Environmental Factors, Biomass, and Function of Wetlands

Yukuan Shi*

High School Affiliated to Renmin University of China, Beijing, China

*Corresponding author: 160608242@stu.cuz.edu.cn

Abstract: Wetlands are an important part of the biosphere. Wetlands not only impact the natural environment but also play vital roles in human life. This paper starts with the classification, distribution, and main functions of wetlands, then analyzes the relationship between wetlands and the biosphere from several aspects, including the factors that affect wetlands, the biomass of wetlands, the importance of wetlands for carbon storage, and the threats that wetlands may face. Based on previous research, wetlands can be impacted by environmental factors, such as water supply and temperature, and biological factors, including aboveground biomass and below-ground biomass. When interacting with these factors, wetlands can play crucial roles in the biosphere, such as facilitating the circulation of energy and materials and the storage of carbon. However, wetlands are facing threats. After analyzing the current state of wetlands, possible solutions are considered. Both research and society can make efforts to improve wetlands ecosystems. This report is significant for understanding the current situation and the direction of future development of wetlands. It is crucial to study the environmental factors affecting wetlands, considering the protection, improvement, and future development of wetland ecosystems depend on their surroundings to a great extent. Interactions between wetlands and the environment directly or indirectly determine the state of wetlands.

Keywords: Wetlands, Biomass, Water Supply, Temperature, Carbon Storage.

1. Introduction

In general, wetlands are locations where water covers the soil, or is present either at or near the surface of the soil all year or for variable periods during the year [1]. Further, wetlands can be roughly categorized into marshes, swamps, bogs, and fens. First, marshes are wetlands that are rich in vegetation. They stored water from rivers and streams, and help reduce damage caused by floods. The two main categories of marshes are tidal and non-tidal. Tidal wetlands are located near coasts and are partially characterized by tides. They are proper habitats for vegetation and animals, ranging from fish to mammals, adapted to salt water [2]. On the other hand, non-tidal wetlands are filled with freshwater and are found in inland areas. Rain, snow, and groundwater are the main factors that can shape non-tidal wetlands. they can be divided into flats, depressions, riverine, swamps, and fens [3]. Second, swamps are saturated with woody plants. Much like marshes, swamps are competent in protecting lands from floods. When focusing on the types of plants, swamps can be divided into shrub swamps and forested swamps. Third, bogs are characterized by spongy peat and moss deposit. Unlike former wetlands, bogs receive water primarily from precipitation. When absorbing precipitation, bogs can mitigate the impacts brought by excessive precipitation and flooding. Generally, bogs are divided into northern bogs, which locate in humid areas, and pocosin, which are far from the main streams. Last, fens receive water from drainage from surrounding mineral soils and from groundwater movement. Compared with bogs, they are less acidic and possess a higher nutrient level [4]. Wetlands are widely distributed around the world. Humid and warm areas tend to maintain more wetlands than relatively arid and cold regions do, considering the higher precipitation in former areas. However, different areas have different kinds of wetlands, depending on regional climates and environmental characteristics [5]. When focusing on the function of wetlands, they can be classified as crucial ecosystems. In other words, wetlands provide suitable habitats for animals and plants. From the perspective of ecology, plants are primary producers, providing oxygen to other organisms. As consumers, animals are important in the energy and material cycles. Most microbes are decomposers, breaking down organic matter into inorganic substances that are stored in the soil. As one of the most important ecosystems, wetlands need continuous research and protection. It is necessary to study the function of wetlands in the biosphere and the potential influencing factors. This information can provide directions for protection and further improvements.

2. Environmental factors

Based on experience and tremendous research, it is reasonable to generalize that environmental factors can greatly impact wetlands in various aspects. More specifically, wetlands' characteristics are mainly determined by water supply, temperature, and sea level. These influence factors will directly affect the overall structures and features of wetlands. In a broader view, the combination of environmental factors is even more remarkable. Therefore, the wetlands rely on the environment at a fundamental level. Meanwhile, there is a close relationship between the environment and wetlands, and the two function mutually in nature.

2.1. Water supply

Among all the potential water sources for wetlands, precipitation is the most essential and direct resource. Wetlands in humid regions possess bountiful water as an available resource for the formation and maintenance of wetlands. However, other water sources, such as ice and snow-melting water, are required to maintain wetlands. Besides the amount of water, the timing of precipitation is also important. Wetlands in the same area may have different characteristics in different seasons, due to the temporary precipitation. Similarly, wetlands in different climates also have different characteristics. On one hand, wetlands in tropical rainforest climates may maintain a relatively stable state throughout the year, since the annual rainfall in the wet season in rainforest climates varies from less than 10 inches to more than 50 inches, which is a considerable statistic [6]. Nevertheless, the exception does exist. Considering rainfall is sufficient only in certain periods of the year in areas among the moist tropics and the deserts [7], wetlands' volume and capacity will fluctuate within a certain range. On the other hand, wetlands in relatively temperate and arid climates tend to reflect a greater variation. However, if precipitation is extremely concentrated in certain seasons, wetlands still possess a stable water supply. For example, although the annual rainfall in the Sanjiang Plain is poor, it is concentrated in summer, which means wetlands can get plenty of water during this period. In addition, the Sanjiang Plain area has low temperatures, low evaporation, and poor drainage. These factors cause water to easily accumulate. In other words, wetlands have access to water for a long time, even without lasting rainfall.

Understanding how water supply will affect wetlands is crucial since it is one of the most direct resources for wetlands. Whether the water supply is sufficient or not can be reflected by both the quality and quantity of wetlands. However, water sources also interact with other influencing factors, as will be discussed in later paragraphs.

2.2. Temperature

Besides direct water supply, temperature also plays a significant role in shaping the development of wetlands. For instance, global warming, which indicates the rising in temperature, affects both plants 'functions in their traits and ecosystems. Since wetlands are essential ecosystems and conditions within those highly depend on vegetation, the change in plants 'function can affect the ecological condition of wetlands to a great extent [8]. In Lindborg's study, a group of researchers conducted a temperature manipulation experiment along the latitudinal gradient. In the experiment, plants responded significantly to the increase in temperature. Plants tended to develop larger leaves and more clones. Consequently, these changes in physical structure affected plants' functions, especially their competitiveness in the environment. According to the study, therefore, it can be speculated that the warming process is influential on wetlands ecosystems.

In general, temperature impacts wetlands mainly in two aspects. To begin with, regional climates, which mostly the temperature, can determine the plant species distribution due to the responses and adaptations of plants [9]. Different species of plants will distribute in different regions partly according to temperatures. To be more detailed, nutrient-dense plants tend to live in areas with high temperatures, whereas plants with intermediate or low nutrients inhabit relatively cold areas. This can be easily understood. In a case study, researchers wanted to find out potential environmental factors that could direct the distribution of nutrient-dense fleshy-fruited plants. Their study indicated that these kinds of plants preferred wet, warm, and stable environments. Although the annual precipitation also contributed a lot, temperatures no doubtfully will affect the distribution of plant types. On the contrary, poor nutrient plants, such as mosses, are expected to prefer lower temperature ranges. The distribution of plant species is essential in studying wetlands vegetation, considering that wetland plants undertake key roles in the ecosystem [10], including the energy cycle through photosynthesis and respiration, and a series of chemical reactions related to the conversion of organic matter.

Further, temperatures can impact vegetation by influencing the activity of microorganisms. Plants will be decomposed after death, and the process of decomposition partially depends on the temperature of the environment. Microorganisms play an important role in decomposition. Normally, microorganisms are relatively inactive in low temperatures, resulting in a low rate of decomposition. Thus, debris of plants accumulates can act as the foundation of marsh wetlands. By contrast, high temperatures can stimulate the activity of microorganisms, which in turn may lead to a higher decomposition rate. From this perspective, cold zones are more appropriate for the formation of wetlands. This is the reason why wetlands are not prevalent in temperate and arid areas. In addition to the temperature, microbial growth and turnover also depend on plant species richness(PSR) [11]. PSR can promote microbial metabolism, including growth and death. In other words, PSR has a positive influence on microbial activity, which further contribute to the soil's organic carbon content, since microorganisms are responsible to convert the organic matter of plants to soil organic carbon. In this case, a higher metabolic rate of microorganisms can enrich the soil conditions, especially the fertility, in wetlands. In fact, the temperature is not an independent factor, it will interact with humidity.

3. Wetlands biomass

As an important ecosystem in the biosphere, the wetland is one of the most biodiverse ecosystems. For instance, from the perspective of ecosystems, vegetations in wetlands are producers, which provide energy for the metabolism of other living organisms. In other words, plants support and consolidate complex food webs in wetlands ecosystems. As mentioned before, when interacting with the atmosphere and soil, plants can promote the circulation of energy and nutrients through photosynthesis and respiration. Therefore, plants can have a great impact on the restoration of wetlands. Based on the long track record, wetlands provide a habitat for a huge amount of plants and animals. Specifically, at least 150 bird species and 200 fish species depend on wetlands, and about 900 terrestrial animal species periodically breed and forage with the use of wetland habitats in the United States [12]. Besides, according to statistics from the second wetland resource survey in China, wetlands in China serve as habitats for about four thousand plants and three thousand vertebrates. Overall, a large number of organisms depend on wetlands. The interactions between organisms and their environment are vital and worth studying. When categorizing the biomass in wetlands, one approach is to divide the whole into aboveground and belowground.

3.1. Aboveground biomass

Investigating aboveground biomass allocations is important for the evaluation of marsh ecosystems, since a variety of processes, such as the cycle of energy and nutrient, and carbon storage [13]. In a study which was conducted in China, researchers measured the biomass of vegetation in herbaceous marshes [14]. These marches can be set into different categories according to their geographical and topographical features. When focused on the temperature and the humidity, herbaceous marshes are scattered from the coast to inland and from tropical to cold temperate zones in China. The average value of the vegetation's above-ground biomass density was the main focus of the examination. The results were obtained by averaging the amount of herbaceous plants in five marsh areas. Taking various regions into account made the survey compelling and comprehensible. In general, coastal marsh regions had the lowest biomass, while temperate humid and semi-humid marsh regions had the most. Since the area of herbaceous marsh in coastal marsh regions was the highest and that of temperate humid and semi-humid marsh regions was the lowest, the density of herbaceous marsh vegetation had the opposite outcome. The pattern was obvious to some extent, at least the temperature and the humidity were crucial to determine the biomass. However, the data was collected in only five regions, exact correlation cannot be drawn. Further, environmental factors, such as regional climate characteristics and surrounding vegetation types, may also lead to discrepancies between research conclusions and reality.

3.2. Belowground biomass

In addition to aboveground biomass, below-ground biomass also plays a significant role in wetland ecology. By definition, below-ground biomass is the complete biomass of all live roots [15]. Further, it will interact with aboveground biomass. Below-ground biomass is about a quarter of the total biomass, therefore, detailed research is important for studying carbon storage. New Jersey Meadowlands consisted of 35,000 hectares of wetlands comprising tidal marshes and lake bodies [16]. Researchers chose four tidal marsh species, Spartina patens, S. alterniflora, Phragmites australis, and Distichlis spicata, comparing the total biomasses of the species' above-ground, below-ground, rhizome, and roots. Further, researchers also took the leaf area index and carbon-to-nitrogen ratio into consideration, because these features could indicate the behavior of biomass toward carbon and greenhouse gas transportation. Although the study could not rule out the influencing factors such as harvesting seasons, which would result in higher biomass, data suggested that most of the below-ground biomass was found in the regions close to the soil surface, which meant that below-ground biomass functioned in these areas to impact the production, consumption, and transport of greenhouse gases. In this aspect, measuring the characteristics of aboveground biomass and below-ground biomass is essential to study greenhouse transportation, since they participate in the carbon cycle in the environment to a great extent.

4. Carbon storage

Wetlands have a strong capacity to store carbon, which means greenhouse gas emission can be reduced in some ways. On one hand, plants can absorb carbon dioxide through their stomata. Then, carbon will be stored in plant biomass as organic matter via photosynthesis. On the other hand, wetland soil is one of the best carbon-storage soils in the biosphere [17]. According to a study conducted in 2016, researchers used the filed data from National Wetland Condition Assessment to estimate the carbon storage capacity of wetlands soil. Results pointed out that wetlands in America(included in the analysis) stored 11.52 PgC(unit of the quantity of carbon stocks). Those wetlands accounted for almost one percent of the world’s organic carbon storage. More importantly, inland wetlands contained far more carbon than tidal wetlands. The data from the analysis was comprehensive since it was collected from both tidal and non-tidal wetlands, which provided valid sources for comparison and conclusion. From this general study, it can be concluded that regardless of the types of wetlands, their importance for carbon storage cannot be ignored. Besides, coastal wetlands are capable of storing organic carbon, which is also known as “blue carbon” [18]. Based on the original data from twenty-five studies related to soil carbon storage, a group of researchers estimated the organic carbon storage in coastal wetlands. To make their estimation more precise, they focused on both tidal wetlands and estuarine salt marshes. After taking environmental factors into the account, such as vegetation and soil texture, researchers reached their conclusion. On average, carbon storage in salt marshes was slightly lower than that of tidal wetlands. The result provided crucial information for studying how wetlands could contribute to carbon storage.

However, wetlands' capability of storing carbon will be strongly affected by human activities. In fact, carbon sequestration (CS) is declining due to human disturbance and will keep decreasing in the future [19]. From perspectives of wetlands protection and future implementation, a study generalized several potential solutions. One of the most direct ways was to increase wetland spatial extent. In this aspect, the ecosystems in which wetlands are located can be enhanced, usually in terms of recycling capacity, resilience, and adaptability. Another effective solution is altering wetlands' characteristics. The reconstruction could result in a higher organic matter input and a longer carbon storage period. Nevertheless, risks still exist. When conducting modification works, both biological and abiotic factors in the ecosystems need to be considered. It is necessary not to disturb the existing ecological balance.

5. Recent states and potential threats

5.1. Degradation

In recent decades, the degradation of wetlands cannot be ignored. Wetland degradation can be reflected in wetland areas, biodiversity, and functions. To begin with, the area of wetlands has been in a tremendous reduction for a long period. Based on the report, wetlands in the Atlantic, Pacific, and Gulf of Mexico and the Great Lakes were lost at an average rate of 59,000 acres lost each year from 1998 to 2004 and around 80,000 acres per year from 2004 to 2009 [20]. Moreover, according to the National Wetland resources survey in 2003 and 2014 in China, there have been huge declines in both natural and constructed wetlands. Overall, the area of wetlands decreased by 8.82 percent. The trend tells us that the loss of wetland areas was increasing, and it is reasonable to extrapolate that the trend will not cease in the near future. Another important aspect is the biodiversity in wetland ecosystems. Biodiversity means a lot to the environment. It can not only maintain the ecological balance but also play an important role in regulating the environment. However, wetlands have been damaged for a long time, which resulted in a loss of biodiversity. Therefore, the conservation of biodiversity is crucial for future development. Last but not the least, the ecological function of wetlands is also degrading, and the degradation will mainly be reflected in reduced productivity and regulatory capacity.

5.2. Potential threats

Although a wetland is a complex ecosystem, which is rich in animals, plants, and microbes, it can be affected by many factors. In some cases, these influences will become potential threats. In general, the influencing factors can be divided into natural factors and human inferences. When focusing on environmental factors, climate change is one of the major threats. Specifically, changes in hydrology and the increase in temperature will lead to unwilling consequences [21]. Via monitoring the gas emission and nutrient release, a review focused on the response of natural and constructed wetlands. The conclusion suggested that higher temperatures could lead to the transformation of wetlands' roles. Both natural and constructed wetlands could shift from a sink to a source of carbon since the inability to the purification of water and the higher rate of decomposition than the production. In this way, wetlands will increase greenhouse gas emissions rather than reduce them. Moreover, a study conducted from 1990 to 2015 has shown the potential implications of climate change on the Prairie Pothole Region of North America. The composition of the vegetation, biodiversity, and hydrologic function would all reflect the consequences. The study was based on a multi-basin model which could maintain clear detection. Together with the building of a long-term wetland monitoring field site, the study claimed that the wetland was sensitive to climate change. A warmer climate would result in more precipitation, which intern could cause a decrease in the effective wetland area [22].

In addition to natural factors, human activities can also threaten the development of wetlands. According to studies, among all potential factors, the most significant were pollution (54%), biological resources use (53%), natural system modification (53%), and agriculture and aquaculture (42%). When focusing on pollution, wetlands near rivers and coasts were the most susceptible. Since people preferred to live near rivers and coasts since ancient times, the overuse of water resources and pollution could limit and destroy wetlands to a great extent. Biological resources in marsh wetlands were damaged, due to the over-exploitation by humans [23].

6. Conclusion

Wetlands are crucial ecosystems in the biosphere. When interacting with the environment, various factors can impact and further shape wetlands. Water supply is one of the most direct influencing factors. Wetlands mainly receive water from rivers, streams, and precipitation. Moreover, ice and snow-melting water are also crucial water sources for wetlands to maintain their function and structures. In addition, the temperature is a key determinant of wetlands characteristics. Considering that precipitation and evapotranspiration are closely related to temperatures, changes can influence wetlands to different extents. Since wetlands provide crucial habitats for plants and animals, wetlands are among the most biodiverse ecosystems. Both aboveground and below-ground biomass contribute to the complicated structure of wetlands. The conversion of energy and matter among aboveground biomass, wetlands, and below-ground biomass is an important component of the energy cycle in the biosphere. In addition, wetlands can help the environment store carbon. Both plants and soil engage in storing carbon. Although wetlands are productive and efficient to a great extent, the state of the wetlands in the world remains problems. On one hand, wetlands are degrading, which results in decreased area and biodiversity. On the other hand, potential threats are imminent. Natural factors, including changes in hydrology and the increase in temperature, and human activities, such as pollution, are detrimental to wetlands in some ways. For future improvement, research need to focus on water pollution and water resources in wetlands, considering water is a vital component in wetland ecosystems. Further, restoration of vegetation and cultivation of nutrient-rich soil are necessary. These approaches ensure the function of wetlands. Last but not the least, societies need to raise public awareness of wetland protection. For instance, communities can engage in protecting wetlands via reasonable discharge.

References

[1] Environmental Protection Agency. (2022, May 12). *What is a Wetland?* EPA. Retrieved October 31, 2022, from https://www.epa.gov/wetlands/what-wetland.

[2] U.S. Department of the Interior. (2016, May 5). *Tidal wetlands*. National Parks Service. Retrieved October 31, 2022, from https://www.nps.gov/subjects/wetlands/tidal.htm.

[3] *Non-tidal wetlands*. DNREC. (2019, May 14). Retrieved October 31, 2022, from https://perspectives.dnrec.delaware.gov/stories/s/Non-Tidal-Wetlands/mw4n-bstg/.

[4] Classification and Types of Wetlands. (2022, January 26). Retrieved November 28, 2022, from https://www.epa.gov/wetlands/classification-and-types-wetlands#undefined.

[5] Tiner, R. (2009). Global distribution of wetlands. *Encyclopedia of Inland Waters*, 526-530. doi:10.1016/b978-012370626-3.00068-5.

[6] Carr, K. (2019, November 22). What are tropical wet and dry climates? Retrieved November 20, 2022, from https://sciencing.com/tropical-wet-dry-climates-8481544.html.

[7] Smith, J. M. (2022, November 10). Tropical rainforest. Retrieved November 20, 2022, from https://www.britannica.com/science/tropical-rainforest.

[8] Lindborg, R., Ermold, M., Kuglerová, L., Jansson, R., Larson, K. W., Milbau, A., & Cousins, S. A. (2021). How does a wetland plant respond to increasing temperature along a latitudinal gradient? *Ecology and Evolution, 11*(22), 16228-16238. doi:10.1002/ece3.8303.

[9] Skálová, H., Moravcová, L., Dixon, A. F., Kindlmann, P., & Pyšek, P. (2015). Effect of temperature and nutrients on the growth and development of seedlings of an invasive plant. *AoB PLANTS, 7*. doi:10.1093/aobpla/plv044.

[10] Parolin, P., Wittmann, F., Schöngart, J., Da Cunha, C. N., Junk, W. J., & Piedade, M. T. (2022). Wetland plants: Adaptations, classification, ecology and Distribution. *Encyclopedia of Inland Waters*, 214-230. doi:10.1016/b978-0-12-819166-8.00060-8.

[11] Prommer, J., Walker, T. W., Wanek, W., Braun, J., Zezula, D., Hu, Y., . . . Richter, A. (2019). Increased microbial growth, biomass, and turnover drive soil organic carbon accumulation at higher plant diversity. *Global Change Biology, 26*(2), 669-681. doi:10.1111/gcb.14777.

[12] May, H. L. (2001, March). USDA. Retrieved November 21, 2022, from https://efotg.sc.egov.usda.gov/references/Public/SC/Wetland_Mammals.pdf.

[13] Tripathee, R., & Schäfer, K. V. (2014). Above- and belowground biomass allocation in four dominant salt marsh species of the eastern United States. *Wetlands, 35*(1), 21-30. doi:10.1007/s13157-014-0589-z.

[14] Shen, X., Jiang, M., Lu, X., Liu, X., Liu, B., Zhang, J., . . . Wang, Z. (2021). Aboveground biomass and its spatial distribution pattern of herbaceous marsh vegetation in China. *Science China Earth Sciences, 64*(7), 1115-1125. doi:10.1007/s11430-020-9778-7.

[15] Ravindranath, N. H. (2010). Carbon Inventory Methods. In *Carbon inventory methods: Handbook for greenhouse gas inventory, carbon mitigation and Roundwood* .. Springer.

[16] Tripathee, R., & Schäfer, K. V. (2014). Above- and belowground biomass allocation in four dominant salt marsh species of the eastern United States. *Wetlands, 35*(1), 21-30. doi:10.1007/s13157-014-0589-z.

[17] Nahlik, A. M., & Fennessy, M. S. (2016). Carbon storage in US wetlands. *Nature Communications, 7*(1). doi:10.1038/ncomms13835.

[18] Byun, C., Lee, S., & Kang, H. (2019). Estimation of carbon storage in coastal wetlands and comparison of different management schemes in South Korea. *Journal of Ecology and Environment, 43*(1). doi:10.1186/s41610-019-0106-7.

[19] Were, D., Kansiime, F., Fetahi, T., Cooper, A., & Jjuuko, C. (2019). Carbon sequestration by wetlands: A critical review of enhancement measures for climate change mitigation. *Earth Systems and Environment, 3*(2), 327-340. doi:10.1007/s41748-019-00094-0.

[20] Dahl, T. E., & Stedman, S. (2013). *Status and trends of wetlands in the coastal watersheds of the conterminous United States 2004 to 2009*. Washington, D.C.: U.S. Department of the Interior, U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

[21] Salimi, S., Almuktar, S. A., & Scholz, M. (2021). Impact of climate change on wetland ecosystems: A critical review of experimental wetlands. *Journal of Environmental Management, 286*, 112160. doi:10.1016/j.jenvman.2021.112160.

[22] Johnson, W. C., & Poiani, K. A. (2016). Climate change effects on prairie pothole wetlands: Findings from a twenty-five year Numerical Modeling Project. *Wetlands, 36*(S2), 273-285. doi:10.1007/s13157-016-0790-3.

[23] Xu, T., Weng, B., Yan, D., Wang, K., Li, X., Bi, W., . . . Liu, Y. (2019). Wetlands of international importance: Status, threats, and future protection. *International Journal of Environmental Research and Public Health, 16*(10), 1818.