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REGULATION OF CARBON SEQUESTRATION POTENTIAL IN THE LAKE-MARSH WETLAND SYSTEM FACING TO CLIMATE CHANGE

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ABSTRACT

With significant impacts of climate change, the water amount and lake-marsh pattern has varied in the lake-marsh wetland system, which would damage the ecological functions. Therefore, several regulation projects were implemented in the natural system, their advantages need to be proved. The Wolonghu Wetlands were applied as an example for exploring the effects of regulation projects on the carbon sequestration potential and corresponding ecological service value. The main results show that the water volume in the Wolonghu Wetlands has basically decreased during 1994 to 2013 as the natural runoff reduced, which further influenced the lake-marsh pattern as the wetland area decreased. The carbon sequestration potential without and with regulation projects was 1,135,900.34 t/a and 1,341,823.80 t/a, respectively. The ecological service value of carbon sequestration potential without and with regulation projects was 8.75 billion yuan/a and 10.33 billion yuan/a, respectively. The carbon sequestration potential and corresponding ecological service value with regulation projects was 18.13% and 18.6% greater than without regulation projects, respectively. It can be inferred that appropriate regulation projects could increase the carbon sequestration potential and corresponding ecological value of the lake-marsh wetland system, which was proved an efficiency approach facing to climate change on achieving the goal of low-carbon development.

Keywords: carbon sequestration, ecological service value, lake-marsh wetland system, climate change, regulation projects, Wolonghu Wetlands

NONMENCLATURE

Abbreviations	
CO_2	carbon dioxide
CSP	carbon sequestration potential
CSR	carbon sequestration rate
NPP	biomass per unit area
ESV	ecological service value
Symbols	
A	wetland area
α	coefficient of CO_2 to the dry matter of wetland plants
W_m	dry matter of wetland plants
P_{CO2}	unit value of carbon sequestration potential
F_{CO2}	reforestation cost
T_{CO2}	international tax rate of CO_2

1. INTRODUCTION

With the increase of carbon dioxide (CO_2) concentration and the aggravated trend of global warming [1,2], the carbon sequestration by terrestrial ecosystems has become more and more urgent at present [3,4]. As one of the three main components of the terrestrial ecosystems, the global wetland area occupies 4% to 6% of the earth [5,6]. While wetland is the world's largest carbon sink, with carbon storage of about 770 billion tons, accounting for 35% of the global carbon storage [7,8]. The global climate change has damaged certain ecological functions of wetland [9,10], how to maintain the ecological functions as well as augment the carbon sequestration potential become hot issues.

China has the most wetland in Asia [11,12], it would be deeply influenced by the climate change and further accelerate the global warming as the carbon sequestration potential decreases. To solve this dilemma, regulation projects were proposed and implemented. However, the effects of regulation projects on the carbon sequestration potential has not been much evaluated.

Under these circumstances, this paper focuses on the effects of regulation projects on the carbon sequestration potential in the lake-marsh wetland system facing to climate change. The main objectives were to: i) propose the calculation method of carbon sequestration potential and corresponding ecological service values; and ii) explore the difference of carbon sequestration potential and corresponding ecological service values with and without regulation projects in the Wolonghu Wetlands. This study could provide references for regulation of carbon sequestration potential, low-carbon development and relevant research. And the results in the Wolonghu Wetlands would support and guide the local adaptation strategies for the climate change.

2. MATERIALS AND METHODS

2.1 Study site

The Wolonghu Wetlands (42°31′-43°02′N, 122°45′-123°37′E) is located in Kangping County, Liaoning Province, northeastern part of China (Fig. 1). The region experiences temperate continental monsoon climate. The annual average precipitation was 556.37 mm during 1961 to 2016, mainly concentrated from June to September, accounting for 74.56% of the annual precipitation.

The Wolonghu Wetlands is an important ecological barrier to resist southward expansion of the Horqin Desert, also is a significant stopover and energy supplement site for the global birds migrating in the route of East Asia to Australia [13,14]. Therefore, the Wolonghu Wetlands plays a significant ecological role in Northeastern China. While the climate change aggravates the water amount in the Wolonghu Wetlands, which decreases the water body area as well as the wetland area. To protect the species diversity and augment the carbon sequestration as much as possible in the Wolonghu Wetlands, it is of great importance to study the appropriate regulation measures and projects, which can guarantee the sustainable development of Wolonghu Wetlands and Kangping County. A L-type dam with total length of 8.7 km has been built since 2014, which could guarantee the food supply and habitat condition for wild birds, especially the migratory birds.

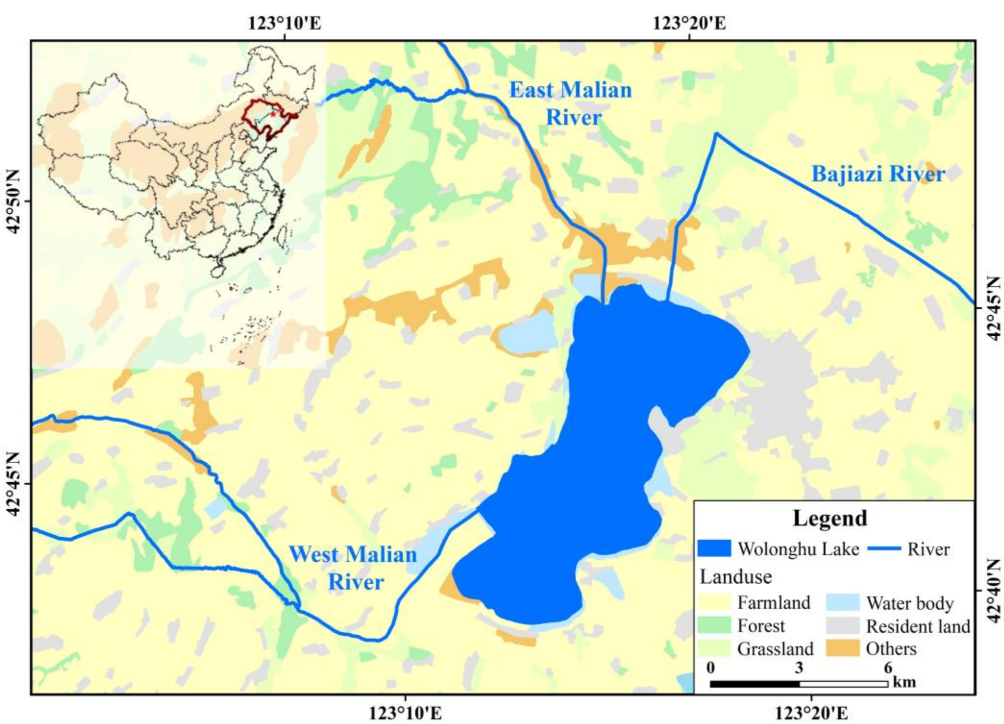

Fig 1 The Wolonghu Wetlands.

2.2 Methods

To understand the climate change impacts on the Wolonghu Wetlands in recent years, we analyzed the annual water volume in the system and the annual runoff from the upstream from 1994 to 2013. Meanwhile, the satellites images were downloaded from Landsat 8 OLI (Operational Land Imager), to analyze the water surface variation under climate change.

Facing to the climate change, regulation projects are proposed to be implemented to maintain the ecological functions in the lake-marsh system. First, the lake-marsh wetland pattern with and without regulation projects was explored on the ArcGIS. Then, the carbon sequestration potential and ecological service value of carbon sequestration potential were evaluated. Finally, we compared the above two indexes in different situations. Notably, we focused on the CO_2 sequestration in the wetland in this study. Eq. (1)-(3) calculate the carbon sequestration potential.

$$CSP = CSR \times A \tag{1}$$

$$CSR = \alpha \times W_m \div A \tag{2}$$

$$W_m = NPP \times A \tag{3}$$

Where, *CSP* is the carbon sequestration potential, *CSR* is the carbon sequestration rate, *A* is the wetland area, *α* is the coefficient of CO_2 to the dry matter of wetland plants (α is equal to 1.63), W_m is the dry matter of wetland plants, *NPP* is the biomass per unit area.

Eq. (4) and (5) calculate the ecological service value of carbon sequestration potential.

$$ESV = CSP \times P_{CO2} \tag{4}$$

$$P_{CO2} = (F_{CO2} + T_{CO2}) \div 2 \tag{5}$$

Where, *ESV* is the ecological service value of carbon sequestration potential, *CSP* is the carbon sequestration rate, P_{CO2} is the unit value of carbon sequestration potential, F_{CO2} the reforestation cost, T_{CO2} is the international tax rate of CO_2.

3. RESULTS AND DISCUSSION

3.1 Evolution of water volume and water surface area in recent 20 years

The annual water volume in the Wolonghu Wetlands varied correspondingly with the annual runoff measure at the Fudedian Station (Fig. 2). During 1994 to 2013, the water volume and annual runoff first decreased from 1994 to 1997, then sharply augmented to the maximum value in 1998, followed by the continuing decrease during 1998 to 2000, with the minimum value in 2000. After 2002, the water volume and annual runoff varied with periodic fluctuation, about 3 to 5 years, while the values generally reduced compared with the former years. Fig. 3 plots the Landsat 8 satellite images of the Wolonghu Wetlands in 1998, 2001 and 2013, it can be learned that the water surface area decreased significantly in 2001 compared to 1998, then recovered in 2013, while still smaller than the status presented in 1998.

With the global warming and decreasing precipitation, the water volume in the Wolonghu

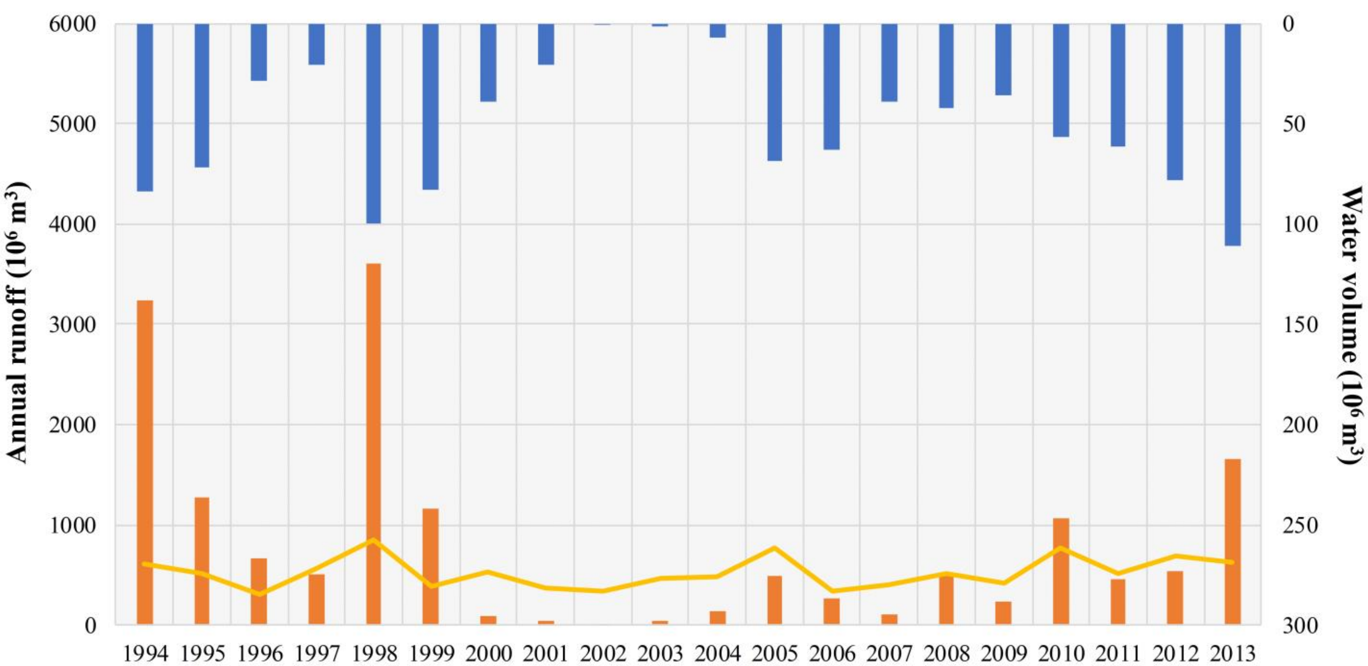

Fig 2 The annual water volume and annual runoff of the Wolonghu Wetlands from 1994 to 2013.

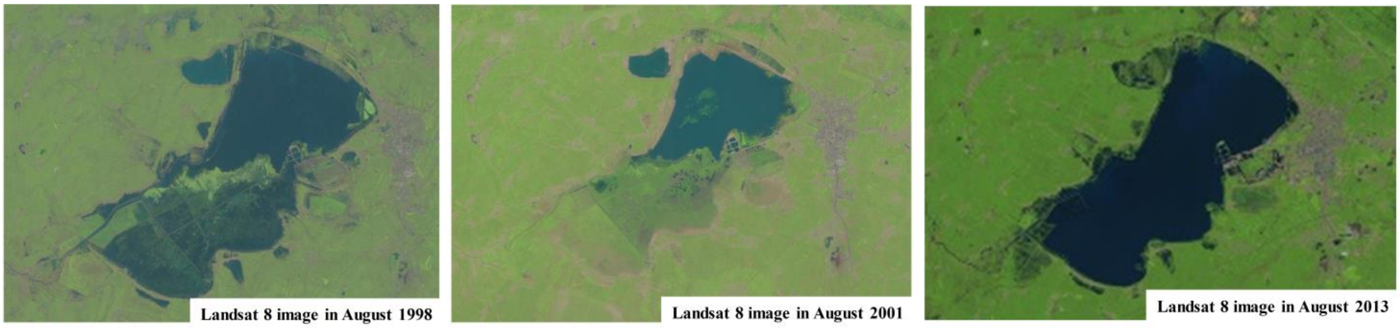

Fig 3 The variation of water surface area of the Wolonghu Wetlands during 1994 to 2013.

Wetlands has basically decreased during the recent 20 years as the natural runoff reduced. The water surface area has reduced correspondingly. The socio-economic development of Kangping County (one of the poor counties in China) aggravates the water competition between the Wolonghu Wetlands and its surrounding environment. Meanwhile, the water interception is serious in the upstream irrigation area. The water and land competition between lake and marsh wetlands also exist inside the Wolonghu Wetlands as to protect the wetland habitat of *Grus leucogeranus*. The natural condition cannot meet the required lake-marsh pattern. Therefore, it is of great significance to apply certain regulation projects.

3.2 Comparison of carbon sequestration potential with and without regulation projects

Fig. 4 presents the lake-marsh distribution pattern without regulation projects (Fig. 4a) and with regulation projects (Fig. 4b) of the Wolonghu Wetlands at water level of 87.2 m, which is the minimum ecological water level according to previous studies [15]. The water surface area was 45.27 km^2 with water level of 87.2m. Considering the optimal water depth demand of the protected animal *Grus leucogeranus* is 0.4 m, the marsh area was 11.97 km^2 without regulation projects, mainly concentrated surrounding the lake. With regulation projects, the lake was basically located in the north of the regulation projects, and the marsh was located in the south of the regulation projects. The corresponding marsh area was 14.14 km^2.

The main plants in the Wolonghu Wetlands are *Nelumbo SP.*, *Phragmites australis* and *Potentilla*

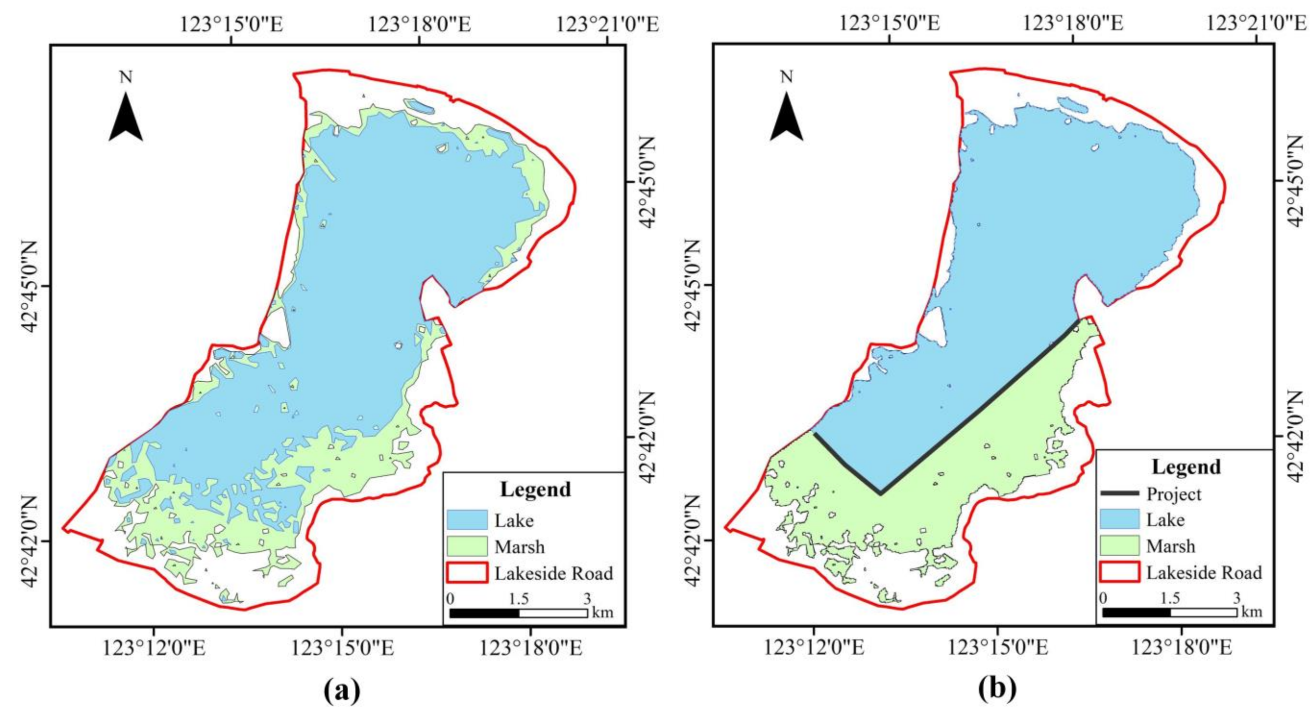

Fig 4 The lake and marsh distribution in different situation. (a) without regulation projects. (b) with regulation projects.

anserina L., with biomass density of 1142.69 t/km^2/a, 33,844.34 t/km^2/a and 23,231.13 t/km^2/a, respectively. Thus, the total biomass density in the Wolonghu Wetlands is about 58,218.16 t/km^2/a. The unit value of carbon sequestration potential is the average value of the reforestation cost and the international tax rate of CO_2, of 770 yuan/t. We calculated the carbon sequestration potential and corresponding ecological service value in both two conditions. For the lake-marsh pattern without regulation projects, the carbon sequestration potential was about 1,135,900.34 t/a, the carbon sequestration value was 8.75 billion yuan/a. For the lake-marsh pattern with regulation projects, the carbon sequestration potential was 1,341,823.80 t/a, the carbon sequestration value was 10.33 billion yuan/a.

It can be learned that the appropriate regulation projects can significantly augment the wetland carbon sequestration potential and the ecological service value of the carbon sequestration potential. Compared to the lake-marsh pattern without regulation projects, the carbon sequestration potential and relevant ecological service value in the lake-marsh pattern with regulation projects increased by 18.13% and 18.06%, respectively. The results demonstrate that the appropriate regulation projects could partially solve the problems causing by climate change, such as, water deficit and wetland area reduction. The core is to achieve the relatively optimal lake-marsh pattern, which could further increase the carbon sequestration potential and corresponding ecological value of the lake-marsh wetland system.

4. CONCLUSION

This paper focuses on the effects of regulation projects in the lake-marsh wetland system facing to climate change on the carbon sequestration potential and corresponding ecological service value. The Wolonghu Wetlands were applied as an example. It is found that the water volume in the Wolonghu Wetlands has basically decreased during 1994 to 2013 as the natural runoff reduced. The climate change has impacts on the lake-marsh pattern, the wetland area decreased. Under these circumstances, regulation projects were implemented to maintain the ecological functions of the lake-marsh system. The carbon sequestration potential without and with regulation projects was 1,135,900.34 t/a and 1,341,823.80 t/a, respectively. The ecological service value of carbon sequestration potential without and with regulation projects was 8.75 billion yuan/a and 10.33 billion yuan/a, respectively. The carbon sequestration potential and correspond ecological service value was 18.13% and 18.6% higher with regulation projects compared to without regulation projects, respectively. This paper indicates that the appropriate regulation projects could increase the carbon sequestration potential and corresponding ecological value of the lake-marsh wetland system, which was an efficiency approach facing to climate change, also reaches the goal of low-carbon development on ensuring the ecosystem functions. The results could support and guide the local adaptation strategies for the climate change in the Wolonghu Wetlands. Meanwhile, this study could guide the regulation of carbon sequestration potential, low-carbon development and relevant research.

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