# Biomass and Carbon Content of Emergent Macrophytes in Lake Manasbal, Kashmir: Implications for Carbon Capture and Sequestration

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***Abstract-*** Hydrophytes are established bio-filters for a spectrum of pollutants and as such remediate gaseous contaminants as well. Carbon capture and sequestration (CCS) by virtue of aquatic plants at a local scale may manifest as invalid at the outset but the marine and inland water stretches do contribute a lot globally. A study pertaining to 15 emergent macrophytes represented by 10 families exhibited predominant carbon sequestration potential (CSP) ranging up to 412 Kg/ha. Organic carbon, biomass and calcium content determination provided the CSP values of each species studied. The correlation and regression analysis of the observed data revealed a highly significant relationship between carbon and biomass cum calcium with correlation coefficient values being close to 1. The interspecific comparison of the emergents confirmed Typha latifolia with the highest carbon content (53.62%) and CSP followed by Phragmites australis (52.02%) and Cyperus difformis (50.91%).

***Index Terms***- biomass, calcium, carbon sequestration, emergent macrophytes, Manasbal lake.

## I. Introduction

Climate change constitutes one of the grave environmental challenges experienced by mankind worldwide today (Field et al., 2012). The precursor being the multitude of anthropogenic activities (Wuebbles and Jain, 2001; Upadhay et. al., 2006) resulting in elevated concentration of greenhouse gases and thereby their radiative forcing. This warming up of the earth's atmosphere in turn switches on a chain of ecological hazards with varied frequency and intensity. Eventually, it evoked multiple integrative and interdisciplinary mitigatory and adaptive responses (Meyers, 2007) including carbon capture and sequestration (CCS) by natural ecosystems (Albrecht and Kandji, 2003; Shin et. al., 2007; Sheps et.al. 2009). The initiative of bio-sequestration has gained significant scope due to considerable (Rytter, 2012) but sustainable regulatory factor of global carbon flux and storage (Plantinga, 2003; Ravindranath, 2007). Although terrestrial and marine ecosystems are featured CCS systems, however, the lake ecosystem as carbon interface and stock components remain neglected or unaccounted (Downing, 2010) presumably due to their relatively small global surface area of~4.2 million $Km^2$ (Downing et al., 2006).

Of the overall global landscape, an estimated 2.1 % inland lake water cover contribute towards 260 $gC/m^2$/yr. of NPP under eutrophic status out of the net global total of 1 PgC/yr (William, 2011). Given the relatively small area of inland waters, an estimated 42 TgC/yr., mostly from primary production is buried in lake sediments at a rate three times greater than that of the oceans (Dean and Gorham, 1998). As such lakes comprise the important hot spots for carbon capture, transformation and storage (Cole et al., 2007; Tranvik et al., 2009; Williamson et al, 2009) and this carbon is being mainly captured by the prolific growing macrophytes via photosynthesis. Till now macrophytes have been studied mainly for providing services like controlling eutrophication, treatment of waste waters, heavy metal remediation, etc.(Nahlik and Mitsch, 2006; Wang et. al, 2009) and their role in carbon sequestration has been given least attention. Therefore, the present investigation was an attempt to study the role and potential of emergent macrophytes in carbon capture and sequestration.

## II. Methodology

Study Site: The study was carried from March, 2011 to March, 2012 on a fresh water lake of Kashmir-Manasbal lake lying between $34^0 15^/$N and $74^0 40^/$E at 1585m (asl). The lake is surrounded by Jarokbal, Gratbal and Kondbal villages on its northern, eastern and southern sides respectively and has a total surface area of 2.80 $Km^2$ with a maximum depth of 13m. The lake harbours a rich diversity of macrophytes, however, the present study focused on the emergent macrophyte species of the lake. Four sites (I, II, III and IV) were selected dividing the lake arbitrarily into four compartments (Fig.1)

Methods: Plant samples were collected at the selected sites on monthly basis from March 2011 to Feb 2012 using quadrat method (Gupta, 1999). Five quadrats of standard size ($1m^2$) were laid at each site. Macrophytes falling in each quadrat were collected, stored in separate plastic bags and taken to laboratory for analysis. Dry weight biomass was obtained by oven drying the samples at $105^0$C for 24 hours (Gupta, 1999). Sub samples(5g) were combusted at $550^0$C for 4 hours in a muffle furnace for determination of organic carbon by using the following formula (Armecin and Gabon, 2008);

OC (%) = OM (%)/1.724

(Where OC is the organic carbon, OM is the organic matter and 1.724 is the van Bemmelen factor i.e. organic matter contains 58% organic carbon).

Ca was analyzed by EDTA titration method (Trivedy et al. 1987). CSP of each species was determined by multiplying the OC in per gram of dry weight to the biomass of that species

(Wang et. al, 2011) and the total CSP of all the emergent macrophytes was obtained by the summationof individual CSP of all species. The mean of the observations of the above analysis for each of the 5 quadrats was taken as the monthly representative value of the respective site.

Statistical Analysis: Correlation and regression analysis was done on the observed data by using SPSS 7.5 for Windows Student Version.

## III. RESULTS AND DISCUSSION

A total of 15 emergent macrophytes species were found to inhabit the Lake Manasbal represented by 10 families {*Alismataceae* (2 sps.), *Asteraceae* (1 sps.), *Apiaceae* (1 sps.), *Brassicaceae* (1 sps.), *Cyperaceae* (4 sps.), *Haloragaceae* (1 sps.), *Lamiaceae* (1 sps.), *Polygonaceae* (1 sps.), *Poaceae* (2 sps.) and *Typhaceae* (1 sps.)} (Table 1).

The carbon (%) content of the 15 emergent macrophytes varied between 34.97 to 50.92, 34.98 to 52.04, 34.96 to 52.01 and 34.91 to 50.94 at sites I, II, III and IV respectively (Table 2). Similarly Ca (%) varied between 0.78 to 1.38, 0.78 to 2.21, 0.80 to 2.24 and 0.79 to 1.38 at sites I, II, III and IV respectively. Biomass (g/m$^2$) ranged from a minimum of 104 to a maximum of 687 at site I, 116 to 1382 at site II, 141 to 1493 at site III and 122 to 635 at site IV (Table 2). However, the minimum mean value of carbon (39.25%) and Ca (0.82%) was observed for *Lycopus europus* and the maximum mean value of carbon was observed for *Typha latifolia* (53.62) (Table 1). *Phragmites australis* showed the highest mean biomass (1423.5g/m$^2$) followed by *Typha latifolia* whereas; the highest CSP was recorded for *Typha latifolia* followed by *Phragmites australis* and the lowest for *Carexsp*. (Table 1). The total CSP by the 15 emergent macrophytes species was estimated to be 411.9Kg/ha. Correlation and regression analysis was done in order to determine the relationship between (i) carbon and biomass and (ii) carbon and calcium. Results showed a highly significant correlation between carbon and biomass (r = 0.802) (Fig. 2)as well as between carbon and calcium (0.827)(Fig. 3) and hence the following regression equations were developed;

**Y= 40.028+ 0.01X (eq.1) (r = 0.802)**
Where Y is carbon (%) and X is the biomass (g/m$^2$).

**Y=32.944+ 10.678X (eq.2)(r = 0.827)**
Where Y is carbon (%) and X is the Ca (%).

Significant variations were seen in the CSP of macrophytes species amongst the analysed emergents depending on their carbon content and biomass values. *Typha latifolia*, having the highest CSP exhibited the highest carbon content of 53.62% which was greater than 44% value reported by Wang et. al, 2011 for *Typha orientalis.* Wang also reported 44.7%, 44.1% and 41.8% of carbon for *Phragmites communis*, *Cyperus malaccensis* and *Eleocharis dulcis* respectively which is lower than the values in our study for *Phragmites australis*, *Cyperus difformis* and *Eleocharis palustris* respectively. The carbon content and hence the CSP in our study was higher when compared with the reported results for *Scirpus lacustris* (44.12), *Eleocharis palustris* (43%) (Fernandez-Alaez et. al, 1999); *Phragmites australis* (29.2%) and *Myriophyllum salsugineum* (15.8%) (Piola et. al, 2008) and *Phragmites communis* (45%)(Baldantoni et. al, 2004). Further, Costa and Henry, 2010 observed the highest carbon content for *E. azurea* {437mg/g (43.7%)}, *Myriophyllum aquaticum* {430mg/g (43%)}, *Cyperus esculentus* {416mg/g (41.6%)} and *Polygonumspectable*{380m/g (38%)}. However, the carbon content reported by Westlake(1969) for *Nasturtium officinale* and that reported by Muraoka, 2004 and Demars and Edwards, 2008 for seaweeds and hydrophytes was in close approximation with that observed in our study. The results obtained for carbon were also in accordance with that obtained by Benoit et. al, 2007. Ca is used as an indicator of carbon content (Negi et al, 2003) as indicated by a highly significant correlation between carbon and calcium. The calculated correlation coefficient being close to 1 prescribes the regression equations (eq. 1 and eq. 2) apt for carbon estimation and thereby CSP.

## IV. CONCLUSION

Macrophytes comprise an essential component of aquatic ecosystems, vital for their steady state. Besides, playing an integral role as limnological assets, numerous accessory resilience and restoration capacities can be accounted thereof. In the context of CSP although they tend to be undervalued because of their size, distribution and seasonality but their effective carbon capture and storage role and rates are encouragingly promising and significantly sustainable.

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**Table 1: Mean Carbon, Calcium and Biomass of each species and its corresponding CSP.**

| S.No. | Name of Plant Species | Family | Carbon (%) | Calcium (%) | Biomass ($g/m^2$) | CSP ($g/m^2$/yr.) |
|---|---|---|---|---|---|---|
| 1 | *Alisma plantago* | *Alismataceae* | 47.75 | 1.26 | 505.0 | 241.14 |
| 2 | *Bidens cernua* | *Asteraceae* | 45.45 | 1.05 | 405.0 | 184.07 |
| 3 | *Carex sp.* | *Cyperaceae* | 34.95 | 0.79 | 120.7 | 42.18 |
| 4 | *Cyperus difformis* | *Cyperaceae* | 50.91 | 1.39 | 695.0 | 353.82 |
| 5 | *Echinocloa crusgalli* | *Poaceae* | 47.46 | 1.23 | 464.5 | 220.45 |
| 6 | *Eleocharis palustris* | *Cyperaceae* | 46.06 | 1.16 | 394.0 | 181.48 |
| 7 | *Lycopus europus* | *Lamiaceae* | 39.25 | 0.82 | 350.0 | 137.37 |
| 8 | *Myriophyllum verticillatum* | *Haloragaceae* | 44.29 | 1.01 | 552.2 | 244.57 |
| 9 | *Nasturtium officinale* | *Brassicaceae* | 44.77 | 1.18 | 412.5 | 184.68 |
| 10 | *Phragmites australis* | *Poaceae* | 52.02 | 2.22 | 1423.5 | 740.50 |
| 11 | *Polygonum amphibium* | *Polygonaceae* | 43.67 | 0.94 | 370.2 | 161.67 |
| 12 | *Sagittaria sagittifolia* | *Alismataceae* | 46.06 | 1.13 | 580.4 | 267.33 |
| 13 | *Scirpus triqueter* | *Cyperaceae* | 46.13 | 1.08 | 367.5 | 169.53 |
| 14 | *Sium latijugum* | *Apiaceae* | 46.11 | 1.22 | 541.6 | 249.73 |
| 15 | *Typha latifolia* | *Typhaceae* | 53.62 | 1.72 | 1382.0 | 741.02 |
| | *Total* | | | | | 4119.54$g/m^2$/yr. |

**Table 2: Peak biomass and its corresponding OC (%) and Ca (%) values for the emergent macrophytes species in Lake Manasbal.**

| S. No. | Name of the Macrophyte species | Site I | | | Site II | | | Site III | | | Site IV | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | OC (%) | Ca (%) | Biomass (g/m$^2$) | OC (%) | Ca (%) | Biomass (g/m$^2$) | OC (%) | Ca (%) | Biomass (g/m$^2$) | OC (%) | Ca (%) | Biomass (g/m$^2$) |
| 1 | *Alisma plantago* | 47.73 | 1.27 | 511.0 | NA | NA | NA | 47.78 | 1.26 | 499.0 | NA | NA | NA |
| 2 | *Bidens cernua* | 45.43 | 1.05 | 387.0 | NA | NA | NA | 45.39 | 1.05 | 452.0 | 45.52 | 1.04 | 376.0 |
| 3 | *Carex sp.* | 34.97 | 0.78 | 104.0 | 34.98 | 0.78 | 116.0 | 34.96 | 0.80 | 141.0 | 34.91 | 0.79 | 122.0 |
| 4 | *Cyperus difformis* | 50.92 | 1.38 | 687.0 | NA | NA | NA | 50.86 | 1.42 | 763.0 | 50.94 | 1.38 | 635.0 |
| 5 | *Echinocloa crusgalli* | 47.48 | 1.22 | 456.0 | 47.42 | 1.25 | 527.0 | 47.43 | 1.24 | 460.0 | 47.50 | 1.22 | 415.0 |
| 6 | *Eleocharis palustris* | 46.05 | 1.16 | 385.0 | 46.09 | 1.15 | 348.0 | 46.03 | 1.18 | 449.0 | NA | NA | NA |
| 7 | *Lycopus europus* | 39.22 | 0.84 | 411.0 | NA | NA | NA | 39.28 | 0.80 | 313.0 | 39.24 | 0.82 | 326.0 |
| 8 | *Myriophyllum verticillatum* | 44.30 | 1.01 | 528.0 | 44.26 | 1.02 | 643.0 | 44.31 | 1.00 | 496.0 | 44.28 | 1.02 | 542.0 |
| 9 | *Nasturtium officinale* | 44.74 | 1.19 | 467.0 | 44.79 | 1.17 | 352.0 | 44.76 | 1.18 | 445.0 | 44.78 | 1.18 | 386.0 |
| 10 | *Phragmites australis* | NA | NA | NA | 52.04 | 2.21 | 1354.0 | 52.01 | 2.24 | 1493.0 | NA | NA | NA |
| 11 | *Polygonum amphibium* | 43.69 | 0.93 | 313.0 | 43.68 | 0.93 | 329.0 | 43.64 | 0.95 | 472.0 | 43.66 | 0.95 | 367.0 |
| 12 | *Sagittaria sagittifolia* | 46.08 | 1.13 | 515.0 | NA | NA | NA | 46.05 | 1.14 | 663.0 | 46.05 | 1.12 | 563.0 |
| 13 | *Scirpus triqueter* | 46.13 | 1.09 | 366.0 | NA | NA | NA | NA | NA | NA | 46.14 | 1.07 | 369.0 |
| 14 | *Sium latijugum* | 46.10 | 1.23 | 683.0 | NA | NA | NA | 46.13 | 1.20 | 418.0 | 46.11 | 1.22 | 524.0 |
| 15 | *Typha latifolia* | NA | NA | NA | 53.62 | 1.72 | 1382 | NA | NA | NA | NA | NA | NA |

NA: macrophyte species not available at the particular site.

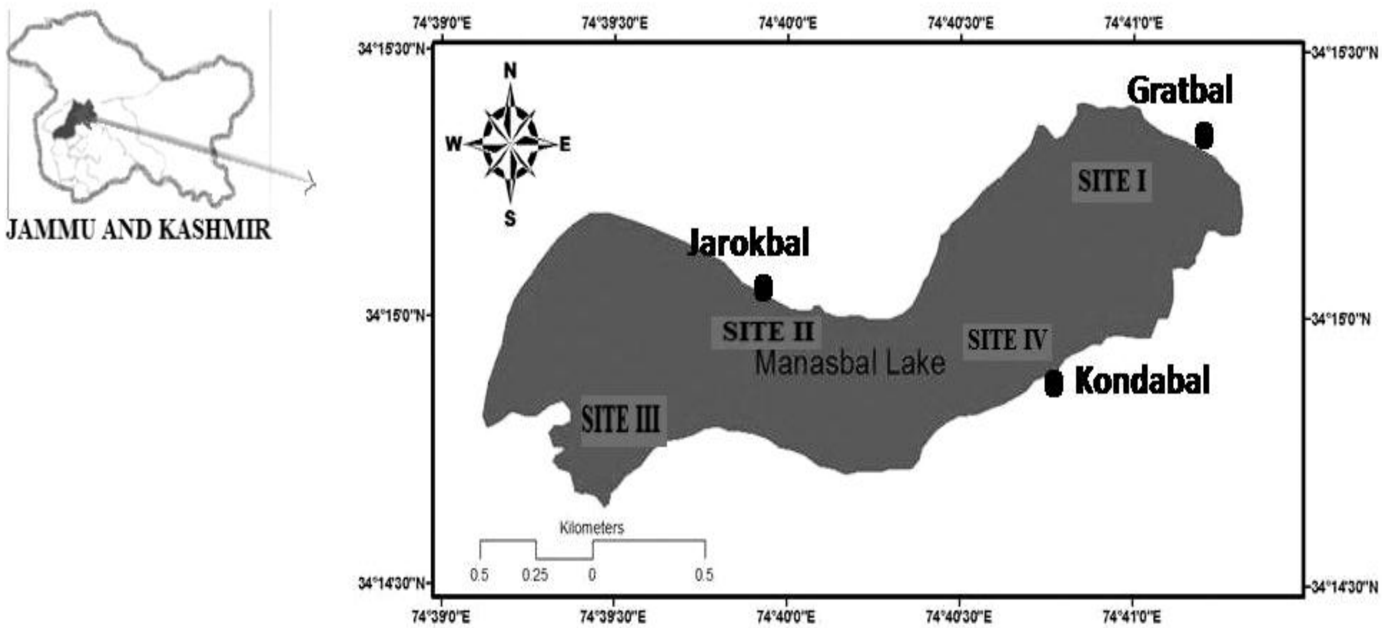


**Fig1: Lake Manasbal, Kashmir, India**.

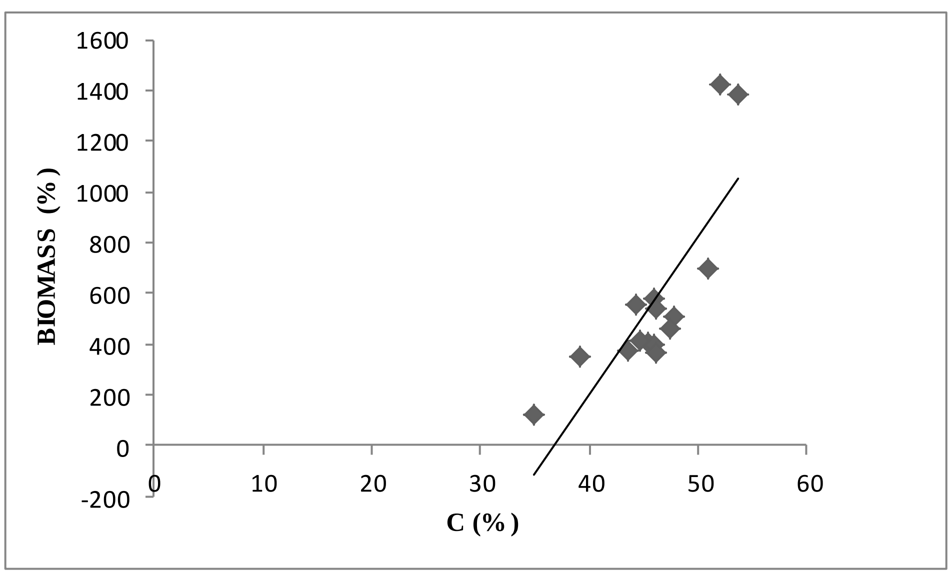


**Fig. 2: Correlation graph for Carbon and Biomass.**

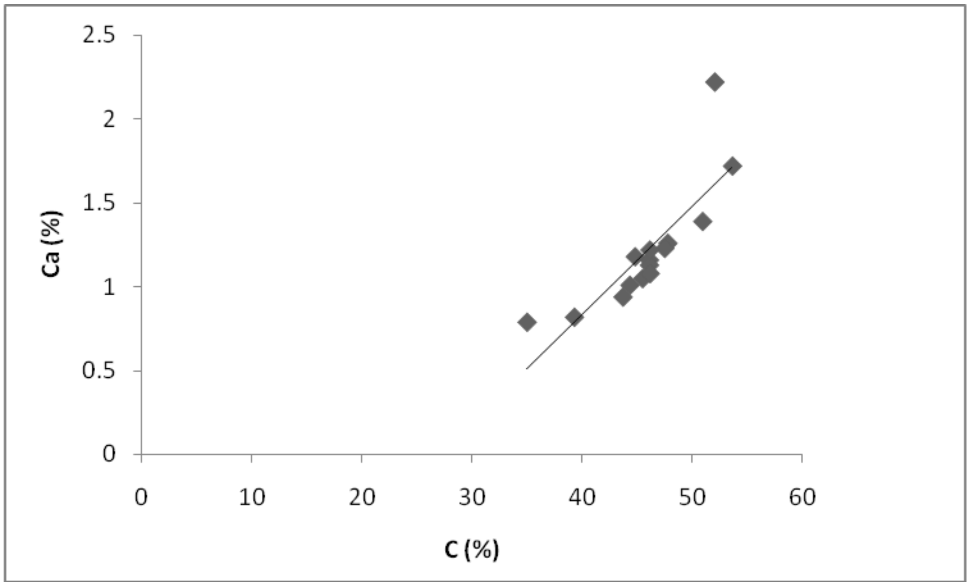


**Fig. 3: Correlation graph for Carbon and Calcium.**