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Current Status of Wetlands in Srinagar City: Threats, Management Strategies, and Future Perspectives

Shahid Ahmad Dar[1], Sami Ullah Bhat[1], Irfan Rashid[2] and Sajad Ahmad Dar[3]*

[1] Department of Environmental Science, School of Earth and Environmental Sciences, University of Kashmir, Hazratbal Srinagar, India, [2] Geoinformatics Program, School of Earth and Environmental Sciences, University of Kashmir, Hazratbal Srinagar, India, [3] Department of Environmental Science, Uttarakhand Technical University, Dehradun, India

Wetlands are the most diverse, highly dynamic, productive, and ecologically sensitive areas in Earth. In Kashmir Himalaya, Srinagar city is bestowed with a large number of picturesque wetlands. These wetlands are important in regulating ecosystem services such as providing fresh water supplies, food products, fisheries, water purification, harbor biodiversity, and regulation of regional climate. These are also important as socio-economic support systems for the city inhabitants and valued as habitats of migratory birds that visit Kashmir valley from different continents of the world. Owing to the increased rate of anthropogenic activities and anthropogenically driven changes in natural processes, these wetlands are degrading at an alarming rate, seriously affecting their health and water quality. The major threats to wetlands include pollution, land use and land cover changes, urbanization and encroachments, and climate change. The intensive agricultural practices, introduction of exotic species, and changes in hydrological flows during the past few decades have resulted in degradation of wetlands over this region. Sustainable management of wetlands is crucial as these ecosystems offer an array of ecological functions that sustain livelihoods all over the world. This review provides special insights about the significant changes in spatial scale, land use and land cover changes, and water quality of major wetlands in Srinagar city.

Keywords: wetland ecosystems, land system changes, water quality, management strategies, Srinagar, Kashmir Himalaya

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***Correspondence:**
Sami Ullah Bhat
samiullahbhat11@gmail.com

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INTRODUCTION

Wetlands are ecosystems intermediate between aquatic and terrestrial systems, which are permanently or seasonally covered with shallow water (Mitsch and Gosselink, 1986). They occupy ~6% of earth's land surface (Maltby, 1988). Wetlands are productive (Ghermandi et al., 2008) and biologically diverse ecosystems (Keddy et al., 2009). They provide numerous socio-economic and ecosystem services (Prasad et al., 2002; Ramsar Convention Bureau., 2002) including wildlife habitat, maintenance and conservation of biodiversity (Mitsch and Gosselink, 2007; Whitehouse et al., 2008), water purification (Brown et al., 2000), fisheries and recreation (Keddy, 2010; Junk et al., 2013), flood control (Penatti et al., 2015), water supply (Lemly, 1994), nutrient removal (Raich and Schlesinger, 1992), carbon sequestration (Turner et al., 2000), and environmental restoration (Fink and Mitsch, 2007; Moreno et al., 2007). Wetlands serve as a means of livelihood for rural

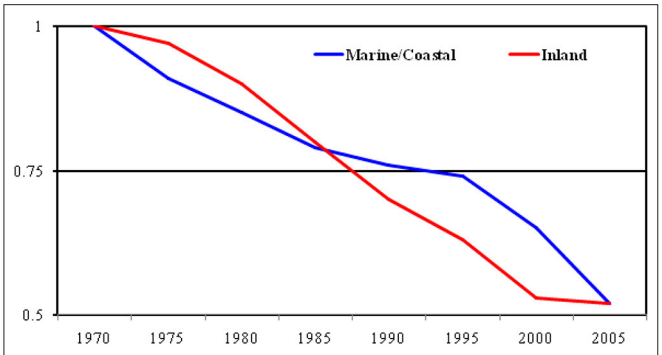

FIGURE 1 | Global Wetland Extent Index (Source: Leadley et al., 2014).

populations (Turyahabwe et al., 2013; Lamsal et al., 2015), particularly in developing nations and are greatly valued by many cultures (Ghermandi et al., 2010; Maltby and Acreman, 2011). Owing to the high potential of wetlands for agricultural productivity, fisheries, and water supply, many of the wetlands of the world have been historically relied upon by human civilizations. In spite of the ecosystem functions and sustenance of human livelihoods, 30–90% of the wetlands of the world are strongly modified or lost (Junk et al., 2013; Reis et al., 2017) and many remain threatened and degraded due to high population pressure and urbanization (Central Pollution Control Board, 2008; Bassi et al., 2014). Davidson (2014) reviewed 189 reports and estimated wetland loses as 64–71% in the twenty-first century. There was a decline of 69–75% in the extent of inland wetlands and 62–63% decline in the extent of coastal wetlands. Wetland losses continue in the twenty-first century. Leadley et al. (2014) found the Wetland Extent Index and estimated ∼40% decline in coverage of both inland and coastal/marine wetland ecosystems during last 40 years due to fragmentation and degradation (**Figure 1**).

Presently, the wetland ecosystems are under tremendous stress due to massive land system changes and infrastructure development (Pramod et al., 2011), as well as intensification of agricultural and industrial activities (Bassi et al., 2014), manifested by the decline in their areal extent resulting in a decline in the hydrological, economic, and ecological functions (Bassi et al., 2014). This has led to adoption of various policies and approaches for conservation, protection, and management of wetlands [Ministry of Environment and Forests (MoEF), 2006].

CURRENT STATUS OF WETLANDS IN SRINAGAR CITY

Srinagar city in Kashmir Himalaya has a rich natural heritage of magnificent lakes and picturesque wetlands (**Figure 2**) lying along the floodplains of river Jhelum, which are famous waterfowl habitats (Kaul and Pandit, 1980; Habib, 2014). Besides being a source of attraction for tourists from all over the world, these freshwater ecosystems of the Kashmir Himalaya have been playing a great role in the socio-cultural activity and economy (Kaul and Pandit, 1980; Pandit, 1982) of the valley since ancient times. They are a great source of natural products like fish, fodder, vegetables, tourism, and a variety of economically important aquatic plants (Pandit and Qadri, 1990; Bano et al., 2018). However, over the last few decades, the deteriorating water quality (Verma et al., 2001; Rashid et al., 2017a) and land system changes (Romshoo and Rashid, 2014; Rashid and Aneaus, 2019) including encroachment of otherwise notified wetland areas and depleting stream flows (Mitsch and Gosselink, 2000; Showqi et al., 2014; Romshoo et al., 2015) have impacted their health (Iwanoff, 1998; Chauhan, 2010; Naja et al., 2010; Reza and Singh, 2010).

Nowadays, wetlands are being recognized as "wastelands" serving as grounds for a variety of waste materials (Khan et al., 2004; Bano et al., 2018). The increasing trend of conversion of agricultural lands into urban areas is currently one of the dominant patterns of land use change in the valley of Kashmir (Rashid and Romshoo, 2013; Rashid et al., 2017b). This pattern of land use change has the potential to alter the composition and functional processes of wetlands by changing the hydrological regimes and sedimentation processes besides the flux of nutrient materials. The ecological consequences of agricultural runoff and municipal wastewater discharges have resulted into widespread eutrophication (Khan and Ansar, 2005; Badar et al., 2013a). The conversion of forested and agricultural areas into built up areas has impaired the water quality (Rather et al., 2016) that has led to the extirpation of local populations of aquatic species. As a result, many freshwater wetlands have altogether vanished or are facing severe anthropogenic pressures. The harmful social, financial, and ecological impacts of declining biodiversity and degrading water quality are a matter of concern (Verma et al., 2001; Bassi et al., 2014). Most of these wetlands used to act as buffers soaking flood waters but the encroachment and infrastructure development within these wetlands has reduced their water holding capacity, increasing the vulnerability of people toward flooding (Romshoo et al., 2017). The central business hub of Srinagar, the capital city, is often affected during a normal precipitation event as the drainage channels that used to drain out storm water runoff have mostly been taken over by concrete surfaces (Rashid and Naseem, 2008). The changes in the spatial extent of lakes and wetlands in Srinagar are presented in **Table 1**. As a result of unplanned urbanization, encroachments, and population pressures, nearly 91.2 km^2 of wetland area has been lost between 1911 and 2004 (Rashid and Naseem, 2008).

Anchar Lake

Anchar is a semiurban, single basin lake situated between 34°07′-34°10′ N latitudes and 74°46′-74°48′ E longitudes at an altitude of 1,583 m above mean sea level (a.m.s.l.). The lake is situated about 14 km from Srinagar city on the northwestern part. The lake covered an area of 19.54 km^2 during 1893–1894 (Lawrence, 1895). Since then, the area of the lake declined substantially to 6.5 km^2 (Jeelani and Kaur, 2012). The current area of the lake is 4.26 km^2 (Sushil et al., 2014; Fazili et al., 2017). The water supply of Anchar Lake is maintained by Sindh, a tributary stream of Jhelum and Achan Nallah in addition to springs along the vicinity of lake. The lake has a vast catchment area that comprised a mixture of residential, forest, agricultural,

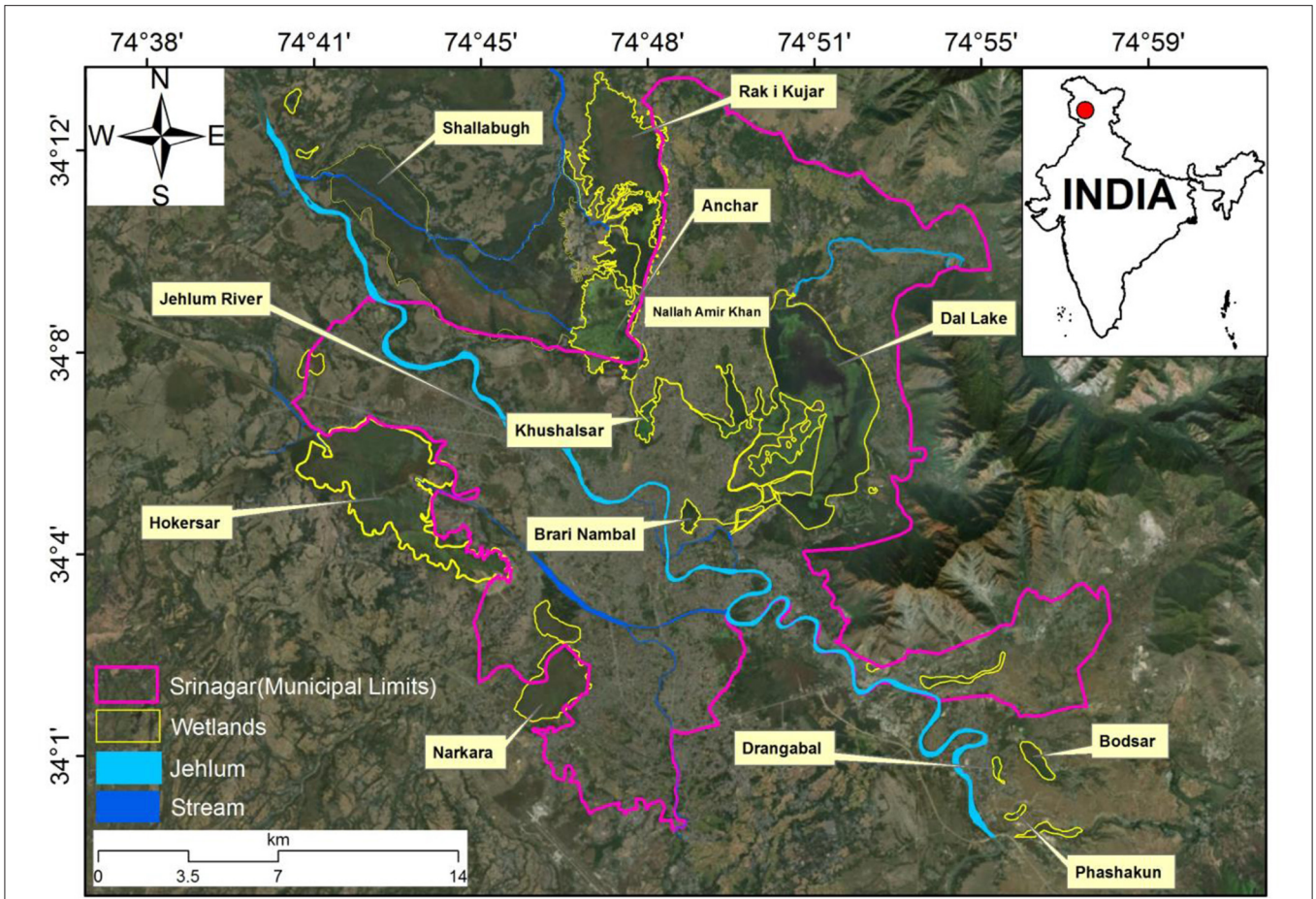

FIGURE 2 | Location of major wetlands in the Srinagar city and its vicinity.

TABLE 1 | Changes in the spatial extent of lakes and wetlands of Srinagar between 1911 and 2004 (Source: Rashid and Naseem, 2008).

S. No.	Class name	Area (km^2)	
		1991	2004
1	Open water surface	40.00	30.65
2	Wetland/marshy area	134.25	64.07
3	Built-up land	17.45	107.91
4	Others	505.05	494.13
	Total	696.77	696.77

TABLE 2 | Long-term water quality changes in Anchar Lake (Source: Kaul, 1977; Kaul et al., 1978; Farooq et al., 2018).

Parameter	1970–1972	1975–1976	2018
pH	7.4–9.6	7.5–9.5	7.2–8.3
Dissolved oxygen (mg L^{-1})	6.88–12.32	4.2–10.85	3.5–6.5
Conductivity ($\mu S\ cm^{-1}$)	132–385	388–555	200–475
Total alkalinity (mg L^{-1})	53–80	75–130	100–399
Ca (mg L^{-1})	16–30	22–24	48.5–74.5
Mg (mg L^{-1})	10–14	9–13	5.3–9.9
PO_4-P ($\mu g\ L^{-1}$)	9–25	12–29	182–698
NO_3-N ($\mu g\ L^{-1}$)	90–57	95–580	558–641
NH_4-N ($\mu g\ L^{-1}$)	70–85	5–18	231–381
Total P ($\mu g\ L^{-1}$)	-	92–666	550–910
Cl (mg L^{-1})	8–10	-	23.5–42

and horticultural land (Jeelani and Kaur, 2012; Bhat et al., 2013). The last few decades have resulted in the decline of the water quality of the lake (Farooq et al., 2018; **Table 2**). The main causes of degradation of Anchar Lake are anthropogenic activities, encroachments, sewage, and dumping of domestic wastes including polythene, clothes, plastic bottles, and effluents from hospitals and wastewater treatment plants (Najar and Khan, 2012; Bhat et al., 2013; Fazili et al., 2017).

Dal Lake

Dal is an urban lake, situated between 34°5′-34°6′ N latitude and 74°8′-74°9′ E longitude at an altitude of 1,584 m a.m.s.l. The lake has been formed due to fluviatile activity of river Jhelum

TABLE 3 | Land system changes within Dal lake from 1859 to 2013 (Source: Rashid et al., 2017a).

Class name	Area (km^2)								
	1859	1903	1962	1972	1979	1992	2001	2010	2013
Aquatic vegetation	2.91	1.35	3.85	8.23	9.42	7.75	8.75	10.40	8.64
Builtup	0.05	0.06	0.84	0.68	0.80	1.83	2.10	2.03	2.02
Floating gardens	0.78	0.82	5.66	1.1288	1.39	1.36	2.52	2.70	2.89
Marshy land	1.49	1.44							
Plantation	6.02	3.99	3.63	3.16					
Water	20.59	23.98	13.84	13.19	12.41	13.10	10.68	8.91	10.50
Total	31.84	31.64	27.82	26.40	24.02	24.04	24.04	24.04	24.04

(Rather, 2012) and is fed by Dagwan stream (Sabha et al., 2019). The lake is under high stress due to anthropogenic influences (Badar et al., 2013b; Khanday et al., 2018). During 1200 A.D., the extent of Dal Lake was about 75 km^2 (Wani et al., 2013). The lake covered an area of ∼32 km^2 in 1859 and has shrunk to 24 km^2 (including the lake interiors) mainly due to the expansion of settlement areas and proliferation of settlements (Rashid et al., 2017a). The lake was abundantly supporting sensitive aquatic macrophytes including *Eurayle ferox* (Lawrence, 1895; Mukerjee, 1921) and *Chara* sp. (Mukerjee, 1921), but as the pollution and eutrophication of the lake continued, the species were pressed to extinction from the lake (Kak, 2010). While it is believed that boatmen (locally known as *Ha'enz*) are the main culprits responsible for changing land use and land cover of the lake (Fazal and Amin, 2012), there are policy failures that have led to the majority of the lake area being highly deteriorated. The land use patterns and land cover of the lake are presently composed of open water (10.5 km^2), aquatic vegetation (8.64 km^2), floating gardens (2.89 km^2), and settlements (2.02 km^2) (Rashid et al., 2017a). The historical changes in the land system of the Dal Lake are shown in **Table 3**.

During the last 50 years, the rapid increase in houseboats, population pressure, encroachment, urbanization, pollution, and sewage has resulted in the decline of the quality of lake water (Amin et al., 2014). About 1,200 houseboats (Fazal and Amin, 2012) present in the lake are a major source of untreated sewage and pollution to the lake (Tanveer et al., 2017). The historical water quality changes in Dal Lake are reflected in **Table 4**.

TABLE 4 | Water quality changes in Dal ecosystem (Source: Trisal, 1977; Abubakr and Kundangar, 2009; Khanday et al., 2018).

Parameter	1974–1976	1985	1996–1997	2006–2007	2018
Dissolved oxygen (mg L^{-1})	10.25	8.7	8.6	6.8	7.07
Total alkalinity (mg L^{-1})	69.5	85.6	104	115	101.75
Nitrate nitrogen ($\mu g\ L^{-1}$)	481	483	272	539	400
Ammoniacal nitrogen ($\mu g\ L^{-1}$)	23.6	37.0	362	438	40
Ortho phosphate phosphorous ($\mu g\ L^{-1}$)	65.5	80.5	135	93	40
Total phosphorus ($\mu g\ L^{-1}$)	187.8	211.5	768	615	200
Total dissolved solids (mg L^{-1})	30.2	32.2	119.8	20	–

Brari Nambal

Brari Nambal is a marshy lagoon situated between 34°05′12.88″N and 74° 48′50″E in Srinagar city. It is connected to the Dal Lake via a channel on the eastern side. Previously, there was an outlet channel known as *Nallah Mar/Mar* canal that used to provide navigability to Dal Lake to Anchar Lake via Khushalsar (Tantray and Singh, 2017). In addition, the Mar canal used to take the excess water from Brari Nambal to Khushalsar Lake. However, the channel was filled and converted into a motorable road during the 1970s (Wani et al., 2014), which resulted into the alteration of the hydrology (**Figure 3**). Brari Nambal has a narrow outlet on the western side and drains into river Jhelum through an underground channel. In 1971, Brari Nambal covered an area of 1 km^2 (water body−0.28 km^2 and Marshy area−0.72 km^2) which reduced to 0.77 km^2 by 2002 (water body−0.21 km^2 and marsh−0.56 km^2) (Fazal and Amin, 2011).

The population pressure, pollution, encroachments, and urbanization have led to great stress on the wetland, thereby deteriorating the water quality to the verge of extinction. Most of the sewage generated in the vicinity is treated at a sewage treatment plant constructed on the southern area of the wetland. The outflows from the sewage treatment plant have become a major source of pollution and nutrients to the wetland. The sewage treatment plant has failed in its operation as per prescribed norms; as a consequence, it discharges partially treated sewage, thereby turning the wetland into a gutter (Mukhtar et al., 2014).

Gilsar and Khushalsar Lakes

Gilsar and Khushalsar are twin lakes in highly deteriorated condition located toward the northwest of Srinagar city. The lakes receive waters from the Nigeen basin of Dal Lake via a water channel—Nallah Amir Khan (Nissa and Bhat, 2016). The total area of the lake is 1.06 km^2, and the average depth of the lake is

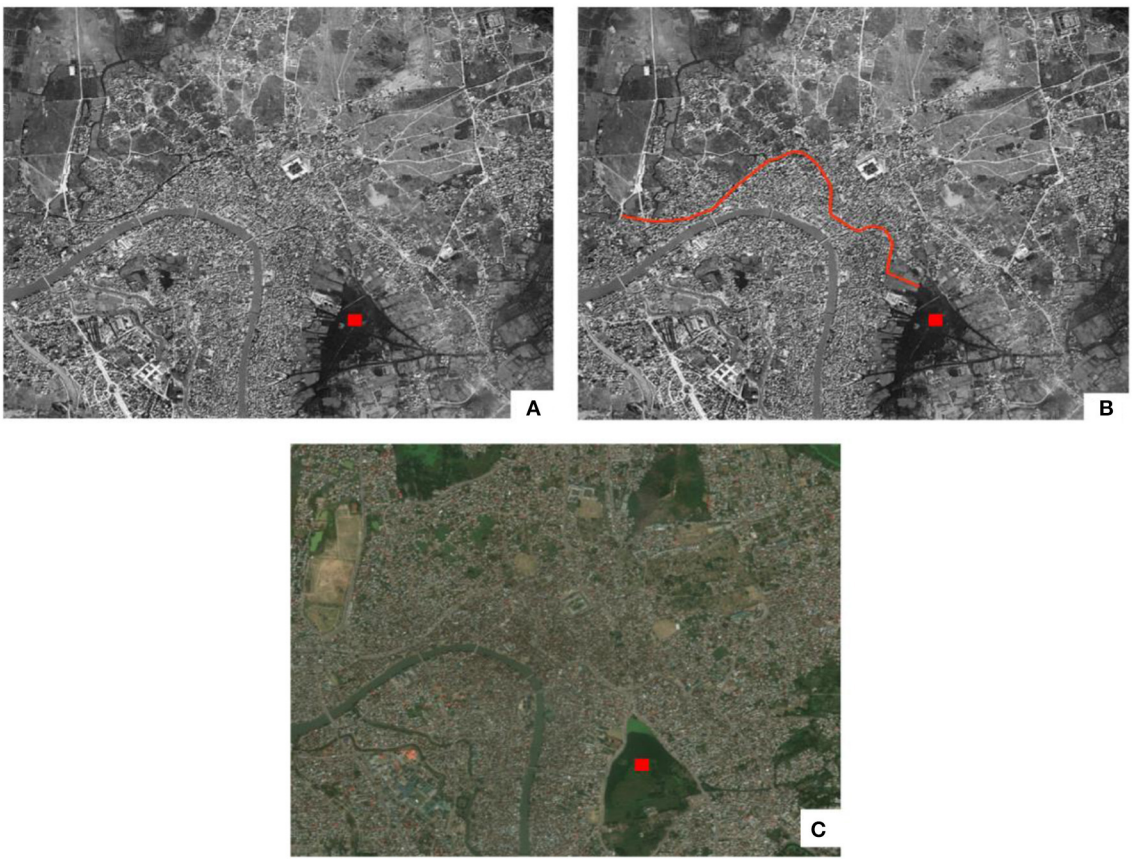

FIGURE 3 | Filling up of Mar Canal as seen from earth observation data **(A,B)** Declassified CORONA spy images showing Mar canal in 1965. Red Line in **(B)** indicates Mar canal. **(C)** Road built by filling up the Mar Canal. Red dot indicates Brari Nambal.

3.6 m. The lakes have been encroached upon at many places with illegal construction and landfilling (Chowdhury, 2017). These lakes receive sewage inputs estimated about 465 million liters per day (MLD) from the catchment containing ∼2 metric tons (MT) of phosphorus and 1.71 MT of nitrogen (Kundangar, 2002) that has resulted into the proliferated growth of aquatic weeds and subsequent degradation of water quality.

Hokersar Wetland

Hokersar is the queen of the wetlands of Kashmir valley situated between 34° 06′ N latitude and 74° 05′ E longitude having an altitude of 1,580 m a.m.s.l. in the northern part of Doodhganga catchment, 10 km west of Srinagar city. The water supply of Hokersar wetland is maintained by the Doodhganga stream on the eastern side and by the Sukhnag stream on the western side. The depth of the wetland varies from a maximum of 2.5 m to a minimum of 0.7 m during spring and autumn, respectively. Hokersar is a game reserve and habitat for about 2 million species of migratory birds of Europe, Siberia, and Central Asia. The marshland supports various ecological and economic services, which include fisheries, food products, freshwater, and purification of water, and regulates global climate (Davis, 1993; Romshoo and Rashid, 2014). The wetland supports a broad range of hydrological functions, for example, regulation of floods, recharge of groundwater, control stream flow (Joshi et al., 2002), and carbon sequestration (Romshoo and Rashid, 2014). In this context, the wetland was designated as a Ramsar site in November 2005. Due to increased human intervention and changing natural processes (Joshi et al., 2002), the area of the wetland has declined from 18.75 km^2 in 1969 to 13.00 km^2 in 2008 (Romshoo and Rashid, 2014; **Table 5**). This wetland has lost 5.75 km^2 of area during the last four decades (Romshoo and Rashid, 2014). During the last two to three decades, macrophytic species like *Acorus calamus*, *Euryale ferox*, and *Nelumbo nucifera* within the wetland had disappeared (Khan et al., 2004). The wetland is now choked by invasive species like *Azolla* spp., *Salvinia natans*, and *Menynanthese* spp. (Khan et al., 2004; Bano et al., 2018). The increased sillt load from the catchment area due to deforestation of higher reaches is the possible cause for the disappearance of the species and depletion of water depth, which has been reported to have reduced from 1.12 m (Pandit, 1980) to 0.63 m (Rather and Pandit, 2002). It is also pertinent to mention that during the last few decades, the water quality of the wetland has deteriorated (Shah et al., 2019) severely (**Table 6**), mainly attributed to urbanization in the vicinity (Romshoo et al., 2011).

TABLE 5 | Area covered by different land use land cover types from 1992 to 2008 within Hokersar wetland (Source: Romshoo and Rashid, 2014).

Class name	Area 1992 (km^2)	Area 2001 (km^2)	Area 2005 (km^2)	Area 2008 (km^2)	Change from 1992 to 2008 (km^2)	% Change
Agriculture	4.26	3.69	3.23	4.95	0.69	3.69
Aquatic vegetation	2.5	3.48	4.56	4.46	1.96	10.73
Built up	0.01	0.05	0.12	0.11	0.1	0.55
Fallow	0.88	0.21	0.27	0.48	−0.4	−2.22
Marshy	7.74	8.06	7.27	5.62	−2.12	−11.86
Open water	0.85	0.43	0.31	0.36	−0.49	−2.72
Plantation	1.82	2.18	2.32	2.16	0.34	1.83
Road	0.03	0.03	0.03	0.03	0	0

TABLE 6 | Range value of various chemical parameters of Hokersar wetland (Source: Kaul et al., 1978; Kaul and Trisal, 1985; Shah et al., 2019).

Parameter	1978	2012–2013
Oxygen (mg L^{-1})	3.2–12	2.4–10.1
pH	7.2–9.0	7.1–8.2
Alkalinity (mg L^{-1})	85–256	91.3–254.7
Conductivity ($\mu S\ cm^{-1}$)	216–348	210–381
Cl (mg L^{-1})	0.0–79.0	10.3–39.3
Dissolved inorganic phosphate phosphorus ($\mu g\ L^{-1}$)	19.0–47	-
Total phosphate phosphorus ($\mu g\ L^{-1}$)	11.2–306	134–390
NO_3-N ($\mu g\ L^{-1}$)	104–327	226.3–631.3
NH_4-N ($\mu g\ L^{-1}$)	3.0–10.0	16.7–242.3
SIO_2 (mg L^{-1})	3.0–9.0	-
Ca (mg L^{-1})	24–61	44.2–107.2
Mg (mg L^{-1})	11.0–18.0	6.2–28.1

BRIEF INVENTORY ON SERVICES PROVIDED BY WETLANDS

Having only a coverage of 0.6% of the Earth's surface, wetlands supply a tremendous proportion of ecosystem services such as recreational amenities, flood control, storm buffering, biodiversity, climate regulation, and socio-cultural values. They are important habitats for biodiversity contributing to primary productivity and home to many important migratory birds. Thus, wetlands have a diverse fauna with a relatively large number of endemic species. Goods and services derived from wetlands include livestock and cultivation, fisheries, fiber for construction and handicraft production, fuel wood, hunting for water fowl and other wildlife, aesthetic value of wetlands, storm buffering, flood water storage and stream flow regulation, water flow, sediment and nutrient cycling—water quality improvements, erosion control, carbon sequestration—climate change and mitigation, and cultural knowledge and traditions (Eftec, 2005). Wetlands are believed to have distinctive ecological features, which provide various goods and services to mankind. They constitute a natural resource of great economic, scientific, cultural, and recreational value. Wetland characteristics such as biodiversity, abiotic components, and ecological processes regulate a large number of functions that are first transformed into a list of services that can then be measured in appropriate units (biophysical or otherwise) and later used for economic valuation. Ecosystem functions represent the potential for benefits that may or may not be used directly by humans. Usually, the same function is linked to two or more ecosystem services. Some of the vital functions of the wetlands are listed in **Table 7**.

TABLE 7 | Ecological and socio-economic importance of wetlands.

Services	Brief description
Regulating	
Air quality regulation	The wetland ecosystems have the ability to maintain air quality by extracting aerosols and chemical compounds from the atmosphere.
Climate regulation	Wetlands through their biologically mediated processes stabilize the micro-climate of the region, however at global scale; they moderate climate vagaries through the land cover and other processes.
Hydrological regimes	Wetlands regulate hydrological cycle and regulate water regime through ground water recharge, evapotranspiration, and by capturing and gradually releasing the water.
Pollution abatement and detoxification	Wetlands drastically reduce the nutrient input from through flowing surface and sub-surface run-off. The biotic and abiotic factors in the wetlands lead to the detoxification of the pollutants and xenic compounds carried into the ecosystem.
Erosion control	Wetland vegetation and biota reduce the erosion of soil through sediment binding and reducing current velocity.
Natural hazard mitigation	Wetlands help to lessen the negative impact of flooding by soaking up the water and reducing the speed at which flood water flows.
Biological regulation	Wetlands regulate population structure of the ecosystem through trophic relation.
Provisioning	
Food	Production of edible plants like *Nelumbo nucefera* and animals like fish (*Schizothorax* sp., *Cyprinus* sp.).
Fresh water	The biotic and abiotic processes taking place in the wetland ecosystem enhances water quality. Wetlands have vast ability to meet municipal water supply in the neighboring areas.
Fuel and fiber	Wetlands are home to a number of species or abiotic components with potential use for fuel or raw material.
Biochemical products and medicinal resources	Wetlands act as huge reservoirs of potentially beneficial chemical compounds having tremendous medicinal and cosmetic properties.
Genetic materials	Wetlands represent areas of high biological diversity and support gene pools of the most diverse assemblages of a wide variety of flora and fauna.
Ornamental species	Wetlands provide vital habitat for many species and other abiotic resources with Ornamental value.
Socio-economic	
Cultural heritage and identity	Wetlands symbolize the culturally significant landscapes by creating the sense of belongingness for certain features and species it beholds.
Tourism and recreational	Wetlands provide panoramic views of landscapes having humongous recreational potential for tourism.
Aesthetic	The aesthetics provided by the wetlands is based on greenness, tranquility, and diversity.

TABLE 8 | Threats perceived by wetlands of Srinagar city.

S. No.	Threats	Perceived impacts
1.	Floating gardens	Construction of floating gardens is a major threat to the lakes and wetlands of Srinagar city. This practice has resulted in conversion of large areas of open water into floating islands. The impact of these floating gardens is very grave, and unless this practice is stopped, the wetlands would be under a severe threat.
1.	Willow plantations	The creation of a network of willow plantations and populus trees within the wetlands (Anchar, Brari Nambal, Dal, Hokersar, Gilsar, and Khushalsar) is a serious threat to wetland ecology. These plantations have obstructed natural flow of drainage, causing deleterious morphological, hydrological, and ecological changes to wetlands.
2.	Houseboats	The direct discharge of untreated sewage from some 1,200 houseboats located in Dal lake is a growing threat to the lake ecosystem. This has resulted into deterioration of water quality, prolific growth of aquatic macrophytes, and pollution of the lake (Parvez and Bhat, 2014).
3.	Mechanical machines/harvestors	The mechanical dredgers and de-wedeers used in wetlands of Srinagar City (Dal lake, Brari Nambal) for removal of sediments and aquatic macrophytes has resulted into loss of species of fish, macro-invertebrates, zooplankton, and other biologically important organisms from the wetlands (Ali, 2014).
4.	Sewage treatment plants (STPs)	Pollutant loads from point sources (STPs) constructed along the banks of Dal lake and Brari Nambal has become the main source of pollution for these water bodies. The STPs have failed to operate as per prescribed norms resulting into increased nutrient loadings mostly nitrogen and phosphorus, organic matter, metals, pathogen, nutrients, and supplementary water pollutants to the wetlands (Mukhtar et al., 2014).
5.	Hospital effluents	The effluents discharged from SKIMS into Anchar lake has resulted into increased nutrient concentrations and toxic compounds into lake ecosystem that are very harmful for lake ecology and sometimes very toxic for fish and other aquatic biodiversity (Bashir et al., 2017; Gudoo et al., 2017).
6.	Red tide	The unprecedented occurrence and frequent seasonal recurrence of red tide in lakes and wetlands of Srinagar city constitutes a new environmental threat to the aesthetics and biological diversity of wetlands. The occurrence of red tide is due to ingress of untreated sewage from nearby residential areas to lakes and wetlands of Kashmir valley (Khan, 2000).
7.	Urban sprawl	Unplanned urbanization in the vicinity of wetlands in Srinagar is the biggest threat and an important cause for the reduction of wetland extent (Kuchay and Bhat, 2014; Romshoo and Rashid, 2014).
8.	Hydrological alterations	Hydrological changes including alterations in inflows and hydrological makeup by surface water extraction, water diversions, and stream channelization for a variety of human uses.
9.	Climate change in Himalayas	Recession of glaciers in Himalayas and changes in precipitation have a significant impact on wetlands and their associated species. Anticipated changes in regional climate could be one of the main drivers besides anthropogenic factors for loss of wetlands in Kashmir region given the depleting streamflow scenario as observed across Kashmir valley (Rashid et al., 2015; Zaz et al., 2019).
10.	Exotic species	Introduction of exotic species either deliberately or naturally into lakes and wetlands of Srinagar city has resulted into changes in wetland ecology, biodiversity, land uses, and water quality. For example, exotic fish species *Cyprinus carpio* introduced in Dal lake have eliminated the native *Schizothorax* sp. from Dal lake.
11.	Siltation and erosion	Siltation and erosion of sediments from the catchment areas is a major threat to the wetlands of the city. These result in loss in water spread area of wetlands.
12.	Roads	Constructions of roads within Dal and Khushalsar have not only fragmented these water bodies into sub-basins but also impacted the hydrology.

THREATS TO WETLANDS

Among the freshwater ecosystems, wetlands are the most widely used and are heavily exploited for sustainability and livelihood (Molur et al., 2011). The main threats to wetlands in Srinagar city are attributed to anthropogenic pressures that include urbanization (Farooq and Muslim, 2014), land use changes (Fazal and Amin, 2011), and large-scale encroachments (Wani and Khairkar, 2011; Kuchay and Bhat, 2014) in the catchment as well as in the wetlands itself (Rather et al., 2016). Besides, natural siltation associated with the anthropogenic siltation brought about by deforestation in the catchment areas has also been an important factor resulting in the loss of wetlands (Pandit and Qadri, 1990; Pandit, 1991; Shah et al., 2017; Amin and Romshoo, 2019). Another important driver of the loss of wetlands comes in the form of problems relating to drainage (Romshoo et al., 2017; Alam et al., 2018). The huge inflow of sewage from the catchment areas into the water bodies has resulted in excessive macrophytic growth (Dar et al., 2014). The main causes of wetland degradation in Srinagar are summarized in **Table 8**.

MANAGEMENT OF WETLANDS

In Srinagar, wetland ecosystems are continuously seen as isolated systems and hardly figure in any management plans. The principal responsibility for management of wetland ecosystems in Srinagar is with the Lakes and Waterways Development Authority (LAWDA), Srinagar. Although one of the wetlands in Srinagar—Hokersar—was declared as a Conservation Reserve by the Jammu and Kashmir Wildlife Protection Act (1978)[1] and selected as a Ramsar site under the Ramsar Convention on wetlands of international importance on 8 November, 2005, the wetland ecosystems are overlooked in management plans. A wetland management plan would be imperative for deriving sustained ecological and socio-economic services from these important freshwater ecosystems. The wetland management plan would adhere to various actions for protection, restoration, and manipulation of wetland ecosystems that provide values and functioning advocating to their sustainable usage (Walters, 1986).

[1]http://www.jkdears.com/eers/pdf/J_K_Wildlife_Protection_Act.pdf

The various strategies involved in management process should aim at:

- Reducing the impact of current anthropogenic pressures and natural processes for long-term protection of wetlands.
- Prohibiting any kind of anthropogenic interference in wetland areas particularly where much of the natural functioning of wetland ecosystems have already been lost.
- Regulating inflows using water quality standards set by organizations for wetlands for their regular functioning while deriving monetary benefits in a sustainable way.
- Creating barrier or green zones for protection of wetland ecosystems, restraining detrimental human actions in the demarcated area of wetland ecosystems for restoring the wetlands.
- Addressing and treating point sources and non-point sources of pollution in the vicinity and catchments that would improve the trophic status of wetlands in peril.
- Setting up of robust treatment plants (STPs) within the wetlands and their immediate catchments that would improve wetland health.
- Involvement of local people, colleges, and universities for regular monitoring of the health of wetlands and establish a civil society–academia–policy interface that will help in the better understanding of these ecologically sensitive areas for formulating effective conservation and restoration efforts.
- Workshops and other programs with active participation of school and university children in the vicinity of wetland ecosystems on a regular basis so that hands-on education is imparted to the dwellers and inhabitants for protection of wetlands.

CONCLUSIONS

Wetlands are biologically most diverse and economically valuable ecosystems all over the world. They cover about 6% of the surface of the earth and provide important ecological and economic services. Srinagar city in the valley of Kashmir has several lakes and wetlands. These are important as socio-economic assets and function as absorption basins for flood waters. They help in the maintenance of biodiversity, purification, and recharge of groundwater. The wetlands of Srinagar city are degrading at an alarming rate mainly due to anthropogenic pressures and climate change. The major threats to wetlands in the city include pollution, siltation, encroachments, urbanization, and establishment of floating gardens. Robust management strategies must be adopted for conservation and protection of wetland ecosystems to ensure sustainable socio-economic and ecological benefits.

FUTURE PERSPECTIVES

Wetlands all over the world function as important ecological assets and contribute largely to the well-being of the people. Studies have shown that the monetary value of wetland services far exceeds those provided by terrestrial ecosystems. Nowadays, there is a growing trend of utilizing constructed wetlands for treatment of wastewaters and industrial effluents. Due to encroachments and land use changes, the area of lakes and wetlands has drastically reduced during the last few decades. Therefore, the future of lakes and wetlands seems to be at stake, which would not only impact socio-economy but also increase the vulnerability of people to disasters. Despite the regulations and the presence of wetland management authorities, wetlands continue to degrade in the Kashmir region. Keeping in view their ecosystem services, wetlands need to be conserved for future generations. The wetland management authorities of Srinagar city need to look into the ecological degradation and the land conversion going on within and around the wetlands. The areas that require aggressive management approaches are restricting the expansion of floating gardens and limiting the growth of aquatic vegetation. It is these hotspots that are earth-filled and used for construction of houses. The siltation of wetlands in Srinagar is another important concern that should be looked into by the policy-makers so as to restore their original water holding capacities. This is important for reducing the vulnerability of population in Srinagar to floods. The effects of mismanagement of city wetlands will become visible only in a few decades and the wetland encroachers will bear consequences similar to what Srinagarites experienced during 2014 mega flood.

AUTHOR CONTRIBUTIONS

ShD, SB, and IR conceived, designed, and drafted this review, while SaD author helped in screening the relevant literature besides giving inputs on draft. All authors together at the end gave final shape to this manuscript.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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