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CARBON AND NITROGEN STORAGE IN HOKERSAR WETLAND (A RAMSAR SITE): POTENTIAL FOR CARBON SEQUESTRATION

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ABSTRACT

Wetlands are the largest nutrient sinks of carbon and nitrogen as they store them in their sediments and also take up into their plant biomass. The overall goal of our study was to quantify C and N storage of Hokersar wetland ecosystem, and to highlight its carbon sequestration potential. Samples of plants and soils were collected in 2016 and 2017, respectively. Plant biomass and its allocation pattern to the aboveground (AG) and belowground (BG) components were studied. We found that the sediment storage of organic carbon (OC) and total nitrogen (TN) of the wetland was of the order of 78.2 Mg C ha^{-1} and 6.9 Mg N ha^{-1} respectively. However, plant biomass represented smaller but sizeable pool when compared with the sediment pool with the figures of OC and TN for AGB of 16.26 Mg C ha^{-1} and 0.93 Mg N ha^{-1} and for BGB, the figures were 12.85 Mg C ha^{-1} and 0.63 Mg N ha^{-1} respectively. The wetland ecosystem however, represented a total OC pool of 107.31 Mg C ha^{-1} and TN pool of 8.46 Mg C ha^{-1} suggesting its higher potential of sequestering carbon and nitrogen and its sink capacity which can be enhanced in future, if its ecological nature is maintained keeping in view the huge anthropogenic pressure on the wetland.

Keywords : Allocation pattern, Anthropogenic pressure, Carbon sequestration potential, Hokersar wetland, Organic carbon, Plant biomass.

1. INTRODUCTION

Wetlands are the most productive ecosystems thereby playing an important role in global carbon dynamics and mitigation of excess nutrients such as nitrogen [1], [2]. They provide many ecosystem services to mankind but carbon sequestration and nutrient burial hold great promise with respect to the current global issues of climate change and eutrophication in aquatic ecosystems. The carbon sequestration rate of wetlands is higher than any other ecosystem on the planet [3], [4]. Wetlands cover only about 5-8% of terrestrial landscape but hold a net carbon sink capacity of 830 Tg/year with average net carbon retention of 118 g C m^{-2} yr^{-1}. Their high sequestration rates are due to high aboveground and belowground productivity, anoxic soil conditions, slow decomposition rates and dense vegetation trapping suspended materials [5], [6]. Plant biomass represents a significant carbon pool and its allocation patterns are instrumental in understanding carbon sink capacity of wetlands. Of the total 306 tonn/ha of carbon stored in wetlands, plant biomass store about 19 tonn/ha of carbon and the rest is stored in the sediments [7].

Wetlands provide a natural and cost-effective option for the retention and long-term storage of carbon and other nutrients like nitrogen and phosphorus. The leaching of nutrients from the surrounding terrestrial environment is one of the major causes of high nutrient loading in fresh water ecosystems [8].This often results in the formation of algal blooms and shifts in species composition of aquatic systems [9]. In recent decades, wetlands have been constructed to mitigate eutrophication of watercourses, lakes and seas by reducing the nutrient loads in discharged water of wastewater treatment plants, farmlands, households or industries[10], [11]. The removal of nutrients from the wetlands occurs mainly because of the macrophytic uptake or by the combination of macrophytes and soil due to sedimentation [12]. The most commonly used macrophytes for nutrient removal in constructed wetlands include species of *Typha*, *Phragmites*, *Scirpus*, *Phalaris* and *Iris* [13]. These macrophytes can regularly be harvested and the nutrients retained by them can then be drained from the system. The harvested biomass can also be used as a bio-fertilizer or as fodder for livestock [14]. In this study, an attempt is made to study the nutrient sequestration capacity of wetland plants and soils to calculate the total carbon and total nitrogen content in the different pools of Hokersar wetland.

2. MATERIALS AND METHODS

2.1. Site Description

The area of interest is located at the north-west Himalayan bio-geographic province of Kashmir (J&K). The wetland lies between 34°.6`N latitude and 74°.12`E longitude at an altitude of 1584m above mean sea level situated in the District Budgam, 10 km west of Srinagar city. Mean annual temperature in the area ranges from 7.5° C in winter to 19.8°C in summer. It is a perennial freshwater wetland, one of the Ramsar sites (No. 1570) of India, also known as the "Queen of wetlands", covering an area of 1326 ha. The dominant vegetation in the majority of area include *Phragmites australis*, *Typha angustata*, *Sparganium erectum*, *Menyanthes trifoliate*, *Ranunculus lingua*, *Nymphoides peltatum*, *Trapa natans*, *Myriophyllum spicatum* and they form different communities in the entire wetland. Emergents occupy the marginal regions and floating leaf types occur mainly in the open water areas [15]. In this investigation, we explored the biomass allocation and nutrient storage capacity of various pools of Hokersar wetland.

2.2. Research methods

2.2.1. Establishment of transects

Plant and soil samples were collected during the study period (2016-2017) from the Hokersar wetland. Samples were collected along three transects (S1, S2 and S3) each measuring 100 m in length [16]. The sampling was done from the same sampling sites with particular community type vegetation (Fig 1). The macrophytes and sediment samples were collected from the same quadrats from all the selected sampling sites to maintain the consistency of the samples collected.

2.2.2. Collection of plant samples

From all the sampling sites, plant samples were collected by Harvest method to estimate both AGB as well as BGB [16], [17]. The biomass was collected during August and September, approximately the time of peak biomass production. Along each site, composition of plant species was investigated and 20 replicates of vegetation (AG and BG) were harvested at the ground surface from 50 x 50 cm squares. Within the plots, all the plant species were collected and kept in large plastic bags and later on separated into AG and BG components in the laboratory.

2.2.3. Collection of soil samples and their analysis

Soil samples were collected using a 5 cm diameter soil cores and the soil was collected from 0-10 cm depths from all the sampling sites. From each sampling site, 20 soil samples were collected. These were collected within 1 x 1 m square plot. 10 of these were oven-dried at 105°C until a constant mass was reached to measure gravimetric soil water content and soil bulk density (BD). The remaining soil cores were air-dried for analysis of physicochemical properties of soil.

2.2.4. Analysis of samples

Plant samples were sorted, identified and then dried in an oven at 65°C to constant weights. All plant samples were identified to at least the family level. The BD of the soil samples was calculated as the dry weight of the soil in the container divided by the container volume. Further analysis of plant and biomass samples were analyzed using CHNS/O elemental analyzer (Thermo scientific FLASH 2000) [18].

2.3. Data analysis

Soil storage of the soil samples was calculated by multiplying OC or TN concentration of each sample with its BD and scaling the values up to one hectare [18]. In case of OC and TN storage in AB and BG plant biomass, their OC and TN concentration was multiplied by their biomass present per unit area. Their storage values were also scaled to one hectare. The total storage values in the wetland ecosystem include OC and TN storage in the aboveground plant biomass, below ground biomass (root biomass) and soil.

3. RESULTS AND DISCUSSION

3.1. AGB, BGB and R/S ratio

The dominant vegetation communities in the Hokersar wetland are *Phragmites australis*, *Typha angustata*, *Sparganium erectum*, *Menyanthes trifoliate*, *Ranunculus lingua*, *Nymphoides peltatum*, *Trapa natans* and *Myriophyllum spicatum.* The distribution of species is related to water table, with *Nymphoides peltatum*, *Trapa natans* and *Myriophyllum spicatum* found mostly in permanent water areas of the wetland while *Phragmites australis*, *Typha angustata* and *Eleocharis palustris* prefer relatively drier areas. The five plant communities and their companion species are shown in Table1.

The mean AGB, BGB, total biomass and R/S ratio values by plant communities in the wetland are given in Fig 2 (A-D). The average AGB, BGB and total biomass in the wetland were 4487.91, 4727.3 and 9215.21 gm^{-2}, respectively, and the average R/S ratio was 1.05. The communities I and III had the largest AGB and BGB followed by II and V communities. Total biomass and BGB were the smallest in community IV and the largest in community I.

The results reveal that BGB represents a significant portion of the total plant biomass and is even a little higher than AGB. The R/S (BGB/AGB) ratio (1.05) for the wetland was in range with the earlier studies on temperate peatland with the observed values of 0.28 - 1.38 [19]. The study on ombrotrophic bog showed results within the range of 0.72-1.27 [20]. The observed higher R/S of the plant biomass can be due to relatively slow decomposition of root carbohydrates in response to low respiration rates in cold environments [21]. The wetland lies in the colder region of J & K state and the resulting higher R/S ratios can thus be associated with the slower root turnover in colder regions [22].

3.2. Organic C and TN storage in aboveground plant biomass (AGB) and belowground root biomass (BGB) of the wetland

The average OC and TN storage in the AGB of the wetland was 16.26 Mg C ha^{-1} and 0.93 Mg N ha^{-1}, respectively (Table 2). Average OC and TN storage in the BGB were 12.85 Mg C ha^{-1} and 0.63 Mg C ha^{-1}, respectively. In AGB, the highest values of OC and TN were recorded in community I and the lowest in community V for OC and for TN it was seen the lowest in community IV. In case of BGB, the highest values were calculated again in community I but the lowest values of both OC and TN were recorded in community IV. In most of the studies on wetlands, BGB has largely been under viewed. Our study signifies the huge potential of OC and TN storage of BGB. The difference in the storage between aboveground and belowground environments may be due to the regular input of plant litter to the soil over time, combined with the large presence of roots to provide soil nutrients [23]. The OC in AGB and BGB was recorded to be in sequel with plant biomass which is in consensus with the earlier studies [24], [25].

3.3. Soil OC and TN of the wetland ecosystem storage of OC and TN

SOC concentration was greater in the community I followed by V whereas it was lowest in case of IV. TN concentration was highest in case of community I and lowest in community IV. The SOC storage in soil was 78.2 Mg C ha^{-1} and TN was calculated of the order of 6.9 Mg C ha^{-1} (Table 3).

In our study, soils represented the largest OC and TN storage among all other pools which is in accordance with the earlier study on average carbon stocks of various biomes including wetlands [7] (Fig 3 and 4). Our results (78.2 Mg C ha^{-1}) are comparable with the study done on the carbon storage in the sedge meadows (top 25 cm of soils) of prairie pothole region of the United States which were reported to be a store house of 83.20 Mg C ha^{-1} [26]. Some studies also revealed a value of about 40 to 90 Mg C ha^{-1} in the top 20 cm of soil of wetlands [27]. A study on the top 20 cm soil of marsh sites of Ohio indicated the SOC storage of 50.8 78.2 Mg C ha^{-1} which were a little lower than our value of 78.2 Mg C ha^{-1} [28].

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3.4. Ecosystem storage of OC and TN of the Hokersar wetland

Overall, the ecosystem storage of OC at Hokersar wetland was 107.31 Mg C ha^{-1} while TN storage of this site was 8.46 Mg N ha^{-1}. The OC of the AGB, BGB and SOC at this site was 16.26 Mg C ha^{-1}, 12.85 Mg C ha^{-1} and 78.2 Mg C ha^{-1}, accounting for 15.15%, 11.97% and 72.87% of the ecosystem storage, respectively. For TN storage, they accounted for 11.02%, 7.41% and 81.57% of the ecosystem storage, respectively.

4. FIGURES AND TABLES

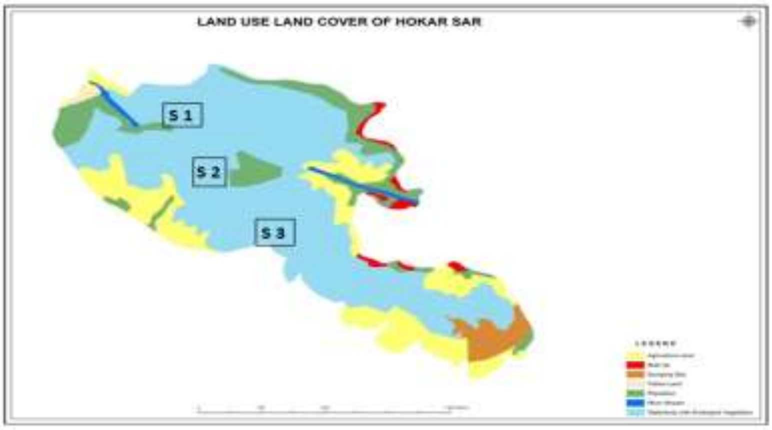

Fig 1 Map of the study site (Hokersar wetland)

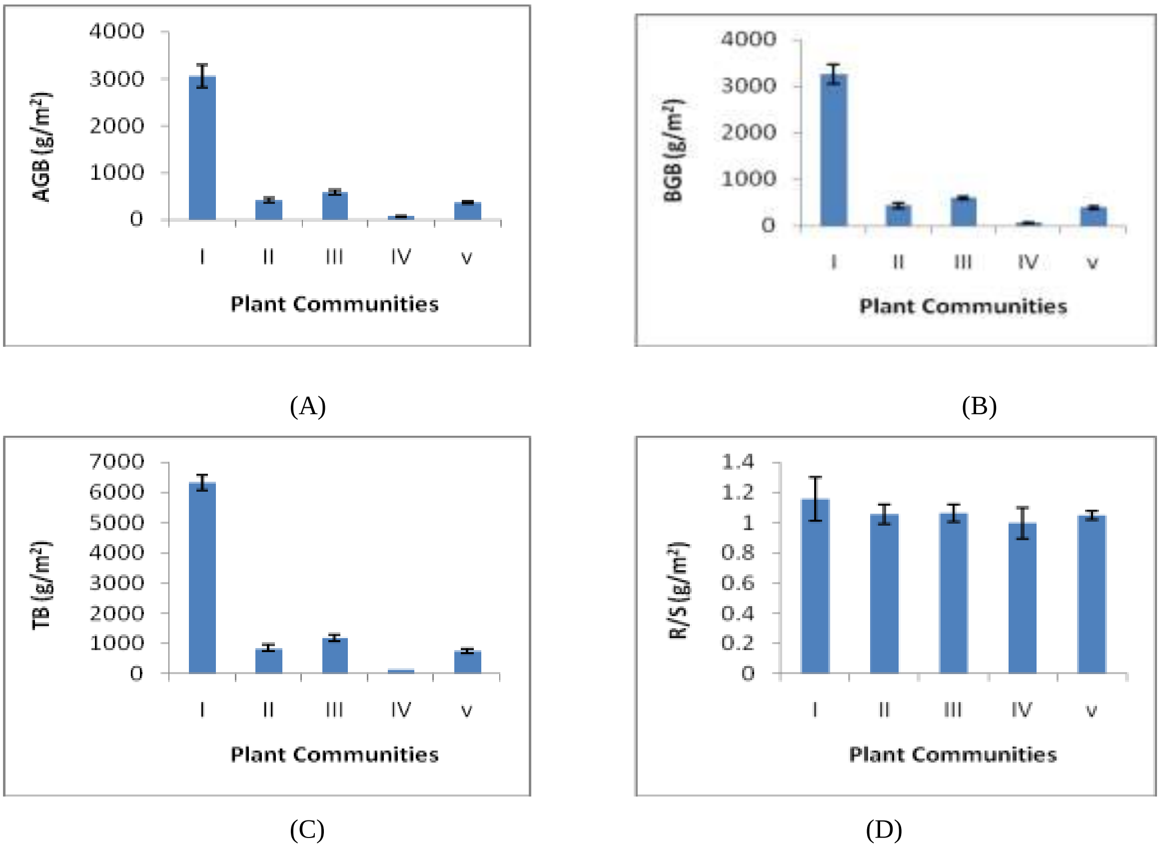

Fig 2 The mean AGB, BGB, TB (Total biomass) and R/S ratio values in the Hokersar wetland.

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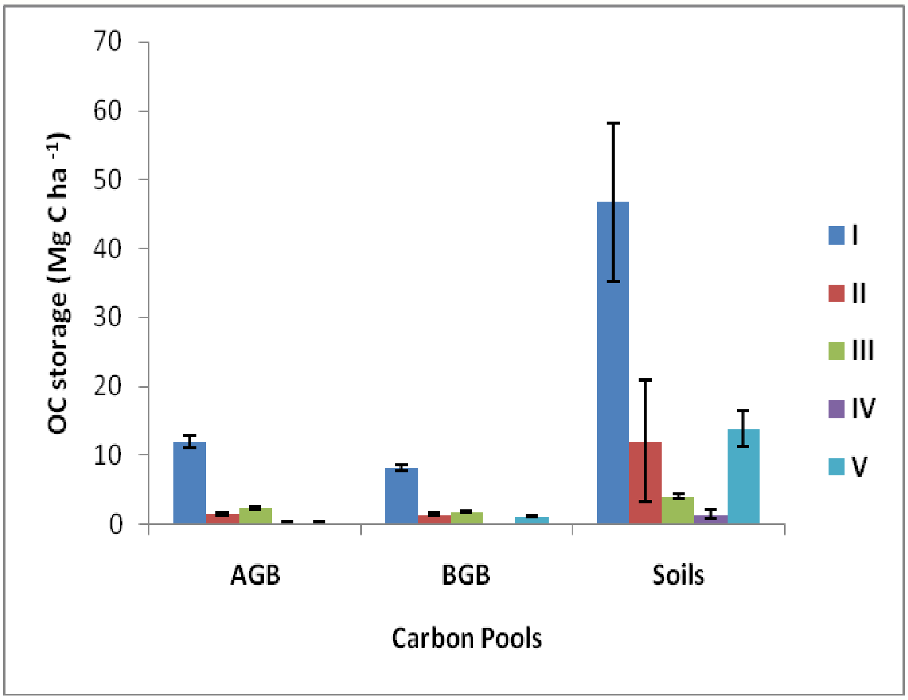

Fig 3 Average storage (Mg C ha $^{-1}$) of organic carbon in different carbon pools of the wetland.

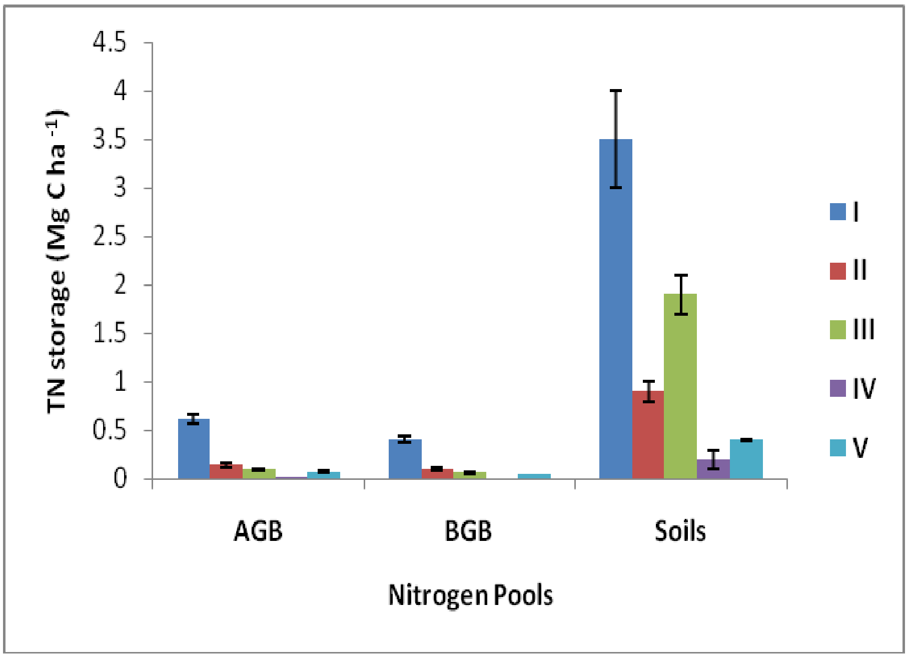

Fig 4 Average storage (Mg C ha $^{-1}$) of total nitrogen in different nitrogen pools of the wetland.

Table 1 Plant communities and their companion species in the wetland.

Community Type	Plant community Designation	Companion species
Phragmites australis + Sparganium erectum	I	*Typha angustata, Saggitaria sagittifolia, Eleocharis palustris, Juncus articulatus*
Nymphaea alba + Nymphoides peltatum	II	*Trapa natans, Hydrocharis dubia, Utricularia aurea, Polygonum amphibium*
Menyanthes trifoliate + Ranunculus lingua	III	*Myriophyllum spicatum, Salvinia natans, Myriophyllum verticillatum,*
Nasturtium officinale + Hippuris vulgaris	IV	*Gallium aparine, Roripa islandica, Mentha arvensis, Altarnanthera sessilis*
Epilobium hirsutum + Lycopus europaeus	V	*Bidens tripartite, Polygonum hydropiper, Potentilla reptans*

Table 2 Total ecosystem storage of OC and TN in Hokersar wetland (mean±SE)

Pools	**AGB**		**BGB**		**Soils**	
	OC storage ($Mg\ ha^{-1}$)	**TN storage ($Mg\ ha^{-1}$)**	**OC storage ($Mg\ ha^{-1}$)**	**TN storage ($Mg\ ha^{-1}$)**	**OC storage ($Mg\ ha^{-1}$)**	**TN storage ($Mg\ ha^{-1}$)**
I	12.01±0.96	0.61±0.05	8.19±0.52	0.41±0.03	46.8±11.5	3.5±0.5
II	1.45±0.18	0.14±0.02	1.42±0.19	0.1±0.01	12.1±8.8	0.9±0.1
III	2.40.±0.24	0.092±0.01	1.89±0.13	0.06±0.005	4.1±0.31	1.9±0.2
IV	0.25±0.02	0.02±0.001	0.21±0.01	0.007±0.0003	1.4±0.7	0.2±0.1
V	0.150±0.11	0.07±0.01	1.14±0.10	0.05±0.005	13.8±2.6	0.4±0.005

Table 3 Soil bulk density (BD), SOC storage, TN concentration and soil TN storage of Hokersar wetland ecosystem (mean±SE)

Community Type		**SOC**		**Soil TN**	
Soil (0-10cm)	BD (gcm^{-3})	Concentration (%)	Storage (Mg ha^{-1})	Concentration (%)	Storage (Mg ha^{-1})
I	0.25±0.04	20.8±6.75	46.8±11.5	1.40±0.05	3.5±0.5
II	0.14±0.03	7.0±4.09	12.1±8.8	0.67±0.04	0.9±0.1
III	0.15±0.007	2.83±0.32	4.1±0.3	1.31±0.14	1.9±0.2
IV	0.05±0.02	2.23± 1.5	1.4±0.7	0.47±0.02	0.2±0.1
V	0.17±0.01	8±1.73	13.8±2.6	0.29±0.03	0.4±0.005

5. CONCLUSION

Our results reveal that Hokersar wetland has a great potential (107.31 Mg C ha^{-1}) for future C sequestration and is of increasing importance for mitigation of climate change. The TN storage of the wetland also signifies its higher nitrogen pool (8.46 Mg N ha^{-1}) and documents its greater nutrient retention capacity. This study highlights the significance of wetlands for waste water treatment in the form of constructed wetlands. Despite providing such important ecosystem services, Hokersar wetland is under various anthropogenic pressures and the most alarming ones include the invasive species which have overrun the wetland and huge siltation inputs to the wetland which if not checked can result in the terristrialization of the wetland. Hence, we might be in a threat of losing this precious wetland having such high carbon and nitrogen pool capacities in near future. Keeping this in view, its ecological nature needs to be maintained so that it continues to provide important ecosystem services and help us in combating climate change.

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