



# Article Evaluation of Ecosystem Services in the Dongting Lake Wetland

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Abstract: The Aeronautical Reconnaissance Coverage Geographic Information System (ArcGIS) 10.2 and Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) model are used to comprehensively evaluate ecosystem services in the Dongting Lake Wetland, focusing on water yield, soil conservation, carbon storage, and snail control and schistosomiasis prevention. The spatial and temporal variations of these services, as well as their variations between different land use types in a period of 10 years from 2005 to 2015, are investigated, and the value of such services is then estimated and analyzed. The results of this study show various temporal and spatial trends in the ecosystem services, such as (1) the overall increase of all these services during the study period (although significant in some services, such as schistosomiasis patient reduction, by 86.8%; and, very slight in some others such as soil conservation, only by 0.02%); (2) different orders of the services values that are based on different land use types; and, (3) the temporal changes in the proportion of the values of different ecosystem services with respect to the total services value. Besides, it is concluded that the evaluation of ecosystem services of a certain wetland is heavily dependent on the characteristics of the area where the wetland is located, and the assessment indicators and methods should be selected based on such characteristics through the analysis of the results and a comparison with the findings of literature.

**Keywords:** InVEST model; wetland; ecosystem service assessment; value analysis; *schistosomiasis* prevention

# 1. Introduction

Ecosystem service is the natural environmental condition and utility that the ecosystem and ecological process form and maintain [1,2]. The millennium ecosystem assessment (MEA) has found that 60% of global ecosystem services have deteriorated, with human activity being one of the main causes of this adverse change [3,4]. Wetlands, as important habitats of humans, only cover 1% of the earth's surface, but they provide habitat for about 20% of all species worldwide [5,6]. Wetland ecosystem services are crucial for the survival of humans and a range of other animals, by supplying freshwater and aquatic products, flood control, climate regulation, biodiversity protection, etc. [7]. It

has been estimated that lake wetland ecosystem services provide 23.2% of the total value of global ecosystem services [8].

Numerous scholars have assessed wetland ecosystems at different geographical locations and scales. For instance, Great Lakes Restoration Initiative Task Force systematically assessed the ecosystem services of the Great Lakes of North America in 2010, and showed that a number of management and engineering measures improved these services [9]. Wong et al. (2016) tested a new approach to evaluate water storage and local climate regulation of a green infrastructure project on the Yong ding River in Beijing, China, showing that the lakes and wetlands have increased local evapotranspiration on the Yongding Corridor by approximately 0.71 mm per day [10]. In another study, Bikash et al. (2015) pointed out that the economic values of the selective ecosystem services of the Koshi Tappu Wildlife Reserve, Nepal, equaled \$16 million per year [11]. Around the world, several countries, including Canada and China, have evaluated their wetland ecosystem services, but no universal evaluation index system of lake wetland ecosystem services has been established, and there has also been no evaluation of the effects of wetland ecosystem services on human health [12–17].

There is a lack of regional validation of parameters in the use of evaluation models, with only a few evaluations on cultural or support services in wetland ecosystem services, which makes the selection of indicators one-sided. In this sense, it is necessary to further unify the methods, indicators, and other aspects of ecosystem services of different scales and landscape types. At present, numerous studies are available regarding the quantitative evaluation, model simulation, and scenario analysis of ecosystem services, while using different types of ArcGIS (Aeronautical Reconnaissance Coverage Geographic Information System)-based support tools to fully integrate geography, ecology, economics, etc. The number and types of models for ecosystem services assessment have dramatically increased over the past decade. IMAGE (Integrated Assessment of Global Environmental Change), SAORES (Spatial Assessment and Optimization Tool for Regional Ecosystem Services), ARIES (Artificial Intelligence for Ecosystem Services), Costing Nature, and LUCI (Land Utilization and Capability Indicator) are some examples. For instance, ARIES is a model built via an expert knowledge method, which might result in the one-sidedness of evaluation results due to experts' knowledge reserve and subjective factors. The models IMAGE, Costing Nature, and LUCI are based on a global data set for ecosystem service evaluation [18,19]. The SAORES model evaluates ecosystem services in the context of ecological restoration and the management of the Loess Plateau in China, ignoring the accuracy verification and uncertainty analysis of service evaluation [20]. The InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) model inputs the relevant data of the study area and reflects the impacts of ecosystem structure and function on service flow and value through the simplification of biophysical processes [21]. The multi-scale data input and the result output have made the InVEST model a comprehensive ecosystem service evaluation and balance model that is widely used in 20 countries and regions, for example in the assessment of freshwater ecosystem services in the Tualatin and Yamhill basins, the Chubute River valley in southern Argentina, the Beijing mountain forest, etc. [22–25].

With the rapid development of social economy and the expansion of global population, the demand for land is constantly increasing in order to survive and obtain economic benefits. Consequently, wetland resources are under unprecedented pressure and are decreasing at the global level [26,27]. The Dongting Lake Wetland is the largest lake that leads to the Yangtze River and the second largest freshwater lake in China. It provides favorable conditions for the breeding of snails and it is a severe epidemic area of *schistosomiasis*, seriously endangering the health of the local people. *Schistosomiasis* is a parasitic disease that affects both humans and animals and, globally, it is the second largest tropical parasitic disease after malaria [28,29]. It is endemic in about 78 countries in the tropical and subtropical regions of the world [30]. More than 95% of the *Schistosomiasis* in China are distributed in the Yangtze River basin tidal land, which seriously endangers wetland ecosystems. *Oncomelania hupensis*, which is a tropical freshwater snail, is the only intermediate host of *Schistosoma japonicum* and it can live in moist, shaded, and alternate land and water wetland environments. Thus, snail eradication is an effective measure for blocking the transmission of *schistosomiasis* [31,32]. At present, there are various technical

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systems for snail control, including drug snail control, agricultural engineering measures, and water conservancy projects. The impermanence of snail control effectiveness, the higher costs on capital, and the labor-intensity are substantial disadvantages between water conservancy projects and ecological environmental protection. The 65th World Health Assembly has passed Resolution WHA65.21, which proposes eliminating *schistosomiasis*, a neglected tropical disease, in low-transmission areas of the world. Previous research has shown that the *Schistosomiasis* Prevented Forestry Project is an important measure for the comprehensive control of *schistosomiasis* in China, with the advantages of long-term effects and prevention [33–37]. The project is based on the construction of forests for snail control and *schistosomiasis* prevention, which aims to change the environment for snail breeding, inhibit the growth and development of snails, isolate the source of infection, and control the epidemic of *schistosomiasis* [38].

Recently, China has built a total of 5189 km<sup>2</sup> of snail control and *schistosomiasis* prevention forests, decreasing the snail density and infection rate of human by 89.8% and 51.0%, respectively [39]. The construction of these forests, which also provide a variety of other ecosystem services, such as carbon fixation, water and soil conservation, and biodiversity protection, has reached 1640 km<sup>2</sup>, in 2015, along the Dongting Lake Wetland beach. However, such ecosystem services, especially snail control and schistosomiasis prevention, have been paid less attention in previous studies on the Dongting Lake Wetland area (e.g., Mao et al., 2007, where some ecosystem services, such as agricultural and fishery productions, tourism and leisure, climate regulation, and flood storage were investigated [40]). On the other hand, most studies regarding the snail control and *schistosomiasis* prevention in the literature have mainly focused on this issue in terms of mechanism and construction technology [39,41]. This study focuses on the ecosystem services in the Dongting Lake area that resulted from the construction of disease prevention forests, including snail control and *schistosomiasis* prevention, water yield, soil conservation, and carbon storage; and, evaluates them in a period of 10 years between 2005 and 2015. For this purpose, ArcGIS 10.2 and InVEST models (with the aid of market value and shadow engineering methods for service value estimations) are applied to (1) study the temporal and spatial variations of these ecosystem services in the study area; (2) explore their variations between different land use types; and, (3) estimate their value in 2005, 2010, and 2015.

## 2. Study Area and Data

## 2.1. Study Area

Dongting Lake is the second largest freshwater lake in China, which covers an area of 18,780 km<sup>2</sup> and combines Xiangjiang, Zijiang, Yuanjiang, Lijiang, and other water-flooded lakes in the Yangtze River floods during the flood season. It is located between N  $27^{\circ}39' \sim 30^{\circ}25'$  and E  $111^{\circ}19' \sim 113^{\circ}34'$ , with an average elevation of 33.5 m above sea level. Average annual temperature in the lake is  $17.0 \,^{\circ}C$ , with an average annual precipitation of  $1100-1400 \,$  mm. The soil pH ranges between 7 and 8.4. From June to August, the area is generally flooded; the difference between the highest water level in the wet season and the lowest one in the dry season in winter can reach 8–10 m, which makes the Dongting Lake Wetland a *schistosomiasis* epidemic area [42]. Figure 1 shows the geographic position of this area, which includes 17 counties and cities, such as Yueyang City, and Xiangyin, Huarong, and Li Counties in Hunan Province, covering an area of  $3.17 \times 10^{6} \,$  km<sup>2</sup>, accounting for 16.5% of the area of the province.

By the end of 2010, the area of snail control and *schistosomiasis* prevention forests totaled 701.86 km<sup>2</sup>, while, in 2015, this area amounted to 1334.66 km<sup>2</sup>, which greatly inhibited snail numbers and decreased the number of *schistosomiasis* patients. The proportion of arable land in the Dongting Lake Wetland accounts for more than 45%, followed by woodland and water area. The proportions of residential, unutilized, and grassland areas are comparatively small and below 5%. From 2005 to 2015, arable land, woodland, grassland, and water area decreased at different degrees, i.e., by 1% (313.90 km<sup>2</sup>), 0.35% (111.09 km<sup>2</sup>), 0.15% (45.99 km<sup>2</sup>), and 0.72% (228.25 km<sup>2</sup>), respectively. In contrast, the proportions of

residential and unutilized lands continued to increase by 1.34% (424.26 km<sup>2</sup>) and 0.88% (279.60 km<sup>2</sup>), respectively. Table 1 presents the land cover types and areas from 2005 to 2015.



**Figure 1.** Geographic location of the study region (**a**) in China; (**b**) in the vicinity of Hubei, Hunan and Jiangxi provinces; and (**c**) elevation map of the study area including Dongting lake.

Land Use Type _	Area				
	2005	2010	2015	Change Area	
Arable land	147.69	146.02	144.55	-3.14	
Woodland	102.29	101.93	101.18	-1.11	
Grassland	3.34	2.93	2.88	-0.46	
Waters	48.27	48.32	45.99	-2.28	
Residential land	8.99	11.01	13.24	4.24	
Unutilized land	6.85	7.25	9.64	2.80	

Table 1. Land cover types of the Dongting Lake Wetland between 2005 and 2015 ( $\times 10^2$  km<sup>2</sup>).

# 2.2. Data Sources and Processing

The land use maps (at a spatial resolution of 30 × 30 m) of the Dongting Lake Wetland from 2000 to 2015 were downloaded from the Resource and Environment Data Cloud platform [43]. Precipitation data of the Wetland during this period were acquired from the National Meteorological Information Center [44]. ArcGIS 10.2 conducted Kriging interpolation in the study area and the surrounding areas on precipitation data from 59 meteorological and hydrological stations and, subsequently, grid maps with a resolution of 30 m were generated for the related years. The Digital Elevation Model (DEM) data were generated in ArcGIS 10.2 by means of interpolation, cutting, and filling digital elevation data of Global Digital Elevation Model Version 2 (GDEM V2), with a high resolution of 30 m, which was sourced from Geospatial Data Cloud [45]. Soil data, including soil texture, topsoil organic carbon, and fractions of topsoil sand, silt, and clay were obtained from the Soil Map of China based on the Harmonized World Soil Database (version 1.1, with a 1:1 million map scale), which was created by the Cold and Arid Regions Sciences Data Center in 2009 [46], and ArcGIS 10.2 was used to obtain the soil grid maps with a resolution of 30 m. The carbon density values for each land use were collected from Li et al. (2003) and Wang et al. (2010) [47,48] based on the principle of similarity within the natural environment of the Dongting Lake Wetland.

#### 3. Methods

The data were firstly processed by using the ArcGIS 10.2 to develop an input for the analysis of the ecosystem services in this section, as discussed in the previous section. The InVEST model is then used, as described in Sections 3.1–3.3, to estimate water yield (the difference between precipitation and actual evapotranspiration), soil conservation, and carbon storage. Moreover, the Raster Calculator of ArcGIS 10.2 is applied to evaluate the snail control and *schistosomiasis* prevention, as presented in Section 3.4. Besides, the market value and shadow engineering methods were employed to calculate the values of the services.

## 3.1. Water Yield Model

The InVEST water yield module is an estimation method that is based on the water balance method, where the water yield of a grid unit refers to precipitation minus actual evapotranspiration, and the generated water yield data are the total amount and depth of water yield [49]. The module formula is as follows:

$$Y_{xj} = \left(1 - \frac{AET_{xj}}{P_x}\right) \cdot P_x \tag{1}$$

where  $Y_{xj}$  and  $AET_{xj}$  are the annual water yield and the actual evapotranspiration of the land cover type *j* in Grid *x* in mm; and,  $P_x$  is the precipitation of Grid *x* in mm. The annual potential evaporation for the 87 meteorological stations in the Dongting Lake Wetland was estimated by the Penman–Monteith equation [50]. Subsequently, Kriging spatial interpolation was used to obtain a map of the annual average potential evapotranspiration of the Wetland. Besides, the market value method was employed to calculate the value of the water yield service.

## 3.2. Soil Conservation

The soil retention module, which was based on the Revised Universal Soil Loss Equation (RUSLE), was used to estimate the amount of soil erosion within the region. The formulas of the module are as follows:

$$A = R \times K \times LS \times C \times P \tag{2}$$

$$RKLS = R \times K \times LS \tag{3}$$

$$SD = RKLS - A \tag{4}$$

where *RKLS* is the total potential soil loss (t) per pixel in the original land cover without the application of factors *C* or *P* from the RUSLE (i.e., equivalent to the soil loss for bare soil); *A* is the estimated average soil loss (t) per pixel in the original land cover  $(t \cdot km^{-2} \cdot yr^{-1})$ ; *SD* is the amount of soil retention (t); and, *R* is the rainfall erosivity (MJ·mm/(km<sup>2</sup>·h·yr)), which is calculated while using the formula of Wischmeier according to the average monthly and annual precipitations in the Dongting Lake Wetland [51]; *K* is the soil erodibility ( $t \cdot km^2 \cdot h/(km^2 \cdot MJ \cdot mm)$ ) calculated while using the formula of Williams based on relevant soil data [52]; *LS* is the slope length gradient factor; *C* is the cover management factor obtained by the FAO [53]; and, *P* is the support practice factor that is available from the USDA Agriculture Handbook [54]. The value of soil conservation was estimated while using shadow engineering method.

## 3.3. Carbon Storage

The carbon module uses land use maps and the carbon density (i.e., above ground biomass, belowground biomass, soil, and dead biomass) of each land use type to estimate the amount of carbon that is currently stored in a landscape, as follows [55]:

$$C_t = C_{above} + C_{below} + C_{dead} + C_{soil}$$
(5)

where  $C_t$  is the total carbon storage (t); and,  $C_{above}$ ,  $C_{below}$ ,  $C_{soil}$ , and  $C_{dead}$  are the carbon storage (t) in aboveground biomass, belowground biomass, soil, and dead biomass, respectively. The value of carbon storage was calculated while using the market value method.

#### 3.4. Snail Control and Schistosomiasis Prevention

The purpose of constructing snail control and *schistosomiasis* prevention forests has been to reduce the density and area of snails and effectively prevent and control the spread of *schistosomiasis*. Therefore, in this study, the snail-control function is evaluated by the reduction of the snail area and the reduction in the number of *schistosomiasis* patients. The Raster Calculator of ArcGIS 10.2 is used to analyze the quality and value of snail control and disease prevention, while using the following equations:

$$\Delta_A = A_{2010} - A_{2015} \tag{6}$$

$$\Delta_N = N_{2010} - N_{2015} \tag{7}$$

where  $\Delta_A$  and  $\Delta_N$  denote the reduced areas that are colonized by the snail and the reduction number of *schistosomiasis* patients, respectively;  $A_{2010}$  and  $N_{2010}$  are the snail area (10<sup>4</sup> m<sup>2</sup>) and the number of schistosomiasis patients in 2010; and,  $A_{2015}$  and  $N_{2015}$  are those quantities in 2015.

The market value and the shadow engineering methods, and then were used to calculate the value of snail control and *schistosomiasis* prevention. The value of snail and disease prevention function (*C*) is computed as the following:

$$C = C_{Snail} \cdot \Delta_A + C_{Patient} \cdot \Delta_N \tag{8}$$

where  $C_{Snail}$  is the cost of snail control (in CNY/m<sup>2</sup>) and  $C_{Patient}$  is the annual treatment cost per patient. Table 2 summarizes the sources used for the collection of parameters.

The Parameter Name	Content or Price	The Data Source	
Water market transaction price	4.51 CNY/t (0.64 USD/t)	Circular on issues relating to the standards for the collection of water resources charges of the People's Republic of China	
The cost of digging up a unit of soil	63.44 CNY/m <sup>3</sup> (9.01 USD/m <sup>3</sup> )	The water conservancy construction project budget quota of the ministry of water resources of the People's Republic of China	
Carbon price	48.52 CNY/t (6.89 USD/t)	A Report by Forest Trends' Ecosystem Market	
The price of medicine to kill snails	0.27 CNY/m <sup>2</sup> (0.04 USD/m <sup>2</sup> )	Chinese journal of schistosomiasis control [56]	
Per capita annual cost of treatment	3230.7 CNY/yr (458.89 USD/yr)	National Bureau of Statistics	
The area of the snail control and <i>schistosomiasis</i> prevention forest	—	State forestry administration	
The snail area and the number of <i>schistosomiasis</i> patients	—	National Bureau of Statistics	

### Table 2. Parameter collection methods.

#### 4. Results and Analysis

In this section, the results of the present study on the variations of different ecosystem services in the Dongting Lake Wetland and an analysis of their values are presented.

# 4.1. Temporal and Spatial Variations of the Ecosystem Services

Figure 2 shows the results of the study on the temporal and spatial variations of the water yield, soil conservation, and carbon storage; and, Figures 3 and 4 present those variations in the reduced snail area and the number of schistosomiasis patients, in the Dongting Lake Wetland, from 2005 to 2015.



**Figure 2.** Distribution of changes in the ecosystem services in the Dongting Lake Wetland from 2005 to 2015.



Figure 3. Temporal and spatial variations of the reduced snail area from (a) 2005 to 2010; (b) 2010 to 2015; and (c) 2005 to 2015.



**Figure 4.** Temporal and spatial variations of the reduction in the number of *schistosomiasis* patients from (**a**) 2005 to 2010; (**b**) 2010 to 2015; and (**c**) 2005 to 2015.

## 4.1.1. Variations of Water Yield

Land use and climatic changes both influence water yield. In 2005, 2010, and 2015, water yield in the Dongting Lake Wetland was  $236.91 \times 10^8$  m<sup>3</sup>,  $339.61 \times 10^8$  m<sup>3</sup>, and  $302.80 \times 10^8$  m<sup>3</sup>, respectively. This shows that it increased from 2005 to 2010 by 43.3% and then decreased 10.8% between 2010 and 2015. The reason for these variations was that the amount of rainfall was higher than evapotranspiration

between 2005 and 2010, while the latter became larger from 2010 to 2015. However, the net change from 2005 to 2015 was an increase of  $65.89 \times 10^8$  m<sup>3</sup> (equivalent to 27.81%). Spatially, water yield during this period decreased in the southwest (Taoyuan and Hanshou Counties), with the largest reduction of 1313.0 m<sup>3</sup>/km<sup>2</sup>, while it increased in the northeast (Yueyang County, and Linxiang and Yueyang Cities), where the largest rise was 1586.8 m<sup>3</sup>/km<sup>2</sup>.

## 4.1.2. Variations of Soil Conservation

In 2005, soil conservation was equivalent to  $1257.23 \times 10^4$  t, while, in 2010 and 2015, it accounted for  $1931.06 \times 10^4$  t and  $1257.44 \times 10^4$  t, respectively, i.e., a total increase of  $0.21 \times 10^4$  t equivalent to a growth of 0.02% from 2005 to 2015. However, the change was not uniform across the area, as in the northwest (Li County) and southwest (Taoyuan County) a decrease was observed with the largest value of 4569.7 t; while, in the northeast (Linxiang City, Yueyang County, and Yueyang City), the amount of conserved soil became larger (with a maximum change of 61,943 t). See Figure 2 for details.

A variety of factors, such as climate, topography, land use, and human activities, influence soil conservation. Among these, precipitation and rainfall erosivity, with temporal variations that were similar to the soil conservation (i.e., increase from 2005 to 2010 and then decrease from 2010 to 2015), were the most significant causes of the large variations in the amount of the conserved soil between 2005 and 2015.

### 4.1.3. Variations of Carbon Storage

In 2005, 2010, and 2015, the total carbon storage was  $3.57 \times 10^8$  t,  $3.63 \times 10^8$  t, and  $3.56 \times 10^8$  t, respectively. This shows a total decrease of  $0.01 \times 10^8$  t (i.e., 0.28%) from 2005 to 2015. Spatially, during this period, the carbon storage mainly changed in the northwest (Li County), northeast (Yueyang County), and southeast (Wangcheng County), with a maximum reduction of 26.2215 t; while, in the areas in the middle (Huarong county and Yuanjiang City), it increased with a maximum change of 26.2215 t (Figure 2). Temporal and spatial changes in the carbon storage were both associated with the changes in the land use. For example, higher variations in the carbon storage were observed in the regions with higher changes of land use.

### 4.1.4. Variation of Snail Control and Schistosomiasis Prevention

The construction of snail control and *schistosomiasis* prevention forests in the Dongting Lake Wetland has considerably changed the environmental conditions for snail breeding. Figure 3 shows the temporal and spatial reductions of snail areas in the study area between 2005 and 2015. In 2005, snails colonized  $176,042.5 \times 10^4$  m<sup>2</sup> of the area. Subsequently, from 2005 to 2015, 10 counties experienced a reduction, with the total amount of  $326.01 \times 10^4$  m<sup>2</sup> (i.e., -0.19%), while an increase of snail area was observed in seven other counties. These variations were as follows. In Taoyuan, Anxiang, Wangcheng, Huarong, Hanshou, and Xiangyin Counties, as well as Yueyang, Yuanjiang, Jin, and Linxiang Cities, there was a reduction in the snail area with a maximum of  $820.37 \times 10^4$  m<sup>2</sup> in Taoyuan County; while, in Nan, Yueyang, and Li Counties and Yiyang, Miluo, Linli, and Changde Cities, the area that was colonized by snails became greater with a maximum of  $700.5 \times 10^4$  m<sup>2</sup> in Li City. The increase in the snail area in the latter, in spite of the presence of the constructed snail control and *schistosomiasis* prevention forests, was that these areas are located along the *Oncomelania hupensis* snail-ridden regions outside embankments of Yangtze river and Dongting Lake, where the infectious sources are various, large in number, and difficult to manage, thus a high risk of schistosomiasis still exists [57].

Except in Linli County, where the number of *schistosomiasis* patients increased from 2005 to 2015 (386 people), this number decreased in all other counties and cities of the study area. In 2005, the total number of *schistosomiasis* patients in the Dongting Lake Wetland area was 210,651, which then reduced by 182,829 (86.8%) from 2005 to 2015. The largest reduction was observed in Yuanjiang City with 27,586 patients, followed by Nan County, while the smallest decrease was found in Wangcheng County with 154 patients. The increase in the number of patients in Linli County was mainly due to

the fact that, in this county, there is a large number of cattle and sheep, which increases the human and animal infection rate [58]. Figure 4 shows these temporal and spatial variations in the study area between 2005 and 2015.

#### 4.2. Variations in Ecosystem Services between Different Land Use Types

Different types of land use showed different changes in the water yield. The amount of water yield per  $km^2$  in unutilized, residential, arable, forest, and grassland areas had a growth of 63.83%, 32.86%, 28.19%, 23.25%, and 25.79%, respectively (Figure 5a). Moreover, it can be seen from this figure that the order of water yield per  $km^2$  in different land use types was as follows: woodland > arable land > grassland > residential land > unutilized land > water area.



**Figure 5.** Ecosystem services per  $\text{km}^2$  of different land cover types in the Dongting Lake Wetland from 2005 to 2015: the amounts of (**a**) water yield; (**b**) soil conservation; and (**c**) carbon storage.

The change in the total amount of conserved soil was different every five years. As shown in Section 4.1.2, it increased by 53.60% in the first five years of the study period, while it decreased by 34.88% in the second 5 years. Soil conservation per km<sup>2</sup> of different land use types from 2005 to 2015 is shown in Figure 5b. Among them, the residential, unutilized and grassland areas experienced an increase of soil conservation per km<sup>2</sup> by 38.74%, 37.40%, and 12.76%, respectively, while the others had a smaller increase. In summary, the soil conservation per km<sup>2</sup> in different land use types between 2005 and 2015 followed this order: grassland > woodland > water area > arable land > residential land > unutilized land.

As shown in Section 4.1.3, from 2005 to 2010, the total amount of carbon storage increased by 1.68%, and then a decrease of 1.93% was observed from 2010 to 2015. Figure 5c presents the changes in the carbon storage capacity per km<sup>2</sup> of different land use types for every five years during the study period. As can be seen, there has been an increase in unutilized land and grassland by 3.94% and 1.14%, respectively; and, a decrease of 4.87%, 0.15%, and 0.03%, respectively, in the residential, arable, and woodland areas. According to the study of Chen et al., (2012) [59] on the carbon storage in Dongting Lake area from 1979 to 2004, soil organic carbon was largely lost when grassland was converted into woodland due to the establishment of forests in the Wetland area. According to the present results, the

order of the carbon storage was as follows: grassland > woodland > unutilized land > residential land > arable land.

#### 4.3. Analysis of the Value of Ecosystem Services

Figure 6 presents the results of the analysis that was carried out on the value of the ecosystem services in the Dongting Lake Wetland while using the market value and shadow engineering methods. The value of these services was estimated to be  $1249.84 \times 10^8$  CNY in 2005, of which water yield, carbon storage, soil conservation, and snail control and *schistosomiasis* prevention accounted for 85.49%, 13.87%, 0.64%, and 0.00%, respectively. In 2010, this value increased to  $1723.85 \times 10^8$  CNY, with the rise in the value of water yield, soil conservation and snail control, and *schistosomiasis* prevention by 3.36%, 0.07%, and 0.23%, respectively, and a reduction of 3.67% in carbon storage. In 2015, the overall ecosystem value reduced to  $1552 \times 10^8$  CNY. This was associated with decreases of 0.88% and 0.20% in the water yield and soil conservation, respectively, and growth of 0.93% and 0.15% in the values of carbon storage and snail control and *schistosomiasis* prevention.



**Figure 6.** Values of different ecosystem services of the Dongting Lake Wetland in (**a**) 2005; (**b**) 2010; and (**c**) 2015.

Besides, it was observed that the values of different land use types per km<sup>2</sup> followed the order of snail control and *schistosomiasis* prevention forest > forest (non-snail control and *schistosomiasis* prevention) > arable land > residential land > unutilized land > water area. This can be seen in Figure 7, where the values per km<sup>2</sup> of different land cover types are presented for years 2005, 2010, and 2015.



Figure 7. Values per km<sup>2</sup> of different land cover types.

In 2010, the value of the ecosystem service of snail control and *schistosomiasis* prevention forests in the Dongting Lake Wetland area was  $54.33 \times 10^8$  CNY, which corresponded to the water yield, soil conservation, carbon storage, and snail control, and *schistosomiasis* prevention by 74.25%, 1.10%, 17.31%, and 7.34%, respectively. In 2015, this value reached 89.11 × 10<sup>8</sup> CNY. Only the carbon storage value increased from 2010 to 2015 (by 2.33%), but the value of the other factors reduced, as seen in Figure 8.





**Figure 8.** Values of different ecosystem services of snail control and *schistosomiasis* prevention forests in the Dongting Lake Wetland area in (**a**) 2010; and (**b**) 2015.

# 5. Discussion

## 5.1. Factors Affecting the Ecosystem Services

Previous studies have found that land use change, precipitation, evapotranspiration, and rainfall erosivity are the main mechanisms that affect ecosystem services [60]. We have carried out a correlation analysis of the ecosystem services with evapotranspiration, precipitation, soil erodibility, and rainfall erosivity while using Statistical Product and Service Solutions (SPSS) to investigate the effects of such factors in the present study. Table 3 presents the result, where it can be seen that, from 2005 to 2015, the ecosystem services show different degrees of correlation with these factors. Specifically, all of the factors significantly positively influenced water yield, soil conservation, and carbon storage; and, the rainfall erosivity positively influenced the reduced snail area at a moderate degree.

			C	5
Ecosystem Services	I	nfluencing Factors		
	Evapotranspiration	Precipitation	Soil Erodibility	Rainfall Erosivity
Water yield	0.931 **	0.969 **	0.895 **	0.954 **
Soil conservation	0.803 **	0.840 **	0.841 **	0.847 **
Carbon storage	0.835 **	0.828 **	0.851 **	0.811 **
Reduced snail area	0.089	0.322	0.296	0.347 **
Reduced patient	-0.008	-0.05	-0.023	-0.073

Table 3. Correlation analysis of ecosystem services and various influencing factors during 2005–2015.

Asterisks indicate significant differences at \*\* p < 0.01.

# 5.2. Selection of Appropriate Evaluation Indexes and Methods

Wetlands provide a variety of ecosystem services. The evaluation indexes of wetland ecosystem services are different due to different characteristics of wetlands. For example, Schallenberg et al. (2013) conducted ecosystem services evaluation on eight lakes in New Zealand, with an area of over 100 km<sup>2</sup> including water supply, fish supply, water purification, flood control, lakeside protection, climate regulation, and recreation, and discovered that they were in the trend of degradation [61]. Zhang et al. (2014) calculated the ecological service value of lakes and wetlands in China from three aspects of biodiversity, water quality, and economic indices. The results showed that the values of lake and marsh wetlands ecosystem services accounted for 54.64% of the total value of China's natural grassland ecosystem services and 30.34% of the total value of forest ecosystem services, respectively [62]. Sun et al. (2017) compared the different results of food security and biodiversity between China's Poyang Lake and Bangladesh's Tanguar Haor wetlands and showed that the trends in food security and biodiversity are declining [63]. Wondie (2018) selected nine wetlands in the region of the Lake Tana (Ethiopia) and estimated the value of wetland ecosystem services in terms of supply, regulation, culture, and support services. They showed that the wetland utilization planning, investment intervention, public land ownership, and other policy decision-making supports are poor, thus resulting in a major challenge to the sustainable use of wetland resources [64]. Mao et al. (2007) estimated the value

of the ecological services in the Dongting Lake Wetland to be  $411.10 \times 10^8$  CNY using the market value, shadow engineering, carbon tax, and alternative expenses methods, but without considering the effect of snail control and *schistosomiasis* prevention forests [40]. We observed that in 2015, this value was  $1552 \times 10^8$  CNY, and the snail control and *schistosomiasis* prevention forests had the highest ecosystem service value among the different land use types. This is mainly due to the fact that such forests provide various benefits, such as water yield, soil conservation, and carbon storage. However, more importantly, they control and prevent *schistosomiasis*, which thereby reduces the cost of snail eradication and *schistosomiasis* treatment and decreases the income loss of *schistosomiasis* patients.

In summary, different assessment indicators are adopted for wetlands in different areas, and quite different results are often obtained. It can be concluded that there is no consensus on a singular best approach for the assessment of wetland ecosystem services, but the selection of appropriate assessment indicators and methods for a certain wetland is heavily dependent on the characteristics of the area where the wetland is located.

#### 5.3. Limitation of the Present Study

Our study has some limitations, as follows. (1) This study only evaluated water yield, soil conservation, carbon storage, and snail control and *schistosomiasis* prevention functions in the evaluation of the ecosystem services of snail control and *schistosomiasis* prevention forests. However, other ecosystem services, such as the provision of wood and forest products, climate regulation, and air purification, which may have significant effects, were neglected. (2) The dynamic impact of afforestation years on the ecosystem services, such as the difference between an old-growth forest and a newly planted forest, was disregarded.

#### 6. Conclusions

In this study, water yield, soil conservation, carbon storage, and snail control and *schistosomiasis* prevention were evaluated in the Dongting Lake Wetland area from 2005 to 2015. Their temporal and spatial changes were studied in detail, where different trends and variations were observed. Different land use types also showed various changes in these services. Subsequently, the value of the ecosystem services was estimated, and a total increase of 24.18% was observed over the 10-year period, where the water yield showed the highest value, which accounted for more than 70% of the total value of the four evaluated ecosystem services; while, the value of the snail control and *schistosomiasis* prevention was about 5% of it. Moreover, through a correlation analysis, it was shown that evapotranspiration, precipitation, soil erodibility, and rainfall erosivity significantly positively influenced some of the ecosystem services in the study area.

There is no singular best approach for the assessment of ecosystem services of wetlands, but the appropriate methods should be selected based on the characteristics of the area where the wetland is located. The potential improvements in the selection of evaluation index system and methods for a similar case to our study include considering the dynamic impact of afforestation years on the ecosystem services and taking the effect of other ecosystem services, such as the provision of wood and forest products, climate regulation, and air purification into account.

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# References

- 1. Ouyang, Z.Y.; Wang, X.K.; Miao, H. A primary study on Chinese terrestrial ecosystem services and their ecological-economic values. *Acta Ecol. Sin.* **1999**, *19*, 607–613. (In Chinese)
- 2. Costanza, R.; D'Arge, R.; De Groot, R. The value of the world's ecosystem services and natural capital. *World Environ.* **1997**, *387*, 253–260. (In Chinese) [CrossRef]
- 3. Millennium Ecosystem Assessment (MEA). *Ecosystems and Human Well-Being: Biodiversity Synthesis*; Island Press: Washington, DC, USA, 2019.
- 4. Li, W.H. Contemporary Ecological Study of China-Volume of Ecosystem Management; Science Press: Beijing, China, 2013.
- Wang, H.Q.; Zhang, C.H.; Zou, J.H. The game analysis of the protection of wetland resources. *Ecol. Econ.* 2011, 235, 174–178. (In Chinese)
- 6. Dugan, P. Wetlands in Danger: A World Conservation Atlas; Oxford University Press: New York, NY, USA, 1993.
- 7. Rudolf, S.G.; Wilson, M.A.; Boumans, R.J. A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecol. Econ.* **2002**, *41*, 393–408.
- 8. Costanza, R.; de Groot, R.; Sutton, P.; Ploeg, S.; Anderson, S.J.; Kubiszewski, I.; Farber, S.; Turner, R.K. Changes in the global value of ecosystem services. *Glob. Environ. Chang.* **2014**, *26*, 152–158. [CrossRef]
- 9. US Environmental Protection Agency. Great Lakes Restoration Initiative Task Force. In *Great Lakes Restoration Initiative Action Plan II Measures Reporting Plan;* 2017. Available online: https://www.glri.us/sites/default/files/glri-measures-reporting-plan-20170926-156pp.pdf (accessed on 12 October 2018).
- 10. Wong, C.P.; Jiang, B.; Bohn, T.J. Lake and wetland ecosystem services measuring water storage and local climate regulation. *Water Resour. Res.* **2017**, *53*, 3197–3223. [CrossRef]
- 11. Bikash, S.; Golam, R.; Nakul, C.; Sharma, B.; Rasul, G.; Chettri, N. The economic value of wetland ecosystem services: Evidence from the Koshi Tappu Wildlife Reserve, Nepal. *Ecosyst. Serv.* **2015**, *12*, 84–93.
- 12. Simon, G.S.; John, B.; Kate, S. Farmer perceptions of wetlands and waterbodies: Using social metrics as an alternative to ecosystem service valuation. *Ecol. Econ.* **2016**, *126*, 58–69.
- 13. Dearing, J.A.; Yang, X.; Dong, X. Extending the timescale and range of ecosystem services through paleoenvironmental analyses, exemplified in the lower Yangtze basin. *Proc. Natl. Acad. Sci. USA* **2012**, *109*, E1111–E1120. [CrossRef]
- 14. Li, C.; Zheng, H.; Li, S. Impacts of conservation and human development policy across stakeholders and Scales. *Proc. Natl. Acad. Sci. USA* **2015**, *112*, 7396–7401. [CrossRef]
- 15. Li, X.; Yu, X.; Jiang, L.; Li, W.; Liu, Y.; Hou, X. How important are the wetlands in the middle-lower Yangtze River region: An ecosystem service valuation approach. *Ecosyst. Serv.* **2014**, *10*, 54–60. [CrossRef]
- Xu, M.; Dong, X.; Yang, X. Using palaeolimnological data and historical records to assess long-term dynamics of ecosystem services in typical Yangtze shallow lakes (China). *Sci. Total Environ.* 2017, 584, 791–802. [CrossRef] [PubMed]
- 17. Feng, J.G.; Ding, L.B.; Wang, J.S. Case-based evaluation of forest ecosystem service function in China. *Chin. J. Appl. Ecol.* **2016**, *27*, 1375–1382. (In Chinese)
- 18. Li, T.; Lü, Y.H. A review on the progress of modeling techniques in ecosystem services. *Acta Ecol. Sin.* **2018**, *38*, 5287–5296.
- Silvestri, S.; Kershaw, F. Framing the Flow: Innovative Approaches to Understand, Protect and Value Ecosystem Services Across Linked Habitats; Environmental Policy Collection; UNEP World Conservation Monitoring Centre: Cambridge, UK, 2010; pp. 26–33.
- 20. Hu, H.T.; Fu, B.J.; Lü, Y.H.; Zheng, Z.M. SAORES: A spatially explicit assessment and optimization tool for regional ecosystem services. *Landsc. Ecol.* **2015**, *30*, 547–560. [CrossRef]
- 21. Sharp, R.; Tallis, H.T.; Ricketts, T.; Guerry, A.D.; Wood, S.A.; Chaplin-Kramer, R.; Nelson, E.; Ennaanay, D.; Wolny, S.; Olwero, N.; et al. *InVEST Version 3.2.0 User's Guide. The Natural Capital Project. The Nature Conservancy, and World Wildlife Fund*; Stanford University: Stanford, CA, USA; University of Minnesota: Minnesota, MN, USA, 2016.
- 22. Dai, E.F.; Wang, X.L.; Zhu, J.J.; Zhao, D.S. Methods, tools and research framework of ecosystem service trade-offs. *Geogr. Res.* **2016**, *35*, 1005–1016. (In Chinese)
- 23. Hoyer, R.; Chang, H. Assessment of freshwater ecosystem services in the Tualatin and Yamhill basins under climate change and urbanization. *Appl. Geogr.* **2014**, *53*, 402–416. [CrossRef]

- 24. Pessacg, N.; Flaherty, S.; Brandizi, L. Getting water right: A case study in water yield modelling based on precipitation data. *Sci. Total Environ.* **2015**, *537*, 225–234. [CrossRef]
- 25. Yu, X.X.; Zhou, B.; Lü, X.Z.; Yang, Z.G. Evaluation of water conservation function in mountain forest areas of Beijing based on InVEST model. *Sci. Silvae Sin.* **2012**, *48*, 1–5. (In Chinese)
- 26. Wilson, M.A.; Carpenter, S.R. Economic Valuation of Freshwater Ecosystem Services in the United States: 1971–1997. *Ecol. Appl.* **1999**, *9*, 772.
- 27. William, J.M.; James, G.G. Wetlands, 5th ed.; John Wiley & Sons Inc.: Hoboken, NJ, USA, 2015.
- 28. Wang, Y. Schistosomiasis epidemic in elation analysis between its prevention and control in China. *Chin. Prim. Health Care* **2010**, *24*, 69–72. (In Chinese)
- Zhou, X.N.; Bergquist, R.; Leonardo, L. Schistosomiasis japonica control and research needs. *Adv. Parasitol.* 2010, 72, 145–178. [PubMed]
- 30. Steinmann, P.; Keiser, J.; Bos, R. Schistosomiasis and water resources development: Systematic review, meta-analysis, and estimates of people at risk. *Lancet Infect. Dis.* **2006**, *6*, 411–425. [CrossRef]
- 31. Ma, L.; Yang, X. Ecosystem services of forests for snail control and schistosomiasis prevention in the Yangtze River Basin. *J. Zhejiang A F Univ.* **2019**, *36*, 133–140. (In Chinese)
- 32. WHO. Resolution WHA 65.21. Elimination of schistosomiasis. In Proceedings of the Sixty-fifth World Health Assembly, Geneva, Switzerland, 21–26 May 2012.
- Zhang, L.J.; Shen, D.W. The evolution of schistosomiasis control strategy in China. J. Hubei Univ. Sci. Technol. 2013, 27, 457–460. (In Chinese)
- 34. Yang, X.; Zhang, Y.; Sun, Q.X. SWOT analysis on snail control measures applied in the national schistosomiasis control programme in the People's Republic of China. *Infect. Dis. Poverty* **2019**, *8*, 13. [CrossRef]
- 35. Liu, Z.C.; He, H.B. Recent advances in control techniques on Oncomelania hupensis in lake and marshland regions. *Chin. J. Vector Biol. Control* **2015**, *26*, 537–540. (In Chinese)
- 36. Guan, W.; Hong, Q.B. Research progress of control techniques on Oncomelania hupensis. *Chin. J. Schist. Control* **2017**, *29*, 246–251. (In Chinese)
- 37. Shi, X.D. Research progress of ecological snail extermination technology. *J. Trop. Dis. Parasitol.* **2018**, *16*, 117–121. (In Chinese)
- 38. Peng, Z.H.; Jiang, Z.H. *China's New Type of Forest Studies on the Snails Control and Schistosomiasis Prevention Forest*; China Forestry Press: Beijing, China, 1995. (In Chinese)
- 39. Yang, X.; Sun, Q.X. Discussion on strategy of development of forestry schistosomiasis control programs of China in new period. *China. J. Schist. Control* **2018**, *30*, 472.
- 40. Mao, D.H.; Wu, F.; Li, J.B. Evaluation on Ecosystem Service Value of Dongting Lake Wetland and Ecological Restoration Counter measures. *Wetl. Sci. Manag.* **2007**, *5*, 39–44. (In Chinese)
- 41. Tang, Y.X.; Wu, M. Effects of Lakeside Plantations on Schistosomiasisi Control. *Wetl. Sci. Manag.* **2006**, *2*, 8–13.
- 42. Peng, Z.H. Mechanism of Forestry Schistosomiasis-Control Project on Snail Control and Schistosomiasis Prevention. *Wetl. Sci. Manag.* **2003**, *9*, 8–10. (In Chinese)
- 43. Resource and Environment Data Cloud. Available online: http://www.resdc.cn (accessed on 2 July 2018).
- 44. National Meteorological Information Center. Available online: http://data.cma.cn (accessed on 10 July 2018).
- 45. Geospatial Data Cloud. Available online: http://www.gscloud.cn (accessed on 2 July 2018).
- 46. Cold and Arid Regions Science Data Center at Lanzhou. Available online: http://westdc.westgis.ac.cn (accessed on 15 September 2018).
- 47. Li, K.R.; Wang, S.Q.; Cao, M.K. Carbon storage of vegetation and soil in China. *Sci. China* **2003**, *33*, 72–80. (In Chinese) [CrossRef]
- Wang, Y.R.; Zhou, J.X.; Zhou, Z.X.; Sun, Q.X. Effects of Different Land Use Patterns under Converting Polders back into Wetlands on Soil Nutrient Pools in the Dongting Lake Region. *Resour. Environ. Yangtze Basin* 2010, 19, 634–639. (In Chinese)
- 49. Tallis, H.T.; Ricketts, T.; Guerry, A.D.; Wood, S.A.; Sharp, R.; Nelson, E.; Ennaanay, D.; Wolny, S.; Olwero, N.; Vigerstol, K.; et al. *InVEST 2.2.1 User's Guide*; The Natural Capital Project: Stanford, CA, USA, 2011.
- 50. Allen, G.; Pereira, L.S.; Raes, D. *Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements;* FAO: Rome, Italy, 1998.
- Wischmeier, W.H.; Smith, D.D. Rainfall energy and its relationship to soil loss. *Trans. Am. Geophys. Union.* 1958, 39, 285–291. [CrossRef]

- 52. Williams, J.R.; Arnold, J.G. A system of erosion—Sediment yield models. *Soil Technol.* **1997**, *11*, 1143–1155. [CrossRef]
- 53. Roose, E. Land Husbandry: Components and Strategy; FAO Soils Bulletin: Rome, Italy, 1996.
- Renard, K.G.; Foster, G.R.; Weesies, G.A. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE); USDA Agriculture Handbook: Washington, DC, USA, 1997; Volume 703, pp. 1–367.
- 55. Jia, F.F. InVEST Model Based Ecosystem Services Evaluation with Case Study on Ganjiang River Basin. Ph.D. Thesis, China University of Geosciences, Beijing, China, 2014. (In Chinese).
- 56. Tao, H.Y.; Xia, A.; Zhao, Y.M. Effect and cost-benefit of Oncomelania snail control by plowing and palnting in Jiaobei Beach of Zhengjiang City. *Chin. J. Schist. Control* **2012**, *24*, 576–578. (In Chinese)
- 57. Hu, B.J.; Zhao, Z.Y.; Xia, M. Study on spatial—Temporal characteristics of Schistosoma japonicum infections among human in Hunan Province, 2004–2011. *Chin. J. Schist. Control* **2017**, *29*, 406–411.
- 58. Wang, Y.M.; Wang, X.Y.; Su, P.C. Terrospective investigation on the schistosomiasis status in Linli County. J. *Trop. Dis. Parasitol.* **2016**, *14*, 204–207. (In Chinese)
- 59. Chen, W.W.; Zhang, J.X. Change rules of soil carbon storage in Dongting lake region within 20 years and its influencing factors. *J. Hunan Inst. Eng.* **2012**, *22*, 88–94. (In Chinese)
- 60. Wang, F.; Zhang, S.L.; Hou, H.P.; Yang, Y.J.; Gong, Y.L. Assessing the Changes of Ecosystem Services in the Nansi Lake Wetland, China. *Water* **2019**, *11*, 788. [CrossRef]
- 61. Schallenberg, M.; Winton, D.; Verburg, P. Ecosystem services of lakes. In *Ecosystem Services in New Zealand: Conditions and Trends*; Manaaki Whenua Press: Lincoln, New Zealand, 2013; pp. 203–225.
- 62. Zhang, Y.; Zhou, D.; Niu, Z. Valuation of lake and marsh wetlands ecosystem services in China. *Chin. Geogr. Sci.* **2014**, 24, 269–278. [CrossRef]
- 63. Sun, C.; Zhen, L.; Miah, M.G. Comparison of the ecosystem services provided by China's Poyang Lake wetland and Bangladesh's Tanguar Haor wetland. *Ecosyst. Serv.* **2017**, *26*, 411–421. [CrossRef]
- 64. Wondie, A. Ecological conditions and ecosystem services of wetlands in the Lake Tana Area, Ethiopia. *Ecohydrol. Hydrobiol.* **2018**, *18*, 231–244. [CrossRef]



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