Assessing land use land cover of Srinagar Municipal Region using Sentinel-2 data for urban planning and management

ABSTRACT

Understanding the changes in land use land cover mostly due to urbanization is crucial in the context of urban planning and management. LULC studies are also important in socioeconomic development, natural resource management, planning and preservation of green spaces, water and land resources. This study attempts mapping and analyzing LULC in the municipal region of Srinagar, Jammu & Kashmir to gain a better understanding of the patterns and drivers of changes.Sentinel-2 satellite data of2022 was used to delineatethe study area into 13 classes viz., agriculture, aquatic vegetation, barren land, built-up, forest, forest scrub, grassland, horticulture, institutional Farm, mixed green space, TOF, waterbody and wetland. Built up occupied the maximum area (8920.73 ha)forming 36.25% of the area, while Institutional farm class took up the least space of 30.74 ha (0.12%). Among other classes that that occupy prominent area include Agriculture (18.8%), Trees outside Forests (9.62%) and Waterbody (7.15%). The overall classification accuracy was observed as 94% with a kappa statistic of 0.93. This study shows that Srinagar city has experienced fast urbanization and loss of green space to builtup.The results of this study could help devise strategy for urban planning under smart city mission to enhance green spaces and ensure a balanced its balanced distribution.

Keywords: Srinagar Municipal Region, Land use land cover (LULC), Trees outside Forests, Waterbody, Sentinel-2

INTRODUCTION

Land use land cover (LULC) is a key driver of worldwide environmental change (Pandey et al., 2021). Urbanization, population increase, depletion of natural resources, and the effects of climate change are the primary drivers of LULC changes (Sam et al., 2023). Remote sensing (RS) technology is a strong instrument that provides a more convenient and efficient method for gathering information about the Earth's surface (Pandey et al., 2021). The combination of Geographic Information System (GIS) and Remote Sensing (RS) has gained popularity in the context of LULC mapping and monitoring, effectively supporting sustainable development projects in a variety of geographic situations (Chen et al., 2022). The Himalayan region has served as a breeding ground for studies that use GIS and RS techniques to examine LULC dynamics and provide valuable insights for long-term planning and management efforts (Mishra

et al., 2019), as well as policy and decision-making processes in other regions, such as (Sari et al., 2023). Undoubtedly, LULC maps are among the most essential documents that provide information for a variety of applications such as land use policy formulation, agricultural monitoring, urban planning, ecosystem services, nature conservation, and dynamic assessment (Thanh noi and Kappas, 2018). Furthermore, GIS-based image classification approaches have made considerable advances in LULC investigations (Abdi, 2019; Belenok et al., 2022), including the assessment and identification of changes in dynamics(Pasha *et al*., 2016; Duarte *et al*., 2019).

Image categorization for geospatial mapping, in particular, has gained a lot of interest due to the availability of medium to high-resolution multispectral satellite data (Tempa and Aryal, 2022), while the global products available are particularly well-suited to local planning and management. Land-use statistics are also required for the examination of ecological processes and problems that must be understood in order to improve or sustain current living conditions and standards (Anderson, 1976). Studies employing Landsat satellite pictures with low resolution (30m) resulted in significant/noticeable inaccuracies in interpreting land use/land cover. As a result, a method was proposed for evaluating an area using satellite images (Sentinel-2) with higher resolution than Landsat images, which was very useful in practice. Sentinel-2, a new imager deployed into orbit in 2015, has piqued the interest of both the scientific community and practical applications due to its multi-spectral band features and reasonably high spatial resolution (10m) (Phuong *et al*, 2024).

Srinagar, being the summer capital of Jammu and Kashmir and the trading heart of the Kashmir valley, has experienced significant environmental change. The urbanization process causes chaotic expansion, deteriorates living conditions, and degrades environmental scenarios, all of which have negative consequences for human health (Hassan et al., 2016). The purpose of this study was to analyze the LULC patterns in the municipal region of Srinagar district, which was accomplished through the identification and delineation of different LULC categories using Sentinel-2 as a data source.

Methodology

Study area

The study was conducted in municipal region of Srinagar city, J&K which lies between 33°59'0"N and 34°13'0"N latitude and 74°40'0"E and 74°58'0"E longitude. The boundary confronts to the extent of urban forest division Srinagar. The Srinagar district is located on the banks of the Jhelum River tributary of the Indus. Spreads between the plains of valley up to the

mountainous region of famous Dachigam forest area. It represents one of the, ecologically fragile, economically developing, tectonically unstable and one of the densely populated mountain ecosystems on the planet. The general relief of the study area is 1580-2500 m above mean sea level. The general terrain is moderate and represents hill topography. Srinagar has a humid subtropical climate. The valley is surrounded by the Himalayas on all sides. Winters are cool, with daytime temperature averaging to 2.5 °C (36.5 °F), and drops below freezing point at night. Moderate to heavy snowfall occurs in winter. Summers are warm with a July daytime average of 24.1 °C (75.4 °F). The average annual rainfall is around 720 millimetres (28 in). Spring is the wettest season while autumn is the driest. The highest temperature reliably recorded is 39.5 °C (103.1 °F) and the lowest is −20.0 °C (−4.0 °F). The population density of the study area is 4407 persons per square Kilometer (Kuchay*et al*., 2016).

Methods

Pre-processing of satellite data

Satellite data for the year 2022 (October) was obtained from European Space Agency (ESA). Using image processing tools like ERDAS Imagine, the satellite data was preprocessed to create a false colour composite (FCC) with the desired band combinations. Additionally, various image enhancing techniques were used for better LULC interpretation in Srinagar city.

Preliminary survey of the research region

A Preliminary survey was conducted in the study area to get primary information concerning land use, topography, accessibility, and so on. The information gained wasparticularly important in determining the nature of the mapping to be done and the number of LULC classes to be specified.

LULC Map Generation

Mapping of satellite data for the year 2022 was carried out through on screen digitization employing mapping software (ArcGIS) at 1:20000 mapping scale. The satellite data was represented into different classes including Agriculture (Ag), Aquatic vegetation (AV), Barren land (BL), Built-up (BU), Forest, Forest scrub (FS), Grassland (Gl), Horticulture (Hc), Institutional farm (IF), Mixed green space (MG), Trees outside forests (TOF), WaterbodyWb) and Wetland (Wl).

Accuracy assessment &Validation: The accuracy assessment of generated LULC map was carried by using ground truth points collected during field visits and from Google earth in case of in accessible areas.

The user's accuracy, producer's accuracy and overall accuracy of the LULC map of Srinagar city (Municipal area) was generated using error matrix and on the basis of these accuracies, KAPPA (KHAT coefficient) was calculated. Producer's accuracy is a measure of error of omission and user's accuracy is a measure of error of commission. KAPPA analysis is a discrete multivariate used in accuracy assessment (Congalton*et al*., 1983)

$$Producer's accuracy = \frac{No.\ of correctly classified pixels in each category}{\text{Total No. of validation points used for that category (column total)}}$$

$$User's accuracy = \frac{No.\ of correctly classified pixels in each category}{\text{Total No. of validation points used for that category (row total)}}$$

$$Overall accuracy = \frac{No.\ of correctly classified pixels}{\text{Total No. of validation points}}$$

$$K = \frac{N\sum_{i=1}^{r} xii - \sum_{i=1}^{r} (x_{i+} xi)}{N2 - \sum_{i=1}^{r} (x_{i+} x_{x+i})}$$

$$Also, K = \frac{observed accuracy - chance agreement}{1 - \text{chance agreement}}$$

Were,

k = Kappa coefficient

r = number of rows in the error matrix

N = Number of observations

xii = the number of observations in row i and column i (on the major diagonal)

xi+ = total number of observations in row i (shown as marginal total to right of the matrix)

x+i = total number of observations in column i (shown as marginal total at bottom of the matrix)

RESULTS

Land use land cover of Srinagar Municipal Region (SMR)

Land use land cover of SMR for the year 2022 was classified into 13 LULC classes among which Built up class took up the most space (36.25%) followed by agriculture 18.80%), TOF

(9.62%), horticulture (8.46%), mixed greenspace (8.10%), waterbody (7.15%), aquatic vegetation (4.44%), forest (3.42%), wetland (2.27%), barren land (0.89%), forest scrub (0.31%), grassland (0.15%), and institutional farm (0.12%) as shown in table 1. The land use land cover map of SMR is presented in Fig 1. Several colors have been assigned to symbolize different land use land cover classes in LULC map of 2022.

Table1. Spatial distribution of LULC classes in Srinagar Municipal Region (SMR)2022.

Class	**Area (ha)**	**%**
Agriculture	4626.95	18.80
Aquatic Vegetation	1091.72	4.44
Barren Land	219.58	0.89
Builtup	8920.73	36.25
Forest	847.26	3.42
Forest Scrub	75.64	0.31
Grassland	37.57	0.15
Horticulture	2082.08	8.46
Institutional Farm	30.74	0.12
Mixed Green	1993.17	8.10
Trees Outside Forests	2367.90	9.62
Waterbody	1760.38	7.15
Wetland	558.20	2.27
Grand Total	**24605.92**	**100.00**

Accuracy Assessment

For accuracy assessment total of 292 ground truth points were collected across the study area. The error matrix generated for the developed map of Srinagar city (2022) is presented in table 2. This was employed for calculating producer's accuracy, user's accuracy of each LULC class. The values for overall accuracy and kappa statistics were 94 % and 0.93 respectively.

Table 2. Error matrix for LULC map (2022)

Class	AV	Ag	BL	BU	Forest	FS	Gl	Hc	IF	MG	TOF	Wb	Wl	Total	Users Accuracy
AV	17	0	0	1	0	0	0	0	0	0	0	0	0	18	0.94
Ag	0	19	0	0	0	0	0	0	0	0	0	0	1	20	0.95
BL	0	0	8	0	0	0	0	0	1	0	1	0	0	10	0.80
BU	1	0	0	90	0	0	0	0	0	0	0	0	0	91	0.99
Forest	0	0	0	0	23	1	0	0	0	0	0	0	0	24	0.96
FS	0	0	0	0	1	45	1	0	0	0	0	0	0	47	0.96
Gl	0	0	0	0	0	1	9	0	0	0	0	0	0	10	0.90
Hc	0	0	0	0	0	0	0	9	0	0	1	0	0	10	0.90
IF	0	0	1	0	0	0	0	0	9	0	0	0	0	10	0.90
MG	0	0	0	0	0	0	0	0	0	20	1	0	0	21	0.95
TOF	0	0	0	0	0	0	0	1	0	1	9	0	0	11	0.82
Wb	0	0	0	0	0	0	0	0	0	0	0	9	1	10	0.90
Wb	0	1	0	0	0	0	0	0	0	0	0	1	8	10	0.80
Total	18	20	9	91	24	47	10	10	10	21	12	10	10	292	
Producers accuracy	0.94	0.95	0.89	0.99	0.96	0.96	0.90	0.90	0.90	0.95	0.75	0.90	0.80	0.94	

Overall Classification accuracy= 94 %

Kappa statistics=0.93

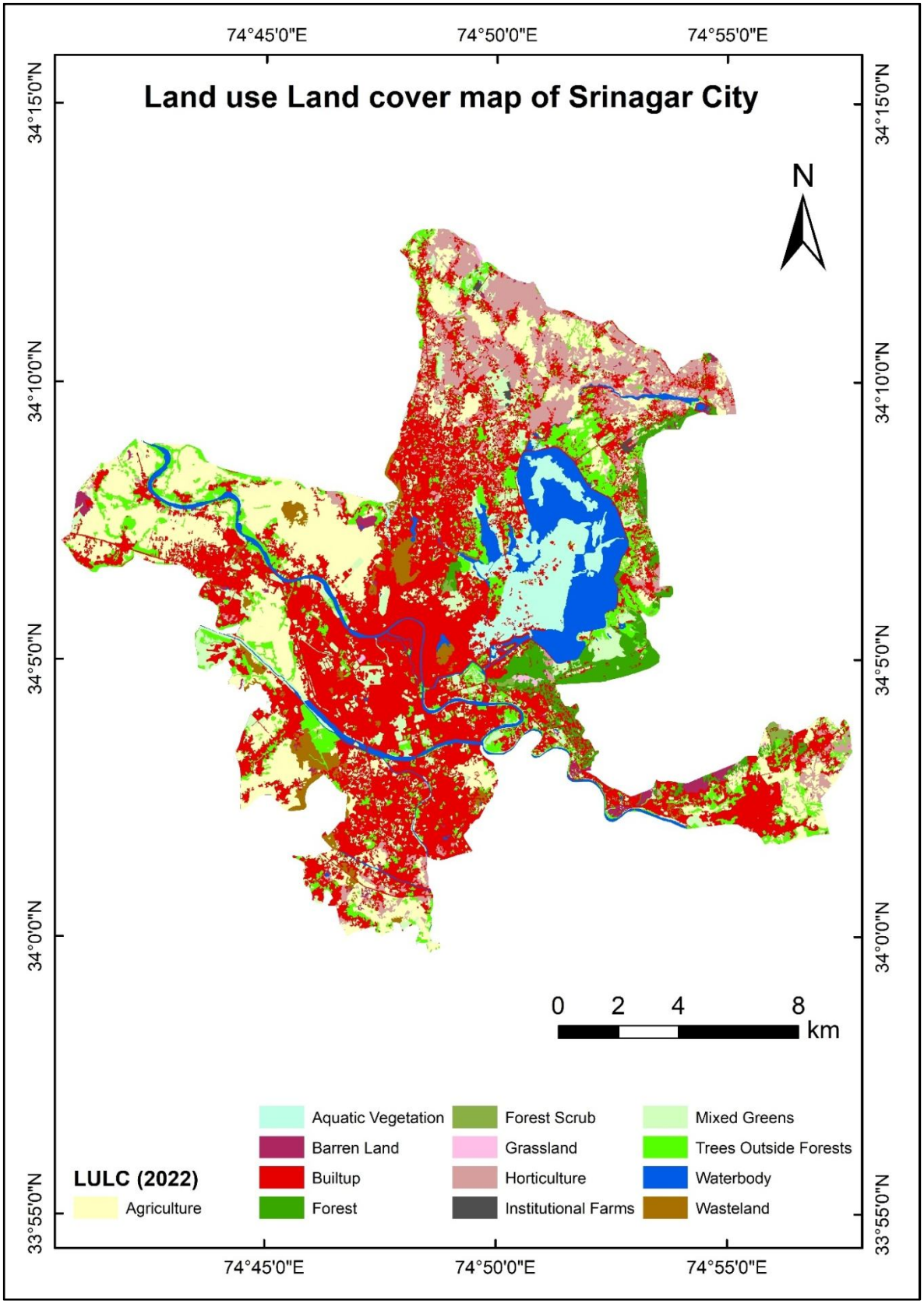

Fig. 1. LULC map (2022) of Srinagar Municipal region (SMR)

DISCUSSION

The current study which was conducted in Municipal region of Srinagar by using ESA based sentinel-2 for the year 2022 as data source. For mapping purpose ArcGIS at a mapping scale of 1:20000 was used and results reveal that the highest coverage was observed under built up (36.25%) > agriculture (18.80%) > TOF (9.62%) > horticulture (8.46%) > mixed greenspace (8.10%) > waterbody (7.15%) > aquatic vegetation (4.44%) > forest (3.42%) >wetland (2.27%), barren land (0.89%) > forest scrub (0.31%) > grassland (0.15%) >institutional farm (0.12%). The current study's findings on the land use and land cover (LULC) classification of SMR, using Sentinel-2A satellite data from 2022, match with earlier research that emphasizes the effectiveness of Sentinel-2A in detailed LULC analysis. The built-up area in Srinagar city has seen the largest LULC change in the past 20 years due to the high rate of urbanization, population growth, migration, and tourism, according to a similar study by Ahmad *et al*., 2024. It increased from 34.53 km^2 in 2000 to 60.63 km^2 in 2020.The study by Degife et al. (2018), which used Sentinel 2A multispectral data to evaluate changes in land use and land cover as well as agricultural farmland expansions in Ethiopia's Gambella region between 1987 and 2017, is one of several studies that have previously used Sentinel 2A data to create LULC maps. In their study of Beijing, Tempa et al. (2024) showed comparable outcomes, highlighting the ways in which Sentinel-2A data facilitated the identification of urbanization and declines in green space. The four main LULC categories—aquatic bodies, vegetation, built-up areas, and barren land—were the emphasis of their image classification. Mehraj et al. (2021) examined LULC, specifically for trees outside of forests (TOF), in the central region of the Kashmir Himalayas using IRS LISS-IV data. The findings showed that TOF's total coverage area made up 6.77% of the whole study area. Among the TOF strata, block TOF had the largest area (6.395%), followed by scattered TOF (0.005%) and linear TOF (0.370%). Numerous other researchers, including Gul et al. (2022), Revuelta-Acosta et al. (2022), Ariez et al. (2022), Sourn et al. (2022), Sarif and Gupta (2021), Wani et al. (2020), Paudyal et al. (2019), Islam et al. (2018), Singh et al. (2018), and others, have also studied LULC classification and evaluation using different kinds of satellite data.

In current study, an overall classification accuracy and overall kappa coefficient of 94 % and 0.93 respectively were obtained. During a study conducted by Phoung et al. (2024) on LULC Change for Thanh Hoa coastal area, VietNam by using Sentinel-2 satellite image data they

documented that Sentinel-2 MSI satellite image data can accurately interpret and classify land cover, with Kappa values ranging from 0.892 to 0.907.Saini et al. (2019) conducted an investigation on LULC change detection using remote sensing and GIS in Srinagar, India from 2008 to 2016. Their study concluded an overall classification accuracy of 78.01 % and 82.72 % respectively and the values obtained for kappa statistics were 0.61 and 0.78.Murtaza et al. (2015) used RS and GIS-based technologies to map Srinagar city geospatially and they achieved an overall accuracy of 89% and a Kappa value of 0.87. Our findings concur with those of Mehraj (2023), Phiri et al. (2020), and Zahoor et al. (2020).

CONCLUSION

The land use land cover of Srinagar is predominantly covered by builtup classes that include roads, infrastructure, and residential colonies. There is a fair percentage of green spaces with the Srinagar municipal region, however its distribution is more towards the peripheries of the city. Moreover, a significant amount of agricultural land, trees outside forests over the years has been lost to habitation due to urban expansion. There is an urgent need to identify spaces that can be covered under green spaces especially under the core city region.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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Details of the AI usage are given below:

1.

2.

3.

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