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Land Use Land Cover Dynamics Around a Western Himalayan Wetland using Geospatial Techniques

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Abstract

Despite having multitude of environmental advantages, wetlands are facing serious anthropogenic threats due to changes in the surrounding area. Therefore, the present investigation has been conducted to evaluate the landuse land cover (LULC) around a 6 km buffer strip of Nowgam wetland located in Kashmir valley. The detection of Land Use and Land Cover (LULC) changes was conducted using Landsat imagery within ArcGIS, spanning a 22-year period from 2000 to 2022. The Landsat imageries of three years (2000, 2010 and 2022) were classified using the supervised classification algorithm (maximum likelihood classification) in ArcGIS. Five LULC classes, viz., water, agriculture, settlement, vegetation and bareland were identified in the study region. The exploration of the classified images revealed the area under water decreased by about 56% where as area under agriculture and settlement increased by 44.7% and 30.9%, respectively. The area under vegetation decreased by 7.3% and area under bareland increased by 8.0%. The outcomes of the present discourse reveal that the changes in LULC around the Nowgam wetland are mostly anthropogenic which may pose serious threat to wetland ecosystem in near future. The present study provides a baseline data regarding ecosystem transformations and acts as an important stimulus for all the stakeholders of wetland in planning and implementation of the strategic conservational measures in Nowgam wetland (Bandipora).

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Introduction

Wetlands are ecosystems characterized by their unique hydrology, where the presence of water, either permanently or seasonally, plays a fundamental role in shaping their physical and biological attributes. As per the definition, "Wetlands are transitional areas between land and water environments, where the water table is typically at or near the surface, or the land is covered by shallow water."[1] Wetlands are included in the most prolific and diversified ecosystems of Earth and play a dynamic role in regulating hydrological processes within watersheds.[2] Indeed, wetlands offer a consortium of ecosystem goods and services that are important for both human welfare and the environmental health.[3,4] For example, carbon sequestration, biological conservation, water filtration, regulation of hydrological cycles (regional & global), maintaining the equilibria between various food chains in a food web, nutrient removal through bioremediation, groundwater recharge, irrigation water, flood control, fisheries, forest products, and recreation are some of the productive services which are extended by the wetlands. Additionally, wetlands serve as a natural filter for pollutants in numerous agricultural and urban settings.[5] In such scheme, wetlands indeed offer numerous economic benefits, particularly in mitigating both point and non-point pollution at a relatively low cost compared to traditional infrastructure solutions.[6] Wetlands regulate water flows and can serve as highly effective flood control mechanisms.[7] Wetlands possess unique consortium of capabilities in acting as a natural barrier, floodplain expansion, soaking surplus water during the peak flows and then the gradual release into other aquatic bodies (sponge effect), and flood risk reduction. Likewise, wetlands play a critical role in recharging groundwater supplies and mitigating the impacts of drought through their water storage and slow release mechanisms. Wetlands contribute to climate change mitigation and adaptation while also providing critical habitat for a wide range of species.[8,9] Integrating wetland conservation into climate policies and adaptation strategies is essential for maximizing the benefits they provide to ecosystems and human communities. By recognizing the importance of wetlands as natural solutions to climate change, we can enhance their resilience and certify their inexorable provision of valuable amenities in a changing climate.

Indeed, despite their significant ecological and societal benefits, wetlands around the world continue to face numerous threats, leading to their loss and degradation.[10] Worldwide, the loss of wetlands has been primarily attributed to a combination of anthropogenic factors including: ecosystem transformation for infrastructure development and intensive agriculture, urban sprawl, pollution from industrial activities, domestic sewage, and agricultural runoff, climate change,[4,8] unsustainable levels of grazing and fishing activities,[11] cultural eutrophication, and nitrate toxicity to humans and animals and phosphate induced eutrophication.[12,13] The loss of wetland areas negatively affects their essential functions and ecosystem services, resulting in deteriorated water quality, increased flood risk, loss of biodiversity, and reduced capacity to mitigate climate change. Protecting and restoring wetlands is essential for maintaining these critical functions and ensuring the continued endowment of ecosystem goods and services to both ecosystems as well as human communities.

The land use land cover (LULC) changes in vicinity of wetland directly influence the wetland health. Therefore, it is important to study transformations in LULC around the wetland.[14] LULC change detection techniques are commonly employed to analyse and understand the spatio-temporal patterns of changes in wetland surroundings, which is important for sustainability and management of wetlands.[15] LULC change detection is important to devise suitable strategies for ecosystem restoration.[16] Remote sensing, GIS and satellite imageries are essential tools for studying LULC changes in wetland ecosystems. Among the various satellite imageries available, Landsat imageries have been most commonly used for to study the change in LULC. Bhattacharjee *et al*. 2021[17] studied the LULC changes of a wetland ecosystem of Bangladesh using RS, GIS and Landsat imageries over the period of 30 years (1989-2019). Ngondo *et al*. 2021[18] evaluated the LULC changes in the Wami–Ruvu Basin, Tanzania using Landsat imageries for 28 years period.

The Kashmir valley, Northern part of Jammu and Kashmir, is bestowed with many water bodies including lentic ecosystems, littorals and wetlands. The area under wetlands in Kashmir is more than

7000 hectares, Hokersar, Shallabugh, Hygam, Freskoori, Narkara, etc. Jamal and Ahmad 2020[14] assessed the changes in and around the wetland ecosystem of Wular Lake, Anchar Lake and Hokersar wetland using Landsat imageries. Alam *et al*. 2011[19] deliberated on the impact of LULC changes on Hokersar wetland. Similarly, Bano *et al*. 2018[20] analyzed changes LULC in Hokersar wetland and Bashir *et al*. 2022[21] evaluated the changes in LULC of Shallabugh wetland. In these studies, it has been reported that the wetlands in valley are facing various types of threats including accelerated eutrophication, increased siltation, over-grazing, decreased water spread, and immense LULC changes. Most of these studies have focused on LULC dynamics within the wetland,[14] neglecting the changes in LULC around the wetland. Many studies have been conducted on these wetlands but no such scientific study has been undertaken in Nowgam wetland, Bandipora. In this context, the present study was conducted to have an insight knowledge regarding changes encountered in the LULC around the Nowgam wetland using the RS, GIS and satellite imageries.

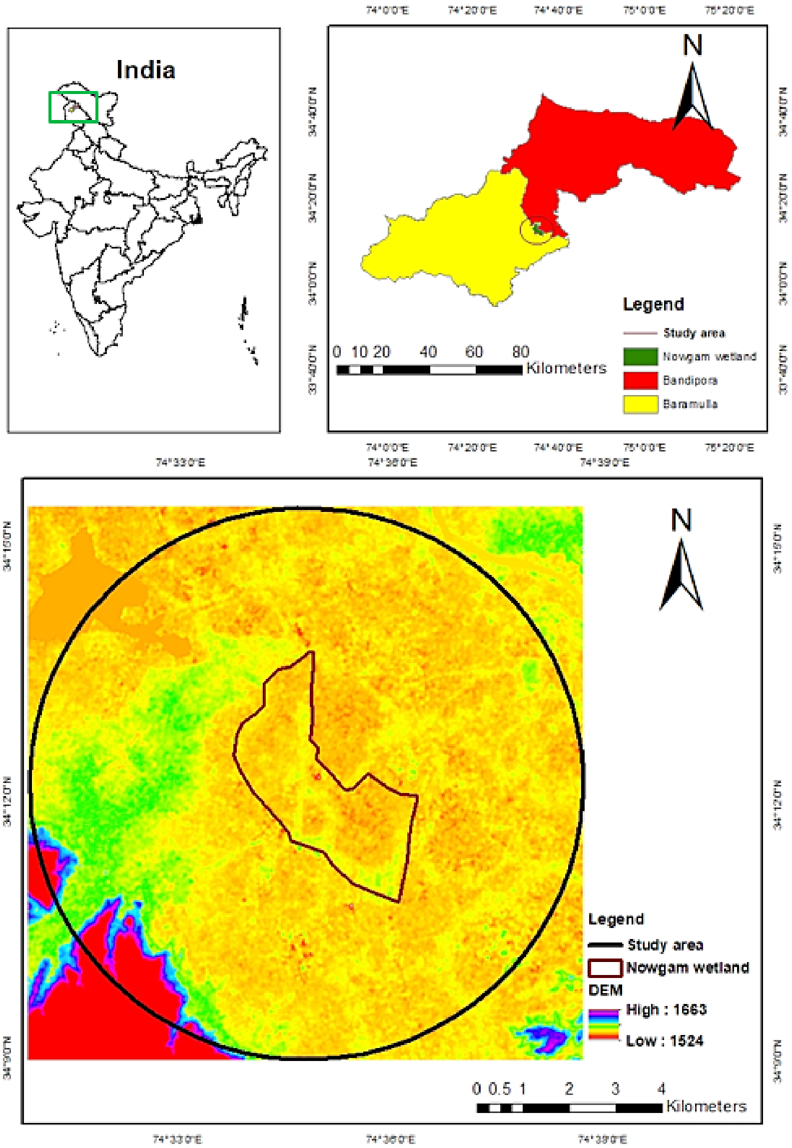

Fig. 1. Study area map

Methodology

Study Area

The Kashmir valley is bestowed with a numerous consortium of wetlands extending in an area of about 7000 hectares[20] but improper management strategies has left them into shambles and Nowgam wetland in Sumbal area of Bandipora (43 Kms in the northwest of Srinagar) is one of such neglected wetlands of the valley. The Nowgam wetland is located at the border of two northern districts, viz., Baramulla and Bandipora of Kashmir valley. Nowgam wetland is geographically located between the coordinates 34°12'03'' to 34° 13' 42'' N and 74° 33' 45'' to 74° 36' 24'' E, occupying an area of about 9.6 km^2. The Nowgam wetland experiences maximum and minimum temperatures of 30.4 ℃ and -3.3℃ in December, respectively. The study area receives an average annual rainfall of approximately 1281 mm, based on data from 1980 to 2022. The study area receives rainfall during March, April and May, followed by relatively dry period during June to August. The weather data, including temperature and rainfall, indicate that the study area experiences a temperate climate with clearly defined seasons, featuring warm summers and cold winters. The wetland is primarily fed by a tributary of river Jhelum, and, is depth wise shallow and temporary/ seasonal in occurrence with very rich biodiversity.

Table 1: Details of Landsat imageries used for the study

Imagery	Data type	Source	Specifications	Date
LANDSAT-7ETM+	Spatial	USGS	"Path/Row 149/36 Resolution 30 m"	11 September 2000
LANDSAT-7ETM+	Spatial	USGS	"Path/Row 149/36 Resolution 30 m"	17 September 2010
LANDSAT-08 OLI	Spatial	USGS	"Path/Row 149/36 Resolution 30 m"	10 September 2022

Table 2: Overall accuracy results of LULC classification for images of (a) 2000 (b) 2010 and (c) 2022

(a) 2000

Class	Water	Agriculture	Settlement	Vegetation	Bareland	Total (User)	User effici -ency (%)
Water	15	1	0	0	1	17	88.24
Agriculture	0	23	0	2	0	25	92.00
Settlement	0	1	21	0	2	24	87.50
Vegetation	0	1	0	30	1	32	93.75
Bareland	0	0	2	1	12	15	80.00
Total (Producer)	15	26	23	33	16	113	
Producer efficiency (%)	100.00	88.46	91.30	90.91	75.00		
Overall efficiency	89.38						
Kappa	0.865						

(b) 2010

Class	Water	Agriculture	Settlement	Vegetation	Bareland	Total (User)	User effici -ency
Water	16	0	0	0	1	17	94.12
Agriculture	0	28	0	3	1	32	87.50

Settlement	0	0	19	1	0	20	95.00
Vegetation	0	1	1	27	0	29	93.10
Bareland	0	0	1	1	13	15	86.67
Total (Producer)	16	29	21	32	15	113	
Producer efficiency (%)	100.00	96.55	90.48	84.38	86.67		
Overall efficiency	91.15						
Kappa	0.887						

(c) 2022

Class	Water	Agriculture	Settlement	Vegetation	Bareland	Total (User)	User effici -ency
Water	19	0	0	1	1	21	90.48
Agriculture	1	24	0	2	0	27	88.89
Settlement	0	1	16	0	0	17	94.12
Vegetation	0	3	0	32	0	35	91.43
Bareland	0	0	2	0	11	13	84.62
Total (Producer)	20	28	18	35	12	113	
Producer efficiency (%)	95.00	85.71	88.89	91.43	91.67		
Overall efficiency	90.26						
Kappa	0.874						

Data Used

Satellite imageries are the primary data for detection of LULC change of any area in a given time. Satellite images of more than one time periods are compared to estimate the transformations in land use over the period of time. In the present study, three cloud-free Landsat imageries, “LANDSAT-7 Enhanced Thematic Mapper Plus (ETM+) (dated 11th September 2000; image data ID: LE07_L2SP_149036_20000911_20200917_02_T1), LANDSAT-7ETM+ (dated 17th September 2010; image data ID: LT05_L2SP_149036_20101017_20200823_02_T1) and LANDSAT-08 Operational Land Imager (OLI) (dated 10th September 2022; image data ID: LC08_L2SP_149036_20220831_20220910_02_T1)” of three separate dates were downloaded from the website (https://earthexplorer.usgs.gov/). Many studies have used Landsat imageries for LULC detection owing to its free cost, better resolution and proper information.[22,23] Autumn images were chosen specifically to ensure cloud-free coverage of the landscape. The particulars of the satellite imageries used for detection of LULC around the Nowgam wetland are depicted in Table 1.

LULC Classification

The classification of the images was carried out using the “*maximum likelihood*” method. The seven bands of the imagery were combined to generate the composite imagery using the image analysis option in ArcGIS 10.4. After conducting image enhancements, the subsequent step in the analysis included gathering an adequate number of training polygons to classify LULC categories. This process was carried out using the training sample manager in ArcGIS 10.4.[24] The area of interest (AOI) (6 km around the wetland) was extracted from the composite imagery and image classification was done on the AOI. Five classes, viz., water, agriculture, settlements, vegetation and bareland have been identified. Approximately 100 training samples were identified for each class and subjected to statistical analysis for similarities. Field visits were carried out in the study area for ground-truthing. In order to check the accuracy of older images, ground-truthing was done with the help of Google earth. The LULC maps were prepared for 2000, 2010 and 2022. These maps were analysed to determine the LULC changes that ensued over the years. The magnitude of each LULC change on the temporal basis was assessed using percent change[25] and transition matrix model.[26,27]

"$PC=(U_x-U_y)/U_y \times 100$"

Where, "PC = percent change in LULC", "U_y= area under particular LULC at beginning of time period", and "U_x= area under particular LULC at the end of time period."

The attribute tables of the classified imageries were transferred to MS Excel to calculate area under each LULC class and change in area of each class.

Accuracy Assessment

An essential aspect of image classification is accuracy assessment, which aims to evaluate the accuracy of pixel sampling in a classified image. This assessment is conducted, measured, and quantified using an error matrix.[28] A total of 100 sample points were selected by adopting the stratified random sampling,[29] which were subsequently verified through extensive ground-truthing. The historical imagery from Google Earth for Landsat-5 TM (30 m, 2000) and Landsat-7 ETM+ (30 m, 2010), and Landsat-8 OLI imagery (30 m resolution, 2010) were utilized for this purpose. The producer's efficiency, user's efficiency, overall efficiency, and kappa coefficient were computed based on the error matrix[30] and were derived using the prescribed formulae:

Producer' s accuracy=(Number of correctly classified pixels in each category)/(Total Number of classified pixels in that category (column total))×100

User's accuracy=(Number of correctly classified pixels in each category)/(otal Number of classified pixels in that category (row total))×100

$$Overall\ accuracy = \sum_{i=1}^{r} Y_{ii}$$

Where, Y_{ii} = diagonal elements in the error matrix; Y = total number of samples in the error matrix.

$$Kappa\ coefficient, K = \frac{n\sum_{i=1}^{r} Y_{ii} - \sum_{i=1}^{r}(Y_i + Y_{+i})}{n^2 - \sum_{i=1}^{r}(Y_{i+} Y_{+i})}$$

Where, r = number of rows in the matrix; Yii = number of observations in row i and column i. Yi+ and Y+i = marginal totals of row i and column i respectively and n = total number of observations (samples/pixels).

Results

Accuracy Assessment

The accuracy assessment of generated LULC maps was conducted by the formulation of an error matrix. The overall accuracy for different maps for year 2000, 2010 and 2022 was 89.38%, 91.15% and 90.26%, respectively. Similarly, the kappa coefficient was found to be 0.865, 0.887 and 0.874 for year 2000, 2010 and 2022, respectively (Table 2). Therefore, the accuracy of the classified maps is deemed satisfactory, indicating that the obtained outcomes of LULC can be regarded reliable.

LULC Changes

Wetland ecosystems of the Nowgam wetland have observed significant changes in LULC over the period of 22 years (2000-2022.) The details of LULC of different land use classes around the Nowgam wetland (2000–2010–2022) including a buffer of 6 km^2 are given in Figs. 2, 3 and 4 and Tables 3 and 4, respectively.

Water

The analysis of classified imageries revealed that the area under the water has continuously decreased over the last 22 years. The total area under water was 36.40 km2 in 2000 which reduced to 27.89 km^2 in 2010 and 16.0 km^2 in 2022 (Table 3). The area under water was about 25.15%, 19.27 % and 11.06 % in 2000, 2010 and 2022, respectively. There was net decrease of about 56.04% in the area under water over the time period of 22 years (Table 4). The area under water has primarily been converted into agriculture and settlements.

Agriculture

The agricultural area has escalated gradually during the research period. The agricultural area measured approximately 29.44 km^2 in 2000, expanded to 31.31 km^2 in 2010, and further increased to 42.61 km^2 by 2022 (Tables 3). It was observed that the area under agriculture increased only by 6.33% from 2000 to 2010, however in the next 12 years (2010-2022), there has been drastic increase of 36.11%. Overall, agricultural area has increased by about 44.73% over the period of 22 years (Table 4). The increase in agricultural area may be due to the adoption of paddy cultivation in submerged and waterlogged areas of the wetland for earning their livelihoods by the inhabitants.

Settlement

The area under settlement has shown an increasing trend during the course of study. The area under this category was about 25.89 km^2, 28.16 km^2 and 33.91 km^2 in 2000, 2010 and 2022, respectively (Table 3). Settlements increased by about 8.80% in one decade (2000-2010) and 20.40% in next 12 years (2010-2022). The net increase in settlements was about 31% from 2000 to 2022 (Table 4). Some area under vegetation and water has been converted into the settlements which may be due to the encroachments into the water and vegetation.

Table 3: LULC statistics of the study area in 2000, 2010 and 2022

Class	2000		2010		2022	
	Area (km^2)	Percent	Area (km^2)	Percent	Area (km^2)	Percent
Water	36.40	25.15	27.89	19.27	16.00	11.06
Agriculture	29.44	20.34	31.31	21.63	42.61	29.44
Settlement	25.89	17.89	28.16	19.46	33.91	23.43
Vegetation	33.00	22.80	31.47	21.74	30.60	21.14
Bareland	20.00	13.82	25.90	17.89	21.60	14.93
Total	**144.72**	**100.00**	**144.72**	**100.00**	**144.72**	**100.00**

Table 4: Overall LULC change in the study area

Class	2000-2010		2010-2022		2000-2022	
	Area (km^2)	Percent	Area (km^2)	Percent	Area (km^2)	Percent
Water	-8.51	-23.37	-11.89	-42.63	-20.40	-56.04
Agriculture	1.87	6.33	11.30	36.11	13.17	44.73
Settlement	2.28	8.80	5.75	20.40	8.02	30.99
Vegetation	-1.53	-4.6	-0.87	-2.74	-2.40	-7.27
Bareland	5.90	29.47	-4.30	-16.58	1.60	8.00

Vegetation

The area under vegetation has marginally decreased over the last 22 years. The analysis showed that the area under vegetation was 33 km^2 in 2000, 31.47 km^2 in 2010 and 30.60 km^2 in 2022, which accounted for 22.80%, 21.74% and 21.14%, respectively (Table 3). This shows that the vegetation in the study area has more or less remained constant over the study period. Table 4 demonstrates the meagre reduction of 4.6% in vegetation area from 2000 to 2010, and further reduction of about 2.74% from 2010-2022. The overall decrease of about 7.27% has been observed in vegetation in 22 years which has been converted into settlements and barelands (Table 4).

Bareland

The area under bareland was about 20.0 km^2 in 2000, which increased to 25.90% in 2010 and then decreased to 21.60% in 2022. The area under bareland increased by 5.90 km^2 (29.47%) from 2000-2010 and decreased by 4.30 km2 (16.58%) from 2010-2022. Overall, from the last 22 years, the area under bareland has increased by 8.02% which accounts for the percent change of about 31%. The upsurge in the barren land may be endorsed to deforestation in the study area.

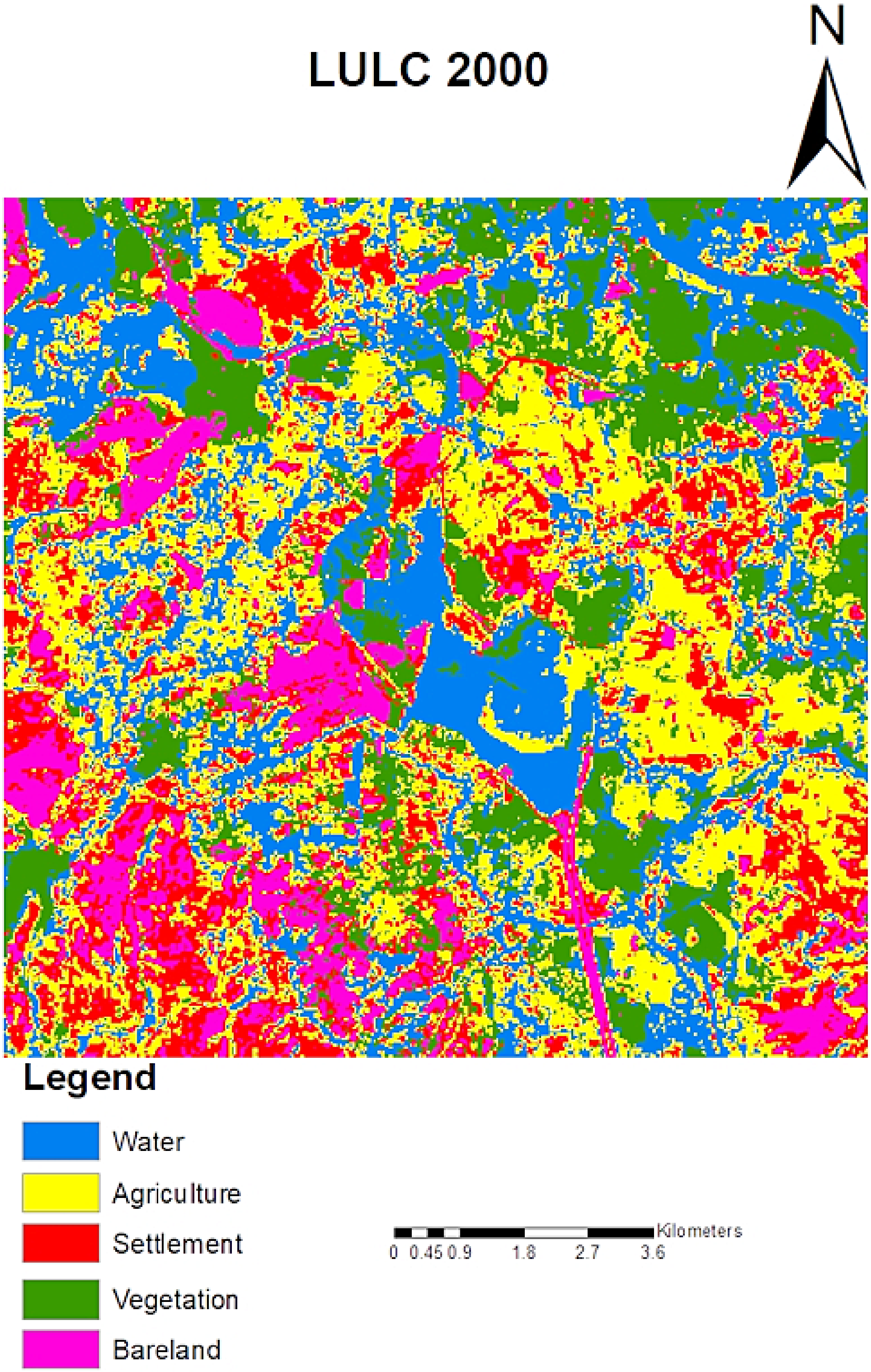

Fig. 2: LULC map around Nowgam wetland (6 km buffer) for the year 2000

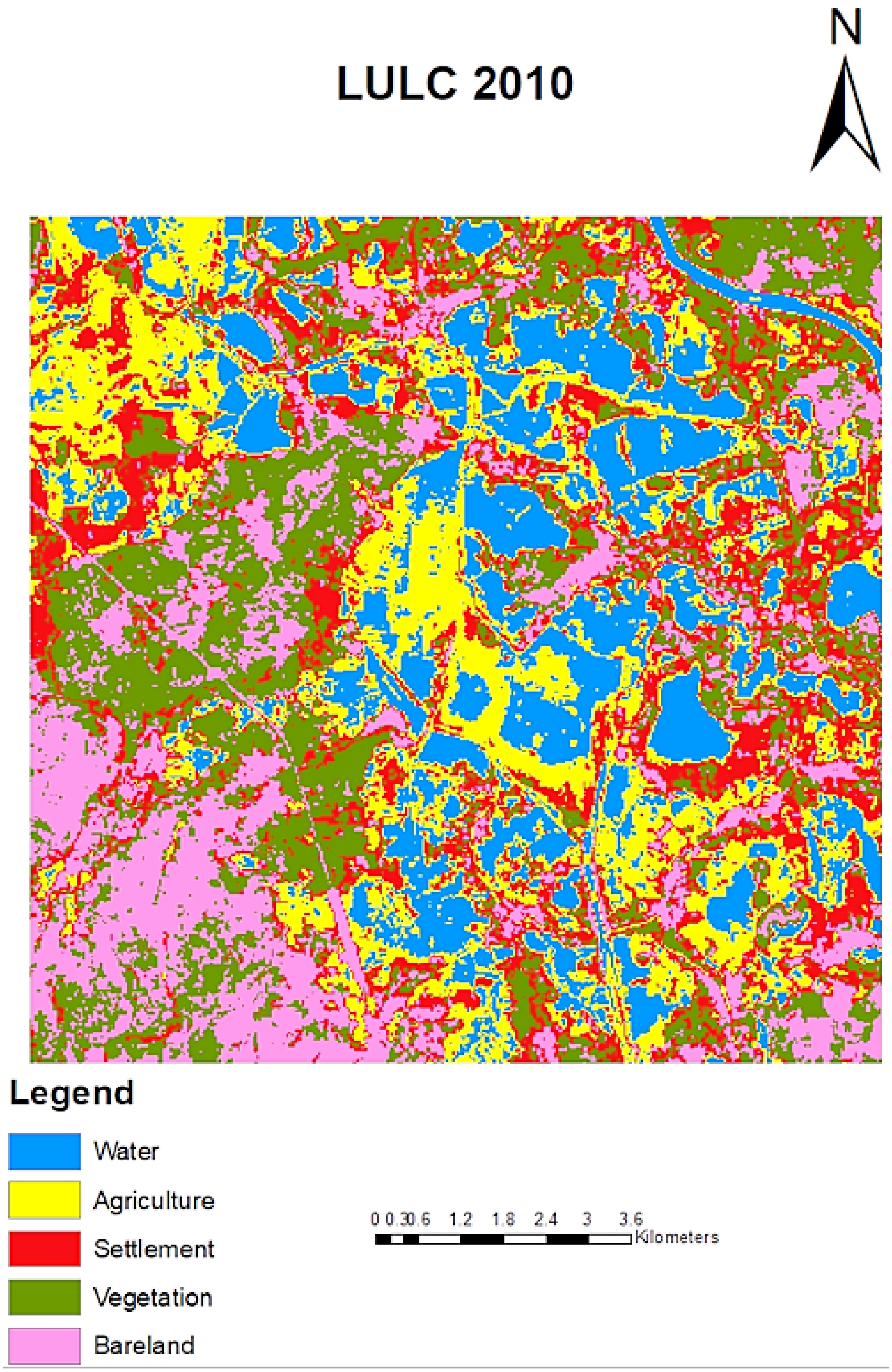

Fig. 3: LULC map around Nowgam wetland (6 km buffer) for the year 2010

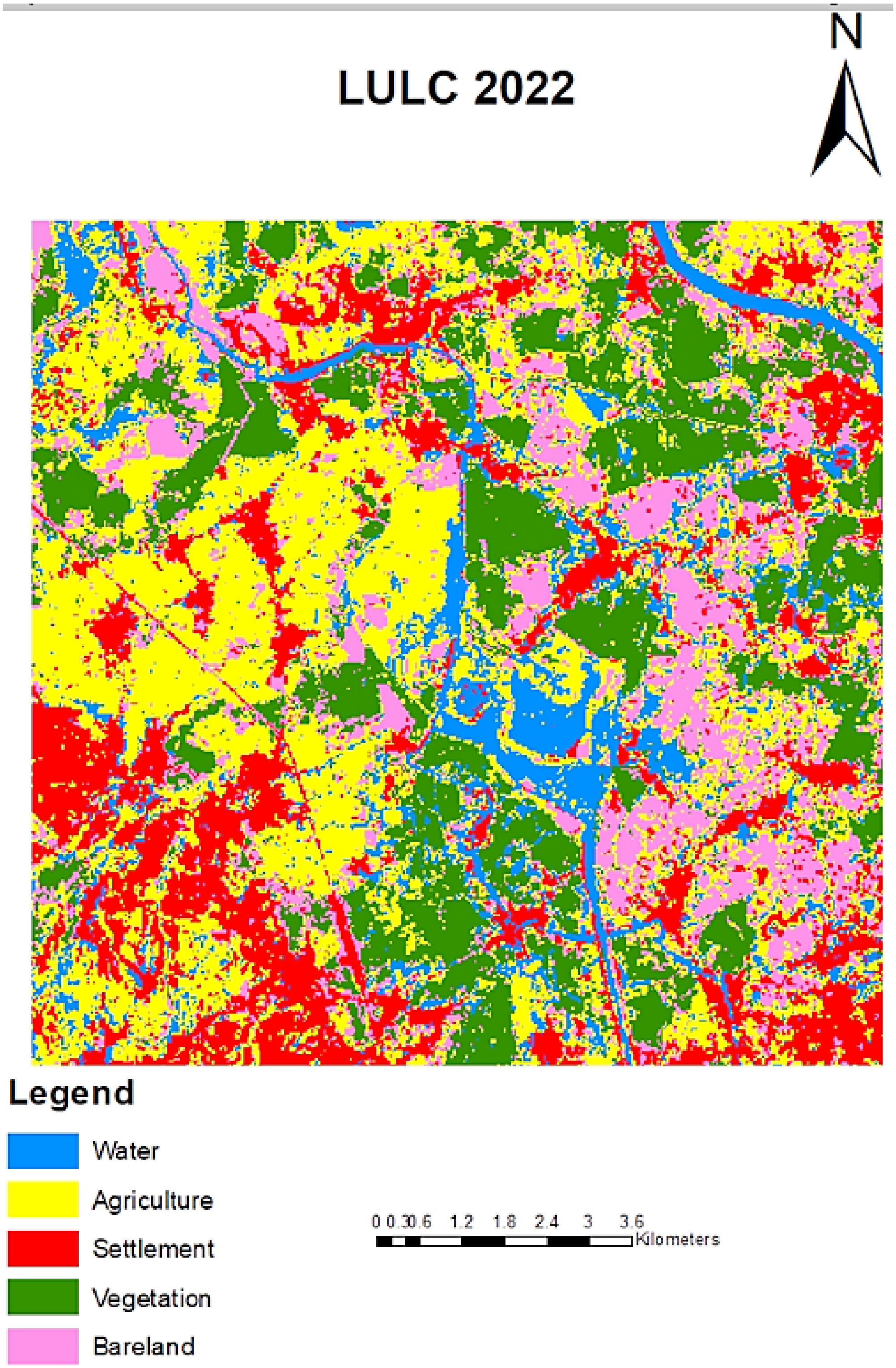

Fig. 4: LULC map around Nowgam wetland (6 km buffer) for the year 2022

Discussion

In context of the results, there are considerable changes in LULC around the Nowgam wetland. The areal decrease under the water may be due to conversion of small water bodies/marshy lands in the tree plantation. It can be observed from Fig. 2 the water bodies in the 2010 have converted into vegetation in 2022. However, some area under vegetation has been converted into the agriculture. Jamal and Ahmad 2021[14] have reported similar results for some other wetland ecosystems including Hokersar and Anchar located in Kashmir Himalayas. The plantation of willow trees (*Salix alba*) in the region has been carried out by state government agencies over the years, which may be the reason for decreased area under water. Bashir *et al*.[21] also reported increase in vegetation area in Shallabugh wetland in Kashmir valley which was primarily due to afforestation/plantation efforts by local community and Forest Department. From the LULC maps, it is clear that some portion of the vegetation has been converted into the agriculture, which is reason of increased area under the agriculture.[22] The motivational stimulus in this perspective is based on the traditional agrarian profession in Nowgam area whose dwellers have been working in the Government Rakhs and Farms from many generations. The area under settlements has increased which may be attributed to the residential needs of the increased demography (construction of new houses, educational institutes and health centres) in the study area.[14] Other research studies have also testified increased settlements in other countries.[31] The increase in settlements may pose a serious threat to the wetland ecosystems. As reported by Bano *et al*.,[20] the migration of migratory birds has considerably reduced in other wetlands of the Kashmir valley.[32] Wetland ecosystems in regions experiencing rapid population growth and economic development tend to have diminished ecological value, a trend also observed in countries like Ethiopia and Zimbabwe.[22,33] Mostly the bareland has converted into the settlements, which has resulted into decreased area under the bare-land during 2010-2022.[31] Alam *et al*. 2011[19] also showed that the expanse under settlements and vegetation has amplified from 1986 to 2005, whereas, area under water has decreased considerably over a particular course of time. Assefa *et al*. 2021[22] also revealed that the area under water bodies around the wetland has decreased while those under the settlements have increased in 35 years period. Therefore, our results are in consonance with many other studies across the globe. These changes in LULC around the wetland may have catastrophic effects on the various characteristics of the wetland.[34] It is thus affirmed that the present investigation may offer a basic insight to policy makers about the LULC dynamics for mitigating the impact of changing landuse around the Nowgam wetland.

Conclusion

The present study assessed LULC changes around a 6 km buffer strip of Nowgam wetland located in Kashmir valley of Himalayas. The LULC changes were determined for last 22 years using the Landsat imageries of 2000, 2010 and 2022. The images were classified using the supervised image classification in ArcGIS. The area under the wetland has gone considerable changes in the LULC during the study period. The area under agriculture, bareland and settlement has escalated, whereas, area under water bodies and vegetation has decreased. The changes in LULC around the wetland may have some serious implications within the wetland ecosystem which need to be studied in future. It is suggested to relate the LULC changes with the soil erosion and sediment deposition within the wetland. This study may provide an insight to the researchers about the changes in LULC around the wetland to frame some conservation measures to mitigate the consequences of the changing LULC on the wetland ecosystem. It is further suggested to carry out the LULC change within the wetland also so as to determine the effect of LULC changes in surroundings on the wetland.

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Conflict of interest

The authors declare no conflict of interest.

Data Availability Statement

The manuscript incorporates all datasets produced or examined throughout this research study.

Ethics Statement

All the data and results pertaining to this current study is the own original work done by the authors in a truthful and complete manner.

Authors' Contribution

All authors contributed to the study conception and design. 1. Concept, Supervision, Review was done by Bashir Ahmad Ganai 2. Data collection, Survey, LULC detection, Formal Analysis, Manuscript preparation and editing was jointly done by Moonisa Aslam Dervash and Abrar Yousuf.

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