Introduction of organisms to address soil quality in wetland ecosystems

Size Xiao [1] and Zilin Zhang [2, *]

[1] Xi'an Jiaotong Liverpool University, Department of health and environmental science, Jiangsu, China

[2] Portledge School, New York, US

* Corresponding author: Size.Xiao22@student.xjtlu.edu.cn

Abstract. The wetland ecosystem, as known as the "lung of the earth", is an important component of the biosphere. The size of wetlands can vary from a few square kilometers to tens of thousands of square kilometers, and the location of wetlands also varies greatly, from inland to coastal, from rural to urban, and is extremely widely distributed. In addition, wetlands are one of the ecosystems with the strongest self-purification capacity in the natural environment, and their purification capacity is 1.5 times that of forests in the same area, so the protection of wetland ecosystems occupies a great position in the field of ecology. This article is going to explain the introduction of organisms into wetland ecosystems to improve soil quality in wetland ecosystems in many ways.

Keywords: Ecology, soil quality, soil salinization, soil erosion, soil acidification.

1. Introduction

1.1. The Importance of Wetland Ecosystems

Wetland ecosystems are as known as the "lung of the earth" and are an important component of the biosphere. The size of wetlands can vary from a few square kilometers to tens of thousands of square kilometers, and the location of wetlands also varies greatly, from inland to coastal, from rural to urban, and is extremely widely distributed.

1.2. Problems People Have Met

Nowadays, there are many wetland ecosystems that are being destroyed, which in turn is caused by soil acidification, soil salinization, and high concentrations of heavy metal ions. the soil quality of wetlands is undergoing tremendous damage, especially severe in developing countries (for example, China, and Russia…)In China, in recent years, with the implementation of the national strategy of large-scale coastal development, along the high-efficiency agriculture, specialty aquaculture, beach tourism, and chemical industry in the maritime area with the rise of the park, a large number of pollutants and atmospheric deposition particles are not allowed avoid wetlands along the beach with nearshore rivers flowing into the beach. The lack of general environmental awareness and expertise among citizens is also an important reason.

1.3. Purpose of the Study

Scientists are searching for methods that can restore wetland ecosystems, as said in this article, an increase in biodiversity in three different dimensions to restore soil quality and thus restore wetland ecosystems is the goal of the research. Introducing decomposers such as earthworms living in the soil water birds such as egrets and algae plants, regularly sample and determine the concentration of metal ions and Ph of the soil, to monitor through the degree of soil restoration. This research will provide a new method for restoring wetland ecosystems in a simple way where no environmentally unfriendly substance is introduced. What is more, insufficient attention to the protection of wetland ecosystems, also leads to their pollution. According to research done by scientists in recent years, the main monitoring indicators for soil quality are Ph, the concentration of heavy metal ions, and biodiversity (including genetic diversity, species diversity, and ecosystem diversity) is an important factor of the ecosystem, and increasing the variety and number of organisms is one way to increase biodiversity. Due to the high biodiversity of wetland ecosystems, the resilience stability is poor, and restoring damaged wetland ecosystems is a difficult task.

In this article, current research on the soil of wetlands is analyzed to demonstrate that introduction of organisms can restore soil quality in wetland ecosystems, providing a new method for restoring wetland ecosystems.

2. Current Pollutions of Wetland Soils

Nowadays, soil in the world is being damaged by people and it exists everywhere. From a global perspective, as shown in Table 1, it is estimated that the world emitted cadmium (Cd) into the environment each year 1.0×10^6t, mercury (Hg) about 1500t, lead (Pb) about 5×10^6t, copper (Cu) about 3.4×10^6t, nickel (Ni) about 1.0×10^6t into the soil, thus soil heavy metal pollution has become a major environmental problem faced by all countries in the world one [1].

Table 1. Concentration of heavy metals in soils [1]

Heavy metal ions	Cd	Hg	Pb	Cu	Ni
Emission each year(t)	1.0×10^6	1500	5×10^6	3.4×10^6	1.0×10^6

Known as the "lungs of the earth", the soil of wetland ecosystems, which are closely related to carbon sequestration, has also been greatly damaged. Wetlands are known as the "kidney of the earth" and are regarded by humans as one of the most important natural living environments on earth. Due to the low-lying terrain, wetlands are prone to a continuous collection of heavy metals produced by human activities under the action of hydrodynamics and have become one of the important sources of heavy metals [2].

Not only that, but salinization is also a huge problem for wetland soils. Cang said saline soil improvement along beaches is an important task. The salt content in the soil is mainly composed of HCO_3^-, CO_3^{2-}, SO_4^{2-}, Cl^- four kinds of anion and Ca^{2+}, Mg^{2+}, and Na^+ three cations, among which NaCl, Na_2CO_3, and Na_2SO_4 are more harmful, and the large amount of Na^+ will make the colloids unable to form an agglomerate structure, resulting in cold, hard, plate phenomena in the soil, endangering plant growth [3].

So, the limits to the soil quality of wetland ecosystems need to be confirmed. Qu Fanzhu et al. and Qu et al. [4] studied the carbon, nitrogen, and phosphorus stoichiometry characteristics of soils in different reed wetlands in the Yellow River Delta and found that C/N was higher than the national and global average, while N/P was lower than average, and the soil of the wetland as a whole was limited by N. Liu Zhanhang et al.[5] studied the soil stoichiometry characteristics of wetlands under different invasion years of rice alterniflora and found that soil C/P and N/P in the wetland of the Yellow River Estuary were affected by soil conductivity, bulk density, and water content. Li et al. [6] found that soil water content, salinity, and pH are important factors affecting soil carbon, nitrogen, and phosphorus and their stoichiometric ratio in wetlands in the Yellow River Delta.

3. Cause of Degradation of Wetland Soil

The soil of wetland ecosystems is destroyed (heavy metal pollution, soil acidification, soil salinization, etc.) for a number of reasons.

3.1. Heavy Metal Pollution

Firstly, the pollution discharged by the factory, residues of fertilizers and pesticides will enter the wetland ecosystem soil along the river, and heavy metals will migrate and transform into different directions of the soil due to the comprehensive influence of factors such as tillage, leaching and tilling after entering the soil. In some wetland ecosystems at high latitudes or altitudes, affected by coal-fired heating and biomass combustion in winter in cold areas, a large number of heavy metal elements are stored in snow cover (snow cover) through atmospheric settlement, and infiltrate into the soil through snowmelt water or generate snowmelt runoff into the wetland ecosystem during the snowmelt period, as a result, different soil layers are contaminated [7].

3.2. Soil Salinization

Climate can affect the movement of water and salt seriously, and it is the main reason for the salinization of the land. The driest climate-- desert climate is nearly not possible to create an environment that forms wetland ecosystems, but there are many wetland ecosystems in the area of monsoon climate, monsoon climates have distinct rainy and dry seasons. When the dry season comes, the evaporation of soil is much greater than the water absorption, the direction of operation of soil moisture is the most important factor, the soluble salts in the origin material of the soil cannot be leached down, the evaporation can raise the groundwater salt to accumulate in the surface soil, and the soil it is hard to discharge, and prolonged accumulation and concentration form a salinized and alkalized soil. Not only that, in warm temperate semi-humid monsoon climate areas, soil salt accumulation is also very likely to occur, rainfall gradually increases from north to south, from inland to coast, dryness gradually decreases, and precipitation contours slope northeast to southwest. In winter and spring, rainfall is less and dry, especially when the surface is warmed up in spring and there is no vegetation cover, the surface evaporation is obvious. In summer, there is more rainfall, and precipitation can account for more than half of the annual precipitation, and the soil moisture at this time is the following: After autumn, the temperature gradually decreases, precipitation decreases significantly, and evaporation increases. Therefore, under such circumstances, salt accumulation in spring and autumn, desalination in summer, and relatively stable winter are formed, and the seasonal distribution of rainfall is an important reason for soil salinization [8].

3.3. Soil Erosion

Additionally, soil erosion, a widely known major environmental problem, is commonly known for being responsible for the loss of topsoil by erosion and has obvious implications for the agriculture industry. However, aside from the potential loss of agricultural productivity, soil erosion, and sedimentation more importantly also result in damaging and destroying wetland habitat. Sedimentation of wetlands reduces wetland productivity, degrades wildlife habitat, and can eventually result in the loss of the wetland itself by infilling.

Normally, soil erosion is a natural process where the soil is carried from one place to another by wind, water, and other forces of nature. However, as human interference steps in, this process is accelerated. Lands, where humans have prepared for planting crops, have looser soil. This causes the soil to get carried away quicker than normal. These sediments would then settle into piles when the speed of the water slows down. Buffer zones of undisturbed vegetation protect wetlands by slowing water flow and allowing most sediment to settle before reaching the wetlands. Wetlands without adequate buffer zones and those closely associated with streams are particularly vulnerable to degradation through soil erosion.

3.4. Soil Acidification

Last but not least, soil acidification, i.e., the change in pH is because of two main reasons. These two reasons are natural acidification and acid deposition. Natural acidification is an inevitable acidification phenomenon commonly found in agricultural production, to a large extent, it means the large number of leaching of salt-based ions in the earth caused by large amounts of precipitation and the exchange of hydrogen and aluminum content. With a large increase in the phenomenon, this acidification rate is slower [9].

Acid deposition, on the other hand, is due to human activities. It is due to wrong application of nitrogen fertilizer and continuous planting of acid-causing plants. Acid deposition refers to the combustion of coal, oil, or natural gas sulfur dioxide (SO2) is produced during the combustion and exhaust emissions of automobiles and sulfur and nitrogen compounds such as nitrous oxide (N2O) undergo diffusion and precipitation. The phenomenon of falling to the ground by processes such as gravity is called acid deposition. Improper application of nitrogen fertilizer application of ammonium sulfate, ammonium chloride, and other physiology acidic fertilizer, ammonium ion oxidation is absorbed by crops and carried away. At the same time, hydrogen is separated increasing the content of seed and aluminum ions, resulting in a decrease in soil pH. Continuous planting of acid-causing plants is sucked during crop growth collecting massive salt-based ions is one of the important causes of soil acidification. One especially long-term cultivation of single plants, carried away by straw and seeds. The salt-based ions have not been replenished for a long time, resulting in an imbalance of soil ions, and pH decreases [9].

4. Solution Towards Problems

According to sampling observations, the middle soil structure is loose and has good permeability, while the compactness and water retention performance of the deep soil are better, and heavy metals will be enriched from the middle layer to the deep layer under the action of precipitation, and the clay content of the deep soil in this study is slightly higher than that in the middle layer, which also explains the peak of some heavy metal elements in the bottom soil to a certain extent cause[2]. Therefore, increasing the degree of looseness and permeability of the soil will help reduce the concentration of heavy metal ions in the soil. Worms in the earth (for example, earthworms) often move in the soil and plays the role of conveying drawings, and microorganisms in the earth can promotes soil permeability. Therefore, the soil is needed to be appropriate amounts of animals and microorganisms are added to improve biodiversity to improve soil quality.

Plants are also important. Yu et al. did research in saline soil of ancient Great Lake wetlands [10]. The samples of original soil (OS), woodland soil (WS), cultivated land soil (CS) and lakeshore soil (LS) were collected from 0-20 cm from the surface, and repeated 3 times under each habitat type conditions, each time 5 small samples (2 m×2 m range in 4 vertices and center points) were taken to remove impurities such as stones and plant roots200 g per part, 5 small sample sites of soil were well mixed, and 5g was loaded into the soil sample live bacteria preservation solution. Label all soil samples in turn and cryostore all soil samples and bring them back to the laboratory. The MIO-BIO PowerSoil DNA Isolation Kit was used to extract DNA from 12 soil samples, and the physicochemical properties of 12 soil samples were determined with reference to the Bosdan soil analysis method, each sample was repeated 3 times, and the PE reads of 12 soil bacterial and fungal samples were obtained by sequencing, and after distinguishing each sample according to Barcode, the sequence was quality controlled and filtered, and the sequence with a length of less than 200 bp was deleted. Barcode and primer sequences were removed, effective sequences of soil bacteria and fungi were obtained, sequence splicing was performed according to overlap relationship, and the spliced sequences were quality controlled and filtered again, and finally the optimized sequences of bacteria and fungi were obtained. At the 97% similarity level, the optimized sequences were clustered into Operational taxonomic units (OTUs) for species classification, and the relative abundance information of each OTU in each soil sample was counted, divided into two groups: bacteria and fungi, as shown in the figure. According to the statistical chart data, the microbial species richness of WS (woodland soil) is much greater than that of OS (original soil).

Thus, increasing the number of plants can also contribute to biodiversity as a whole and can restore the soil more efficiently. Not only that, but this research also found that soil clay, SOM and weight of the metals were significantly positively correlated, and the average particle size was significantly negatively correlated with each heavy metal, because fine-grained soil had a large specific surface area and higher surface activity, which was more conducive to the adsorption of heavy metals. While SOM has a high cation exchange amount, and has a large number of different functional groups, they can adsorb metal elements through surface precipitation, complexation and ion exchange. In addition to V, soil pH is significantly negatively correlated with each heavy metal element, because the lower the soil pH, the more H^+, the more heavy metals are desorbed, the stronger their activity, so heavy metals are not easy to enrich. TP had no significant correlation with each heavy metal, and it could be seen that TP had a very weak effect on the enrichment of heavy metal content in wetland soil, while TN was significantly positively correlated with each heavy metal, and TN in soil was mainly organic nitrogen, and TN and SOM were positively correlated in this study [10]. Therefore, the content of sand in the soil needs to be increased and pH value of the earth needs to be risen appropriately to reduce the pollution of heavy metals.

There is another experiment in article of Li et al. [11]. The root soil (0-2cm, 2-25cm) was collected on June 20 of the plant growing season, and the soil samples were fully mixed at 5 points in each test sub-section, and the fresh soil samples were divided into 2 parts after passing through a 2mm sieve, one part was brought back to the laboratory with low temperature refrigeration and frozen at -20 °C for the determination of soil microorganisms, and the other part was brought back to the laboratory for indoor air drying for the determination of soil physical and chemical attributes. In addition, the Mothur software was used to calculate the diversity index (Chao-1, Shannon and Simpson index). Clustering analysis based on Bray-Curits distance algorithm was performed using R software. The Pearson correlation coefficient is used to analyze the correlation between soil physicochemical attributes and the diversity of soil bacterial communities. R software was used to perform redundancy analysis (RDA) of environmental factors and bacterial community structure. The Duncan method in SAS was used to test the significance of differences between soil properties and microbial indexes at different points ($P < 0.05$). It is illustrated that the bacterial diversity index and richness index were significantly negatively correlated with K+ and Cl- ($P < 0.05$), and soil water content and Chao-1 index ($P < 0.05$) in 0-2 cm soil layer as shown in fig. 1 [11].

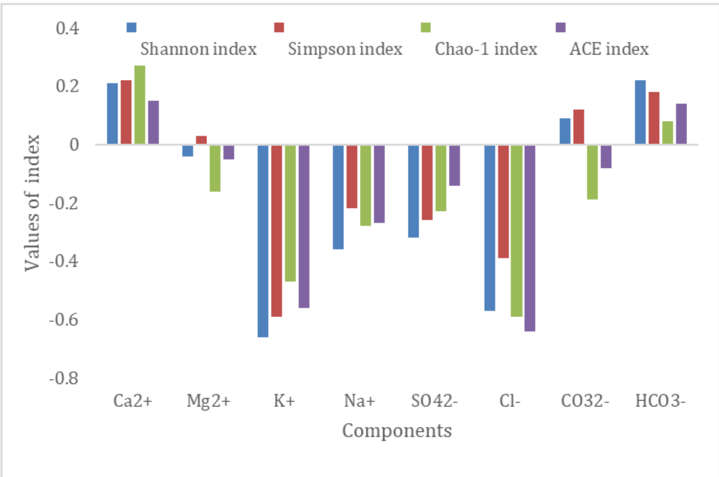

Figure 1. Relation between index and concentration of metal ions in 0-2cm soil layer [11]

The bacterial diversity and richness index of 2-25 cm soil layer was significantly negatively correlated with soil EC and SO_4^{2-}, it can be seen that microorganisms can reduce the concentration of salt ions in the soil as shown in fig. 2 [11].

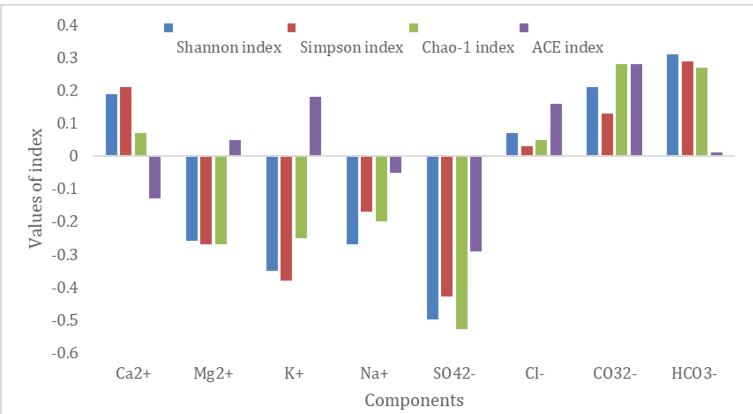

Figure 2. Relation between index and concentration of metal ions in 2-25cm soil layer [11]

As for soil erosion, plants can play a big role. The mechanism of vegetation to prevent water erosion, first of all, is that the vegetation canopy and dead branches and leaves can reduce raindrop splashing and intercept part of the precipitation, decrease surface runoff, and guard against surface soil erosion. Secondly, having a great structure, vegetation is a must factor, and vegetation can improve soil porosity and water permeability, thereby reducing surface runoff and its flow rate. Third, the litter layer can filter sediment and sponge-like water absorption and prevent the further development of surface runoff erosion and surface erosion and trench erosion through the stagnation, filtration and dispersion of surface runoff. Fourth, the root system of plants, intertwined like a network in the soil, consolidates the soil, prevents the formation of slope erosion, reinforces slopes and fixes steep slopes, enhances the erosion resistance of soil, and reduces the occurrence of landslides, debris flows and flash floods. Therefore, increasing the number of vegetation species can control soil quality in wetland ecosystems [12]. All in all, plants, animals, microorganisms are all very important for the quality of soil in wetland ecosystems, thus increasing biodiversity is a good method to restore the soil quality.

5. Conclusion

Therefore, in view of the current situation of soil destruction in different wetland ecosystems, different approaches should be taken to improve biodiversity to restore soil quality. As for wetland ecosystems in monsoon climate zone, soil erosion and salinization are common. Introduce more plants that can resist wind and water erosion to protect the soil; Introduce an appropriate number of bacteria, fungi to reduce the concentration of salt ions in the soil. As for wetland ecosystems near the beach, salinization is the most important problem, it can also be introduced a large number of bacteria, fungi and other microorganisms. As for wetland ecosystems which are close to factories or cities, heavy metal pollution and soil acidification are the most noteworthy problems. In these wetland ecosystems, the introduction of soil animals is necessary. Improving the biodiversity of wetland ecosystems can not only restore the soil, but also avoid the production of too many harmful substances and cause bio enrichment, and then return a beautiful environment to the "lungs of the earth".

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

References

[1] Chen Shibao, Wang Meng, Li Shanshan, et al. Current situation and problems of prevention and control of heavy metal pollution in farmland in China [J]. Earth Science Frontiers, 2019, 26 (06): 35 - 41. DOI: 10.13745/j.esf. sf.2019. 8. 6.

[2] Ge Lei, Fang Fengman, Zhou Hao, et al. Vertical distribution characteristics and migration of heavy metals in different types of soil in Caizi Lake wetland [J/OL]. Environmental Chemistry: 1-9 [2023-08-13]. http://kns.cnki.net/kcms/detail/11.1844.X.20230628.0926.004.html.

[3] Cang Jinshun. Review of heavy metal pollution control and saline-alkali soil improvement in wetlands along beaches [J]. Journal of Yancheng Institute of Technology (Natural Science Edition), 2016, 29 (03): 15 - 17+45.DOI: 10.16018/j.cnki.cn32-1650/n.201603003.

[4] Qu Fanzhu, Meng Ling, Fu Zhanyong, et al. The stoichiometry characterization of carbon, nitrogen and phosphorus in different reed-dominated coastal wetland habitats [J]. Acta Ecologica Sinica, 2018, 38 (5): 1731 - 1738.

[5] Liu Zhanhang. Stoichiometry characteristics of vegetation and soil ecology in coastal wetlands under the invasion of the Yellow River Delta [D]. Ludong University, 2022.DOI: 10.27216/d.cnki.gysfc.2022.000683.

[6] Li Dongxue, Li Yina, Xie Yiliang, et al. Effects of ecological restoration on soil biogenic elements and their ecological stoichiometry in the Yellow River Delta, China [J]. Frontiers in Marine Science, 2022, 9, doi: 10.3389/fmars. 2022. 993202.

[7] Zhang Fuxiang. Study on heavy metal pollution and ecological environment effects in typical wetland ecosystem of Sanjiang Plain [D]. Northeast Agricultural University, 2021.DOI: 10.27010/d.cnki.gdbnu.2021.000105.

[8] Hu Minghua. Investigation of soil pollution status and environmental protection [J]. Modern Agricultural Research, 2021, 27 (05): 36 - 37.DOI: 10.19704/j.cnki.xdnyyj.2021.05.015.

[9] Yu Tianyi, Sun Xiushan, Shi Chengren, et al. Chinese Journal of Ecology, 2014, 33 (11): 3137 - 3143. DOI: 10.13292/j.1000 - 4890.20141022.005.

[10] Yu Shaopeng, Shi Chuanqi, Hu Baozhong et al. Analysis of saline-alkali soil microbial community structure and diversity in ancient Great Lake wetland [J]. Acta Ecologica Sinica, 2020, 40 (11): 3764 - 3775.

[11] Li Ming, Bi Jiangtao, Wang Jing. Distribution characteristics of bacterial community diversity and its influencing factors in salinized soil in different areas of Ningxia [J]. Acta Ecologica Sinica,2020,40(04): 1316 - 1330.

[12] Li Chunfeng, Wu Lidong. The role and application of plant measures in soil and water conservation in development and construction projects [J]. Science and Technology in Western China, 2011, 10 (19): 18 - 19.