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Monitoring and Management of Asan Reservoir Wetland and Environs Using High Resolution Satellite Data

RAJASHREE NAIK[1,2,*], SARNAM SINGH[1,3] AND ARCHANA BAHUGUNA[4]
[1]*Indian Institute of Remote Sensing, ISRO, Dehradun 248 001, India*
[2]*Central University of Rajasthan, Ajmer, Rajasthan, 305801, India*
[3] *Nalanda University, Rajgir, Bihar 803116 India*
[4]*Zoological Survey of India, Dehradun 248 001, India*
E-mail: rajashree.bini06@gmail.com, sarnam.singh@nalandauniv.edu.in, archana.bahuguna65@gmail.com
ORCID Id: 0000-0002-8303-0015 (RN), 0000-0003-1829-7941(SS)
***Corresponding author**

ABSTRACT
Asan Conservation Reserve (ACR) is one of 42 wetlands of International Importance under Ramsar convention and lies in the Central Asian-Indian Flyway and East Asian-Australian Flyway of migratory birds in Doon Valley in Western Himalaya. The valley-landscape is unique and complex with a mix of land use/land cover such as forests, rivers, urban as well agricultural landscape in the Himalayan Biodiversity Hotspot region with high seasonality, water flow and area fluctuations, vegetation physiognomy and phenology, tourism, etc. Even though the migratory and resident birds occupy wetland for most of their stay time, however, the role of the adjacent land use practices play a very important role in food supply chain. We used six-time high resolution time-series temporal (summer and winter) satellite images of LISS IV sensor for the years 2004, 2013 and 2016 to understand the wetland dynamics and its unique ecological significance in terms of conservation and management of ACR for avifauna, specially migratory birds and aquatic vegetation. The area analysis of wetland and its environs between 2004 to 2016 indicates decreasing trend of about 3% (0.14 km^2), 4% (0.65 km^2), 1% (0.18 km^2) and 15% (2.02 km^2) in wetland area, riverine scrub, mango orchards and agriculture land, respectively. An increasing trend has been observed by 4% (0.348 km^2), 1% (0.067 km^2), 3% (0.18 km^2), 4% (0.2 km^2) and 5% (0.35 km^2) in settlement area, siltation, total forest cover, water body and wet riverbed, respectively. However, dry riverbed has remained almost unchanged occupying about 17%. The water and vegetation ratio is nearly ideal in the ratio of 60:40, and if needed, desiltation may be carried after mid-March.

Key words: IRS LISS IV, LULC monitoring, Conservation Reserve, Migratory Avifauna, water and vegetation ratio.

INTRODUCTION

Since 1971, Ramsar Convention on wetlands has been addressing significance, emerging challenges, threats, opportunities, wise use, newer ways to conserve and manage wetlands globally (Ramsar Convention 2013, 2016). About 4.6% of land in India is wetland which is about 15.26 million ha and conservation needs have been highlighted from time to time (MoEF 1990, 2007; Prasad et al. 2002). Of these 42 sites are designated as Wetlands of International Importance (Chandra et al. 2021). India also has very unique and diverse wealth of wetlands habitats (MoEF 1990, 2007, Bassi et al. 2014, Chandra et al. 2021). In totality, wetlands are more diversified and represent almost all taxonomic groups starting from unicellular algae, diatoms, bryophytes, mosses, vascular plants - primitive ferns to woody angiosperms, and the faunal diversity extends from unicellular protozoa to mammals (Gopal et al. 2000, Chandra et al. 2021). These provide a range of habitats for resident and migratory birds, amphibians, reptiles, annelids, fishes, turtles, mammals, butterflies, insects, aquatic vegetation, etc., and are well-known for important multiple ecosystem and environmental services such aquifer recharge, ground for feeding, breeding, nesting, roosting places for avifauna and grazing grounds for wild and domestic animals and also important sources of drinking water for domestic cattle, wildlife, human consumption, irrigation, pisciculture, retting, fox-nut cultivation, bathing for man and animals, environment regulation being part of hydro-bio-geo-chemical cycle, tourism, cultural and religious values, and are recognized vital for national and global ecosystems and economies (Acharya 2000,

Bullock and Acreman 2003, MEA 2005, Hussain 2007, Bassi et al. 2014, Kumar et al. 2020, Chandra et al. 2021). The bird species of duck, egret, dove, cormorant, coot, hornbill, grebe, stork, heron, eagle, hawk, tern, cuckoo, owl, kingfisher, bee-eater, hoope, barbet, woodpecker, parakeet, minivet, shrike, drongo cuckoo, treepie, magpie, fantail, crow, lark, bulbul, babbler, robin, myna, bushchat, starling, sunbird, sparrow etc. reside in the ACR region throughout the year. Deepa and Ramchandra (1999) reported that 20 % of the fresh water biodiversity is supported by wetlands in India. The wetlands are also grazing ground for wild and domestic animals, reed collection, growing edible plants flowers *Nelumbo* sp. (lotus), *Trapa* species (water caltop/ chestnut) and vegetables such as *Euryale ferox* Salisb. (fox-nut), *Ipomoea aquatica* Forsk., *Typha* sp., etc. Since these are considered as common property resource, traditionally majority of these have open access without payment to extractive use (Verma 2001). Wetland are also part of habitat for flagship species such Tiger, Elephants, Antilope, Rhinoceros, etc. (Kushwaha et al. 2000, SACON 2004, Meena and Sharma 2019) and other invertebrates such butterflies, dragon flies, etc.

The northern and north-western region of India is quite rich in Ramsar wetlands. Uttarakhand state is part of Endemic Bird Area of Western Himalaya, has 17 International Bird Areas and three Conservation Reserves (Rahmani et al. 2016). The state is rich in terms of natural resources, ecosystem diversity, rivers basins, watersheds with important rivers such as Yamuna, Ganges, Kali, etc. originating from the state. The river and stream systems are most dominant type of wetlands with 77.14 per cent share of all the wetlands (81,033 ha). Doon valley has several man-made as well as natural wetlands, and is one of the important destinations of migratory birds in India, and is part of Central Asian-Indian Flyway (Kumar et al. 2005). Asan Conservation Reserve (ACR) is one of 42 wetlands of International Importance under Ramsar convention (Rahmani et al. (2016) and is part of Central Asian-Indian Flyway of migratory birds in Doon Valley forming chain of Ramsar sites (Wular-Hokera-Surisar-Tsomoriri-Chandrataal-Harike-Keoshopur-Miani-Nangal-Pong-Renuka-Asan) in north-western Himalaya. It is a fresh water man-made wetland system at the confluence of Yamuna and Asan rivers, and was first Conservation Reserve declared in 2005 and then designated Ramsar site in 2020 with Ramsar site number 2437 and is one of the favorite destinations of migratory water birds from Central Asia during summer as well as winter, and also for indigenous Himalayan avifauna. During winter it is common to see 5000 waterfowl, and the population in this International Bird Area exceeds the threshold four times and thus qualifies for A4i criteria set out by Wetland International in 2012 (Rahmani et al. 2016). About 327 (Mohan et al. 2016) and 332 Chandra et al. 2021) cumulative number of species of birds have been recorded in wetland including critically endangered Red-head vulture, White-rumped vulture, Slender billed vulture and Baer's Pochard for whom Uttarakhand is very important. More than 78 species of invertebrates, 51 fishes, 4 amphibians, 1 reptile and 20 mammals (Tak et al. 2003, Bharadwaj et al. 2012; Mohan and Sodhi 2015, Hussain 2015, Bhatt et al. 2016, Singh et al. 2016, Chandra et al. 2021). Mohan et al. (2016) reported RET species: vagrant (11), vulnerable (6), near threatened (13), critically endangered (3) and endangered (2), however, Rahmani et al. (2016) reported 8 species critically endangered, two endangered, 8 vulnerable and 14 near threatened. This number would be higher as the Birds enthusiasts increase. It is interesting to note that in close by upstream in north of the ACR is Dakpathhar barrage wetland, bigger than ACR and in the same climatic and geographic set up, but faunal diversity of migratory birds is very less there. ACR serves as feeding and migration path for birds, and spawning ground for several fish species because of its unique set of deep and shallow waters, submerged islands, sand, marshy land with vegetation, continuous flow of nutrient rich waters from Yamuna and Asan rivers. The landslides are frequent in the catchment of Asan and Yamuna rivers and bringing silt to reservoir. However, as a part of management, the water level, spread of water area as well as depth are maintained by occasional desilting by the management. This practice may be deleterious to the fauna and food chain but important to maintain long-term viability of the wetland.

The wetlands are being rampantly reclaimed by dumping solid waste and e-waste, and then constructing housing or other complexes in most part of the India (Deepa and Ramchandra 1999). The mapping of wetlands for more than 56.25 ha was

carried out by SAC (1998), and then Vijayan et al. (2004) used better resolution satellite data of LISS III (23.5 m spatial resolution) to map these with about 2 ha area to study land use, wetland class, turbidity and aquatic vegetation and reported shocking loss of about 38% wetland in India from 1994 to 2004, and in some states up to 88%. They reported fluctuating trends in area during before and after rainy season in Northern India and recorded as many 26 out of 60 wetlands in Uttar Pradesh have the problems of solid waste and sewage disposal and untreated effluents from the industries. Vijayan et al. (2004) reported dumping of 3500 tonnes of municipal waste every day in Pallikarnai wetland in Tamil Nadu and which has precious germplasm of wild rice (*Oryza ruifipogon*). One of major reasons of wetlands loss is attributed to the non-existence of 'wetland(s)' as land use class in the statistical records and revenue maps/records of the state governments in India. Many wetlands in rural and sub-urban are not governed by Indian Forest Act 1972 or Wildlife Protection Act 1972. Since wetlands are classified as 'wastelands' in revenue records, it become easier to allow to 'change' the land use by government agencies, therefore, prevention of land use diversion and lack of governance and management becomes difficult (Kumar et al. 2013). The entire system has been insensitive and non-caring, and the callous attitude of the government system as well as society has led to the diversion of large-scale reclamation of wetlands to urbanization, industrialization, garbage dumping, etc. causative factors to these changes.

ACR is a multipurpose wetland for hydroelectric, irrigation, biodiversity conservation, pisciculture, tourism, etc. and thus has several stakeholders in management (Hussain 2007). It is an Important Bird Area in western Doon valley has the privilege to be the first Conservation Reserve of the country declared in 2005 (Mohan et al. 2016) and the other nearest Ramsar site Renuka wetland (Julka and Mehra 2000, Julka and Paliwal 2000, Sinha, 2000). ACR represents four very characteristic life-forms: (a) migratory and resident birds, (b) butterflies; (c) amphibians; and (d) fishes and other groups such insects, annelids, mollusks, etc. These are very significant in maintaining the ecological balance and interface between terrestrial-aquatic ecosystem services for ecological factors, genetic linkers, seed dispersers, pollinators, resource linkers, trophic and non-trophic process linkers, ecosystem engineers, raptors, scavengers, insectivores, soil formation and nutrient depositors (Burger 2006, Sekercioglu 2006). The reservoir is outside protected area network and therefore, it needs special management plans (Mohan et al. 2009) Because of its uniqueness, several researchers were attracted to study various aspects of faunal components (Tak et al. 2003, Kumar et al. 2005, Rizvi 2007, Grewal and Sen 2008, Mohan et al. 2009, Hussain et al. 2015; Singh et al. 2016, Bhatt et al. 2016). It is categorized as an Important Bird Area (Islam and Rahmani 2004) and falls in Category 2 for conservation prioritization (Vijayan et al. 2004). Therefore, to achieve various objectives it is desilted at a regular interval which disturbs the water-marsh-lands-vegetation ratio, important to retain biodiversity and conservation value.

Manjrekar and Singh (2012) recorded more than 116 wetlands including glacial lakes in Uttarakhand. The total number and area of wetlands varies because of satellite data used and the minimum mapping unit adopted. Kumar and Porwal (1998), Kumar et al. (2005) carried out LULC mapping of ACR for the time period (1996-98) using LISS II data and concurrently studied winter migratory population of herbivorous water fowls. Kumar et al. (2005) reported an increase in emergent vegetation and herbaceous vegetation area due to growth of *Lantana camara, Typha elephantiana, Pogostemon pectinatus, Ipomea,* etc. and decrease in open water area and shrubby vegetation. Their study indicated that increase in vegetation cover in wetland has positive impact arriving migratory birds - 125% in Coot, 250% in Brahminy Duck and 306% in Gadwall. They concluded that the ratio of water and vegetation cover should be in the range of 50:50 to 30:70 (Kumar 2003). The present communication is a part a study for ecological assessment of ACR for habitat characterization for target groups such as birds, butterflies and amphibians, vegetation/plant communities and dynamics of water using high resolution satellite data of LISS IV sensor. This is perhaps first study of mapping ACR using high to very high resolution satellite data, which has several advantages in the form of information content, boundary delineation, area analysis, accuracy, etc. to understand the dynamics considering desilting and maintenance of long-term conservation values.

MATERIALS AND METHODS

Study area

Located in west Doon valley, ACR is in the biogeographic province 4.8.4 (Indo-Gangetic monsoon forest) and wetland Type 17 (Water storage reservoirs, dams) (Hussain and De 1993). It is a man-made wetland created as a result of construction of a barrage in the year 1967 on Asan river with an area of about 4.44 km^2 (Chandra et al. 2021). It is situated between latitude 30°24'N to 30°28'N and longitude 77°40'E to 77°44'E near confluence of the Yamuna river and its tributary Asan (Fig. 1). The barrage is 287.5m long and the river bed is 389.4 m amsl (Hussain, 2007). Upstream, Asan river is fed by several smaller rivers (Tons nadi, Sitla rao, etc.) originating from Mussorie hills and a Hydel-cum-irrigation canal from Yamuna river from Dakpatthar. Though water flow is continuous, fluctuations expose swampy islands attracting marsh loving bards (Tak et al. 2003). ACR has different ecosystems diversity as microhabitats of fresh running to stagnant water to swamp areas, organically rich soil to sandy islands to boulders; floating, submerged grasses to tall plants to tree within and is surrounded by natural vegetation, agriculture landscape and human settlement. ACR seems to have most of these. However, unplanned rapid urbanization, infrastructure development and irresponsible attitude of society and to some extent of governments as well towards wetlands are leading to the loss and shrinking of wetlands. The complex mosaic of habitats and niches which support food-web for birds, butterflies, insects, amphibians, mollusks, annelids, mammals, etc., is sustained by continuous flow nutrient rich waters from Asan river and canal originating from Yamuna river. The ecological communities and reasons for attracting large number of migratory birds have been analyzed. The waterbody, marshy land, agriculture, settlement, riverine forest, tall grasslands, orchards, sandy riverbeds, shallow and deep water, stagnant and flowing water, aquatic vegetation, etc. provide unique conditions for wildlife. These along with birds, butterflies, insect, annelids, amphibians, fishes, etc. form a self-sustaining chain of food-web in complex ecosystem. The natural setting of the ACR is a mosaic of riverine forest, riverine scrubland, agricultural area, wetland, orchard and plantation (Mohan et al. 2009). The riverine forest is dominated by trees like *Acacia catechu* and *Dalbergia sissoo*. Tree species like, *Bombax ceiba, Phoenix sylvestris, Ficus palmata*, etc. are also found. Aquatic vegetation includes *Hydrilla verticillata, Polygonum* spp., *Eichhornia crassipes, Ageratum conyzoides, Abrus precatorius, Senna tora, Artemisia* sp., *Ocimum basilicum, Trevia nudiflora, Gomphrena serrata, Bidens pinnata, Adenostemma lavenia, Pogostemma benghalensis, Veronica anagallis-aquatica*. *Potamogeton crispus* and *Ceratophyllum demersum* are two aquatic species found within the reservoir. Shrubs like *Lantana camara, Murraya koenigii, Colocassia* spp., *Ipomoea nil. Ipomoea fistulosa, Ipomoea carnea, Vitex negundo, Solanum torvum,* etc. are conspicuous and dominant floristics forming pure stands as well as associations. *Scirpus mucronatus* and *Cyperus digitatus* are two dominant sedges and *Typha elephantine* the dominant grass within ACR (Mohan et al. 2009). There are about 78 invertebrate species which include odonata, coleptera, annelida, and molluscs and 160 vertebrate species which include Pisces, amphibians, reptilians, aves and Mammalia indicating the rich faunal diversity in a small area. Two artificial lakes one each on right and left side of the area were constructed in order to provide an alternate habitat for the migratory and resident water-birds (Tak et al. 2003) and this management intervention is proven to very effective for active breeding and wintering sites for water birds. Monitoring of wetlands, management of populations and distribution of migratory as well as resident water birds and their habitat are of prime significance. Kumar (2003) emphasized the importance of population variation resulting from success or changes in their 'homing' grounds enroute for feeding and moulting areas till final destination. The conservation issues include spread of invasive species, increase settlement, resorts, hotels, non-sustainable tourism, draining of waters at wrong time and poaching, drudging timing, pesticides, etc.

Data and field work

Two seasons time-series high spatial resolution (5.8 m with 10 bit radiometric resolution) satellite data of LISS-IV sensor of IRS-P6 and Resourcesat-2 satellites procured from NDC National Remote Sensing Centre (NRSC), Hyderabad were used. The details of two seasons time-series images of LISS IV sensor of IRS-P6 and Resourcesat-2 are given in

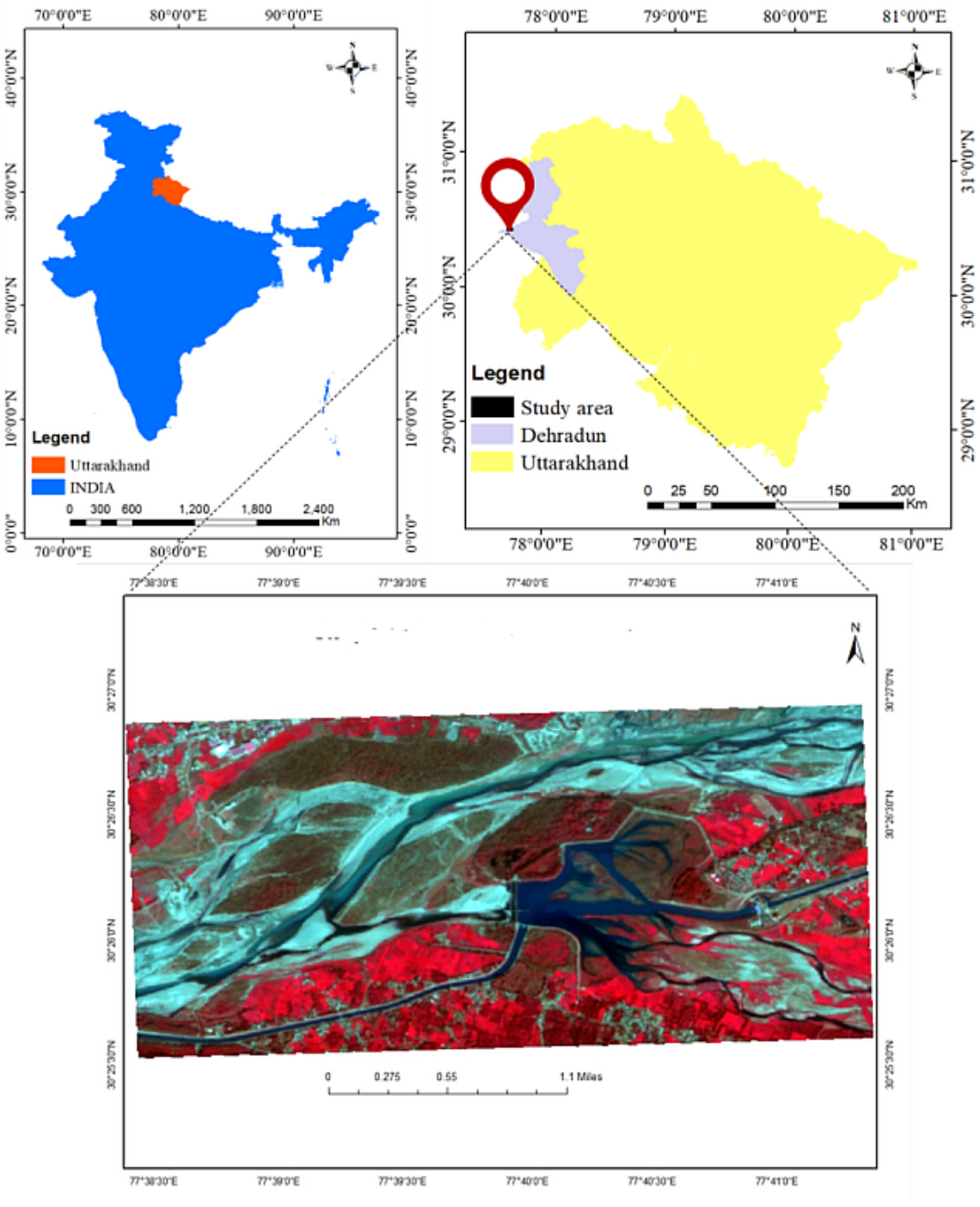

Figure 1. Location of ACR and its surrounding environs

Table 1.

Ancillary data of recent surveys available with Zoological Survey of India (ZSI) Dehradun such as list of birds (2016), butterflies (2017) and amphibians (2017), Botanical Survey of India (BSI) Dehradun on plant diversity of Asan Wetland; and Chakrata Forest Division Management Plan of Asan (2009-2014) were generously used. Additional ground data on vegetation types, land use/ land covers, wetland

Table 1: Details of satellite data used

	Spacecraft	Sensor	Acquisition Date
1.	IRS-P6	LISS IV	May 29, 2004
2.	IRS-P6	LISS IV	December 17, 2004
3.	Resourcesat-2	LISS IV	March 31, 2013
4.	Resourcesat-2	LISS IV	November 26, 2013
5.	Resourcesat-2	LISS IV	May 26, 2016
6.	Resourcesat-2	LISS IV	October 17, 2016

vegetation community, water, etc. were also collected covering whole mosaic of the wetland during 2016-17.

METHODOLOGY

Wetland and Land Use/Land Cover Mapping

All the six satellite data were rectified for atmospheric and geometric distortions with UTM projection system with WGS-1984 datum. Area of Interest (AOI) was extracted considering the wetland and surrounding environs, possibly influencing the wetland. To classify satellite data with uniform and purposive Level III classification scheme and supervised classification approach on 1:10,000 scale was adopted. Same training sites and classification scheme were used to classify all the data and wherever necessary additional training sites were added (Fig. 1). Wetland classes included water body, aquatic vegetation, *Typha*, grasses and sedges, swampy area and marshy area. The non-wetland classes include surrounding vegetation *Acacia*, cropland, *Dalbergia sissoo*, dry riverbed, fallow land, mango orchards, mixed riverine forest, settlement, riverine scrub, Sal forest, silted, water body and wet riverbed. Mapping accuracy was done for all the LULC maps. The transition change analyses was done in GIS domain.

RESULTS

Wetland and Land Use/Land Cover Mapping

The time-series wetland and land use/land cover (LULC) maps are given in Figures 2, 3 and 4 and accuracy for each map in Table 2. In 2004 about 6% (0.77 km^2) was under waterbody, 4% (0.54 km^2) under wet riverbed and 19% (2.28 km^2) under wetland area (comprising of aquatic vegetation, grasses and sedges, marshy area, swampy area and *Typha*). About 8% (0.92 km^2) of total area was under vegetation cover (which included *Acacia*, *Dalbergia,* mixed riverine forest and Sal forest patches) and about 16% (1.88 km^2) under riverine scrub in the surrounding terrestrial environment. The area under agricultural land (cropland and fallow land) was about 26% (3.11 km^2), 17% (2.05 km^2) under dry riverbed, 5% (0.57 km^2) under Mango/Litchi orchards. The area occupied by siltation and settlement was very negligible.

The wetland and LULC map of 2013 revealed that about 7% (0.92 km^2) is under waterbody, 21% (2.63 km^2) under wet riverbed and 12% (1.5 km^2) under wetland area (comprising of aquatic vegetation, grasses and sedges, marshy area, swampy area and *Typha*). And about 16% (2.02 km^2) of the ACR was under agricultural land (including both cropland and fallow land), 14% (1.79 km^2) under dry riverbed, 5%(0.71 km^2) under Mango/Litchi orchard, 13%(1.68 km^2) under riverine scrub, 2% (0.23 km^2) under settlement area, 10% (1.25 km^2) under total forest cover (which includes *Acacia*, *Dalbergia,* mixed riverine forest and Sal forest patches), The area occupied by siltation area was still very negligible.

The 2016 map revealed that in 2016 that about 10% (0.97 km^2) under waterbody, 9% (0.89 km^2) under wet riverbed and 22% (1.5 km^2) under wetland area (comprising of aquatic vegetation, grasses and sedges, marshy area, swampy area and *Typha*). And about 11% (1.09 km^2) of the ACR was under agricultural land (including both cropland and fallow land), 17% (1.70 km^2) under dry riverbed, 4% (0.39 km^2) under Mango/Litchi orchards, 12% (1.23 km^2) under riverine scrub, 4% (0.35 km^2) under settlement area, 1% (0.07 km^2), under siltation cover 11% (1.1 km^2) under total forest cover (which includes *Acacia*, *Dalbergia,* mixed riverine forest and Sal forest patches).

Wetland and Land Use/ Land Cover Dynamics

Since the core of ACR wetland is very less (4.44 km^2), therefore, minor changes are also significant. Since ACR is manmade and dammed wetland only minor but significant changes can happen in terms of the water flow from catchment of Asan river and adjacent vegetal cover. The canal flow is more of less maintained throughout the years with fluctuating water quantity. Even though the resident birds are present round the year but the presence of migratory birds has seasonality. Therefore, we analyzed season-wise changes in summers and winters. In May 2004 summer, the core wetland in and around had an area of aquatic vegetation 0.45 km^2 (3.86%), grasses and sedges 0.13 km^2 (1.12%), mixed riverine forest 0.16 km^2 (1.37%), riverine scrub 1.88 km^2 (16.14%), swampy area 0.24 km^2 (2.06%), and Typha 0.21 km^2 (1.80%) (Table 3). In March 2013, the area in and around core wetland were aquatic vegetation 0.56

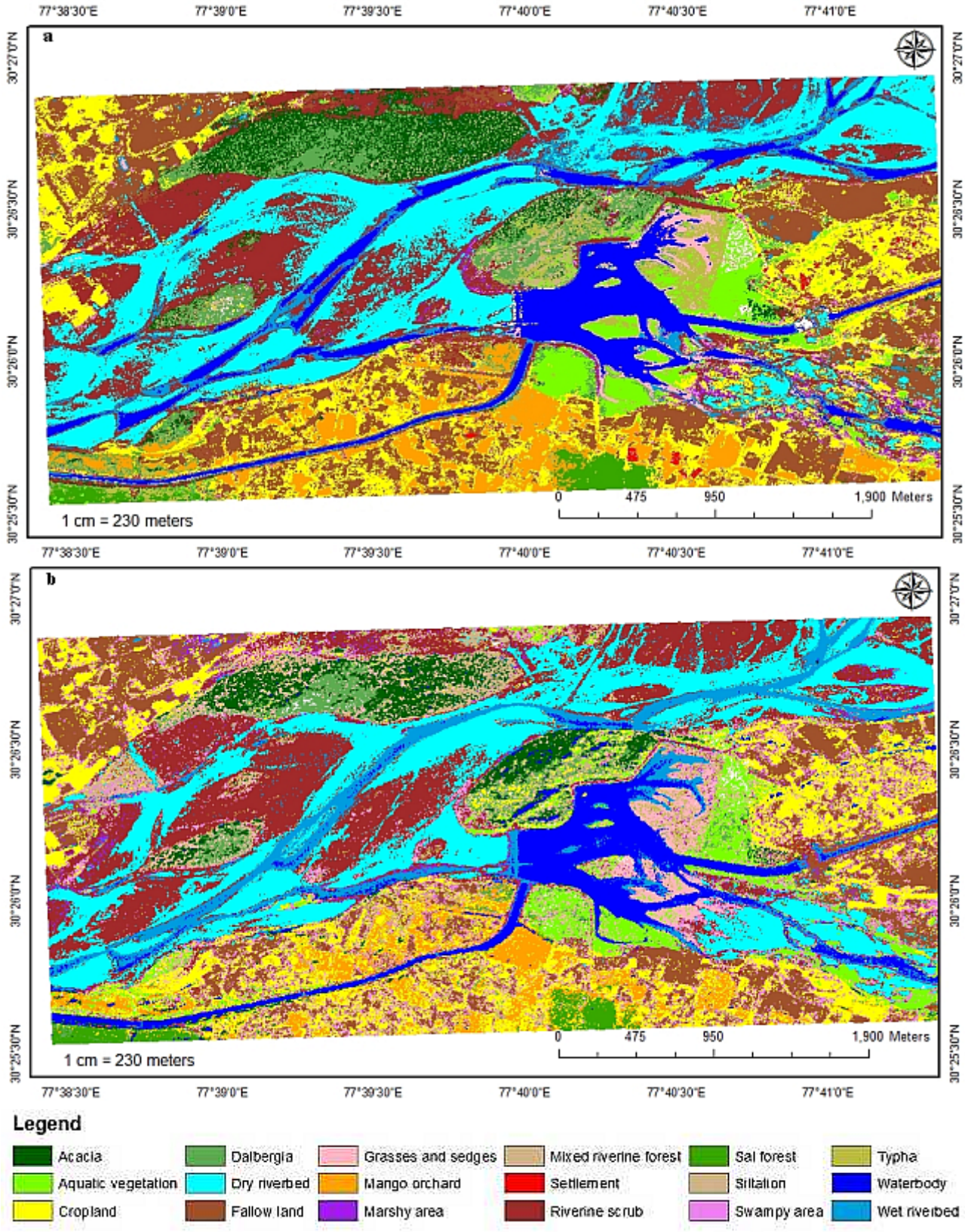

Figure 2. Wetland and LULC map of (a) May, 2004 (summer), (b) December, 2004 (winter)

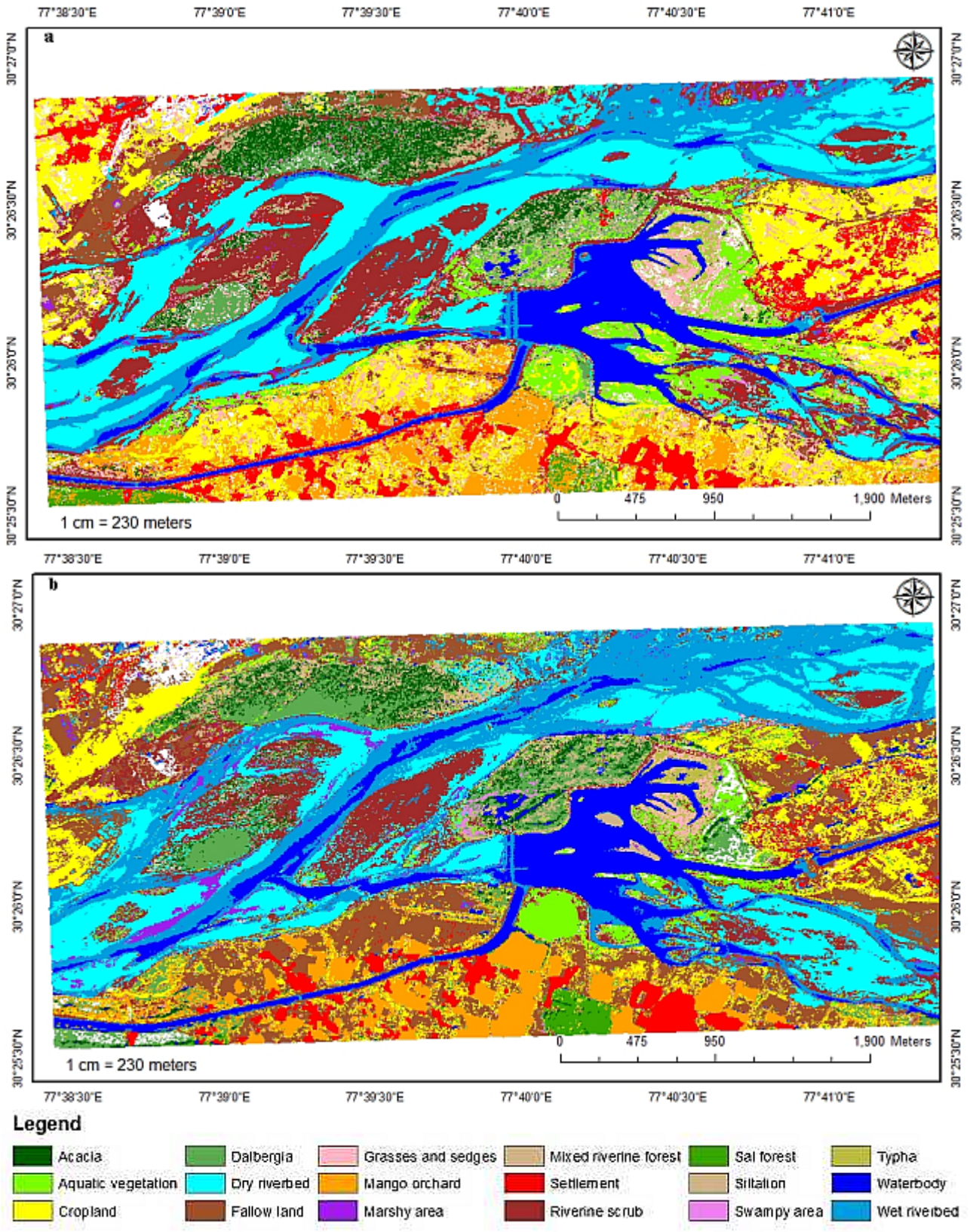

Figure 3. Wetland and LULC map of (a) March, 2013 (summer), (b) November, 2013 (winter)

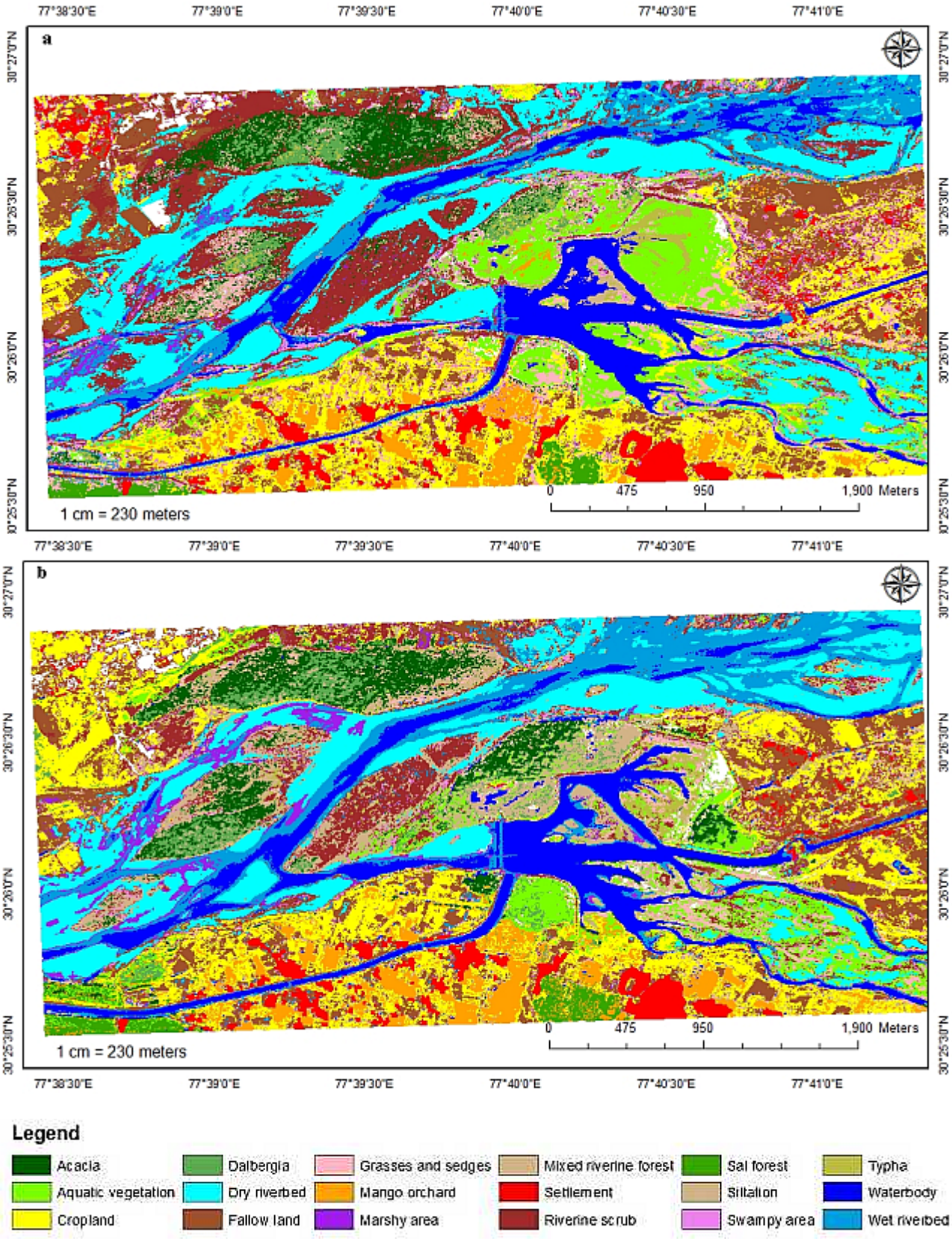

Figure 4. Wetland and LULC map of (a) May, 2016 (summer), (b) October, 2016 (winter)

Table 2. Classification accuracy of wetland and LULC maps

Year	Classification Accuracy (%)	Kappa Statistics
1. May 2004	90	0.8766
2. December 2004	96	0.9534
3. March 2013	84	0.8214
4. November 2013	88	0.8635
5. May 2016	86	0.8459
6. October 2016	92	0.9081

Table 3. Annual area fluctuations of different Wetland and LULCs in summer season

	LULC Classes	May-2004		March-2013		May-2016	
		km²	%	km²	%	km²	%
1	Acacia	0.49	4.21	0.4	3.67	0.43	3.71
2	Aquatic vegetation	0.45	3.86	0.56	5.14	0.81	6.98
3	Cropland	1.48	12.70	1.67	15.34	1.47	12.67
4	Dalbergia	0.6	5.15	0.36	3.31	0.19	1.64
5	Dry riverbed	2.14	18.37	1.87	17.17	1.97	16.98
6	Fallow land	1.63	13.99	0.35	3.21	1.34	11.55
7	Grasses and sedges	0.13	1.12	0.59	5.42	0.51	4.40
8	Mango orchard	0.57	4.89	0.71	6.52	0.39	3.36
9	Marshy area	0.22	1.89	0.07	0.64	0.19	1.64
10	Mixed riverine forest	0.16	1.37	0.2	1.84	0.21	1.81
11	Settlement	0.02	0.17	0.24	2.20	0.43	3.71
12	Riverine scrub	1.88	16.14	1.68	15.43	1.23	10.60
13	Sal forest	0.14	1.20	0.09	0.83	0.11	0.95
14	Siltation	0.00	0.00	0.01	0.09	0.05	0.43
15	Swampy area	0.24	2.06	0.18	1.65	0.49	4.22
16	Typha	0.21	1.80	0.1	0.92	0.14	1.21
17	Water body	0.85	7.30	0.82	7.53	0.91	7.84
18	Wet riverbed	0.44	3.78	0.99	9.09	0.73	6.29

km² (5.14%), grasses and sedges 0.59 km² (5.42%), mixed riverine forest 0.2 km² (1.84%), riverine scrub 1.68 km² (15.14%), siltation 0.01 km² (0.09%), swampy area 0.18 km² (1.65%), and Typha 0.1 km² (0.92%). In May 2016, aquatic vegetation 0.81 km² (6.98%), grasses and sedges 0.51 km² (4.40%), mixed riverine forest 0.21 km² (1.81%), riverine scrub 1.23 km² (10.60%), siltation 0.05 km² (0.43%), swampy area 0.49 km² (4.22%), and Typha 0.14 km² (1.21%) occupied the area. The total area is presented graph for better visualization (Fig. 5**).** The area increasing trends from 2004-2013-2016 indicates that aquatic vegetation increased from 0.45 km² to 0.81 km², grasses and sedges from 0.13 km² to 0.51 km², mixed riverine forest from 0.16 km² to 0.21 km², settlement 0.2 km² to 0.43 km², siltation nil to 0.43 km² and swamy area 0.24 to 0.49 km². whereas area under in Dalbergia, dry river bed, water body and Typha has decreased from 0.6 km² to 0.19 km², 2.14 km² to 1.97 km², 0.85 km² to 0.91 km² and 0.21 km² to 0.14 km², respectively. The increase in vegetated area, marsh land, grasses and sedges and mixed riverine have added to ecosystem diversity and are being habitat utilized by amphibians, butterflies, other insects and birds. However, increase in settlement, resorts and hotels in particular in the south of the wetland area is a sign of warning as these activities have increased the vehicular traffic, noise, halting time and tourism activities.

In the winter, soon after the monsoon, Doon valley is surrounded by natural as well as artificial lush green vegetation and good water supply. The monsoon season also supports breeding of micro-fauna such amphibians, butterflies, fishes, etc. thus abundance of food for birds, and increase vegetation productivity as well. Detail area analyses is tabulated in Table 4 and depicted graphically (Fig. 6). In this season during 2004 to 2016, it is observed that there is increase in area of aquatic vegetation from 0.46 km² to 0.63 km², marshy area from 0.17 km² to 0.26 km², mixed riverine forest from 0.28 km² to 0.87 km², water body from, 069 km² to 1.03 km² and wet riverbed from 0.63 km² to 1.04 km². Minor decrease in area was noticed in dry river bed from 1.96 km² to 1.42 km², grasses and sedges from 0.79 km² to 0.28 km², riverine scrub from 1.89 km² to 0.71 km², Swamy area from 0.58 km² to 0.27 km² and Typha from 0.27 km² to 0.24 km².

From Figures 5 and 6 it may be seen that the settlement area is increasing and the agricultural land is decreasing. The use of pesticides and unawareness among society and managers about the importance of flying flowers may put adverse impact on the present population of butterflies, at bottom of the food chain. This loss will collapse the entire ecosystem. Chalfoun & Schmidt (2012). explains: "Birds plan their whole breeding season around when caterpillars will be most abundant". In spite of these facts, ACR still holds good habitat for the butterflies, as they do not solely depend on agricultural field or gardens. ACR is gifted with diverse LULCs. It constitutes 11% of agricultural area, 17% dry riverbed, 4% mango orchard, 12% riverine scrub, 4% settlement, 1% siltation,11% forest cover, 10%

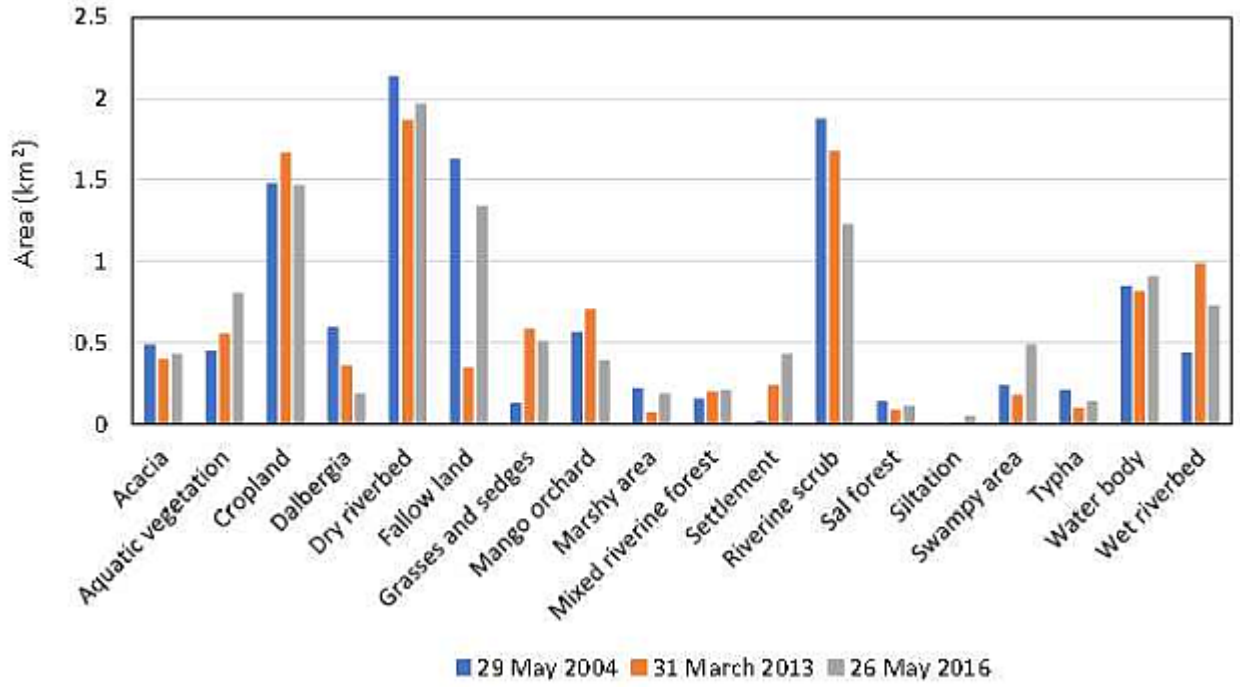

Figure 5. Trends in and around wetland in summer season

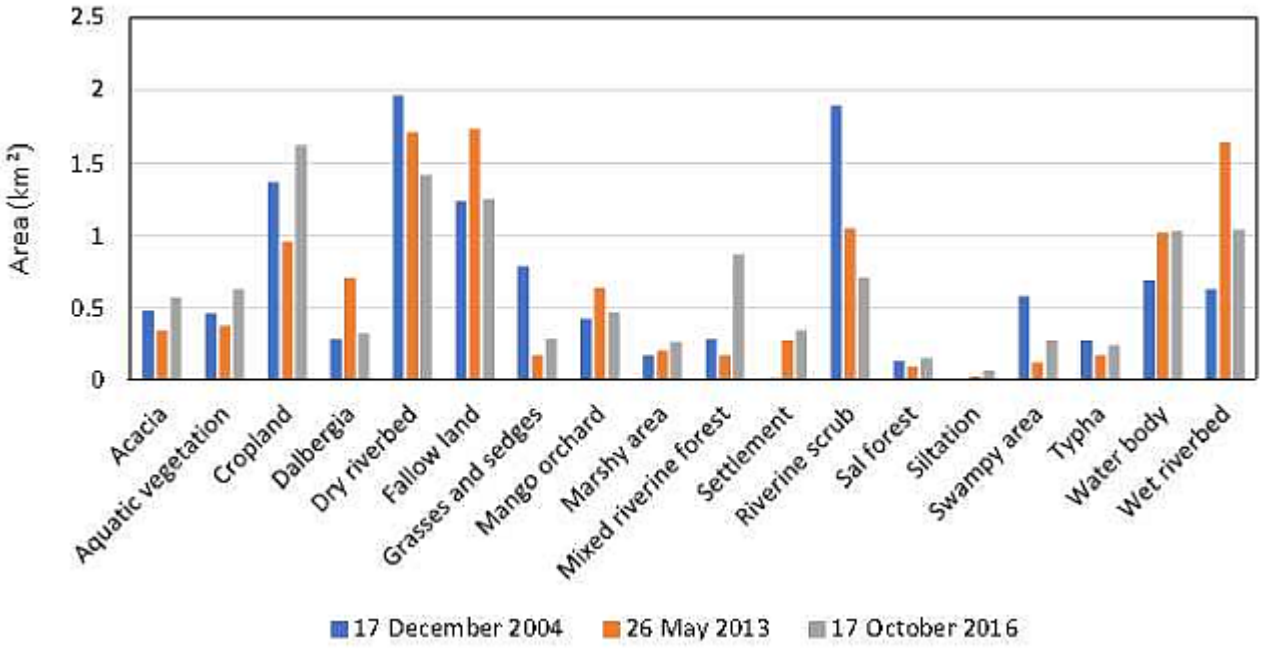

Figure 6. Trends in and around wetland in winter season

water body, 9% wet riverbed, and 22% wetland cover.

ACR also provides wide range of terrestrial habitats adjacent to wetlands and streams, typically consisting of leaf litter, coarse woody material, boulders, and small mammal burrows, crack in rocks, rocky pools, for foraging. Damp areas, river streams, swamps, marshy areas, mud puddles, and moist soil, wet and dry riverbed are helpful to burrow in order to keep their skin moist. They generally breed and lay eggs in wetland where they remain throughout their larval stage. Since ACR is rich in faunal diversity with vertebrates and invertebrates, it provides food during larval as well as adult stages of amphibians. The tadpoles of frogs and toads feed algae, plant detritus, leaves, other tadpoles; larvae of salamanders feed on insects and other

Table 4: Wetland and LULC area analysis of winter season

	LULC classes	December 2004		November 2013		October 2016	
		km²	%	km²	%	km²	%
1	Acacia	0.48	4.12	0.34	2.99	0.57	4.94
2	Aquatic vegetation	0.46	3.95	0.37	3.25	0.63	5.46
3	Cropland	1.37	11.76	0.96	8.44	1.62	14.05
4	Dalbergia	0.28	2.40	0.71	6.24	0.32	2.78
5	Dry riverbed	1.96	16.82	1.71	15.03	1.42	12.32
6	Fallow land	1.24	10.64	1.73	15.20	1.25	10.84
7	Grasses and sedges	0.79	6.78	0.17	1.49	0.28	2.43
8	Mango orchard	0.42	3.61	0.64	5.62	0.47	4.08
9	Marshy area	0.17	1.46	0.2	1.76	0.26	2.25
10	Mixed riverine forest	0.28	2.40	0.17	1.49	0.87	7.55
11	Settlement	0.01	0.09	0.27	2.37	0.34	2.95
12	Riverine scrub	1.89	16.22	1.05	9.23	0.71	6.16
13	Sal forest	0.13	1.12	0.09	0.79	0.15	1.30
14	Siltation	0	0.00	0.02	0.18	0.06	0.52
15	Swampy area	0.58	4.98	0.12	1.05	0.27	2.34
16	Typha	0.27	2.32	0.17	1.49	0.24	2.08
17	Water body	0.69	5.92	1.02	8.96	1.03	8.93
18	Wet riverbed	0.63	5.41	1.64	14.41	1.04	9.02

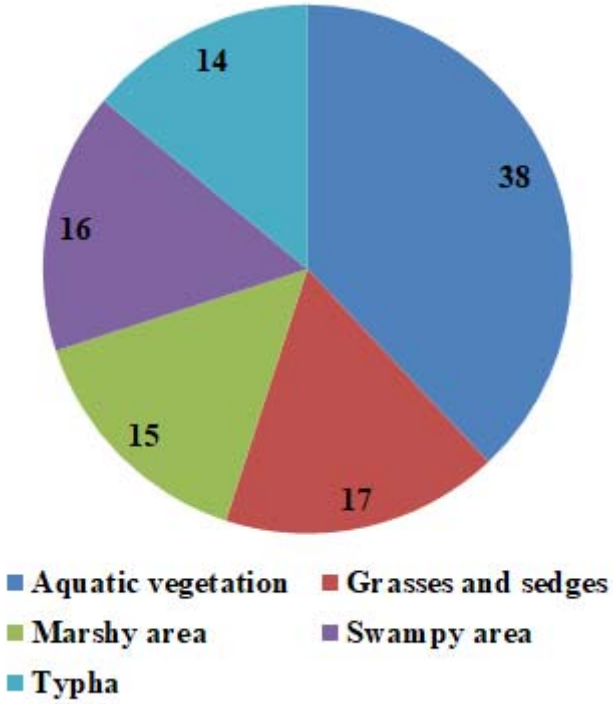

Figure 7. Area under different categories in Core wetland

invertebrates, small crustaceans, tadpoles, zooplankton, other salamander larvae. Adults of frogs, toads and salamanders take worms, insects, mice, reptiles, small snakes, snails, slugs, spiders, termites and other invertebrates. The total wetland cover of ACR in 2016 is represented figure below (Fig. 7)

DISCUSSION

Globally, there are 257 water storage or reservoirs types of Ramsar Sites covering 21,619,834 ha. Even there are other human-made wetlands categories with their Ramsar sites numbers, such as Canals and drainage channels or ditches (365), Seasonally flooded agricultural land (290), Water storage areas/ Reservoirs (257), Irrigated land (183), Ponds (170), Aquaculture ponds (160), Salt exploitation sites (82), Excavations (80), Wastewater treatment areas (35), and Man-made subterranean hydrological systems (13) (RSIS, accessed on 7 August 2021). These wetland are receiving attention not only for their revenue generation but also for irrigation, power generation, navigation, flood control, municipal and industrial water supply, recreation, or low-flow regulation. However, their ecological values are ignored. Present research is to highlight such neglected wetland ecosystems that might help to monitor management, conservation and restoration processes during the United Nations Decade on Ecosystem Restoration (2021-2030).

The ACR has drawn attention because of the presence of large number of migratory birds (Gandhi and Singh 1995, Singh 2000, 2002, 2006). Minor variations have been noticed in the area in different seasons 2004-2016. However, minor change in hydrological parameters have the high potential to alter the growth, reproduction and development of aquatic fauna along with their number and diversity which ultimately impacts the succession. There is spurt in construction of housing, resorts, educational and industrial areas and other related infrastructure in the upstream of Asan river in west Doon valley. The flood plain as well as river terraces of Asan river, and small waterbodies have been either heavily encroached or allotted for the development of offices and educational institutes, hotel, schools, industry, etc., because such lands cost less and are under government control. Around ACR there is 4% increase in settlement area and as a consequence of

which there is decrease in wetland area (3 %). Drudging of wetland area is done at regular interval to main its ecosystem services as well as viable reservoir capacity and was done in 2017. Rahmani et al. (2016) suggested the drudging needs to be done after 15th March. Proper and regular management is inevitable as many aquatic invertebrates residing at ACR have narrow habitat requirements and cannot cope up to abrupt changes in their habitat. Like removal of silt will reduce population of annelids, amphibian, butterflies, etc. drastically. A study to assess various component ACR before and after the drudging is needed to understand the impact because in an aquatic body the physico-chemical properties change more drastically as compared to terrestrial ecosystem.

The presence of wet grassland, agricultural land, rivers, fresh waters, plentiful submerged and fringing vegetation along with reservoirs with large areas of open water, reed-beds, marshes and swamps attracts birds like *Anser anser* (Graylag goose), *Spatula clypeata* (Northern Shoveler), *Anas crecca* (Green-winged Teal), *Netta rufina* (Red-crested Pochard), *Aythya ferina* (Common Pochard), *Aythya fuligula* (Tufted Duck), *Pandion haliaetus* (Osprey), *Circus aeruginosus* (Eurasian Marsh-Harrier), *Tringa nebularia* (Common Greenshank) and *Tringa totanus* (Common Redshank) find it suitable for their nesting and feeding activities

The gradual increase in the total riverine forest, presence of water in the reservoir along with the adjacent agricultural land, ACR also attracts summer migratory birds. Forest birds like *Clamator jacobinus* (Jacobin Cuckoo), *Cuculus canorus* (Common Cuckoo), *Surniculusl ugubris* (Square-tailed Drongo-Cuckoo), *Phylloscopus trochiloides* (Greenish Warbler) and *Niltava sundara* (Rufous-bellied Niltava) are seen to be attracted by the mixed forest patch. Birds like *Gymnoris xanthocollis* (Chestnut-shouldered Petronia) prefer open dry forest, thorny scrub/trees, at the edge of cultivation and also near plantation

As ACR is surrounded by agricultural land along with plantation and orchard offering another set of ecological requirement for like *Streptopelia decaocto* (Eurasian Collared-Dove), *Cuculus canorus* (Common Cuckoo), *Eumyias thalassinus* (Verditer Flycatcher) and *Phoenicurus ochruros* (Black Redstart). *Motacilla alba* (White Wagtail) visits the reserve for its breeding purpose (Grimmet et al., 2011). Birds like *Ciconia episcopus* (Woolly-necked Stork) and *Ixobrychus sinensis* (Yellow Bittern) require flooded paddy and other irrigated agricultural land in addition to aquatic vegetation

The landscape mosaic of village tanks, reservoirs, ditches, swampy marshy ground, wet grasslands, and riverine scrubland in slow moving and shallow rivers attracts birds like *Tachybaptus ruficollis* (Little Grebe), *Apus apus* (Common Swift), *Merops philippinus* (Blue-tailed Bee-eater), *Phylloscopus trochiloides* (Greenish Warbler), *Niltava sundara* (Rufous-bellied Niltava), *Luscinia svecica* (Bluethroat) and *Saxicola caprata* (Pied Bushchat) ACR is not only rich in aquatic and terrestrial vegetation but also rich in faunal diversity which attracts various passage migrants also. Birds like *Phalacrocorax carbo* (Great Cormorant), *Nycticorax nycticorax* (Black-crowned Night-Heron), *Circus aeruginosus* (Eurasian Marsh-Harrier), *Milvus migrans* (Black Kite), etc. visit ACR for roosting, nesting and feeding and feed on very wide range of fish prey species such as amphibians, turtles, snakes, lizards, adult and larval insects (beetles, bugs, grasshoppers, crickets, flies and dragonflies), spiders, crustaceans, molluscs, leeches, small rodents, bats; and eggs and chicks of other bird species, which are available in plenty.

CONCLUSION

It is well known that an aquatic ecosystem evolves through several successional stages such as marsh, grassland, woodland that culminates in a forest ecosystem. Each of the transition takes several years to occur. From the results obtained it is observed that the trend line of wetland area is increasing gradually. Riverine forest is also increasing at slow pace. This is leading to the provision of good habitat for birds, butterflies and amphibians. Waterfowls require shallow water and mud banks to feed on. With the increase in siltation area within the reservoir they are able to roost. With the increase in swampy and marshy area site is getting more suitable for the amphibians. Since these are food of birds they are coming in more numbers due to availability of food and nesting sites. The growth of taller vegetation *Typha* and other species of Cyperaceae favors population of birds like coots, moorhen, warblers of

which numbers are increasing. In summer the mud banks get exposed which also attracts summer migrants more in number. The surrounding area consists of farmland and mango orchard. Many birds feed on the insects and amphibians that are found in agricultural land and orchard. Since it is decreasing and settlement area is increasing it may put negative impact on the bird's habitat suitability.

Wetlands are very dynamic in terms of area and water level and also to a large extent controlled by rainfall pattern. For accurate mapping very high to high resolution data of appropriate season data with high water level (late September to November) as well as dry season data (March-June) may be used to appropriate management planning and monitoring. The preservation of wetlands is crucial for the survival of both resident and migratory birds because they provide the birds with specialized microhabitats and different kinds of food sources. Birds also provide supporting services, provisioning services, regulating services, cultural services to maintain the environment. Loss of wetlands and introduction of new age chemicals in agriculture is threatening the life support system. Bird conservation practices like prevention or reduction in habitat loss, habitat deterioration and habitat fragmentation need to focus on the small details like shielding bird nests, protecting migratory neighborhoods and providing an eco-friendly environment in order to better appreciate the large spectrum of life. Since bird's crisscross oceans and continents, they belong to all of humanity. It is in our power to protect and nurture some of these extraordinary life forms. We need to walk through this world and leave an eco-friendly foot print which protects the interest of both, man and bird.

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