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Review Paper

A Review of Carbon Dynamics and Sequestration in Wetlands

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Abstract

Wetlands are among the most important natural resources on earth. They provide a potential sink for atmospheric carbon but if not managed properly, they become a source of green house gases. However, only limited studies have been conducted to assess the roles and potentials of wetlands in carbon sequestration. Wetlands occupy approximately 5% of the total land area in Nepal, some of these being of international importance. However, there are major knowledge gaps in accurately quantifying carbon stored in them, as well as their carbon sequestration potential. Therefore, further research is needed to better understand the processes of carbon sequestration in wetland vegetation and soils.
Key words: wetland, sink, carbon sequestration

Introduction

Wetlands are found in all climatic zones ranging from tropics to the tundra (except Antarctica which has no wetlands). Occupying about 5% of the earth's land area, wetlands are dynamic and natural ecosystems characterized by water logged or standing water conditions during at least part of the year. In most wetlands, water levels fluctuate seasonally instead of being stable, a property that accounts for making wetlands highly productive environments. Productivity among wetlands varies depending on the type of the wetland, climatic condition and vegetation communities. Along with productivity, decomposition is another complicated process that involves both aerobic and anaerobic processes. The rate of decomposition is a function of climate (temperature and moisture enhanced microbial activity) and quality (composition) of organic matter entering the system (Schlesinger 1997). In general, however, wetland characteristics lead to the accumulation of organic matter in the soil and sediment serving as carbon (C) sinks and making them one of the most effective ecosystems for storing soil carbon (Schlensinger 1997). It has been estimated that different kinds of wetlands contain 350-535Gt C, corresponding to 20-25% of world's organic soil carbon (Gorham 1998). However, the actual quantity of carbon stored in wetlands can only be estimated with a broad range of uncertainty. Hence, carbon fluxes and pools vary widely in different wetlands. This paper provides a review that summarizes carbon storage along with mechanisms and factors affecting carbon dynamics in wetland ecosystems with a limited focus on Nepalese wetland through all secondary information and literature available.

Methodology

This paper is based on literature review and consultation with experts.

Results and Discussion

Possible Mechanism of Carbon Storage in Wetland

Wetland ecosystems have unique characteristics as they are the sources of cultural, economic and biological diversity. These unique characteristics affect carbon dynamics and there are few mechanisms that aid in carbon storage in wetland ecosystem. In mechanism photosynthesis, wetland trees and other plants convert atmospheric carbon dioxide into biomass. Hence carbon may be temporarily stored in wetlands as trees and plants and the living material which feed upon them, and detritus including fallen plants and animals which feed upon them. Many wetland plants are known to use atmospheric carbon dioxide for their main C source, and their death/decay and ultimate settlement at a wetland bottom can have profound effect on C sequestration. Even this mechanism of storage through photosynthesis depends along the latitudinal gradient as growth of vegetation is slow for high latitude wetlands with less sun, nutrient and colder temperature. Secondly, carbon rich sediment are trapped and stored that are brought along floods, hurricanes or even drained from watershed sources. However, long term storage is often limited due to rapid decomposition processes and rerelease of C to the atmosphere such as in case of paddy fields. Hence, wetlands are dynamic ecosystem where significant quantities of C from both wetland and non-wetland sources may also be trapped and stored in wetland sediments.

Factors Influencing Carbon Deposition and Long Term Storage in Wetlands

The balance between carbon input (organic matter production) and output (decomposition, methanogenisis, etc.) and the resulting storage of carbon in wetlands depend on several factors such as the topography and the geological position of wetland; the hydrological regime; the type of plant present; the temperature and moisture of the soil; pH and the morphology. Thus clearly carbon accumulation in wetlands is a complicated process influenced by many factors. In general, the following key questions should be asked while studying C sequestration in wetlands:

- ✓ Can wetlands function as an effective C sink to mitigate atmospheric C?
- ✓ What are the effects of C storage on the function of wetland ecosystems including water quality and biodiversity?
- ✓ Is C sequestration in wetlands economically viable and environmentally sound?

A number of studies have compared carbon storage in wetlands in various regions with factors affecting the storage. There is a strong relation between climate and soil carbon pools where organic carbon content decreases with increasing temperatures, because decomposition rates doubles with every 10oc increase in temperature (Schlensinger 1997).

Tropical wetlands store 80% more carbon than temperate wetlands according to findings based on the studies conducted to compare ecosystems in Costa Rica and Ohio (Bernal 2008). Tropical wetland in Costa Rica accumulated around 1 ton of carbon per acre (2.63t/ha) per year, while the temperate wetland in Ohio accumulated 0.6 tons of carbon per acre (1.4t/ha) per year (Bernal 2008).

Of various wetland types, peatland has been recognized worldwide as highly important for carbon storage since it accounts for nearly 50% of the terrestrial carbon storage with only 3% cover of world's land area (Guo 2007).

Bridgham et al. (2006) studied fresh water mineral soil wetlands and estuarine wetlands of North America and concluded that North American wetlands contain about 220 Pg C, most of which is in Peat.

Post et al. (1982) reported that wetlands cover a total land area of 280 million ha worldwide, and the average carbon density in wetland is 723t per ha. This amounts to a total of 202.44 billion tons of carbon in wetlands of the world.

Many studies express the carbon content in soil of wetlands on a percentage (weight) basis, making it difficult to derive the carbon storage per unit area if the depth of organic matter is unspecified. In peat soils (peat soil is different from a wetland soil) the carbon densities (tC/ha) that is directly affected by the depth of the peat. Adjusting the density to a depth of 1.5m and using their own estimates for the temperate area (357 million ha), Maltby and Immirzi (1993) estimated that temperate region storage could be as high as 392 Gt.

Gorham (1991) calculated the pool in boreal and subarctic peatlands alone to be 460Gt. Whereas the carbon stored in peat could be 44-71% of the whole carbon held in the terrestrial biota (737 Gt), according to Matthews et al. (1987).

As estimated by Lal (2007), the total soil organic pool is 1550Pg and the wetlands are responsible for 150Pg, one third of this pool, despite the fact that they cover a very small portion of the total earth's surface.

However, quantifying the extent of wetlands soil carbon pool worldwide, difference between wetland types, its morphology, climatic regions and the effects of disturbances to wetlands and management practices adopted in wetlands have not been studied adequately and hence requires further research.

Wetlands, Global Carbon Cycle and Climate Change

The role of wetland flux of carbon in the global carbon cycle is poorly understood. Wetlands may affect the atmospheric carbon cycle in four ways. Firstly, many wetlands especially boreal and tropical peatlands have highly labile carbon and these wetlands may release carbon if water level is lowered or management practices results in oxidation of soils. Secondly, the entrance of carbon dioxide into a wetland system is via photosynthesis by wetland plants giving it the ability to alter its concentration in the atmosphere by sequestrating this carbon in the soil. Thirdly, wetlands are prone to trap carbon rich sediments from watershed sources and may also release dissolved carbon into adjacent ecosystem. This in turn affects both sequestration and emission rates of carbon. Lastly, wetlands are also known to contribute in the release of methane to the atmosphere even in the absence of climate change.

Kasimir-Klemedtsson et al. (1997) examined the conversion of bogs and fens to different cropping types that led to 23 fold increase in carbon dioxide equivalent emission.

According to an estimation by Maltby et al. (1993) when peatlands are drained, the mineralization process starts immediately and results in emission of carbon dioxide ranging between 2.5 and 10t C2.5 and 10t C/ha/yr.

Degradation of wetlands and disturbance of their anaerobic environment lead to a higher rate of decomposition of the large amount of carbon stored in them and thus release green house gases (GHGs) to the atmosphere. Therefore, protecting wetlands is a practical way of retaining the existing carbon reserves and thus avoiding emission of carbon dioxide and GHGs.

Impacts of climate change on wetlands are still poorly understood. The diverse functions of wetlands make it more difficult to assess the relation between climate change and wetlands. The projected changes in climate are likely to affect the extent and nature of wetland functions. It even affects the role of wetlands as a sink of GHGs and reduces carbon storage and sequestration within them. It is uncertain if the conservation of wetland will be integrated into international trading schemes of emission as in Kyoto Protocol as of Forestry.

Even trading of emission certificated may become an established pathway, and then mechanism can be applied to those wetlands with high carbon sequestration potential.

Data and Knowledge Gap in Context of Nepal

Wetlands are some of the most diverse and productive ecosystems in Nepal. Wetlands occupy approximately 5% of the total area of Nepal ranging from high altitude glacial lakes to hot springs, ponds, ox-bow lakes to river flood plains, swamps to marshes. Rich in biodiversity and supporting migratory birds that come from thousands of miles north, the wetlands of Nepal are of global importance.

In view of the significance of wetlands on various aspects like biodiversity richness, livelihood of the wetland dependent people and its contribution on the purification of water sources, Nepal became signatory to the Ramsar Convention on Wetlands on 17th April 1988. Presently, Nepal has nine wetlands of International Importance. Four of these are in the lowland Terai; the other four are high-elevation wetlands and one recently added “Mai-Pokhari” of Ilam.

Although Nepal has shown its commitment to wetland conservation, problems of over-exploitation, illegal harvesting, over hunting, fishing, encroachment and pollution, among others, are still prevalent. The role of these wetlands as carbon sink locally as well as globally are still not realized and no scientific database on the stock of carbon deposited has been maintained. Therefore there is a need to assess and analyze thereby integrating scientific methods for sediment C, dissolved organic C and biomass calculation as well as the management practices in wetlands of Nepal.

Conclusion and Recommendations

This review shows a broad consensus about wetlands being important reservoirs of carbon in their biomass, litter, peat and sediment. It is difficult to evaluate the net carbon sequestering role of wetlands because decomposition of organic matter, methanogenesis and sediment fluxes are extremely complex and there exists a huge gap in scientific quantification and knowledge. Thus, wetland mechanisms can facilitate low cost approach of Kyoto Protocol in lowering net emission of GHGs; at the same time can help to advance the goals of Convention of Biological Diversity. In such synergies of approach, there are no losers and the winners are both C sequestration and biodiversity protection lobbyists. A combination of literature surveys, scientific consensus- building measures (workshops), field research and laboratory studies are needed in order to protect, enhance and restore wetlands as carbon reservoirs and also to create an incentive mechanism for each tons of C sequestration if markets for carbon projects are to be made operational.

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