivated land (60.15%) and scrubland (36.52%) were the predominant land cover classes. The LULC classification achieved an overall accuracy of 91 per cent with a Kappa coefficient of 0.89, indicating a high level of agreement between the classified map and reference data. Comparable classification accuracies have been reported by Rawat and Kumar (2015) ^[2] (90.29-92.13% overall accuracy; Kappa 0.82-0.91), Das and Angadi (2020) (92.16-95.16 per cent overall accuracy; Kappa 0.90-0.94), and Koppad *et al.* (2020) ^[3], who achieved an overall classification accuracy of 97.09 per cent using IRS LISS-IV imagery. These findings confirm that the generated LULC map is sufficiently accurate and reliable for subsequent analyses such as carbon stock assessment, soil erosion modelling, land suitability evaluation and watershed management planning. The results revealed that the classified LULC map achieved an overall accuracy of 91% with a Kappa coefficient of 0.89. The obtained accuracy statistics indicate a high level of agreement between the classified LULC map and the reference data used for validation. The study conducted in Simlipal block, Bankura district, W. Bengal by Kiran and Srivastava (2014) ^[5] shows the potential of LISS 4 data in land use land cover classification. The study shows the supervised classification accuracy of 90-95%.

Table 1: Area under various current land use land cover types of Nidnegal MWS

Sl. No.	Major Land Use	Area in ha	Area (%)
1	Built up	20.54	2.23
2	Agriculture/Crop land	488.75	52.95
3	Plantation	24.41	2.65
4	Scrub Forest (Hillock)	372.35	40.34
5	Fallow land	1.031	0.11
6	Water body	15.94	1.73

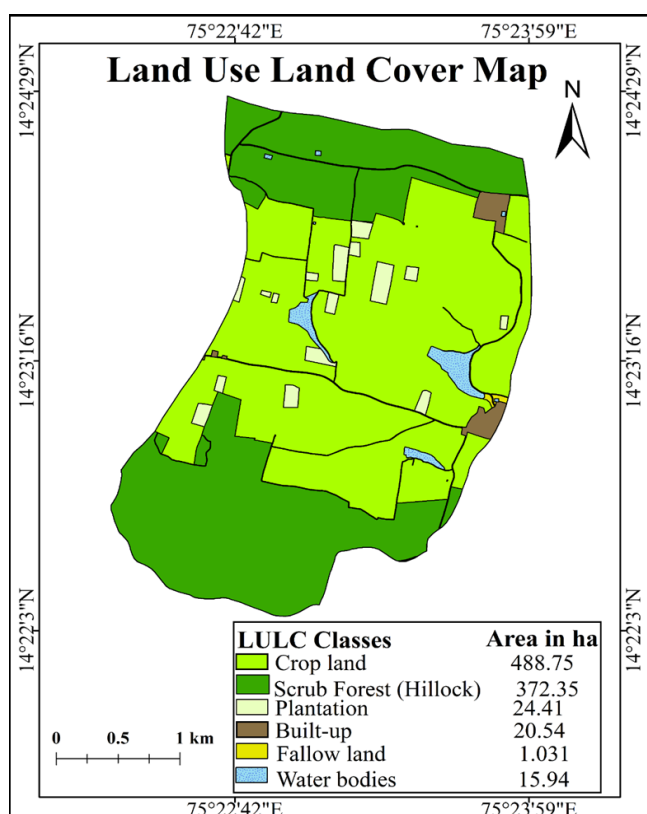


Fig 2: Land use land cover map of Nidnegal MWS

Conclusion

The LULC analysis indicated that the Nidnegal micro watershed is predominantly characterized by agricultural land and scrub forest, which together occupy more than 93 per cent of the total geographical area. The dominance of cropland reflects the agricultural importance of the watershed, while the extensive scrub forest on hillocks plays a significant role in protecting the landscape from soil erosion and maintaining ecological stability. The comparatively smaller extent of plantations, built-up areas, water bodies and fallow land suggests limited urban expansion and localized land-use diversification. Furthermore, the high overall classification accuracy (91.00%) and Kappa coefficient (0.89) confirm the reliability of the generated LULC map, demonstrating its suitability as a baseline dataset for soil erosion assessment, land suitability evaluation for agroforestry interventions and watershed management planning.

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