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ORIGINAL ARTICLE

Assessing human interactions and sustainability of Wetlands in Jammu, India using Geospatial technique

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Abstract
Worldwide it has been observed that wetlands are facing severe threats due to ever-increasing anthropogenic activities. Therefore, this study is aimed to examine the threat and criticalities faced by the wetlands in different physiographic regions of Jammu Division. The study encompassing all the selected wetlands ecosystem aspects including limnology, eutrophication, biodiversity, and land use/land cover (LU/LC), so as to frame an ecologically balanced conservation strategy for the aquatic ecosystem of the region. The Landsat data has been used for LU/LC classification of the selected wetlands and finally change detection technique was used to quantify the changes. Evaluation of LU/LC revealed that all the selected wetlands are under stress due to diverse anthropogenic pressure. Except for Sanasar the two other wetlands under study showed human encroachment. Maximum encroachment was noticed around Gharana wetland (about 5 hectares area) and water body decreased by 02 hectares during the period 2008–2018. For threat assessment of the wetlands parameters such as biodiversity, the area under water bodies, Eutrophication and water quality were taken into consideration. The result showed that water quality was badly affected in terms of nitrogen and dissolved oxygen which could a cause for the sustainability of aquatic flora and fauna. Gharana wetland was found most threatened whereas Mansar, moderately and Sanasar the least threatened wetland. Further, the analysis shows that the impact of anthropogenic activities on wetlands decreases with an increase in altitude. All possible factors causing threats to wetlands have been discussed to formulate proper management strategies to conserve the wetlands.

Keywords Anthropogenic activities · Eutrophication · Encroachment · Threat · Wetland ecosystem

Introduction

Wetlands are one of the most highly productive diverse ecosystems of the earth and are highly sensitive to natural as well as anthropogenic changes (Wanjala et al. 2020; Talukdar and Pal 2019; Ghermandi et al. 2010). They provide several socio-economic and ecological services such as protection, conservation, and maintenance of wildlife and biodiversity, water purification and flood control, environmental restoration, etc. (Xu et al. 2020, 2019). The services provided by wetlands include water for irrigation, fish production, recreation, non-timber forest products, etc. (Bassi et al. 2014; Islam and Kitazawa, 2013). The wetlands are sometimes described as the 'kidneys of the landscape' for their functions they perform in hydrological and chemical cycles and as downstream receivers of wastes from both natural and human sources (Mitsch et al. 2015; Medugu 2015). However, they are shrinking and degrading due to the expansion of agricultural land, conversion of wetland into urban areas, climate change, and disconnection of wetland with river channels in flood plains (Xu et al. 2020; Hu et al. 2017, 2020; Rashid and Aneaus 2019).

According to the Ramsar convention, the wetlands in India are found in form of both natural water bodies such as rivers, lakes, lagoons, mangroves, etc. as well as manmade water bodies such as farm ponds, irrigated fields, salt pan, reservoirs, canals, etc. (Ramsar Secretariat 2013). However,

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only 37 wetlands have been listed as the Ramsar sites, thus other numerous wetlands are continuously being ignored in the policy process (The Hindu 2020; Sharip et al. 2016; Bassi et al. 2014). As a result, many wetlands are under threat of degradation due to increasing population pressure and economic activities (Everard et al. 2019; Hasnat et al. 2018). Almost all the existing wetlands of the world are experiencing increasing pressure from human activities (both direct and indirect), irrespective of their locations in the developed and developing nations (Pal and Talukdar 2018).

Wetlands play an irreplaceable role in regulating the global climate, maintaining the global hydrological cycle, protecting the ecosystem diversity, and safeguarding human welfare (Xu et al. 2019; Sutton-Grier and Sandifer 2019; Cao et al. 2012). Wetland ecosystems can not only bring indirect services to human beings but also bring direct economic values to human beings (Pasupalati et al. 2017; Bassi et al. 2014; Barbier 1993). The value per hectare of wetland ecosystem services ranks first among all kinds of ecosystem services, and the total values of wetland ecosystem services account for 47% of the values of the global ecosystem (Talukdaret al. 2020a; Reynaud and Lanzanova 2017; Costanza et al. 2014). Therefore, it is one of the most important and productive ecosystems (Kumari et al. 2020; Sutton-Grier and Sandifer 2019; Mitsch et al. 2015). Economically wetlands are very important for people because it supports millions of people either directly or indirectly by providing various services and benefits including agriculture and tourism (Sun et al. 2020; Guareschi et al. 2020; Verhoeven and Setter 2010). Even though these benefits, wetlands are endangered among all-natural resources due to anthropogenic intrusion (Grzybowski and Glińska-Lewczuk, 2019). Anthropogenic activities often generate effects which also interfere in the ecosystem functioning of the wetlands (Xu et al. 2019; Sievers et al. 2018). The main reason behind the deterioration of these productive ecosystems is ignorance. More than 50 per cent of the world's wetlands have altered, degraded or lost in the last 150 years (O'Connell 2003). The main effects of anthropogenic activities on the wetlands include decline in area, changes in water regime and water quality as well as the introduction of alien species (Galatowitsch 2018; Jakariya and Islam 2017; Erwin 2009). Further, the degradation of wetlands is also due to the livelihood generating actions by the poor communities residing near the wetlands and their dependency on the wetland resources (Kumar et al. 2011). Thus a wide range of human activities have altered wetlands around the world and caused their degradation (O'Connell, 2003). Wetlands serve as a means of livelihood for rural populations particularly in developing nations (Lamsal et al. 2015; Rebelo et al. 2010), and are greatly valued by many cultures (Ghermandi et al. 2010; Maltby and Acreman 2011).

As elsewhere wetlands play an important role in the economic, socio-cultural, and religious activities in Jammu and Kashmir (Dar et al. 2020). Many cultures do live in and among wetlands and use them for daily subsistence for the production of food and fiber (Mitsch and Gosselink 2015). These wetlands provide support to a wide range of biodiversity including animals and plants and plays important role in maintaining ecological diversity (Halls 1997). However, due to continuous pressure from a growing population coupled with climate change has affected the wetland ecosystems which ultimately have reduced their capacity to support biodiversity and maintain ecological diversity (Ficken et al. 2019; Sintayehu 2018; Halls 1997). Further, the Wetlands of Jammu Province faces significant threats for their existence primarily due to the increase in population in the last few decades (Romshoo et al. 2010). Therefore, this study aims to analyze the impact of human interference on the three wetlands (Mansar, Gharana and Sanasar wetlands) located in the Jammu division of the Jammu and Kashmir union territory of India which is located in the lesser Himalayas. Although the region is sparsely populated, and the human interference is less on these wetlands in comparison to the other wetlands of Indian sub-continent, these wetlands have experienced a decline in their areas as well as loss of biodiversity and introduction of exotic crops during recent past (Pandotra and Sahi 2014; Sharma and Saini 2012; Kumar et al. 2006). Therefore, the main objectives of this study are to analyze the land use/ land cover (LU/LC) changes taken place during the period 2008–2018 and to examine the magnitude of threat due to human interference on selected wetlands.

Study area

Jammu division is situated in the north-western part of India and lies between 32° 17 to 34° 12 North latitudes and 73° 58 to 76° 47 East longitudes. It covers an area of 26,293 km^2 and forms the southernmost part of the Union Territory of Jammu and Kashmir. For this study, three wetlands namely Mansar, Gharana and Sanasar lakes have been selected which are located in the Jammu province (Fig. 1). The Mansar Lake is situated nearly 60 km east of the Jammu city at an elevation of 650 m above mean sea level (MSL). The lake is situated in the subtropical climatic region which has average annual rainfall of about 1500 mm and the temperature varies between as low as 3 °C to as high as 42 °C (Kumar et al. 2006). The geology of the lake catchment is made up of sandstone and siltstone along with mudstone and clay of the Siwalik ranges. The catchment area of the Mansar Lake is 1.67×10^6 m^2. The lake is surrounded by human settlements and agricultural fields from the north-eastern sides while from the southern sides, the forest and hills surrounds it (Dwivedi 2012).

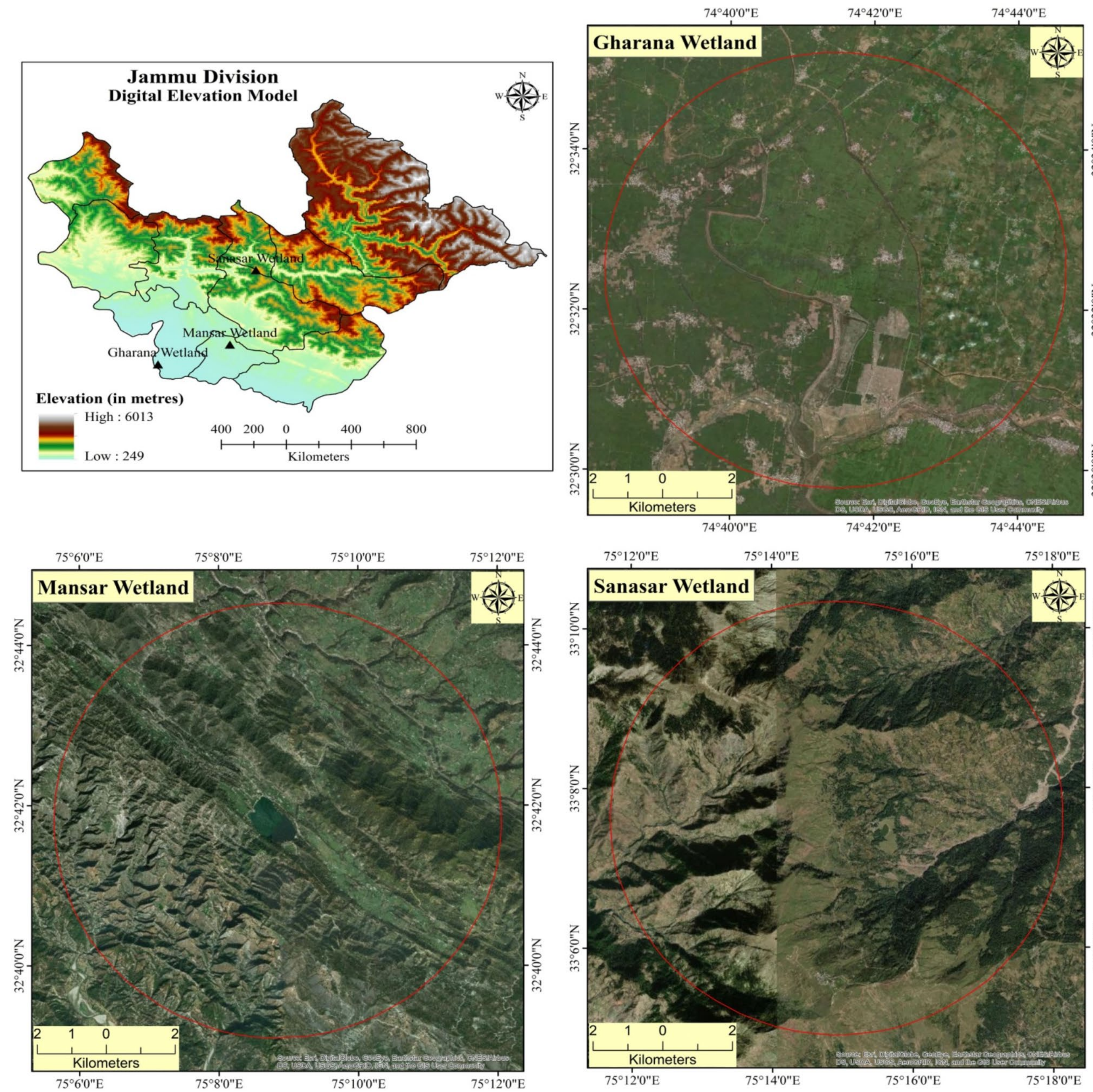

Fig. 1 Location of the selected wetlands in Jammu Division

Gharana wetland is located 30 km west of Jammu city approximately 400 m above MSL. The geology of the wetland catchment is made up of sandstone, mudstone, and clay materials. The wetland lies in the R. S. Pura tehsil of Jammu district and is the home of several plant species such as *Lantana camara* (Jari), *Meliaazadirachta* (Drenk), *Acacia nilotica* (Kikar), *Cannabis sativa* (Bhang), etc. A village named Gharana is situated along the catchment of the lake which has about 300 inhabitants engaged in mainly agriculture, fishing, and forestry. The third lake selected for this study i.e., Sanasar Lake is located nearly 80 km north-west of the Jammu city. It is located at an elevation of 1500 m above MSL, it is a tourist destination with a number of adventurous activities. Due to the tourism industry and activities by local inhabitants from nearby villages, the lake is facing a number of serious problems during the past 2 decades such as plastic pollution, loss of biodiversity etc.

Data sources and methods

Data sources

The present study has been done using both field-based primary data, secondary data collected from the local governing bodies as well as satellite data. The Landsat 5 Thematic Mapper (TM) for 2008 and Landsat 8 Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) for 2018 were downloaded from the United States Geological Survey website https://glovis.usgs.gov/ and have been used for the preparation of LU/LC maps of the selected lake and their surroundings. The pH value of water, dissolved oxygen, nitrogen, and phosphorus were determined using the water sample from the lakes, while the data on terrestrial and aquatic flora and fauna were collected through direct sightings, evidences and personal communications with locals and cattle herders in the area. A brief description of the data used in this research has been presented in Table 1.

Methods

In the present study, both field and laboratory-based work was undertaken to generate the necessary data for examining the human interactions and its impacts on the selected wetlands. Therefore, firstly the LU/LC maps were prepared using the Landsat 5 (TM) and Landsat 8 (OLI/TIRS) datasets. Further, on the basis of the physiographic variation, the importance of wetland-specific characteristics of the selected wetlands (Gharana, Mansar and Sanasar) were selected and analyzed. To find out the anthropogenic impact on wetlands, 5 km buffer around each wetland was prepared and the LU/LC mapping as well as sample collection and field survey were done within the buffer. A detailed model of the whole methodology used in the study has been presented in the flowchart (Fig. 2).

Preparation of LU/LC maps and accuracy assessment

The LU/LC classification technique is used for obtaining or extracting the information from the satellite imageries (Lam 2008). Numerous techniques have been used for the LU/LC classification among which the supervised and unsupervised techniques are the most widely used techniques (Talukdar et al. 2020b; Lu and Weng 2007). These two classification techniques differ as the outcome of the supervised classification is based on a set of sample pixels (training samples) selected by the user for the classification while in the unsupervised technique, the outcome is based on the software analysis (Naikoo et al. 2020; Lu and Weng 2007). In this study, the optical bands of the downloaded Landsat data were utilized for the preparation of LU/LC maps. Firstly, the layer stack was done using optical bands (near-infrared, red and green bands), and then radiometric and atmospheric corrections were performed. Finally, the subset of the study area was taken using the shapefile of the study area. The maximum likelihood classifier (MLC) technique was applied using the Erdas Imagine software (version 14) for the preparation of LU/LC maps of the lakes and their surroundings.

Finally, the accuracy assessment was done for the prepared LU/LC maps using Kappa coefficient. Several techniques like Error Matrix, Kappa coefficient, and indices-based techniques were applied for the accuracy assessment of LULC maps produced (Shahfahad et al. 2020; Talukdar et al. 2020b). The Kappa coefficient was applied using 200 sample points from the classified maps and for the same locations from the field-based survey. For 2008, the field survey data was not available; hence the sample points were taken from the Google Earth Pro domain. The overall accuracy of the classified maps of the Gharana lake basin and surroundings were 84.087% for 2008 and 87.679% for 2018, while for Mansar lake basin and surroundings, the overall accuracy was 86.067% and 88.547% for 2008 and 2018, respectively. The overall accuracy of Sanasar lake basin and surroundings were 85.794% and 89.673%.

Table 1 Description of the data used in the study

Data type	Data source	Data of acquisition	Resolution	Bands used
Landsat 5 (TM)	USGS (https://glovis.usgs.gov/)	28-Nov-2008	30 m	4, 3 and 2
Landsat 8 (OLI/TIRS)	USGS (https://glovis.usgs.gov/)	10-Dec-2018	30 m	5, 4 and 3
Water pH	Sample testing at laboratory	Sample collected during Oct-Nov 2018	–	–
Dissolved Oxygen, Nitrogen and Phosphorus	Sample testing at laboratory	Sample collected during Oct-Nov 2018	–	–
Identification of flora and fauna	Direct sightings and personal communications with locals	Field visit during Oct-Nov 2018	–	–

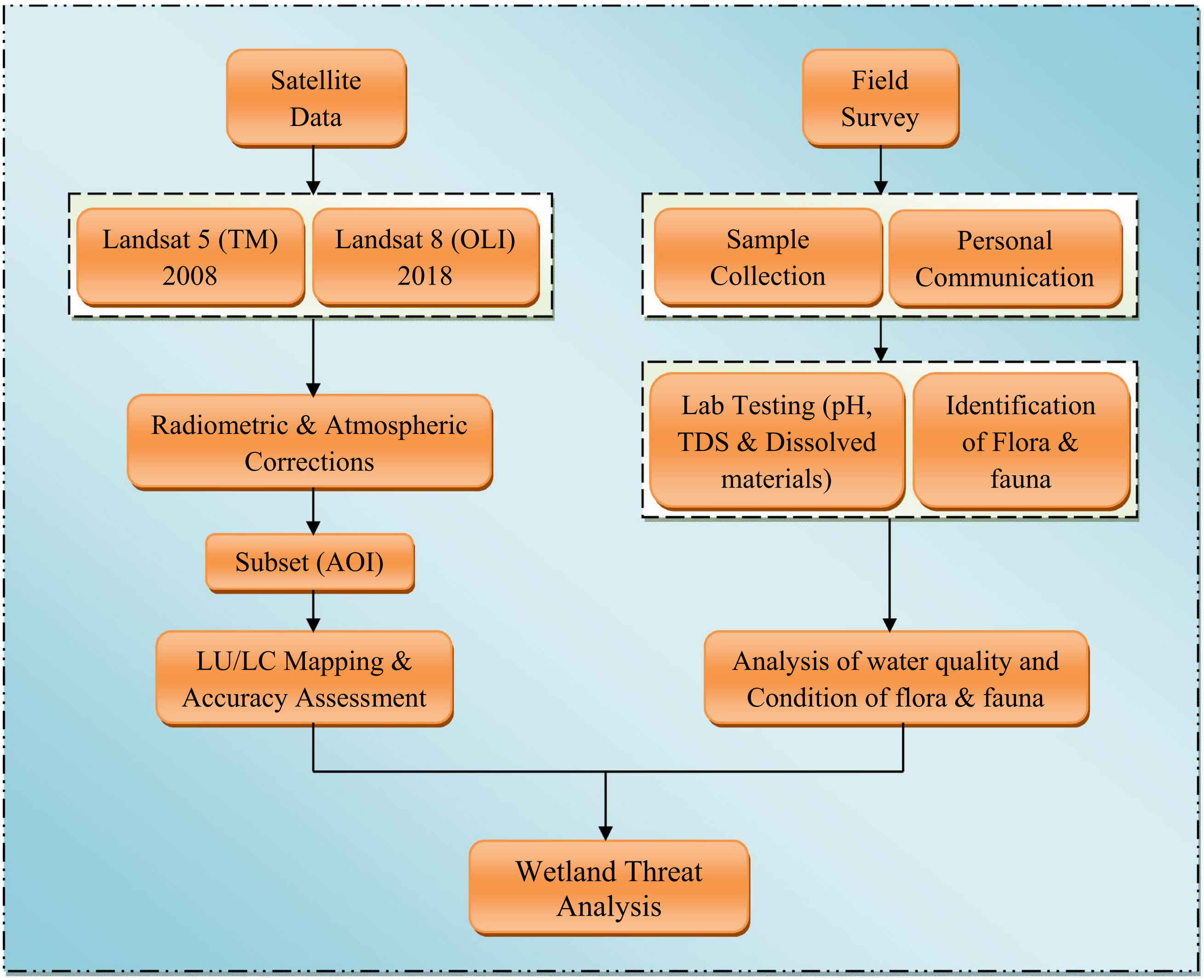

Fig. 2 Flowchart of the methodology

Analysis of water and sediments samples

The sampling of the water was done manually using a water sampler and the sediment samples were collected randomly from the littoral regions of the wetlands. The necessary data of water and sediment samples were carried out in the laboratory.

pH pH of the water sample was determined with the help of a portable field pH meter (Hanna).

TDS Electrical conductivity and TDS were measured by Century water/ soil analyzer kit, CMK 731.

Dissolved oxygen Dissolved Oxygen was determined by Sodium Azide Modification of Winkler's Method.

Nitrogen Available nitrogen content of bottom sediments was determined by the alkaline permanganate method.

Phosphorus Available phosphorus content of sediment samples was determined by using 0.5 N Sodium bicarbonate (pH 8.5).

Identification of flora and fauna

The data of terrestrial and aquatic flora were collected during the field visit. During this all species observed were recorded, photographed and specimens for unknown species were collected. The information on mammals in the wetland catchment was collected based on direct sightings, evidences as well as personal communications with locals and cattle herders in the area. Fishes, reptiles and amphibians were studied either by taking photographs or by identifying dead specimens (Figs. 3, 4, 5).

Wetland threat analysis

Data for threat assessment of the wetlands were collected based on the parameters, such as: Biodiversity (presence of 'The International Union for Conservation of Nature'-IUCN Red list species), Area of the water body, eutrophication and water quality. The standard and composite standard score have been calculated for threat assessment to all the three wetlands under study by using Eq. 1, 2, respectively.

$$Z_{ij} = \frac{X_{ij} - X}{\sigma} \quad (1)$$

$$SS = \frac{\sum Z_{ij}}{N}, \quad (2)$$

where,

Z_{ij} is the standard score, ij is the original value of the ith indicator, $\bar{X}$ is the average of all values of the X, N is the number of variables and CSS is the composite standard score.

Fig. 3 Samples of the terrestrial flora near the wetlands

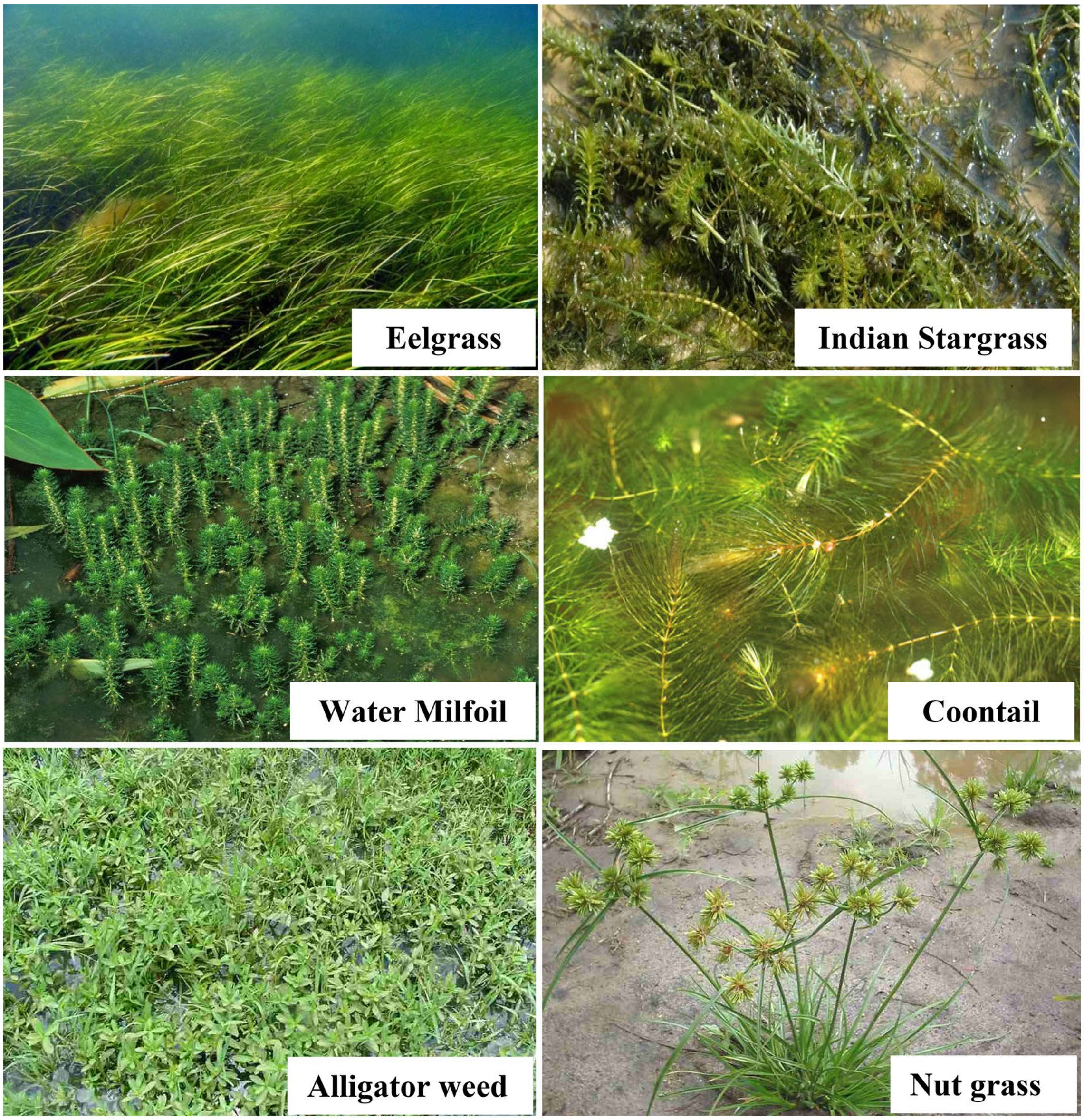

Fig. 4 Samples of the aquatic flora near the wetlands

On the basis of above score analysis three categories of wetlands have been assessed in terms of least, moderate and most threatened.

Results

Criticalities faced by Mansar wetland

Mansar wetland is under tremendous biotic pressure due to increased human and cattle population in the catchment along with an increase in tourist influx, which has resulted in changes in its physical, chemical, and biological characteristics. Environmental degradation of this wetland either directly from domestic discharges and encroachments or indirectly due to excessive deforestation, indiscriminate use of chemical fertilizers, insecticides, and pesticides in the catchment etc. has gradient potential for introducing enduring changes in their ecological structure and functions. During 2008–2018, a minor but significant change has been noticed in the LU/LC pattern of fringe area of the wetland. The LU/LC change has occurred mostly in the form of expansion of barren land over the forested areas and scrublands (Fig. 6).

Table 2 shows the impact of anthropogenic activities on the water body, forest area, agriculture, and fringe area around Mansar wetland over a period of 10 years i.e., (between 2008 and 2018) 6.33 hectare of forest area

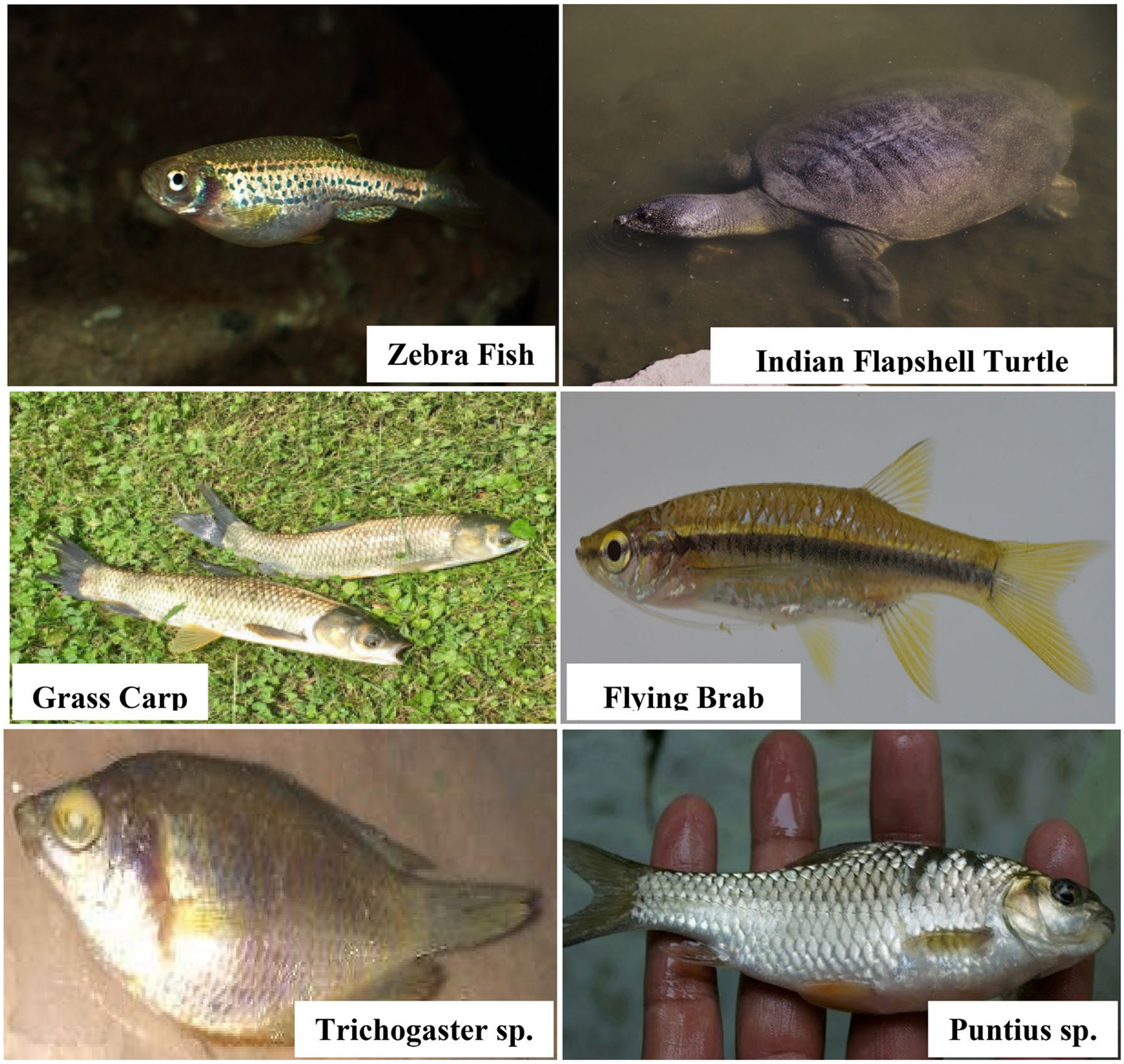

Fig. 5 Samples of the aquatic fauna in the wetlands

cleared, 15.35 hectare area encroached and 3.02 hectare area increased under agricultural activities. However, the area under water bodies remains the same. The analysis shows that the forest area decreased to meet the increasing demands of timber and resin (extracted from *Pinusroxburghii* in the catchment*),* excessive deforestation around Mansar wetland leading to denudation of the catchment which results in an increase of silt load in the wetland. Encroachment and unplanned growth of human habitation in the vicinity of wetland and increased pressure on the catchment have resulted in the deterioration of water quality as well as aquatic life. Concrete construction along the periphery of wetland as well as the construction of building structures (shops, *dhabas*, sitting sheds, and other commercial sheds) around the wetland have greatly reduced the area for percolation of rainwater into the soil and are responsible for the declining water level in the wetland. Besides, a floating population of nomadic tribes like Gujjars, visits the area during winter putting additional pressure on the wetland. The various agricultural activities in the catchment area of Mansar Wetland contribute nutrients to the water body and lead to cultural Eutrophication.

Table 3 highlights the impact of human-induced activities on water quality and the Eutrophication status of Mansar wetland. During the present period of investigation i.e., from 2015 to 2018, value of pH decreased by 0.8% but within acceptable limits of BIS criteria. TDS increased by 4 ppm, but within acceptable limits of BIS criteria. DO shows a minute increase of 0.1 mg/l in its level, less then acceptable limits, which is a matter of great concern. The value for available nitrogen content of sediment increased by 0.48% and the value of available phosphorus also increased by 0.21% clearly gives an indication of Eutrophication in near future. The analysis reveals that the main reason for the

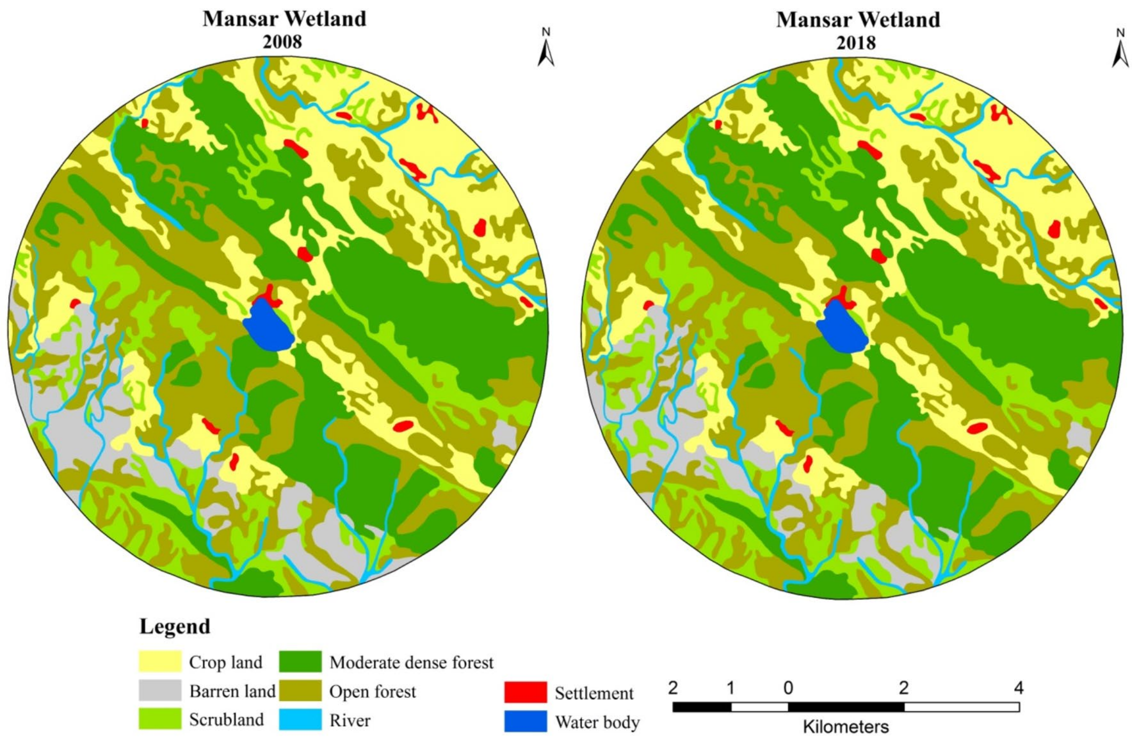

Fig. 6 LU/LC pattern of Mansar wetland fringe area

Table 2 Impact of anthropogenic activities on the water body, forest area, agriculture and fringe area around Mansar wetland

Categories	Area (in ha) 2008	Area (in ha) 2018	Status
Deforestation (Area under forest)	5119.5	5113.17	6.33 ha forest area cleared
Encroachment	180.57	195.92	15.35 ha area encroached
Agricultural activities	1978.37	1981.39	3.02 ha area increased under agricultural activities
Waterbody area	61.26	61.26	Waterbody area remained the same

Table 3 Impact of human induced activities on water quality and eutrophication status of Mansar wetland

Parameters		Unit of measurement	2015	2018	Status
Water Quality	pH	–	7.9	7.1	Decrease in pH but within acceptable limits
	TDS	ppm	127.5	131.5	Increase in TDS but within acceptable limits
	DO	mgL-1	4.7	4.8	Minute increase in DO but less than acceptable limits, which is matter of concern
Eutrophication	Nitrogen	%	1.34	1.82	Increase in nitrogen level gives an indication of eutrophication in the near future
	Phosphorus	%	0.18	0.21	Increase in nitrogen level gives indication of eutrophication in near future

Source: Sample results, Central Water Commission, Jammu and SKUAST-J (2015 & 2018)

deterioration of water quality of Mansar wetland is sewage drains in the form of non-point pollution from the market area and habitation and solid waste arising out of the houses, restaurants, market area etc. along with the runoff from the catchment. Other sources of pollution include entry of residues of construction activities, agricultural waste, animal excreta, dumping of garbage and waste coming from wildlife sanctuary (located near the periphery) as well as waste arising out of various rituals like *Mundan* ceremonies (shaving hair of child) performed along the wetland periphery. Also, various religious activities like mass bathing, organizing of fares etc. aggravated this pollution problem. Mansar, being an important tourist spot, is visited by a number of tourists throughout the year, and their activities like boating, offering food to fishes in the form of flour balls, eating and throwing waste into wetland puts additional pressure on the wetland. These entire practices increase the pollution load in the wetland and further degrade its water quality. Agricultural runoff and chemical detergents enter into the Mansar wetland leading to an increase in inorganic content in the water causing Eutrophication which is detrimental to the living fauna residing in or near water bodies.

Criticalities faced by Sanasar wetland

Human interference threatened Sanasar wetland. With the increase in population, water pollution, deforestation, road building, overexploitation of catchment area for agriculture purposes and so on, the existence of wetland is facing threat. Many aquatic species have vanished over the years, while others have been declared endangered. Figure 7 shows the LU/LC pattern of the fringe area of the Sanasar wetland. Similar to Mansar wetland, the LU/LC change in Sanasar wetland has also occurred in the form of expansion of barren land over the scrubland and open forests. However, the scrubland has also increased in some parts Fig. 8.

Table 4 portrays the impact of anthropogenic activities on the water body, forest area, agriculture, and fringe area around Sanasar wetland over a period of ten years i.e. (between 2008 and 2018) 3.44 hectare of forest area cleared, 2.79 hectare area encroached and 5.68 hectare area increased under agricultural activities. Area of water body increases by 3.66 hectare. The analysis of Table 4 reveals that Cutting of trees in the adjoining areas of wetlands for agriculture purposes and for timber extraction causes denudation, thus enhancing the silting process. Encroachment in Sanasar wetland is due to unplanned growth of human habitation in the vicinity of the wetland but as compare to the other three wetlands it is less encroached wetland. However, increased agricultural practices in the catchment areas deteriorate the quality of water.

Table 5 shows the Impact of human-induced activities on water quality and Eutrophication status of Sanasar wetland. During the present period of investigation i.e. from 2015 to 2018, value of pH decreased by 0.2% but within acceptable limits of BIS criteria. TDS increased by 7.5 ppm but within acceptable limits of BIS criteria. DO shows a decrease of 0.1 mg/l in its level but it is less than acceptable limits, which is a matter of great concern. The value for available nitrogen content of sediment increased by 0.19% and the value of available phosphorus also increased by 0.03% clearly gives an indication of Eutrophication in near future. The analysis of Table 5 has revealed that the deterioration of water quality and

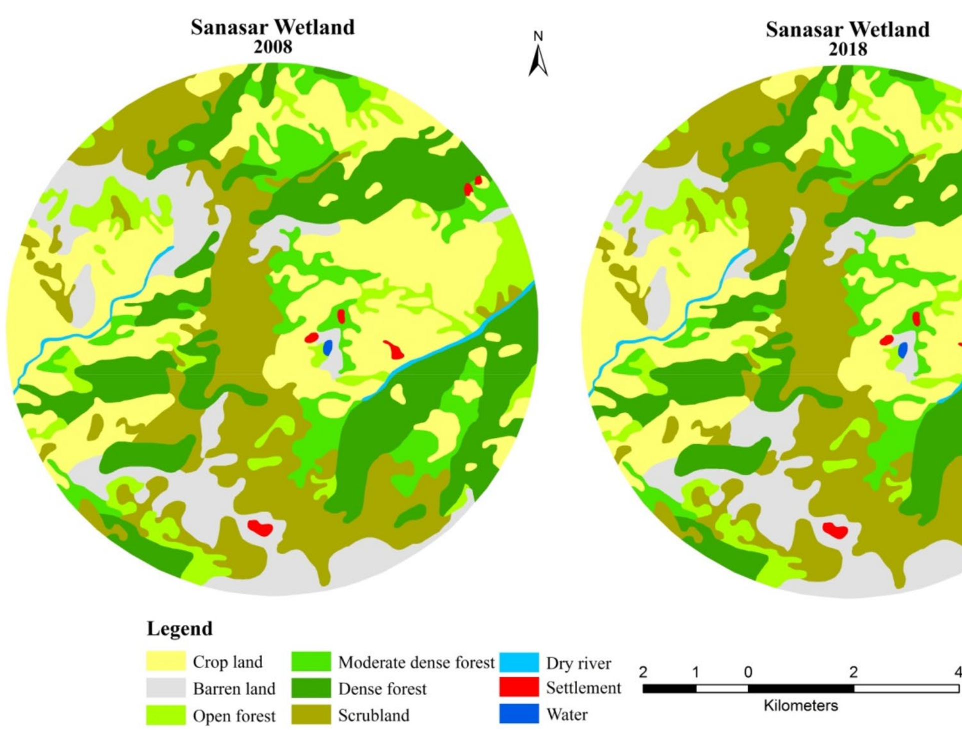

Fig. 7 LU/LC pattern of Sanasar wetland fringe area

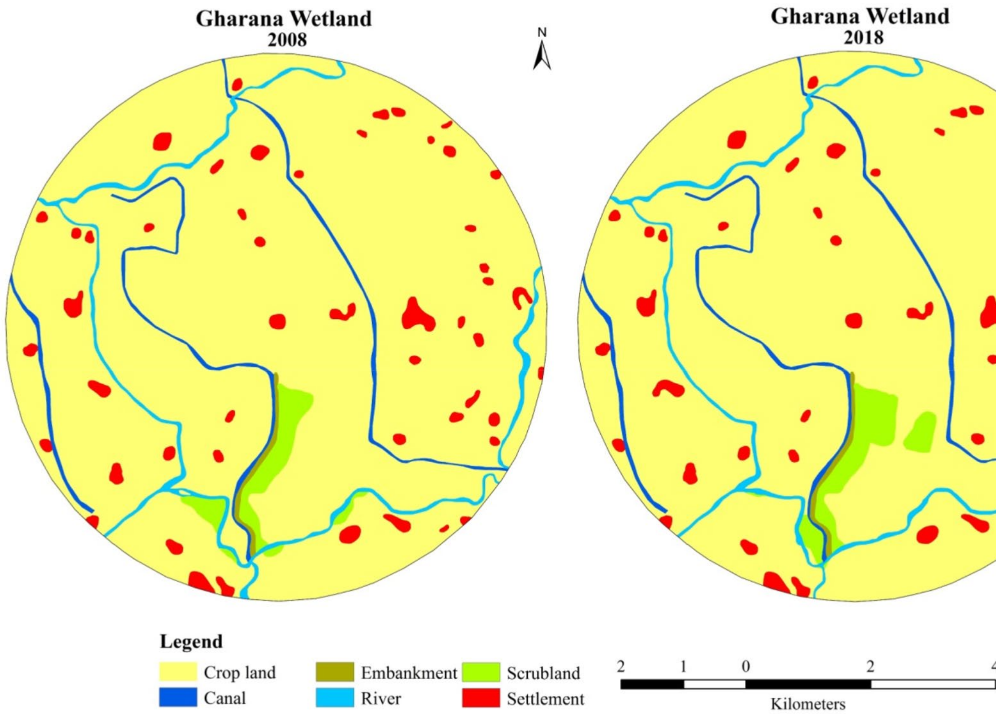

Fig. 8 LU/LC pattern of Gharana wetland fringe area

Table 4 Impact of anthropogenic activities on the water body, forest area, agriculture and fringe area around Sanasar wetland

Categories	Area (in ha) 2008	Area (in ha) 2018	Status
Deforestation (Area under forest)	2748.31	2739.87	3.44 ha forest area cleared
Encroachment	13.15	15.94	2.79 ha area encroached
Agricultural activities	1138.7	1143.38	5.68 ha area increased under agricultural activities
Water body area	7.69	8.66	Waterbody area increased

Table 5 Impact of human induced activities on water quality and eutrophication status of Sanasar wetland

Parameters		Unit of measure-ment	2015	2018	Status
Water Quality	pH	–	7.4	7.6	Increase in pH but within acceptable limits
	TDS	ppm	132	139.5	Increase in TDS but within acceptable limits
	DO	mgL-1	5.75	5.65	Decrease in DO but less then acceptable limits, which is matter of concern
Eutrophication	Nitrogen	%	1.97	2.16	An increase in nitrogen level gives indication of eutrophication in the near future
	Phosphorus	%	0.10	0.13	Increase in nitrogen level gives indication of eutrophication in near future

Source: Sample results, Central Water Commission, Jammu and SKUAST-J (2015 & 2018)

increase in the level of Eutrophication is due to unplanned agricultural activities, excreta of grazing animal, ritual wastes and clearing of forest which also leads to siltation problem in Sanasar wetland.

Criticalities faced by Gharana wetland

Gharana wetland is seriously threatened by conversion to non-wetland purposes, encroachment through landfilling,

Table 6 Impact of anthropogenic activities on the area of water body, agriculture and the fringe area around Gharana wetland

Categories	Area 2008 (in ha)	Area 2018 (in ha)	Status
Encroachment	711.11	716.11	5.0 ha area encroached
Agricultural activities	6509	6508	1.0 ha area increased under agricultural activities
Water body area	77	75	Water body area decreased

Table 7 Impact of human-induced activities on water quality and eutrophication status of Gharana wetland

Parameters		Unit of measurement	2015	2018	Status
Water Quality	pH	–	7.4	7.5	Increase in pH but within acceptable limits
	TDS	ppm	129	133.5	Increase in TDS but within acceptable limits
	DO	mgL-1	6.2	6.4	Increase in DO level, above shows good proportion of DO
Eutrophication	Nitrogen	%	2.02	2.42	Increase in nitrogen level gives an indication of eutrophication in the near future
	Phosphorus	%	0.9	0.13	Increase in nitrogen level gives indication of eutrophication in near future

Source: Sample results, Central Water Commission, Jammu and SKUAST-J (2015 and 2018)

pollution (discharge of domestic and disposal of solid wastes), hydrological alterations (water withdrawal and inflow changes), and over-exploitation of their natural resources. This results in loss of biodiversity and disruption in goods and services provided by the wetland.

Table 6 highlights the impact of anthropogenic activities on the water body, forest area, agriculture and fringe area around Gharana wetland over a period of ten years i.e. (between 2008 and 2018) 5.0 hectare area encroached and 1.0 hectare area increased under agricultural activities. But the area of water body decreases by 2.0 hectare. The analysis of the above table reveals that Illegal occupancy of wetland areas by people has resulted in the shrinking of these wetlands. The Gharana wetland has reported a very disappointing picture of shrinkage from the original area. Reports reveal that local people have made the wetland a garbage dumping ground and then they grab over the land. The major threat to this wetland is from agricultural field expansion by farmers which is consuming the area of natural wetland.

Table 7 depicted the Impact of human-induced activities on water quality and eutrophication status of Gharana wetland. During the present period of investigation i.e., from 2015 to 2018, value of pH increased by 0.1% but within acceptable limits of BIS criteria. TDS increased by 4.5 ppm this value but within acceptable limits of Bureau of Indian Standards (BIS) criteria. DO show an increase of 0.2 mg/l in its level is above acceptable limits, which shows healthy water. The value for available nitrogen content of sediment increased by 0.4% and the value of available phosphorus also increased by 0.8% clearly gives an indication of eutrophication in near future. The analysis of the table revealed that

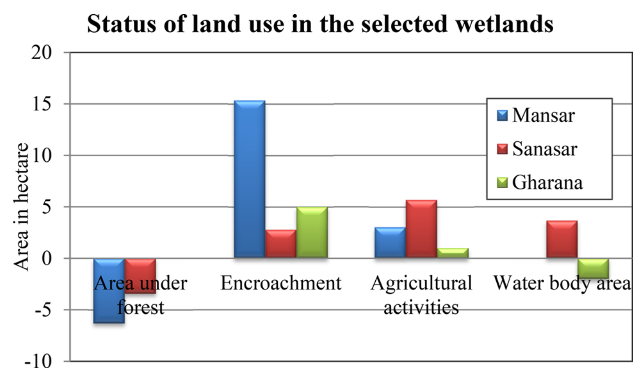

Fig. 9 Status of land use changes in the selected wetlands due to anthropogenic interference (2008–2018)

increased air temperature, shifts in precipitation, increased frequency of droughts, and floods increased carbon dioxide concentration also affects wetlands. People in the adjoining areas are mostly farmers. The use of fertilizers and manures in fields ultimately finds way to the wetlands and result in eutrophication.

Threat assessment of the selected wetlands

Figure 9 shows the status of changes taken place in forest area, fringe area, agriculture, and water body in and around the selected wetlands due to anthropogenic interference over a period of 10` years i.e., (between 2008 and 2018). Data reflected in the above mentioned table clearly shows that the maximum area under forest decreases in the buffer zone of Sanasar wetland i.e., 39.97 hectare followed by Mansar.

Gharana wetland has no forest area in its buffer zone. If we talk about encroachment, buffer zone of Mansar has maximum encroachment where 15.35 hectare area encroached followed by Gharana. The buffer zone of Sanasar wetland shows minimum encroachment of 2.79 hectare. Agricultural activities increased by 5.68 hectare in the buffer zone of Sanasar wetland. Gharana wetland buffer shows minimum increase in agricultural activities i.e. 1.0 hectare. Waterbody of Sanasar wetland increased by 3.66 hectare and of Gharana wetland decreased by 2.0 hectare.

As discussed earlier the Threat assessment of selected wetlands was based on the parameters such as biodiversity (presence of IUCN Red list species), the area under water bodies, eutrophication and water quality. The information generated from the analysis gives a clear picture depicting the threats of intense anthropogenic pressure on all the selected wetlands. Tables 8, 9 shows that the Gharana wetland is the most threatened wetland, Mansar is moderately threatened whereas Sanasar is the least threatened wetland. It is seen that the locals were totally ignorant about the result of their activities in and around the respective wetland. Finally, it is analyzed that the impact of anthropogenic activities on wetlands decreases with an increase in altitude.

Table 9 Composite Standard Score and Magnitude of Threat for the selected wetlands

Wetlands	Composite standard score	Magnitude of threat
Sanasar	Below − 0.5	Least
Mansar	− 0.5–0.5	Moderate
Gharana	0.5–1.00	Most

Discussion

Anthropogenic interventions possess a serious threat to the sustainability of wetlands in the study area. Likewise Wangela et al. 2020, examined the variability in the area covered by wetlands portion mainly caused by anthropogenic activities. This can easily be seen in the case of selected wetlands under study. Within the buffer zone of 5 kms, the wetland located at the lower altitude reported lot of criticalities due to human interventions in terms of their sustainability. Xu et al. (2020) analyzed the shrinkage of Hubei Province was due to human activities. Similarly, the results of the present study revealed that due to anthropogenic activities the water body area of Gharana wetland decreased because of the population increase around its catchment. Bassi et al. (2014) analyzed that the deterioration in water quality affects the economic value as this water serves benefits for fisheries, livestock, and forestry activities. Likewise in the present study, the quality of water was found deteriorated as in the case of Sanasar wetland where DO in water decreased which is a matter of concern. Apart from this the increase of nitrogen level in all the wetlands indicated the human Eutrophication and thus in turn possesses a threat for the sustenance of aquatic biodiversity in the future. Dar et al. 2020, made similar studies where in they focused on the importance of wetlands' role in economic, socio-cultural, and religious activities in Jammu and Kashmir. The present study also revealed that along with economic values, Mansar wetland was found as an important site for religious and cultural ceremonies. Mistch and Gosselink (2015) in their study focused on the role of wetlands to provide support of biodiversity. Likewise in our study area, the wetlands were found to be the home of the large number of flora and fauna. Gharana wetland is a famous wetland for migratory birds and has always been a focus point for bird watchers especially during winters. Kumar et al. (2011) in their study emphasized the degradation around the wetlands were due to livelihood generating forces by communities. Similarly, Mansar and Gharana wetland were found to be under tremendous pressure due to the increase in human and cattle population in their catchment, which was the main cause of LU/LC change.

LU/LC dynamics have been studied in all the selected wetlands using a supervised classification technique. MLC technique was applied for the preparation of LU/LC maps and accuracy assessment was done using Kappa co-efficient. Finally, the change detection analysis was done on the classified image. Similar studies have been done by Talukdar et al. (2020a, b), Shahfahad et al. (2020), for the LU/LC classification and change detection technique to quantify the LU/LC change. Overall results of LU/LC change detection were observed in the selected wetlands and it was found that due to human interventions around the wetlands the forest area has been cleared and encroachment was done. About 6.33 hectares of forest area around Mansar was cleared and about

Table 8 Standard and Composite Standard Score (CSS) for assessing threat magnitude for the selected wetlands

Wetlands	Standard score				CSS
	Biodiversity	Water body area	Eutrophication	Water quality	
Mansar	0.05	0.00	− 0.75	0	− 0.18
Gharana	1.38	1.25	− 0.08	0.91	0.87
Sanasar	− 0.93	− 1.25	1.45	− 1.36	− 0.52

15.35 ha area was encroached illegally. Similarly around 3.44 ha forest area was cleared in the vicinity of Sanasar wetland and about 2.79 ha area encroached. Whereas 5 ha area was encroached around Gharana wetland. This is the only water body which reported to decrease in the area by 02 ha. Similar results were examined by Talukdar et al. (2020a, b) in their study, wherein they found LU/LC changes have taken place due to anthropogenic activities which influence the ecosystem services.

Regarding anthropogenic threat for the sustainability of wetlands, it was found that Gharana wetland was most threatened with a composite score of 0.5 to 1.00 and Sanasar wetland which is located at higher altitude was least threatened due to anthropogenic factors. Dar S.A et al. 2020 examined the trends of LU/LC among the different lakes of Srinagar city from 1859 to 2013 and it has been observed that water in most of the lakes has been shrinking. Contrary to these three wetlands selected under different physiographic units of Jammu Division shows different trends. Surprisingly the water area of Sanasar located at an altitude of 1500 m above msl increased over a period of one decade (i.e., 2008–2018). Whereas, MansarLake located at an altitude of 700mts above msl showed no change in the water area. On the other hand, huge change in the water area of Gharana Lake is observed which is located at an altitude of 400 mt above msl.

At the higher altitudes, the wetlands are more prone to natural factors whereas the wetland located at lower altitudes are facing the criticalities due to land use dynamics by human interferences. Therefore the present study altogether examined the comparative analysis of wetlands located in different physiographic regions and can be used as a supplementary document for planning and development of wetlands located at varying physiographic units.

Conclusion

Land use/ land cover changes are regarded as an important indicator to understand the interactions between human and natural systems. The results of the present study indicated that human activities around the catchment of selected wetlands caused loss and degradation in their quality. The geospatial technique for land use classification and change detection analysis using Landsat data of 2008 and 2018 helped to understand the land use dynamics. The analysis validated that all the selected wetlands observed land use changes due to human interventions. Degradation in wetlands was primarily due to encroachment, expansion in agricultural activities, forestry, eutrophication, and other land use activities in their catchment. The quality of water was badly affected which ultimately can disturb the aquatic as well as terrestrial biodiversity. However, it was found that Mansar and Gharana wetlands were under severe stress than the Sanasar wetland due to the anthropogenic factor. The comparative analysis of these three wetlands proves that the stress on wetlands for their sustainability increases with an increase in human population and their resultant interactions.

Thus the conceptual model for threat analysis used in the present study can be helpful to carry out similar research. The outcome of the present study emphasized that the wetlands located at different altitudes need to have different planning for their sustainability.

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