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High-Resolution Land Use and Land Cover Mapping in Northern Region of Kashmir Himalayas Using LISS IV Data

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Abstract: Land use/cover change (LULC) studies are important for understanding environmental dynamics and ensuring sustainable management of resources. This study used LISS IV satellite data of 2016 to map and classify three forest divisions viz., Langate Forest Division (LFD), JV Forest Division (JV) and Special Forest Division Tangmarg (SFD) of Kashmir Himalayas. Using high resolution satellite data (LISS IV), the study area was delineated into 11 LULC classes: agriculture, built-up, forest, forest scrub, grassland, horticulture, snow, trees outside forest (TOF), waterbody, wetland, and wasteland. Dominant land cover was recorded in class forest with highest percentage of 49% in JV Forest division, followed by Langate forest division (42.21%) and SDF Tangmarg (22.26%). Horticulture was dominant land use in Langate Forest division (23.46%) and SDF Tangmarg (22.26%), while agriculture was most prominent in SDF Tangmarg (22.56%). Snow cover (9.26%) and wetlands (2.51%) was observed highest in SDF Tangmarg (9.26%) due to its higher altitudes. An overall accuracy of 93.52% and a kappa coefficient of 0.928 was observed. Producers and users accuracy was highest in agriculture (97.78 and 95.65%), grassland (96.43 and 96.43%) waterbody, (97.22 and 92.11%) and wasteland classes (95.45 and 95.45%). In comparison, wetland and forest classes showed slightly lower accuracies due to spectral overlap being 81.25 and 92.86% for wetland and 95.83 and 88.46% for forest. The individual and integrated LULC maps of three distinct forest divisions provided a detailed spatial representation of land use patterns, vital for decision making for land management and conservation planning. The study provide baseline data for addressing ecological challenges in the region and will contribute for future research in temporal LULC changes to assess their impact on ecosystem services and regional sustainability.

Keywords: LULC, LISS IV, Kashmir Himalaya, Forest division

Land is one of the essential natural resources, which support life and use it for a lot of developmental activities 'Hohol, Nedilska 2021).. One of the main triggers for a variety of land-based changes is land use/cover change (LUCC). LUCC affects the Earth's energy interconversion, which in turn affects the water cycle, ecosystem stability, socioeconomic aspects, and regional climate conditions (Kopittke et al., 2022, Chen et al., 2024). It provides a basis for human existence and development. LULC data is very essential for natural resource management, monitoring environmental changes, modelling, carbon cycle studies, policy formulation, hydrology, and analysis of global climate change (Song et al., 2011). Analysis of land use and land cover (LULC) provides crucial details about the region's historical development (Vijay and Varija 2024).

The LULC pattern of a region reflects the influence of natural and socioeconomic factors over time and space (Kumar et al., 2019). Unregulated changes in LULC usually degrade the environment, reduce availability of water, and lower world food security; therefore, it is a global concern. Land use is significantly affected by the interaction between natural land potential, cultural contexts, societal conditions, and physical needs (Tsai et al., 2019). Anthropogenic pressures that include population growth and increased human demand for terrestrial resources strongly alter land cover, hence causing a range of changes throughout different land systems making land a scarce resource (Shiferaw, 2011, Qasim et al., 2013, Desta and Fetene 2020, Singh et al., 2020). Hence quantifying the change in land use land cover is important for highlighting impact of human activities on the earth's surface (Deng and Quan 2023). Monitoring LULC changes gives insight into how ecosystem transformations affect the environment(Kayet, 2015, C hokkavarapu et al, 2018, Metha and Singh 2021).To address these challenges, the physical and socioeconomic drivers of land use changes and their implications in land use management policies must be understood. Despite such changes providing economic benefits, the natural environment is destabilized, affecting LULC classes and causing further ecosystem degradation (Betru et al., 2019, Schürmann et al., 2020).

Space technology developments have increased the resolution and access to remote sensing data; therefore, remote sensing data have become useful for examining local to global-scale phenomena (Rogan et al., 2008). Integrating remote sensing with GIS has improved the mapping and

classification of LULC in tremendous ways; this permits analysis on different temporal scales (Lillesand et al., 2015). Studying LULC changes requires linking a set of socioeconomic factors- economic diversification, technological advancement, population pressure among others and biophysical properties of land (Reid et al., 2000). In the Himalayan area, especially in the Kashmir Himalayas, such changes have created decreased productivity of land, therefore development concerns. Human activities in these fragile ecosystems have triggered the transformation, such as converting farmlands and abandoned areas into horticultural businesses. The main motivation is the desire to maximize profits (Shafiq et al., 2016, 2017, Fayaz et al., 2020).

The northern Kashmir Himalayas region is identified by unique topography and climatic conditions and with diverse ecosystems. The LULC in this region has registered significant changes over the recent decades. This has made changes to traditional land uses, degraded natural resources, and made it difficult to sustain in the face of development requirements. Thus, there's a need to assess these LULC patterns in this area to know the extent and intensity of change and inform some strategies to be aimed toward sustainable resource management (Wani et al., 2019, Rasool et al., 2021). .

High-resolution remote sensing data, specifically LISS-IV image, are used as valuable tools to acquire integrated information about spatial and temporal variation, especially concerning LULC phenomena (Zhu et al., 2018, Wani et al., 2019). LISS-IV sensors have fine spatial and multispectral capabilities for assessing various landscapes, especially from the Kashmir Himalayas. Once a researcher combines this data through GIS technology, then true mapping, monitoring, or classification of changes in LULC can be carried out with excellent accuracy.

The aim of this study is to identify dominant LULC classes and change over time among these divisions. The findings can help in better understanding of the dynamics involved in land use in the area and facilitate efforts toward alleviating the environmental and socio-economic consequences of LULC changes.

MATERIAL AND METHODS

Study area: This study was conducted in Langate Forest Division (LFD), JV Forest Division (JV) and Special Forest Division Tangmarg (SFD) of Kashmir Himalayas, covering a total area of 5732 km^2 (Fig. 1). The area is located at 34o0′0″ to 34o30′0″ north latitude and 74o0′0″ to 74o40′0″ east longitude and occupies northern part of Kashmir Himalayas. The area experiences temperate type of climate and with and annual rainfall of 660-1400mm and average annual temperature of around 13 °C. The study area consists of different forest types viz., lower west Himalayan temperate, dry temperate deciduous and sub alpine Fir forests, deciduous alpine scrub and alpine pastures (Wani et al., 2019). The Langate Forest Division (LFD) encompasses the regions of Mawar, Magam, Rajwar, and Rafiabad. The JV Forest Division (JV) includes the areas of Baramulla, Doabgah, Boniyar, and Uri. The Special Forest Division Tangmarg (SFD) covers Gulmarg, Soil Conservation, and Beerwah. The region is mainly composed of evergreen species including *Pinus wallichiana, Cedrus deodara, Abies pindrow and Picea smithiana* (Mehraj et al., 2025).

Land use land cover mapping: For LULC mapping, satellite data was obtained from United States Geological Survey (USGC) for 2016. The attained satellite data was pre-processed with aim for making a False Color Composite (FCC) using image processing software. Field survey was carried in study area to get primary information about the land use, topography, vegetation types and biodiversity etc. The information so generated was used in decision making while mapping. At 1:50000 scale mapping software was used in carrying out mapping of satellite data. The ground truth data collected from the field was used for accuracy assessment (Producer's Accuracy, User's Accuracy and Kappa). Different land use types (LULC) and forest classes delineated based on crown viz., Forest scrub, Grassland, Agriculture, Trees outside forest/ Agroforestry, Horticulture, Habitation, Water body, Wetland, Wasteland and Snow.

Map validation: The forest density map was generated using appropriate software and validated through ground truthing. Field data were collected for accuracy assessment, including information on forest type, latitude/longitude, altitude, crown density, tree density (per 0.1 ha), and slope percentage. An error matrix was prepared to evaluate the classification accuracy of the forest density map. Metrics such as producer's accuracy, which measures omission error and user's accuracy, which quantifies commission error, were calculated. Overall accuracy and Kappa coefficient of the map was also calculated (Congalton et al. 1983)..

RESULTS AND DISCUSSION

Eleven land classes have been identified in the study area viz., agriculture, built up land, forest, forest scrub, grassland, horticulture, snow, trees outside forest, water body, wetland, and waste land (Table 1 , Fig 2). LULC across the three forest divisions under study showed significant differences in land use pattern. Among different LULC classes, forest cover was highest in JV forest division with an area of 48,345.58 ha (49.00%) of the total area. SDF Tangmarg recorded lowest

forest cover of 16431.55 ha (18.24 %) while as Langate Forest division recorded 30,623.64 ha (42.21 %) of forest cover.

Horticulture is a major land use class in SDF Tangmarg and Langate Forest Division, covering 22.26% (20,055.36 ha) and 23.46% (17,021.87 ha), respectively, while it is significantly less in JV Forest Division (13.51%). Similarly, agricultural land use is most prominent in SDF Tangmarg, occupying 22.56%, compared to 15.34% (in Langate and only 7.78%) in JV Forest Division. Built-up land shows a higher percentage in SDF Tangmarg (8.74%) compared to JV Forest Division (6.06%) and Langate Forest Division (5.29%), reflecting greater urbanization in SDF Tangmarg. Grasslands were more prevalent in Langate Forest Division, covering 3.24% ha), while they occupy only 2.14 and 0.84% in SDF Tangmarg and JV Forest Division, respectively. Snow cover is a distinct feature of SDF Tangmarg, covering 9.26% (8,337.98 ha), indicative of its higher altitudes, whereas was minimal in JV Forest Division (0.36%) and negligible in Langate (0.05%). Wetlands were observed only in SDF Tangmarg, (2.51% -2,260.90 ha), while were absent or negligible in the other divisions.

The majority of LULC classes obtained high levels of accuracy. Among all the classes agriculture, grassland and wasteland showed both Producers and Users Accuracy exceeding 95%. In comparison wetland and forest classes recorded relatively lower accuracies. Users accuracy of 88.46% was in class forests, while as wetland class recorded Producers accuracy of 81.25%. These variations are likely due to spectral overlaps and challenges associated with distinguishing specific LULC classes. Overall accuracy of 93.52% was recorded, with an overall Kappa coefficient of 0.928 (Table 2). The maximum area under horticulture (22.26%) in the more urbanised

Some studies, in SFD Tangmarg indicate noticeable shiftfrom agriculture towards horticulture, due to the economic benefits of horticultural crops which led to rise in horticulture plantations(Shafiq et al., 2016, 2019, Mishra and Rafiq, 2017). These studies further explain that over time, a

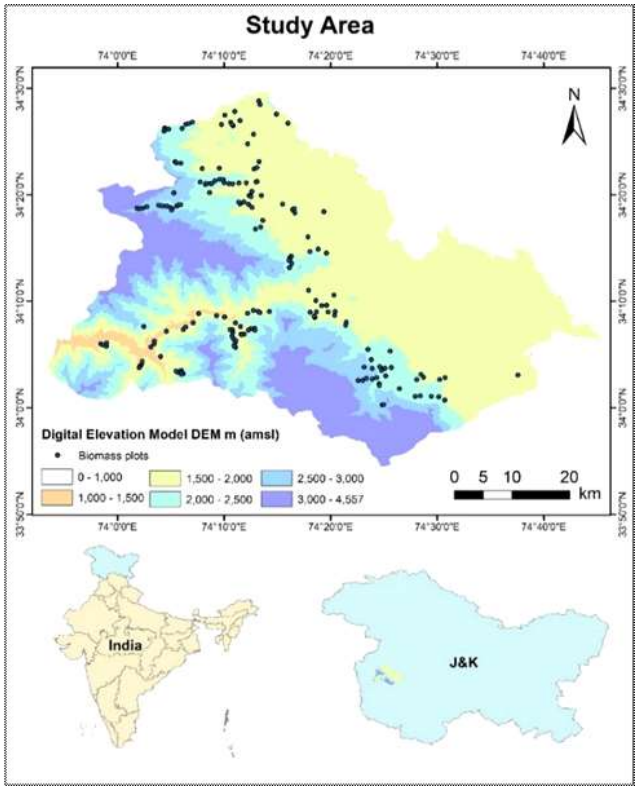

Fig. 1. Study area

Table 1. Land use land cover practices in different forest divisions

Classes	JV Forest Division		SFD Tangmarg		Langate Forest Division	
LULC	Area (ha)	%	Area (ha)	%	Area (ha)	%
Agriculture	7677.942	7.78	20325.59	22.56	11126.1	15.34
Built-up	5980.104	6.06	7877.27	8.74	3837.292	5.29
Forest	48345.58	49.00	16431.55	18.24	30623.64	42.21
Forest Scrub	3305.625	3.35	3521.66	3.91	1147.934	1.58
Grassland	829.9418	0.84	1931.04	2.14	2349.091	3.24
Horticulture	13331.46	13.51	20055.36	22.26	17021.87	23.46
Snow	355.6376	0.36	8337.98	9.26	33.2836	0.05
Trees Outside Forest (TOF)	2055.955	2.08	4928.91	5.47	2486.895	3.43
Waterbody	2066.655	2.09	2340.93	2.60	1248.537	1.72
Wetland	0	0.00	2260.90	2.51	28.95828	0.04
Wasteland	14722.22	14.92	2079.87	2.31	2639.044	3.64
Grand Total	98671.12	100	90091.05	100	72542.64	100.00

rise in temperature accompanied by a decrease in precipitation led to increasing evapotranspiration and hence adaptation of horticulture by people. Present study is in also in conformity with Fayaz et al. (2020) for the period 1992-2018 also observed that the rate of change of LULC classes was high. The area of the land use types like horticulture, sparse forest, scrub lands, pasture lands, barren lands and human settlement tends to increase. The present study revealed an overall classification of 93.52% and kappa coefficient of 0.928 for LULC classification. The LULC in south Kashmir revealed an overall accuracy of 85% and a Kappa coefficient of 0.856 for the year 2022 and the area of horticulture expanded to 1236.59 km^2, representing 22.72% of the total land area from the year 2000 to 2022(Mushtaq et al., 2024). Similarly the forest area showed an increase of 74.76 km^2 (5.05%)due to conservation efforts which is similar to present sub-study area's SFD Tangmarg, Langate Forest Division and JV Forest Division, respectively.

In all the three divisions spatially heterogeneous geographic areas are characterized by interacting patches of different diverse ecosystems, ranging from relatively natural terrestrial and aquatic systems such as pastures, forests, water bodies and plant community to human-influenced habitats and agricultural as suggested by Gardner (2015) .

The study area also has a prominence of forest cover in the form of horticulture and trees outside forests forming 15.59 % in JV forest division, 27.73% in SFD Tangmarg and 26.89% in Langate forest division. TOFs have great potential in offsetting climate change through carbon capture).Wani et al. (2019)while using high resolution LISS IV satellite data for

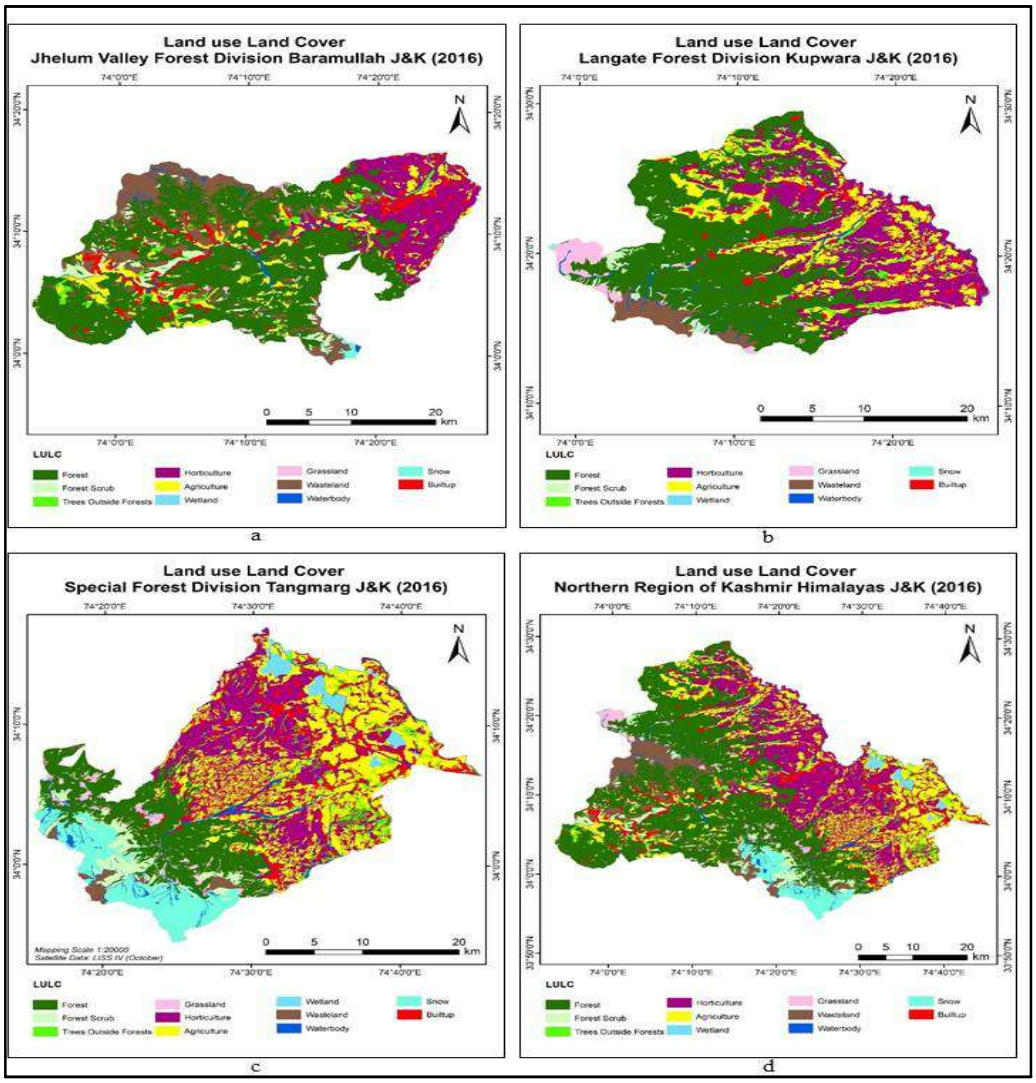

Fig. 2. LULC map of study area

assessing the area under TOF in the same study area found that the highest percentage of TOF was recorded in Special Forest Division Tangmarg that is about (5.47%) and the same was observed true for current study. Mehraj et al. (2021)using the LISS IV data for LULC classification of central region of Kashmir Himalayas observed that the overall area under TOF of district Ganderbal is 6.77% of total geographical area of the district. The overall classification accuracy of LULC map was 85.00% and kappa coefficient of 0.8333.Several other workers have carried similar studies on land use land cover classificationin different study areas (Ganguly et al., 2016, Fayaz 2023, Behera et al., 2024, Alvarez Gebelin et al., 2024, Jaiswal et al., 2025,).

The findings of this study the occurrence of different land use characteristics of each forest division. JV Forest division being predominantly natural and with minimal human intervention showed highest forest area (49.00%) among all other studied divisions. In comparison, SDF Division Tangmarg showed agriculture (22.56%) and horticulture (22.26%). Langate Forest Division exhibits a mixed landscape dominated by forests and horticulture, with noticeable grassland cover and limited snow and wetland presence. These variations underscore the importance of tailoring land management and conservation strategies to the specific ecological and socio-economic contexts of each division.

CONCLUSION

LULC mapping of the study area for 2016 identified 11 distinct land classes, indicating significant spatial variations across three forest divisions. JV forest divisions showed highest area for class forest, while SDF Tangmarg recorded the lowest forest cover In SDF Tangmarg, horticulture class represented major land use, area. Agricultural land use was most pronounced in SDF Tangmarg reflecting diverse land use practices. In case of snow and wetland classes, highest area was found in SDF Tangmarg. These findings highlight the heterogeneity in LULC patterns, driven by ecological, topographical and anthropogenic factors.

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AUTHOR's CONTRIBUTION

AAW initiated and conceptualized the study. All authors (AFB, AAW, AAG, MAI, SM and SF) contributed to field data collection and lab work. AAW and AFB contributed to data evaluation. All authors (AFB, AAW, AAG, MAI, SM and SF) contributed to writing and reviewing the manuscript.

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