Assessing the spatiotemporal changes in China's core supply and supporting ecosystem services

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Abstract：

The supply of ecosystem services (ES) is critical to sustaining human livelihoods, and understanding their driving mechanisms and impacts can contribute to sustainable ecological management. This paper aims to reveal the spatiotemporal changes and dynamics of ES in China from 1992 to 2015.SC (Soil conservation), WY (Water yield), NPP (Net primary productivity) and FS (Food supply) are selected for evaluation. The ability of ES to provide is increasing; the area where ES synergy is more dominant accounts for about half of the total land area, and ecological restoration here has a very high added value; in addition, we do not think that we cannot blindly pursue forest coverage during the ecological restoration The specific case is that afforestation activities in the Loess Plateau and Continental basin have exacerbated water shortages. It is the practical significance of this paper to clarify and reverse the regional ES trade-off relationship to achieve sustainable development.

Key words:

Ecosystem services, soil conservation, food supply, NPP, water yield, land use change

INTRODUCTION

Costanza defines ecosystem services (ES) as the benefits people get from the ecosystem, whic directly or indirectly affect human well-being and ecological security （Costanza *et al.*1997）,Conditions and processes where ecosystems create or help generate benefits for humans (Guerry A D *et al.* 2015),and are generally divided into four categories – supply, regulation, support, and cultural services(MA. 2005). ES assessment is an important scientific topic for solving sustainable development issues(Bai Y *et al.*2018).Its other core concept is that biological nature's contribution to human well-being has not been fully recognized and underestimated, which has led to changes in the ecosystem and degradation of the resource base on which people depend.(Lele *et al.*2013).

Some services at the expense of other services (Qin K *et al.* 2015) ,have led to more complex trade-offs and synergies between ecosystem services (Fengwei R *et al.* 2019). When the supply of one ES is increased and the supply of another ES is reduced, or when a stakeholder captures more specific ES at the expense of other ES's(Howe *et al.*2014).Today, with rapid economic development, we urgently need to make some trade-offs between the protection of ecological and economic development, so as to provide more reference for improving human well-being (Yijie S *et al.* 2019).

In recent years, ecosystem trade-offs and synergy research have become the frontiers and hotspots of related discipline research. The current distribution of ecosystem services in Denmark is determined by history and current socio-ecological impacts (Turner KG *et al.* 2014); European habitats with favorable conservation provide more Biodiversity (Maes J *et al.* 2012); potential interactions between food production and climate mitigation in sub-Saharan Africa, finding that deforestation and land degradation areas overlap with hunger and poverty (Palm CA *et al.* 2010) .Trees in the grain green area of northern Shaanxi, China have a strong impact on SC and atmospheric carbon regulation, and shrubs have been found to have a strong inhibitory effect on surface WY (Xiaoqing J *et al.* 2014); At the same time, there are more and more studies on changes in ecosystem services with changes in land use/land cover (Barbier *et al.* 2008).Some scholars (Wu J *et al.* 2017) found that the impact of trade-offs between ecosystem services can be reduced and transformed into synergies by optimizing land management technology; the overall upward trend of ES in the Yangtze River Economic Belt in China between 2000 and 2015 depends on the spatial pattern and scale of land use(Xibao X *et al.* 2018). Santiago (Madrigal-Martínez Santiago *et al.* 2019)provides a method for promoting the integration of ecosystems on multiple scales based on the land change dynamics and ES change trends in the Pune region of the Central High Andes, a method for promoting the integration of ecosystems on multiple scales is provided to promote regional development of land management decisions.

Although the current research on ecological services has achieved some considerable achievements, there are still some problems, such as: less research on the ES correlation in China as a whole; ES research is mainly a static study of a single time node, lacking long Dynamic research on time series; research on trade-offs and synergy are mostly based on quantitative analysis of statistical relationships to reflect the overall regional differences, lacking the spatial expression of spatial-temporal differences within regions (Yijie S *et al.* 2017).

Recent empirical evidence from China shows that although economic growth and its related supply services have gradually increased, regulatory services have been declining over time (Dearing *et al.* 2012). Therefore, in order to reveal how China 's ecosystem services change and clarify future ecological development strategies, this paper selects four ES, SC, WY, NPP, and FS to analyze the spatial-temporal differences in trade-offs and synergies between 1992 and 2015, and explore land use changes and the influence of climate factors on ES trade-offs and synergies. Provide scientific basis for the region to make rational land management decisions and understand the spatiotemporal changes and sustainable management of ES in China. Clarifying the trade-offs between ecosystem services provides a reference for regional planning decisions that will make a meaningful contribution to addressing sustainability challenges (Goldstein JH *et al.*2012).

RESEARCH METHODS

data source

This study used eight data types (Table 1): (1) DEM data with a resolution of 1 km, obtained from the Geospatial Data Cloud (http://www.gscloud.cn); (2) Vector data such as NDVI and administrative boundaries are from the Resource and Environmental Science Data Center of the Chinese Academy of Sciences (http://www.resdc.cn); (3) Socio-economic data comes from the National Bureau of Statistics of China (http://www.stats.gov.cn);(4) Meteorological data are from the China Meteorological Science Data Sharing Network (http: // data. cma.cn); (5) 1km of soil data is from the World Soil Database (Harmonized World Soil Database version 1.1) (HWSD) constructed by the Food and Agriculture Organization of the United Nations (FAO) and the Vienna International Application System Institute (IIASA). Data in China The source is 1: 1 million soil data provided by the Nanjing National Soil Survey of the Second National Land Survey. Data format: grid grid format, projection is WGS84. The soil classification system adopted is mainly FAO-90; (6) The land use data of 300m comes fromGLOBELAND30(http://www.globallandcover.com)(7) The NPP data used in this paper uses China's monthly monthly meteorological data, national soil texture data, and land cover and vegetation index data products based on MODIS and AVHRR remote sensing images. They are input into the Carnegie-Ames-Stanford Approach (CASA) model and developed at 18 ° North To the north of China's terrestrial ecosystem in 31 years, the monthly primary productivity 1 km raster dataset (1985-2015), only 1992-2015 data is used in this article. The data research and development range is 18 ° N-53.5 ° N, 65 ° E-138 ° E. In this interval, the values of the land and sea parts outside China are set to zero, and the rest of the data are NPP values. The resolution is 1km x 1km. The data set consists of 1488 data files. Relevant research results based on this data set were published in《Remote Sensing》No. 9 2017（Pengfei C *et al.*2019）.

Table 1 Eight datasets were used to estimate four ecosystem services

Date	**Scale/form/resolution**	**Source**
DEM	1km	Geospatial Data Cloud site, Computer Network Information Centre, CAS (http://www.gscloud.cn)
NDVI	1km	Resource Environment Data Cloud Platform(http://www. resdc.cn)
Socioeconomic data	Chinese provinces and cities	Statistical Yearbook (http://www.stats.gov.cn)
Administrative boundary and other vector data	Vector	Resource Environment Data Cloud Platform (http://www. resdc.cn)
Meteorological data, precipitation, evapotranspiration	0.05	China Meteorological Science Data Sharing Network（http：//data.cma.cn)
Soil data	1km	China Soil Dataset of the World Soil Database(HWSD)(v1．1) (http://westdc.westgis.ac.cn)

Land use data	300m	GLOBELAND30(http://www.globallandcover.com/GLC30Download/index.aspx)
NPP	1992-2015	Global Change Science Research Data Publishing System(http://www.geodoi.ac.cn)

Analysis method

Soil retention model

Estimating soil loss through a revised general soil loss equation(RUSLE)(Renard *et al.* 1997),This model has a wide range of uses and strong operability. The calculation formula is:

$$\mathbf{A_m=R\bullet K\bullet L\bullet S\bullet C\bullet P} \quad (1)$$

$$\mathbf{Ap=LS\bullet K\bullet R} \quad (2)$$

$$\mathbf{Ac=Ap-Am} \quad (3)$$

A_m is the average actual soil loss （$t\cdot hm^{-2}\cdot a^{-1}$）, Ap is the average potential soil loss （$t\cdot hm^{-2}\cdot a^{-1}$）, and Ac is the average soil retention （$t\cdot hm^{-2}a^{-1}$）, R is the rainfall erosivity factor （$MJ\cdot mm\cdot hm^{-2}\cdot h^{-1}\cdot a^{-1}$）, K is the soil erodibility factor ($t\cdot h\cdot MJ^{-1}\cdot mm^{-1}$), L is the slope length factor, S is the slope factor, C is the crop cover and management factor, and P is the soil conservation measure factor.

Water Yield model

The InVEST water production model algorithm is used(Bei W *et al.*2016). This method considers the influence of rainfall and evapotranspiration on water production(Shihan G *et al.*2017). The equation is:

$$TQ=(P-ET) \cdot Ai \quad (4)$$

TQ is the total water source conservation (m^3), P is the annual rainfall (mm), ET is the evapotranspiration, and Ai is the area of a single pixel.

NPP model

Using land-to-month meteorological data from 1992-2015, national soil texture data, and soil cover and vegetation index data products based on MODIS and AVHRR remote sensing images, the CASA(Potter, C.S. *et al.*1993) model was input with a resolution of 1km • 1km.

$$NPP(x,t) = APAR(x,t) \times \varepsilon(x,t) \quad (5)$$

In the formula: APAR(x,t) represents the photosynthetically active radiation （MJ/m^2） absorbed by the spatial position x in time t; ε(x, t) represents the actual light energy utilization of the pixel x in time t （g·MJ）.

Food Supply Evaluation Model

Combine the land use image and statistical yearbook data to measure the total food output value of each land use in the study area and realize the spatialization of food supply(Yijie S *et al.*2019). Calculated as follows:

$$Gi = Ai \cdot Ni \quad (6)$$

$$Ni = Fi / Si \quad (7)$$

Where, Gi is the total output value (yuan) of the food i corresponding to the grid of the study area, Ai is the area of the land use type corresponding to various foods i (m^2), and Ni is the output value per unit area of the food i (yuan/m^2). Fi is the total output value of food i, and Si is the total area of each land use type.

Trade-off and synergistic correlation analysis statistical methods

Ecosystem services are complex. In the same region, changes in one ecosystem service will inevitably lead to changes in another ecosystem service or even multiple ecosystem services. Therefore, it is necessary to eliminate the influence of unrelated factors. Analyze the relationship between the two ecosystem services, namely the correlation analysis.Calculated as follows:

$$r_{12(ij)} = \frac{\sum_{n=1}^{n}\left(ES1_{n(ij)} - \overline{ES1_{(ij)}}\right)\left(ES2_{n(ij)} - \overline{ES2_{(ij)}}\right)}{\sqrt{\sum_{n=1}^{n}\left(ES1_{n(ij)} - \overline{ES1_{(ij)}}\right)^2 \sum_{n=1}^{n}\left(ES2_{n(ij)} - \overline{ES2_{(ij)}}\right)^2}} \quad \textbf{(8)}$$

Normalization

To explore the differences and changes in the four types of services in different territories, the normalized linear function conversion formula is used to calculate the normalized values(Bradford, J.B. *et al.*2011):

$$Y=（X-Min)/(Max-Min) \quad \textbf{(9)}$$

X and Y are the values before and after the conversion, and Max and Min are the maximum and minimum values of the sample, respectively.

RESULTS

Changes in ecosystem services

By calculating the four ES in China, the spatial distribution map is obtained. The results show that the eight provinces and cities in southern China account for only 20.33% of the national area, but provide 51.82% of the country's soil conservation, 38.74% Water yield, 36.84% food supply and 33.98% NPP.

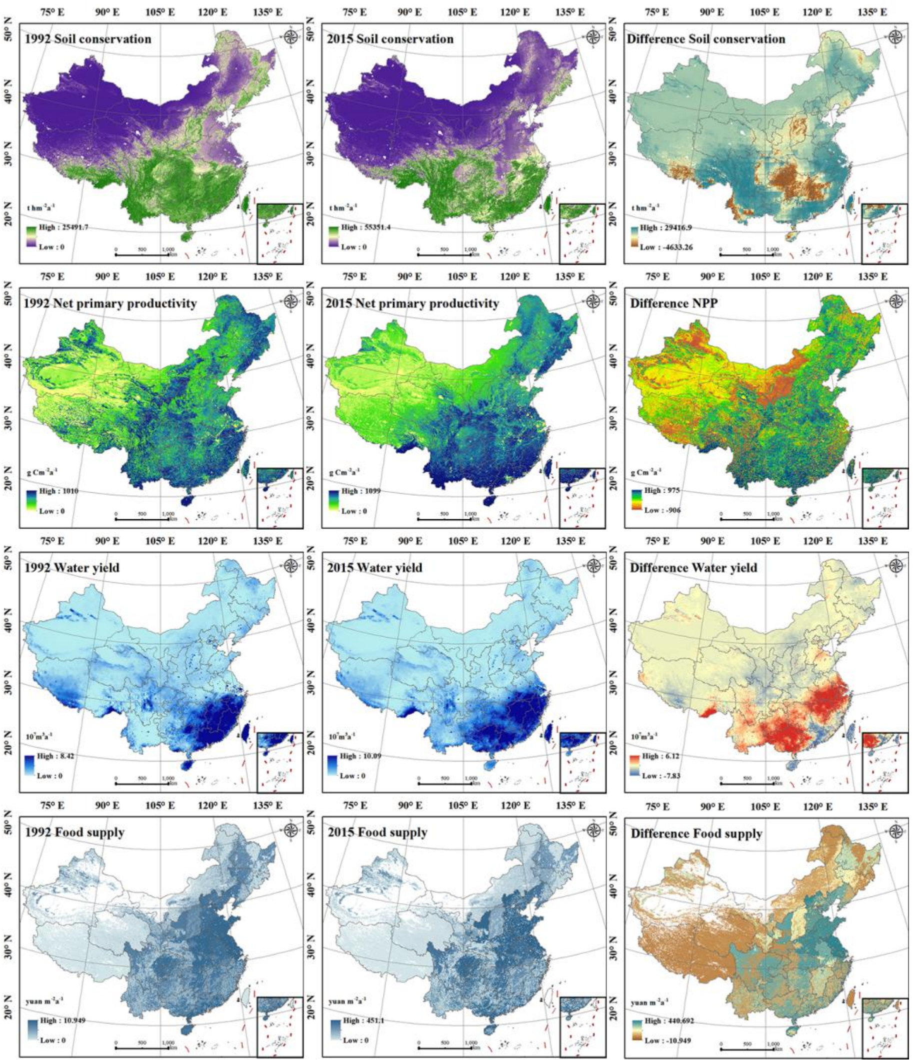

Figure 1

Spatial change map of ecosystem services from 1992 to 2015

The growth of WY, SC and NPP at the junction of the southeastern part of the

Qinghai-Tibet Plateau and the Hengduan Mountains is very significant. The SC has increased from $1521.96t\cdot hm^{-2}a^{-1}$ to $3617.06t\cdot hm^{-2}a^{-1}$, which is one of the most significant areas for SC growth in the country. WY increased from $4.45\cdot 10^{7}m^{3}$ in 1992 to $9.77\cdot 10^{7}m^{3}$ in 2015, and the average annual water yield increased by $2.32\cdot 10^{6}m^{3}$;the national vegetation NPP average was $227.61gCm^{-2}a^{-1}$in 2015, the southeastern part of the Qinghai-Tibet Plateau NPP is between $420gCm^{-2}a^{-1}$ and $830gCm^{-2}a^{-1}$, which is 2-4 times higher than the national average NPP value.

As global temperatures continue to rise, FS is concentrated in the Northeast Plain, North China Plain, the middle and lower reaches of the Yangtze River, and the Sichuan Basin.

Dynamic time relationship of ecosystem services

Based on the time series from 1992 to 2015, the dynamic trend analysis of the changes in the average value of four kinds of ES in China, Showed that all kinds of ecosystem services have undergone a certain degree of change. Although there have been ups and downs, the overall ecological situation of China has become more and more better and evolve in a good direction.

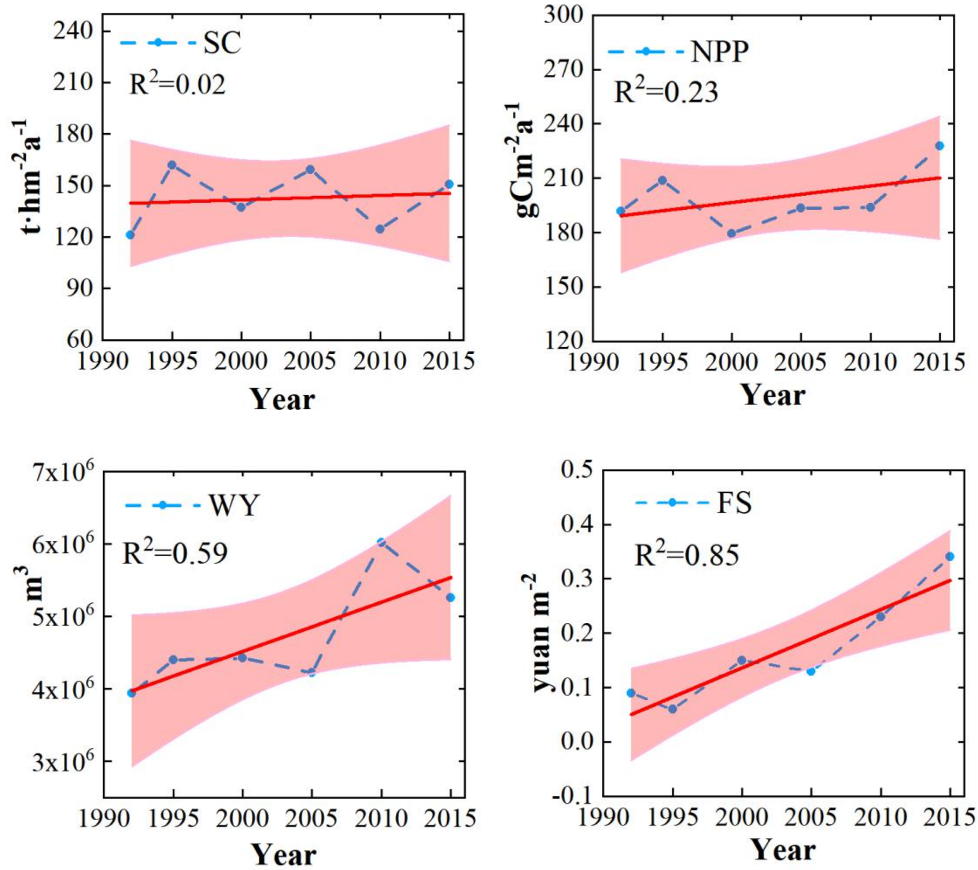

Figure 2

Four ES Mean Line Charts from 1992 to 2015

Compared with 1992, The increase in FS was the most significant, with an increase of 277.78%,WY increased by 33.46%, SC increased by 24.13% and NPP increase by 18.63% in 2015. It can be seen from Figure 1 that not all areas in space keep rising. For example, the northwestern part of the Qinghai-Tibet Plateau NPP and SC in the southeast have declined.

Spatial relationship of ecosystem services

Through the ecosystem service space map (Fig. 3), the correlation distribution between ES in various regions of China can be better revealed. The results show that China has more than half of the area SC and WY synergistic relationship, and the trade-off relationship is scattered. The SC and FS in the Loess Plateau and Tibet Province are negatively correlated with the complete and basically occupy the whole region, while the Sanjiangyuan region in Qinghai province and the lower reaches of the Yangtze River have a synergistic relationship. The trade-off between WY and FS is mainly distributed in northern China.

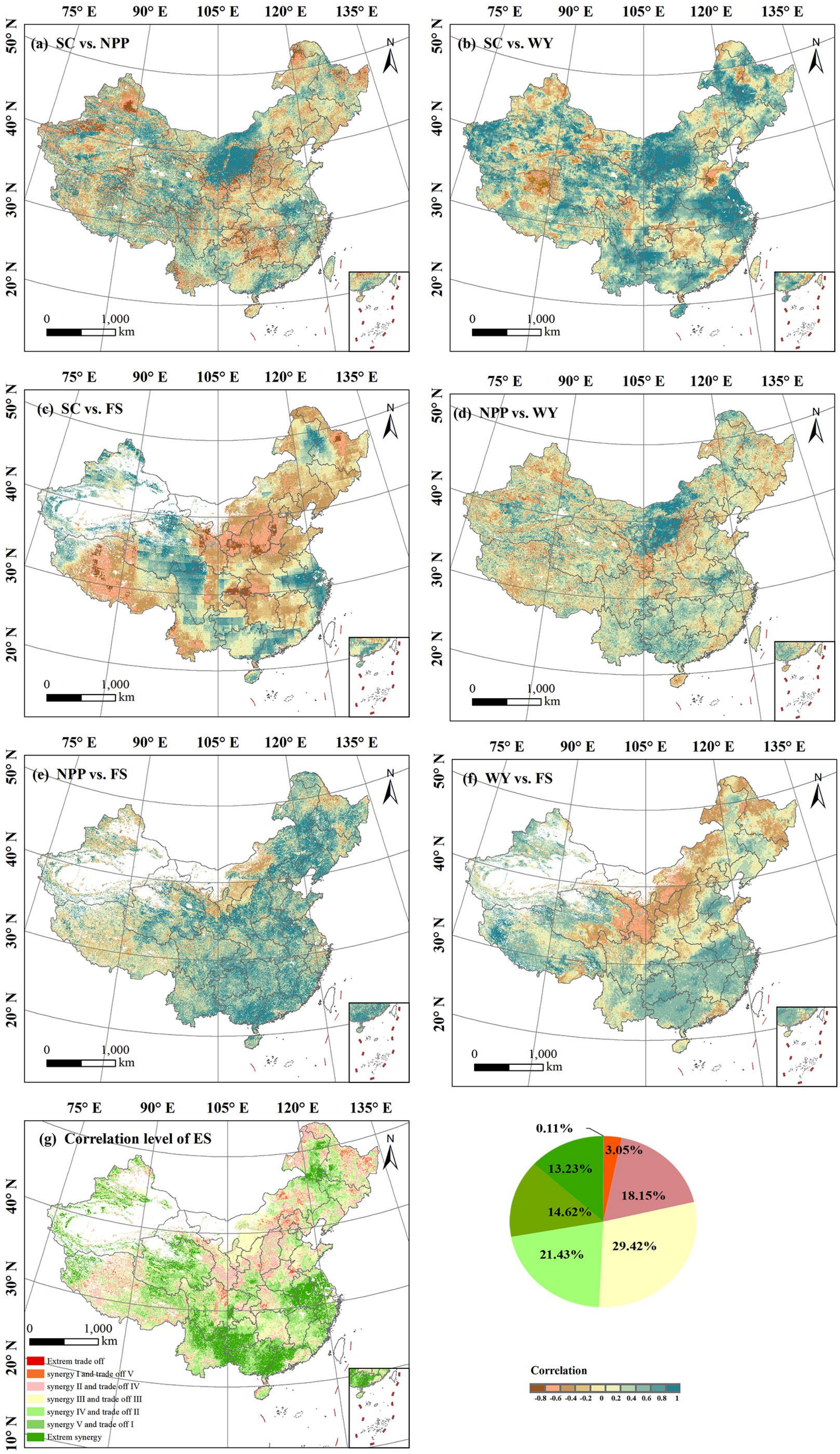
(a) SC vs. NPP
(b) SC vs. WY
(c) SC vs. FS
(d) NPP vs. WY
(e) NPP vs. FS
(f) WY vs. FS
(g) Correlation level of ES
75° E
90° E
105° E
120° E
135° E
50° N
40° N
30° N
20° N
10° N
N
0
1,000
km
Extrem trade off
synergy I and trade off V
synergy II and trade off IV
synergy III and trade off III
synergy IV and trade off II
synergy V and trade off I
Extrem synergy
0.11%
3.05%
13.23%
18.15%
14.62%
21.43%
29.42%
Correlation
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

Figure 3

ES correlation space map(a: SC-NPP correlation b: SC-WY correlation c: SC-FS correlation d: NPP-WY correlation e: NPP-FS correlation f: WY-FS correlation g:correlation levle of ES)

Some scholars Bennett, E.M. *et al.* (2009) analysis of the interaction between drivers and multiple services shows that it is possible to manipulate ES drivers to generate synergies or avoid trade-offs in many cases. if you only focus on one ES and ignore the trade-off relationship between ES When making decision management, it will cause an unnecessary decline in some ES(Millennium Ecosystem Assessment 2005； Diaz＆ Rosenberg 2008), considering this situation, this article Dividing the trade-offs and synergies into 7 levels (Figure 3g), it can be clearly seen that the areas where synergy is more dominant (the three green areas in the figure) account for about half of the total area (49.28%), while the extreme synergy accounts for Compared with 13.23%, it accounted for 26.84% in regions with better synergy. The overall trade-off area is the smallest (0.11%). It can be seen that in the overall ES relationship in China, the coordinated regions occupy a dominant position, and the extreme coordinated regional distribution is concentrated, mainly including: the Northeast Plain, the lower Yangtze River, some provinces in the southwest, the three river source regions, and the northwest margin. The restoration of a single ecological service function in this area can greatly enhance other ES functions, with high added value, and will greatly promote local ecological development.

Differences in ecosystem services in different land types

Combined with land use data, the average value of four ESs in cultivated field, woodland and grassland was obtained, and the four ES factors in various land use types were extracted by sampling.

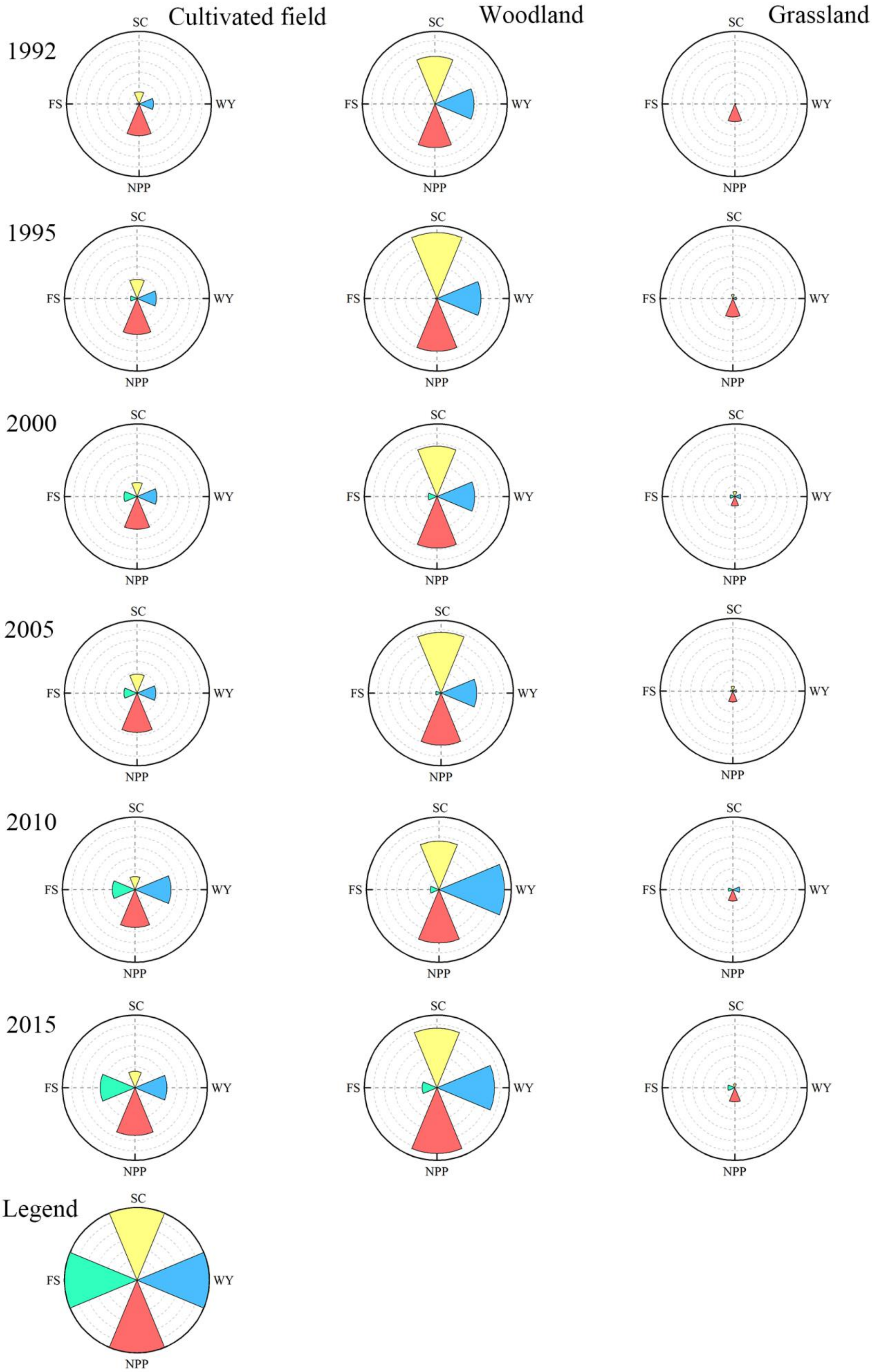
Cultivated field
Woodland
Grassland
1992
1995
2000
2005
2010
2015
Legend
SC
WY
NPP
FS

Figure 4

China's ecosystem services rose map from 1992 to 2015

Use the normalization formula to normalize the four ES to between 0-1 and get a rose diagram. It can be seen from the rose diagram that among the three land types, NPP is the highest overall, and the woodland is the main provider of regional ES. The contribution rate of woodland to SC, NPP, and WY is 54%, 40%, 37%. However, for FS, the relative contribution of cultivated field is greater than that of woodland and grassland (Jian P *et al.* 2017). In cultivated field, NPP is the highest and SC is the lowest; in grassland, NPP is the most significant, FS is rising.

In the past 23 years, the four ESs have been on the rise in both cultivated field and woodland. Although the area of cultivated field decreased in 2000-2015, due to the increase of annual rainfall and the rapid development of modern agricultural irrigation technology in China, the yield per unit of grain increased. And the amount of water yield in the forest and the increase in NPP. And because of the rapid growth of hybrids, multiple cropping, irrigation, fertilization, pest control, high-quality seeds, agricultural mechanization and other reasons (reference paper), the value of food supply in cultivated field has increased in recent years (Mengya H *et al.* 2017) .

DISCUSSION

Land use change

China's land use/land cover changed dramatically from 1992 to 2015. The urban land area actively expanded 253%, and wetlands increased by 6.9%. The reduction in unused land is most pronounced.

Table 2 Table of Changes in Areas of Land Use Types from 1992 to 2015（$10^4 km^2$）

Land use type	1992	1995	2000	2005	2010	2015	1992-2000	2000-2015	1992-2015	Total rate of change
cultivated field	270.58	271.73	275.82	274.63	274.48	272.86	5.24	-2.96	2.28	0.8%
woodland	183.55	182.79	181.68	182.75	182.33	182.27	-1.87	0.59	-1.28	-0.7%
Grassland	299.43	298.52	296.86	296.34	296.22	296.61	-2.56	-0.26	-2.82	-0.9%
wetlands	3.44	3.44	3.49	3.59	3.66	3.68	0.05	0.19	0.24	6.9%
Urban land	3.49	3.81	4.37	7.01	9.62	12.31	0.88	7.94	8.83	253%
Unutilized land	190.32	190.53	188.53	186.41	184.39	182.87	-1.80	-5.66	-7.45	-3.9%
Waters	12.64	12.61	12.68	12.70	12.74	12.85	0.04	0.17	0.21	1.7%

Taking 2000 as a node, we explored the land use change before and after the implementation of the policy of “Grain for Green Project”. Looking at the change of cultivated field area, it was found that it increased by $5.24 \cdot 10^4 km^2$ between 1992 and 2000, and decreased by $2.96 \cdot 10^4 km^2$between 2000 and 2015. Looking at the comparison of the area of Woodland and grassland around 2000, we can find that China's policy of “Grain for Green Project” has achieved corresponding effects; the wetlands area has been growing; urban land has increased the most significant area in all land types, with an overall growth of 253%. The area of unutilized land decreased rapidly after 2000. The waters maintains a steady and small increase.

Combined with Table 3 and Fig.5, we can see the changes and spatial distribution of localities in China over the past 23 years. China's reduced land use is basically the same as the increased land use area. Even if the area transferred to cultivated field is nearly 164 million mu, due to the influence of policies, there are also nearly 150 million mu of cultivated field converted into woodland and grassland; and the reduction of unutilized land was the most significant, and most of it was transferred to grassland and cultivated field. The increase in urban land is mainly due to the return of cultivated field and grassland.

Table 3 1992-2015 Land Use Transfer Matrix（km^2）

Land use type	Cultivated field	Woodland	Grassland	Wetlands	Urban land	Unutilized land	Waters
Cultivated field	/	56841.01	41190.69	1080.83	60418.79	1742.73	4463.97
Woodland	109642.26	/	12098.78	607.44	2302.53	240.45	889.56
Grassland	66801.34	48190.32	/	289.43	10597.36	36354.66	4439.77
Wetlands	509.17	213.31	180.23	/	302.79	24.49	265.23
Urban land	1577.79	63.24	34.71	0.74	/	1.94	26.07
Unutilized land	22731.62	22.88	86265.58	74.67	870.81	/	1878.96
Waters	4185.73	437.29	2521.25	1913.47	654.59	936.22	/
Transferred area	205447.91	105768.03	142291.25	3966.57	75146.87	39300.49	11963.56

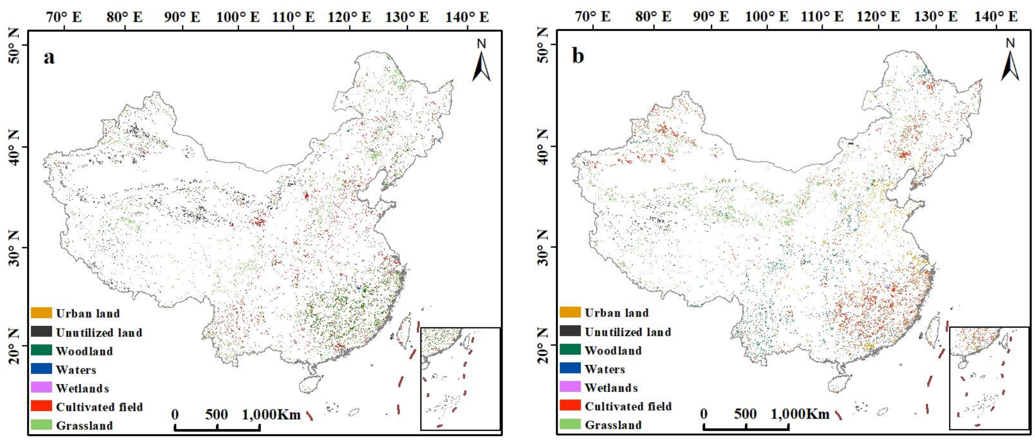

Figure 5

Decreased and increased land covers from 1992 to 2015.

a Decreased type b Increased type

ES synergy and trade-off relationships have high spatial heterogeneity, which largely depends on the spatial pattern of land use (Xibao X *et al.* 2018). Some scholars (Zhihui T *et al.* 2019) take the Yellow River Basin as an example, it is found that the increase of woodland and grassland has reduced the overall loss of vegetation NPP, It can be seen that the implementation of the policy of"Grain for Green Project" has achieved results. Basically, the reduction of woodland and grassland area caused the annual average NPP value to change from 1995 to 2000 . The annual average NPP value in grassland decreased from $167.40gCm^{-2}a^{-1}$ to $120.28gCm^{-2}a^{-1}$. The increase in woodland after 2000 has led to an upward trend in annual average NPP and SC.

Another scholar (Yaru Z *et al.* 2019) proved that land use change mainly affects the actual evaporation by changing the condition of the underlying surface, thus affecting the WY. Afforestation will increase NPP, but the process of tree growth will lead to an increase in evapotranspiration, and reduce water utilization, and there is a negative interaction(Fahey & Jackson 1997; Engel *et al.* 2005). This conclusion is consistent with the findings found in this paper. For example, the annual average WY in grassland decreased from $2.61 \cdot 10^6 m^3$ in 1992 to $2.41 \cdot 10^6 m^3$ in 2015. The FS is mainly affected by cultivated field, the area of cultivated field is increasing, and FS is also rising.

Impact of rainfall and temperature on ES

Precipitation and temperature play an important role in influencing WY and NPP. Relevant research shows that there is a positive correlation between annual average NPP and rainfall in 97.15% of the country (Miaomiao Z et al 2019), and the increase in precipitation significantly increases the amount of WY. For example, southern Tibet is one of the fastest growing regions in China. The average rainfall in this region has been around 3000mm in the past 15 years, which is higher than 26 provinces and cities in China (except Guangdong, Guangxi, Jiangxi, Fujian, Taiwan, Anhui and Zhejiang). Province).

Taking the Loess Plateau as an example, the history of this area has been due to sparse vegetation cover, periodic high-intensity heavy rain and long-term agricultural history, and it has a high rate of soil erosion, which has become one of the key areas for China to implement the policy of “Grain for Green Project” . However, vegetation restoration on the Loess Plateau is highly restricted by water supply. One of the most important negative effects of “Grain for Green Project” is to make the shallow and deep local soils extremely dry (Qiang F *et al.* 2017). Some scholars (Fang *et al.* 2016) have found that low precipitation and high evaporation and climate warming and drying trend are the main reasons for the negative correlation between NPP and WY in the Loess Plateau, there is located in arid and semi-arid regions, rainfall is lower than the national average, and the results of this study show that the area of woodland and grassland increased during the 15 years after the implementation of the policy of “Grain for Green Project”, while the total amount of evapotranspiration increased by 16.41%. The mean value increased from 351.49mm to 409.17mm, and compared with 2000, the annual average runoff of the entire Loess Plateau decreased by 25.53mm in 2015.

Another typical area is the Continental Basin of one of China's nine major river basins in arid and semi-arid regions. Climate elements play dominate role of the local ES. The average annual rainfall of this region is 190.87mm in 2000, and the average value in 2015 is 176.33mm. The annual average rainfall is significantly reduced, and the transpiration rate exceeds the normal level. The average annual runoff value in 2005 is 53.96mm, the average value in 2015 is 44.9mm. The resulting average WY decreased from $1.64 \cdot 10^6 m^3$ in 2000 to $1.36 \cdot 10^6 m^3$ in 2015, mainly due to the significant decrease in WY in the south. It can be seen from the spatial distribution map that the decrease in rainfall is the main reason for the decrease in WY. And some scholars (Kathleen A *et al.* 2005) have shown that planting trees may reduce WY by half or more where natural runoff accounts for 30% of precipitation. Increasing afforestation will not only improve water-saving functions, but also exacerbate water shortage(Z.X.Zhou *et al.* 2017).Through the study of this paper, it is found that the average annual runoff of Continental Basin only accounts for one quarter (25%) of the rainfall. The ES correlation of the nine major river basins is calculated through sample collection. It is found that only the Continental Basin NPP and the nine river basins in China WY showed a negative correlation, and the correlation index was -0.17*** ($p<0.01$).

Therefore, the findings of this paper validate the viewpoints of the aforementioned scholars that vegetation restoration may further reduce runoff and soil moisture in arid and semi-arid areas, and aggravate water scarcity.

Table 4 Land use transfer matrix of Continental Basin from 2000 to 2015 (km^2)

Land use type	Cultivated field	Woodland	Grassland	Wetlands	Urban land	Unutilized land	Waters
Cultivated field	/	294.04	12847.3	15.39	632	1273.45	50.79
Woodland	336.81	/	1779.82	0	0	186.44	24.06
Grassland	15610.5	3472.5	/	124.28	445.39	32179.3	3013.36
Wetlands	54.91	0	115.02	/	0	13.4	33.68
Urban land	17.14	0	11.7	0	/	1.94	0
Unutilized land	20679	2.61	71148.8	62.84	319.92	/	1414.68
Waters	237.47	20.46	1041.31	307.75	0	643.55	/

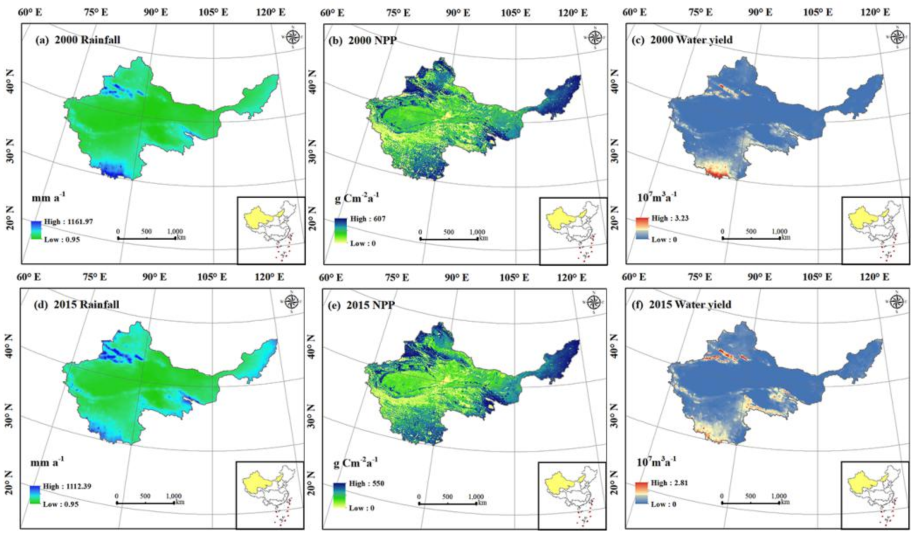

Figure 6

Spatial map of rainfall, NPP and WY in Continental Basin from 2000 to 2015

Reflections on China's Future Ecological Restoration and Development

Looking at the overall changes in China's four ESs over the past 23 years,we can find that China's overall ecological environment is getting better, For example, it has greatly promoted the increase of vegetation coverage in China(Yujie Y *et al.*2019).but there is also a partial deterioration. National major ecological projects have played an extremely important role in eliminating the negative impact of human activities on ES, but in some special environmental areas, enhancing one ES will affect the degradation of another ES function, as mentioned above. The Loess Plateau and Continental Basin have increased environmental degradation in order to increase forest cover because it ignores the climate, ecological and hydrological factors that are not suitable for afforestation (Shixiong C *et al.* 2010). Therefore, we can think that clarifying the trade-off relationship between multiple ES and utilizing the capital investment of stakeholders to coordinate the ecosystem service functions required by various regions can help achieve the desired results in many aspects(Zheng H *et al.*2019). According to its spatial distribution, in the process of ecological restoration, the forest coverage rate should not be pursued blindly, but appropriate control measures should be taken according to the actual local conditions.

First, simulate local related hydrological effects to determine whether it is suitable for afforestation, establish vegetation planting locations and select suitable vegetation based on slope, location, slope direction and soil characteristics (Tim R. *et al.* 2007). In some economically underdeveloped regions, carefully select the appropriate type of vegetation to restore optimal vegetation services based on local climate constraints (especially precipitation)(Xiaoming F *et al.* 2013). Related studies (Xiaoqing J *et al.* 2014) have shown that shrubs have a strong inhibitory effect on the surface WY while seabuckthorn is the most suitable afforestation plant in arid and semi-arid regions. (Qiang F *et al.* 2017).

Second, establish a tree plantation threshold. In order to maintain a sustainable ecological and hydrological environment in the region, vegetation regrowth to prevent negative effects caused by excessive ecological measures, thresholds should be urgently set to limit further deterioration.

More importantly, the main purpose of dealing with ES trade-offs is to improve regional environmental issues, using appropriate land management to transform trade-offs into synergies (Renard D *et al.* 2015) to achieve sustainable development. Establishing environmental protection policy development in the coordination of different ecosystem services is essential. According to the trade-off relationship between NPP and WY in the inland river basin and the Loess Plateau, in the future, the forest community structure can be adjusted to reduce water consumption, ensure the basic water volume of the basin, and improve water quality to ensure production and domestic water. From a sustainability perspective, future development projections should be guided by the UN Sustainable Development Goals.And how to achieve a win-win result requires the development strategy tailored to local conditions, and may change as market or environmental conditions change（Hua Z *et al.*2019）.

In addition, the spatial heterogeneity of geographic environment will lead to scale effects of changes in ecosystem services' trade-offs and synergistic relationships (Mengya H *et al.*2017). This article considers this factor and calculates the national multi-year trade-offs and synergistic relationships while calculating The ES correlation of several significant areas was discussed separately, and it was obtained that afforestation in arid and semi-arid areas would lead to further loss of water production.

Although through the research of this paper, we find that the ES have improved and China's overall ecological environment is relatively good, but if we want to provide better ecological guidance for the future, this article should make progress in the following areas. First, collect a finer-resolution data source. Second, the dynamic changes and influencing factors of ES trade-offs and synergies are explored based on different scales, and various types of conflicts in land resources are weighed according to different regional characteristics in order to propose more precise land management policies. Third, due to the multiple interactions between human society and natural systems. Although land use / land cover is often regarded as the main impact factor affecting ecosystem services, existing land cover classification systems greatly simplify human impacts on the landscape(Ellis＆Ramankutty 2008). The social characteristics of the region can help determine the changes in ES correlations across the region(Delphine Renard *et al.*2015), such as climate Change and accumulation of organic pollutants. These studies will improve human well-being and our ability to adapt to changes in the ecological environment in a more comprehensive and credible way.

In the future, we will further consider what is the most effective way to weaken or reverse the ES trade-off relationship and enhance the synergy relationship; Are the correlations between ecosystem services strong, How does the strength of this relationship change over time, management, and scale.

CONCLUSION

China's overall ecosystem environment tends to improve, FS growth of 277.78%, WY increased by 33.46%, SC increased by 24.13%, NPP increased by 18.63%;

Of the eight provinces in the south, which accounted for 20.33% of the country's total area, provided 51.82% of SC, 38.74% of WY, 36.84% of FS and 33.98% of NPP;

The southeastern part of the Qinghai-Tibet Plateau is one of the fastest growing regions of WY, SC and NPP in the country. The SC increased from 1521.96$t \cdot hm^{-2}a^{-1}$ to 3617.06$t \cdot hm^{-2}a^{-1}$, and the average annual water yield increased by $2.32 \cdot 10^6 m^3$. The growth rate of NPP has reached half of the national NPP growth rate, which is 2-4 times higher than the national average NPP .

The area where the synergy is more dominant accounts for about half of the total land area. The ecological restoration project in this area can greatly promote the development of the ecological environment and has extremely high added value.

By exploring the impact of different land types on ES, it is found that the contribution rate of forest land to SC, NPP, and WY is 54%, 40%, and 37%, respectively.

Afforestation activities in the Loess Plateau and Continental Basin increased evapotranspiration, reduced water yield and soil moisture, and afforestation in this area would aggravate water shortage.

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