

# Enhanced Ecosystem Services by Land Use Composition Adjustment Can Reduce Weather Disasters Loss under Climatic Change

Yixiao Kuang<sup>1</sup>, Yu Peng<sup>1,\*</sup>, Bing Sun<sup>2</sup>, Chunqian Jiang<sup>3</sup> and Weiguo Sang<sup>1</sup>

<sup>1</sup>College of life and Environmental Sciences, Minzu University of China, 27 South Street, Zhongguancun, Haidian District, Beijing 100081, China.

17400195@muc.edu.cn (K.YX); swg@muc.edu.cn (S.WG)

<sup>2</sup>Institute of tropical forestry, China Academy of forestry 510520, Guangzhou, Guangdong, China.

<sup>3</sup>Institute of forestry, China Academy of Forestry Sciences, Beijing, 100091, China.

\*Email: yuupeng@163.com

**Abstract:** How to evaluate ecosystem services has been intensively documented. However, the function of ecosystem services in alleviating the economic loss of weather disasters has been seldomly noticed. In Hunan Province of China, we investigated the loss of weather disasters: drought, flood, hail, rain storm, and heavy snow from 120 counties during 1980-2010. The land use changes and ecosystem services were also assessed. The results indicated that enhanced ecosystem services brought by land use changes have substantially reduced the intensity of weather disasters, and reduce the loss of disasters if they occurred. These potential function in mediating weather disaster should be considered in the assessment of ecosystem services. With global climate changes, we should optimize the land uses to face increasing weather extremes.

## 1. Introduction

Natural disasters have increasingly happened along climate change, seriously affects the survival of human life, property security and social and economic sustainable development. According to the World Bank's latest report, "Undestructible: Enhancing the Resilience of Poor People to Natural Disasters", extreme natural disasters force 26 million people into poverty every year, causing global losses equivalent to \$520 billion in annual consumption [1]. To a certain extent, the occurrence of disasters destroys the harmonious development between eco-economy. It is urgent to carry out the survey of potential natural and ecological disasters, protect the ecological environment and promote the sustainable development of economy and society [2].

However, few studies have examined whether the intensity of natural disaster (indicated by economic loss) is associated with ecosystem services and how people evaluate [3] and consider the function of alleviating loss for natural disasters in ecosystem services assessment [4]. Natural disasters can cause severe destruction for livelihoods of local rural communities. It can further reduce life quality.

To clarify the relationship between ecosystem service and natural disaster is key for exploring an alternative pathway to combat increasingly extreme weathers and consequently natural disasters, promoting the sustain development of local population, economy and society. The key object of the study is to identify the contribution of ecosystem services in reducing intensity and economic loss of natural disasters. This assessment can provide valuable reference for decision-making managers in the coordinated management of regional ecosystems [5], especially where has ecological red line [6]. It is of theoretical and practical significance.



## 2. Materials and Methods

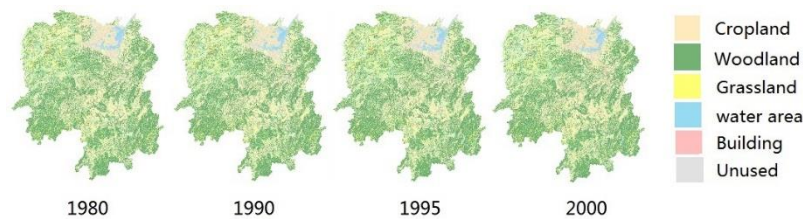
### 2.1. Study Area

Since 5000 years ago, there have been ancient human activities. Now Hunan Province has 13 provincial municipalities, 1 autonomous prefecture, with a total area of 218,000 square kilometers. Hunan is a continental subtropical monthly rheumatic and humid climate. It is cold and warm in spring, and the weather changes dramatically. It often accompanies with strong convective weather processes such as gale, hail and rainstorm. There is little rain in summer and autumn, and drought almost every year, which has a serious impact in varying degrees. In July 2017, the cultivated land area was 3.788 million hectares, the natural grassland area was 6.373 million hectares, and the forest area was 10.369 million hectares.

### 2.2. Methods

#### 2.2.1. Land use change analysis methods

Landsat-TM remote sensing images are used as the basic data source. the land uses of Hunan province during 1980-2000 were identified by the method of human-computer interaction interpretation, field investigation and verification. The land uses of Hunan Province in 1980, 1990, 1995 and 2000 are demonstrated in Figure1.



**Figure 1.** Land use change from 1980 to 2000 in Hunan Province produced by Landsat TM imageries

The spatial overlay is carried out by using GIS tools according to map algebra method. Based on the analysis, the transfer matrix of land use/cover types in each time period was obtained.

$$C_{ij} = A_{ij}^k \times 100 + A_{ij}^{k+1} \quad \text{formula (1)}$$

Among them,  $C_{ij}$  is from Period  $k$  Land Use/Cover Change Map to Period  $k+1$ .  $A_{ij}$  denotes the change of land use/cover types from  $i$  to  $j$  in  $k+1$  period Area of type.

#### 2.2.2. Valuation methods of ecosystem services value

We used the method of Wang et al. [7] to evaluate the ecosystem service values (ESVs). We calculated the ecosystem service values of Hunan province at county level from 1980 to 2000 by formula (2).

$$U = \sum_{i=1}^n S_i \times A_i \quad (2)$$

In this formula,  $U$  is the total value of ecosystem services of a county,  $S_i$  is the ecosystem service value of one kind of ecosystem, and  $A_i$  is the area value of this ecosystem,  $i$  is the  $i$ th order, and  $n$  is the number of ecosystem types. In this study,  $n$  is 6.

#### 2.2.3. Natural Disaster Data Source and Analysis

The data of natural disasters in this paper are derived from *Xiangxi Statistical Yearbook, Hunan Volume of China Meteorological Disasters* and *Statistical Yearbook of China Meteorological Disasters*. We calculated the total loss of each county in Hunan province to match the tempo-spatial scale which land uses and ecosystem service used.

Pearson correlation coefficients between ecosystem service values and economic loss of natural disasters were calculated, aiming at to reflect the degree of linear correlation between two variables.

### 3. Results

#### 3.1. Land Use Change Transfer Matrix

From 1980 to 2000, land use change has summarized in Table 1.

**Table 1.** Land Use Transfer Matrix of Western Hunan from 1980 to 2000

1980\2000	Cropland	Woodland	Grassland	Water	building	Unused	roll-ou
Cropland	61093	256	8	338	274	5	881
Woodland	135	131820	95	110	86	2	428
Grassland	10	133	7480	9	3		155
Water	75	17	1	6582	8	5	
building					2429		
Unused	4	9	0	57	1	744	71
roll-in	224	415	104	514	372	12	

Results show: The largest transfer out of cultivated land is 881 square meters, followed by water area followed by forest land 428 square meters. Cropland was mainly converted to water area, followed by urban construction, Woodland mainly converted to cultivated land, followed water area.

#### 3.2. Change of Ecosystem Service Values

We calculated the change of ecosystem service values from 1980 to 2000, shown in Table 2.

**Table 2.** Change of ecosystem service values in Hunan Province from 1980 to 2000 (RMB. ¥ 10<sup>4</sup>)

Year	Cropland	Woodland	Grassland	Water	Unused	Total
1980-1990	-37391.00	2243.1408	1086.0724	153742.096	-1053.365	118626.943
1990-1995	-43167.69	41124.248	-10395.26	181695.204	-184.801	169071.687
1995-2000	11448.368	-48227.5272	1396.3788	-63892.8192	147.8408	-99127.7587

Corresponding to land use, from 1995 to 2000, the total value of ecosystem services in Hunan Province decreased by 99127.7587 million yuan, respectively.

#### 3.3. Occurrence and Economic Loss of Meteorological Disasters

The losses caused by meteorological disasters in Table 3 basically shows:

**Table 3.** Natural disaster losses in Hunan, 1980-2000

Year	Farmland loss (10 <sup>4</sup> hm <sup>2</sup> )	food loss (10 <sup>8</sup> kg)	collapsed houses (10 <sup>4</sup> )	population casualties	livestock casualties	total loss (10 <sup>4</sup> yuan)
1980	239.1	19.24	15.2	365	930	45808.72
1990	388.3	22.43	12.78	339	10876	299246
1995	287.6	22.63	1.63	633	978	1400000
2000	317.1	11.26	14.98	176	7600	1081796

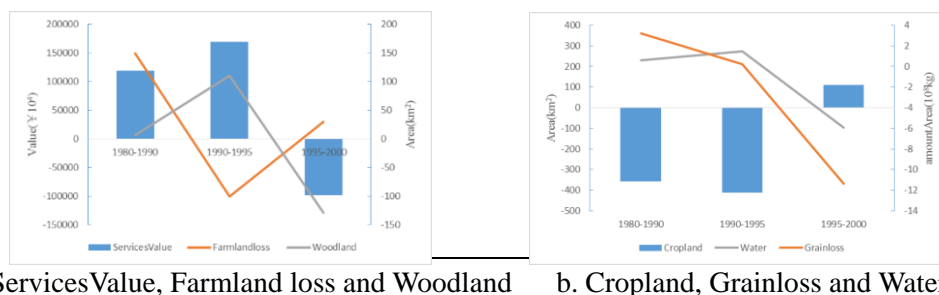
In Farmland disaster area, the affected area of farmland increased by 1.492 million hectares in 1990, decreased by 1.07 million hectares in 1995 and increased by 295,000 hectares in 2000; Grain loss increased by 319 million kg in 1990, by 0.2 billion kg in 1995 and by 1.137 billion kg in 2000; The direct economic losses in 1990 decreased by 253437.307 million yuan compared with 1980, increased by 1100753.973 million yuan in 1995 and decreased by 318204 million yuan in 2000 compared with 1995. The loss situation were the largest in 1990, the largest reduction in grain production in 1995 and

the largest direct economic loss of 14000 million yuan in 1995.

The spatial regularity subregion is mainly in Western, southern and Northern Hunan Yueyang, among which Western Hunan is more serious, with the largest loss in 1980 being Yueyang 3227.44 million yuan, followed by Sangzhi County 12.31 million yuan; in 1990, the largest loss was Longshan County 51.26 million yuan, followed by Yongshun 30.75 million yuan; in 1995, the largest loss was Sangzhi County 104.94 million yuan, followed by Linwu. County 90.6 million yuan; the largest loss in 2000 was 113.2 million yuan in Cili County, followed by 45.486 million yuan in Yongshun County.

### 3.4. Service Effects of Ecosystem Services on Reducing Natural Disaster Losses

The above analysis of land use, ecosystem service value, and meteorological disasters of their respective changes in the law. According to the results of principal component analysis and R-type cluster analysis, followed by the use of polygonal maps for further analysis of the relationship between them. Divide into two groups according to the associated indicators, as shown in Figure 2:



a. ServicesValue, Farmland loss and Woodland

b. Cropland, Grainloss and Waterland

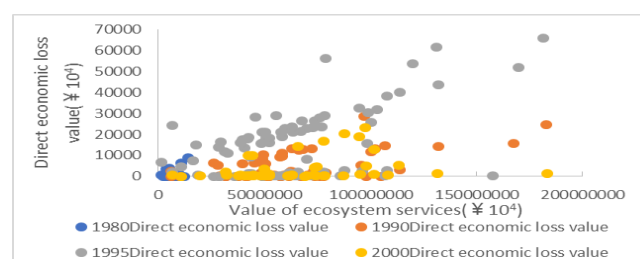
**Figure 2.** The Relation between the Change of Service Value and Shear of Meteorological Disasters

Fig.2a shows the value of ecosystem services increases first and then decreases with the increase of forest land area, and the affected area of farmland decreases first and then increases with the year. Fig.2b Reflections the loss of grain decreases with the increase of farmland area or with the decrease of water area. Therefore, ecosystem services can reduce the loss of meteorological disasters to a certain extent.

The generally show that the value of cultivated land services increased by 233.39 million yuan in 1990 compared with 1980, and the loss of natural disasters decreased by 170.536 million yuan; in 1995, the value of cultivated land services decreased by 89.035.74 million yuan compared with 1990, and the loss of natural disasters increased by 137.124.64 million yuan; in 2000, the value of cultivated land services increased by 1794.4529.26 million yuan compared with 1995, and natural disasters decreased by 318.24 million yuan. The situation of sub-counties is more obvious in Yueyang and Western Hunan, such as Cili County, Baojing County and Guzhang County, which shows that the total value of ecosystem services has increased and the loss of natural disasters has decreased.

### 3.5. Relationship Between Ecosystem Service and Natural Disaster Loss

The Pearson's correlation coefficients between ecosystem service value and economic loss has been calculated. Scatter plots of ecosystem services response to natural disasters in Hunan counties and districts in 1980, 1990, 1995 and 2000 were analyzed to reveal the relationship between two datasets.



**Figure 3.** Scatter plots of ecosystem service value and economic loss value, respectively

Figure 3 reflects the trend of approximately linear relationship between ecosystem service value and direct economic loss in each county in each year. Pearson correlation, regression and significance test was obtained by inputting SPSS 22.0 software for correlation analysis in four years as shown in the Table 4. The integration is as follows:

**Table 4.** The correlation and regression analysis of ecosystem services to natural disaster losses

Year	Correlation analysis		regression analysis		
	coefficient	p-value	coefficient	F	p-value
1980	0.387	0.046	-716.488	3.603	0.016
1990	0.546	0.000	-2242.189	6.802	0.000
1995	0.519	0.000	3716.331	6.305	0.000
2000	0.479	0.055	2454.660	0.884	0.543

The results showed that the correlation coefficient between ecosystem services and meteorological disasters was 0.3-0.6 in 1980-2000, which was moderately correlated. The P value of the first three years was less than 0.05 significantly correlated, as same as meteorological disasters and the regression of six types of land use, reflecting that there was a certain correlation between ecosystem services and the spatial distribution of meteorological disasters in the counties.

The situation of sub-counties is more obvious in Yueyang and Western Hunan, such as Cili County, Baojing County and Guzhang County, which shows that the total value of ecosystem services has increased and the loss of natural disasters has decreased.

#### 4. Discussion

In calculating the value of ecosystem services, this paper also can use Xie Gaodi et al [8]. to estimate the value of different types of ecosystem services, different methods will bring some errors to the results. No matter which method is used, the criteria for the same kind of comparison are the same, and the price can be analyzed and counted on the same benchmark. The results are objective and consistent.

According to the spatial distribution data of geological hazards in the Resource and Environment Science Data Center of the Chinese Academy of Sciences, 7 types of geological hazards in 8181 geological hazards in Hunan Province are 793 collapses, 755 collapses, 354 debris flows, 9 land subsidence, 77 ground fissures, 5337 landslides and 856 slopes. According to previous data and investigations, the main geological hazards in Hunan are concentrated in the northwest, west, South and east areas of Hunan. The main geological hazards occurred in Yuanling County, followed by Shimen County, Guidong County, Cili County, Yanling County, Anhua County, Xupu County, Xinshao County, Zhangjiajie City and Chenzhou City. A total of 54 counties and cities had geological hazards, accounting for 44.3% of the total counties and cities in the province [9].

The occurrence of natural disasters and direct economic losses in Xiangxi Prefecture show the regular pattern of periodic fluctuation in a period of six years. after the construction of the Yangtze River Gorge Reservoir in 2004, the area of water ecosystem has increased, the ecosystem services have increased, the occurrence of flood disasters has decreased, and the affected area and direct economic loss of cultivated land caused by natural disasters in Hunan Province have started from 2004. Compared with 2003, it has a large decrease [10].

On November 5, 2019, on the occasion of the 40th anniversary of the first World Climate Conference (Geneva, 1979), 11263 scientists from 153 countries warned in bioscience that the whole world is facing a climate crisis, threatening the fate of natural ecosystems and human beings [11]. The status of ecosystem services is a key factor for the occurrence or severity of natural disasters. Therefore, the key to effectively avoid and mitigate natural disasters is to restore and protect ecosystem services [12].

This paper studies the relationship between ecosystem services and natural disasters in Hunan Province. The results of correlation analysis and regression analysis of Hunan counties and districts in

2010 were compared. It can also refine the correlation analysis between farmland, forest land, farmland, grain, house collapse, livestock casualties and other indicators, and select other representative years, such as the effect of ecosystem services on meteorological disasters in 2013 or 2016. The results are different in numerical value, but the qualitative impact of ecosystem service capability on natural disaster reduction is unchanged.

## 5. Conclusion

This paper compares the correlation relationship between ecosystem service indicators and natural disasters by land use change in four natural years of Hunan Province and counties from 1980 to 2000, as well as the changing regularity of four years and the spatial distribution regularity of 120 counties. The results show that the coefficients of spatial-temporal correlation analysis and regression analysis of natural disasters are Medium correlation, while significance test p value is less than 0.05, which affect the ecosystem service efficiency. It should be the most remarkable. The following conclusions are drawn:

(1) On the spatial scale, the ecosystem service value of Hunan Province and its counties is related to natural disasters to a certain extent, with large land area and high ecosystem service value, complex terrain, underdeveloped economy, less exploitation and utilization, natural disasters occur frequently, but the intensity of natural disasters in counties with high ecosystem services is significantly lower than that in regions with low ecosystem services, ecosystem services play a role in reducing meteorological natural disasters to a certain extent.;

(2) On the time scale, with the increase of forest land, the ecosystem service value increases, the disaster area decreases, and the cultivated land area increases. The area of water area is less, and the loss of grain is reduced. The improvement of ecosystem service capacity has a certain effect on the reduction of natural disasters.

Usually, the ultimate goal of ecosystem services effectiveness assessment is to estimate marginal value and provide decision-making information to balance the impact of ecosystem services on human well-being before decision support [13].

## 6. References

- [1] New World Bank report says natural disasters cause economic losses of \$520 billion . *J. International Finance*, **2017** (1): 72-72.
- [2] Fan Yuanyuan. Coupling relationship between ecological environment, Regional Disasters and socio-economic activities. *Shanxi University of Finance and Economics*, **2018**.
- [3] Lau J D, Hicks C C, Gurney G G, et al. Disaggregating ecosystem service values and priorities by wealth, age, and education. *J. Ecosystem Services*, **2018**, 29:91-98.
- [4] Deng Min. Progress in Environmental Risk Assessment of Natural Disasters. *J. Journal of Jilin Radio and Television University*, **2018**.
- [5] Wang Xiaofeng. Assessment of ecosystem service effect of national ecological barrier area. *Beijing. Graduate School of Chinese Academy of Sciences*. **2014**.
- [6] Zhou Tingting. Radiation effects of ecological protection red line and its ecological services in typical flood storage areas. *Inner Mongolia University*, **2016**.
- [7] Wang M , Sun X . Potential impact of land use change on ecosystem services in China. *J. Environmental Monitoring and Assessment*, **2016**, 188(4):248.
- [8] Xie Gaodi, Lu Chunxia, Leng Yunfa, Zheng Du, Li Shuangcheng. Valuation of ecological assets in Qinghai-Tibet Plateau. *J. Journal of Natural Resources*, **2003**, 18 (2): 189-196.21:4050.
- [9] Yangyuelong, Zhou Qun, Lin Jian. The relationship between major geological hazards and topography in Hunan. *Hazardous Science*, **2007**, 22 (3): 36-40.
- [10] Gong richao, Xiao Guoan, Zhou Changfeng. Study on the trend model of natural disaster loss in Hunan Province. *Journal of natural disasters*, 2010,19 (05): 69-74.
- [11] William J Ripple, Christopher Wolf, Thomas M Newsome, Phoebe Barnard, William R Moomaw Author Notes. World Scientists' Warning of a Climate Emergency. *BioScience*,05 November **2019**,biz088, <https://doi.org/10.1093/biosci/biz088>
- [12] Li Wenhua. Ecosystem Service Function and Natural Disaster Mitigation [A]. Paper

Compilation VIII of the 2002 Symposium on Natural Disaster Mitigation of the Chinese Association of Science and Technology [C]. Chinese Association of Science and Technology, Chinese Society of Ecology, **2002**:8.

- [13] Nemec K T, Raudsepp-Hearne C. The use of geographic information systems to map and assess ecosystem services. *Biodiversity and Conservation*, **2013**, 22(1): 1–15.