How to effectively improve the ecosystem provisioning services in traditional agricultural and pastoral areas in China?

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ABSTRACT

The provisioning services of ecosystems are fundamental for people's livelihoods, health, and survival, yet provisioning services are highly dependent on land use/cover change (LUCC), especially in fragile alpine ecosystems. In the Qilian Mountains, one of China's traditional farming and pastoral areas, changes in provisioning services are related to regional well-being. This study focuses on the multi-scale evolution, driving factors, and sustainable development strategies for providing farmland and grassland ecosystem services from 2000 to 2020. The results showed an overall upward trend in the value of providing services by grassland and cropland ecosystems over the past 20 years, increasing by US $249 million and US $67.35 million, respectively. The economic benefits of livestock products provided by grassland and agricultural products from farmland accounted for 70.5% and 29.5% of the total income of farmers and herdsmen, respectively. However, in the past 10 years, the contribution of grassland and farmland ecosystems to provisioning services has decreased by 0.2% and 1.7% respectively. The reduction of contribution will directly affect the capacity to provisioning services, which is not conducive to regional development. It is found that human factors such as policy system change, urbanization process and ideological change are the main driving factors for the change of supply services in traditional agricultural and pastoral areas, and climate change has played a certain role in promoting. In order to effectively improve the ability of traditional agricultural and pastoral areas to provide services, we put forward the development strategy of "Ecological Husbandry + Precision Agriculture (EHPA)". and promote the "Production, Learning, Scientific research and Practical application" of ecosystem services from the five aspects of ecological space, industrial layout, ecological industrial development, ecological technology and ecological policy system, so as to improve the ability of ecosystem provisioning services.

1. Introduction

Ecosystems provide humans with a wide range of direct and indirect services, including regulation, support, provisioning, and cultural services, which are fundamental for economic development and human well-being (Costanza et al., 1997; MA, 2005; TEEB, 2010). Examples include the provision of basic needs through food, water resources, wood, biological raw materials, etc., benefits from water conservation, climate regulation, carbon sequestration, soil conservation, windbreak and sand fixation, etc.; and intangible cultural value benefits obtained after contact with nature (Haines-Young and Potschin, 2018). Alpine ecosystems are essential providers of social ecosystems (Briner et al.,

2013). Globally, the types of alpine ecosystems are complex and diverse, including alpine forests (Silva et al., 2016), alpine grassland ecosystems (Liu et al., 2018), alpine glaciers and permafrost (Wei et al., 2021), and alpine creatures (Stokstad, 2020), and the interactions between ecosystem services are complex (Huber et al., 2013). Due to unique topography, complex social composition, and diverse policy management, alpine regions are more vulnerable to climate change and human activities (Huber et al., 2013). Therefore, alpine ecosystems are susceptible to climate change and human activities.

Land use/cover change, namely LUCC, is one of the most significant pressures facing mountain regions and affects the production, composition, functions, and services of several ecosystems, ultimately

threatening human well-being (Egarter Vigl et al., 2017; Locatelli et al., 2017). Along with the rapid industrialization and the increasing challenges resulting from climate, ecosystem services have become more critical to sustaining human-beings development (Di Sabatino et al., 2013). However, when people participate in land use management, they often pursue only one or several types of ecosystem services (Bennett et al., 2009; Haase et al., 2012), resulting in the demand for one service function at the expense of other services. During the past decades, countries and regions worldwide have strengthened their efforts to protect ecosystems, especially in China, where ecological protection has achieved remarkable results (NDRC, 2013; Wu et al., 2019; Zhang et al., 2020; Yang et al., 2022). Under current institutional circumstances, making full use of the exploitable ecosystem types and maximizing the value of ecosystem services is of great significance for understanding the relationship between alpine ecosystem services and LUCC caused by human activities and the service value provided by unique ecosystems for regional economic and social development.

The Qilian Mountains are a significant ecological security barrier in Western China, and the ecosystem service value is enormous. However, during the past 20 years, the LUCC has undergone significant changes, resulting in decreased ecosystem services mainly caused by massive human activities (Ding et al., 2018). After a series of environmental protection measures, forests, grasslands, glaciers, and other ecosystems have been strictly protected; and human economic activities have been greatly restricted (withdrawal of mines and hydropower, prohibition of grazing in grasslands, withdrawal of tourism projects, etc.) (Ding et al., 2018), the ecosystem continues to develop for the better, but at the same time, it also affects the regional economic development to a great extent. To further alleviate the contradiction between humans and land, it is necessary to discuss making full use of the exploitable ecosystem and implementing measures such as protective animal husbandry, farming systems, and crop types to maximize the service value provided by the ecosystem. To optimize the management and policy formulation and implementation of alpine ecosystem services and promote mountain ecology and economy's sustainable and stable development.

Grassland and farmland ecosystem are the main contributors to provisioning services in the Qilian Mountains. The change in provisioning service of grassland and farmland ecosystem is related to the survival and development of nearly 0.7 million people in the region. Therefore, this study focused on evaluating and analyzing the service value of ecosystems (grassland and farmland) in the Qilian Mountains from 2000 to 2020 under LUCC. We aimed to understand: (1) How has the provision of grassland and cropland ecosystem services evolved in space and time? (2) What is the dynamic change of grassland and farmland ecosystems? (3) Which are the main driving forces causing grassland and farmland ecosystem services changes? And (4) Propose countermeasures for sustainable and stable development of mountainous areas.

2. Materials and methodology

2.1. Study area

The Qilian Mountains (93.4°-103.4°E, 35.8°-40.0°N) locate in the intersection zone of the Tibetan, Inner Mongolia-Xinjiang, and Loess Plateaus (Wang et al., 2019) (Fig. 1); it is also the intersection of the Eastern monsoon region, northwest arid and semi-arid region and Qinghai-Tibet Plateau alpine and cold region, a fragile and sensitive region to climate change (Wang et al., 2019). Therefore, it has a pivotal and irreplaceable position in maintaining ecological security, water source protection, and species diversity in western China (Zang et al., 2021), and more critical, as the supplier of numerous ecosystem services, such as water regulation, soil erosion control, biodiversity protection, and carbon sequestration (Yang et al., 2018). In addition, it maintains the survival and development of nearly 700,000 people (Ding et al., 2018).

2.2. Data sources

The administrative boundary and topographic data were obtained from the Resource and Environment Science Data Center of the Chinese Academy of Sciences. The LUCC data set from 2000 to 2020 is provided by the Data Center for Resource and Environment Science, Chinese Academy of Sciences (RESDC) (https://www.resdc.cn). The spatial resolution is 30 m (Landsat 8), the land-use types are reclassified into 22 land-use types, and two land-use types, grassland and farmland are reserved according to research needs. The temperature and precipitation data for 2000–2020 were sourced from the China Meteorological Administration Meteorological Data Center (https://data.cma.cn/); agriculture, animal husbandry, population, labor force, and other data sourced from the statistical yearbooks of Wuwei and Zhangye (https://www.gswuwei.gov.cn/; https://www.zhangye.gov.cn/).

2.3. Ecosystem services assessment

In the classification framework of ecosystem services proposed by
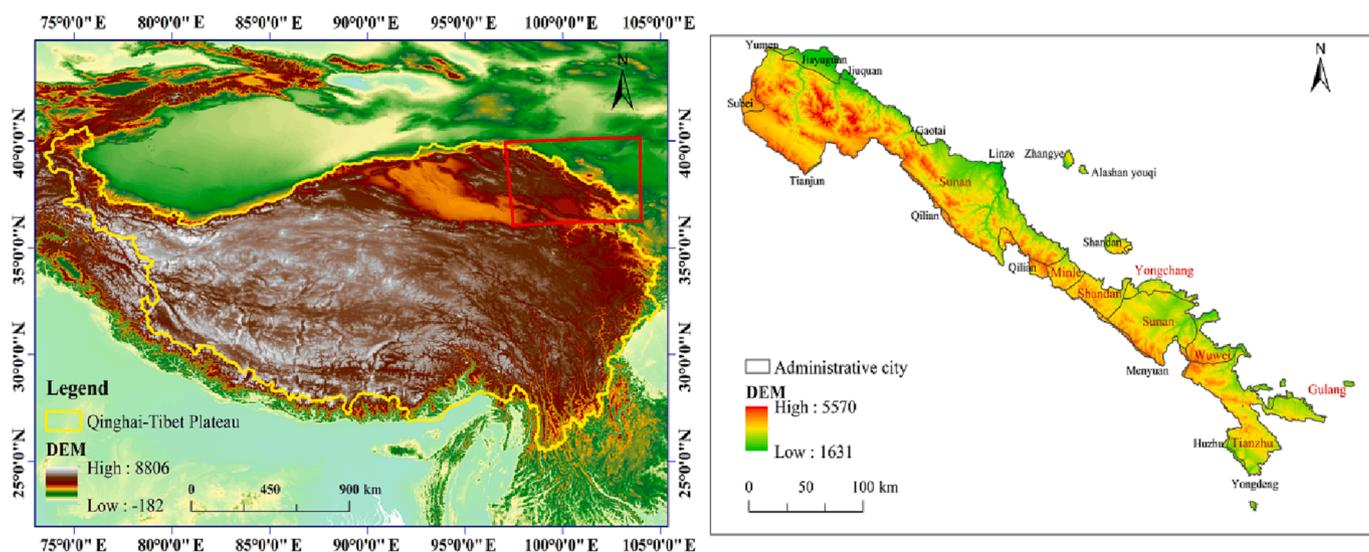

Fig. 1. Location of the study area.

the International MA Initiative, ecosystem services are divided into provisioning services, regulating services, supporting services, and cultural services (MA, 2005). To study the changes in the provisioning services of ecosystems under different land-use types, therefore, regulating services, supporting services, and cultural services are not included. This study focuses on the value of food production(FP), raw material production(RWP), and water supply(WS) for provisioning services.

2.4. Food production (FP)

This study calculated the food production value of farmland and grassland ecosystems using FP data from Wuwei and Zhangye statistical yearbooks and the market value method.

$$FL = A \times Y \times P \tag{1}$$

$$GL = M \times P - (F + O) \tag{2}$$

The main crops in the study area are wheat, potato, and rapeseed. Therefore, wheat, potatoes, and canola are the primary providers of farmland supply service value. *FL* stands for the value of food production in research farmland (Ma et al., 2020), *A* represents the planting area of crops, *Y* represents the crop yield per unit area, and *P* represents the unit price of crops. The difference of crop prices in different regions will affect the accuracy of the assessment. Therefore, we conducted field investigation on crop prices in four counties in the study area (Table 1).

GL stands for research on the value of grassland food production. Considering that the dominated industry in the studied area is animal husbandry, the secondary and product (beef and mutton yield) of the grassland were dominated for evaluation. *M* represents the annual output of beef and mutton, *P* represents the unit price of beef and mutton, *F* is the expenditure on feed purchase, and *O* is another expenditure on breeding. Considering that livestock needs to buy a large amount of feed, we will deduct the purchase of feed in the calculation process to supply the grassland value accurately. All prices refer to the Gansu Provincial Grain and Material Reserve Bureau (https://lscb.gansu.gov.cn/) and the Gansu Provincial Market Supervision Bureau (https://scjg.gansu.gov.cn/).

2.5. Raw material production (RMP) and water supply (WS)

The value of services provided by grassland and cropland was estimated using the methodologies developed by Costanza et al., (1997); Xie et al., (2017), and Sannigrahia et al. (2018) for the value assessment of ecosystem services. The basis equivalence coefficient per unit area is extracted from the source by Xie et al. (2015) (Table 1).

$$V_i = \sum_{k=1}^{n} UV_{ik} \tag{3}$$

$$ESV_t = \sum_{i=1}^{n} V_i \times A_i \tag{4}$$

V_i is the total value of ecosystem type i, which equals the sum of n kinds of ecosystem service unit value (UV_{ik}) obtained from (Table 2). A_i is the area of ecosystem type i, which depends on LUCC data and is automatically calculated by ArcMap 10.6. The total ecosystem service value

Table 1
The Crop prices in 4 counties of the study area ($/kg).

City	County	Wheat ($/kg)	Potato ($/kg)	Rapeseed ($/kg)
Wuwei	**Tianzhu**	0.36	0.24	0.90
	Shandan	0.42	0.18	0.75
Zhangye	**Minle**	0.39	0.21	1.01
	Sunan	0.35	0.20	0.87

(ESV_t) is the sum of the products of V_i and A_i of ecosystem types.

3. Results

3.1. Temporal variation of LUCC in the Qilian Mountains

As shown in Fig. 2, there are significant differences in the transfer of land use over time. From 2000 to 2020, more than 55% of LUCC in the study area has changed, and the total area of transformed land has reached 74709 ha, including 37385 ha from 2000 to 2010 and 37268 ha from 2015 to 2020, indicating that the change of land use is more drastic. Specifically, the area of LUCC changed significantly from 2000 to 2010. In particular, the area of forest land, grassland and wetland increased by 0.68%, 1.0% and 1.22% respectively, which is closely related to the reduction of human activities caused by the policy of closing mountains and prohibiting grazing at this stage. However, we also found that from 2015 to 2020, the area of farmland and grassland in Qilian Mountain decreased by −0.02% and −1.12% respectively, which affected the sustainability of regional ecosystem supply services. Therefore, we focused on the farmland and grassland ecosystems in this period.

3.2. Spatial-temporal variation of provisioning services in the Qilian Mountains

Overall, from 2000 to 2020, the value of provisioning services showed an overall growth trend, from US $ 2.65 billion to US $ 3.07 billion, but there is still a downward trend in some areas. It can be seen from Fig. 3 that the high-value areas of FP are mainly located in the valleys and piedmont plains at medium and low altitudes, and the low-value areas are mainly distributed in high-altitude areas. Specifically, the FP has changed significantly from 2000 to 2020, and it was US $ 490 million, US $ 540 million, US $ 600 million, and US $ 870 million in 2000, 2010, 2015, and 2020, respectively. However, since 2015, the FP in the low altitude valley of the Qilian Mountains has shown a downward trend, closely related to the change in the farmland ecosystem in the valley. The high-value areas of the RMP are mainly in the middle-altitude regions, which are related to a large number of forests and grasslands distributed in the middle-altitude distribution. The overall change in 2000 and 2020 was smaller, at US $ 700 million and US $ 710 million, respectively, with the main growth area in the central region. The high-value areas of the WS are mainly at medium and high altitudes, and the large-scale distribution of forests and grasslands plays a positive role, and the eastern part is significantly higher than the western part, which is related to the significant precipitation in the eastern part. From a time scale, an increase of US $ 0.4 billion from 2000 to 2020 has a lot to do with the increase in regional vegetation coverage (Liang et al., 2016). At the same time, as the temperature continues to rise, the melting of glaciers also increases the freshwater supply (Yang et al., 2021).

From the perspective of the main ecosystem types (Fig. 4), forest, grassland, and farmland ecosystems are the main contributors to the provisioning services of the Qilian Mountains. With the change of time, from 2000 to 2020, the contribution of provisioning services of forest ecosystems increased by 1.4% (16.1%-17.5%); the contribution of provisioning services of grassland ecosystems changed relatively minor, but from 2015 to 2020 decreased by 0.2% (16.4%-16.2%); the contribution of farmland ecosystems to provisioning services changed significantly, decreased by 1.7% (9.0%-7.3%) from 2010 to 2020. The decrease of ecosystem service supply contribution will directly affect the service supply capacity, thus affecting regional development. Therefore, this study will not discuss the reasons and benefits of the increase in the contribution of forest ecosystem services. We will focus on the driving factors of the decrease in the contribution of grassland and farmland ecosystem services, and further try to construct a utilization and development model of grassland and farmland to maximize the value of

Table 2
The equivalent coefficient per unit area of ecosystems and value of per unit area ($/ha).

| Ecosystem classification		Provisioning		Ecosystem classification		Provisioning ($/ha)	
Primary	Secondary	RMP	WS	Primary	Secondary	RMP	WS
Farmland	Paddy field	0.09	−2.63	Farmland	Paddy field	684.35	45.29
	Dry farmland	0.40	0.02		Dry farmland	427.72	201.28
Forest	Closed forest land	0.63	0.33	Forest	Closed forest land	135.86	317.02
	Shrub land	0.43	0.22		Shrub land	95.61	216.38
	Sparse wood land	0.56	0.31		Sparse wood land	191.22	281.79
Grassland	Grassland	0.24	0.13	Grassland	Grassland	80.51	120.77
Water area	River	0.23	8.29	Water area	River	402.56	115.74
	Glacier and snow	0.00	2.16		Glacier and snow	0	0
Wetland	Wetland	0.50	2.59	Wetland	Wetland	256.63	251.60
Barren land	Desert	0.03	0.02	Barren land	Desert	5.03	15.10
	Gobi	0.00	2.00		Gobi	0	0
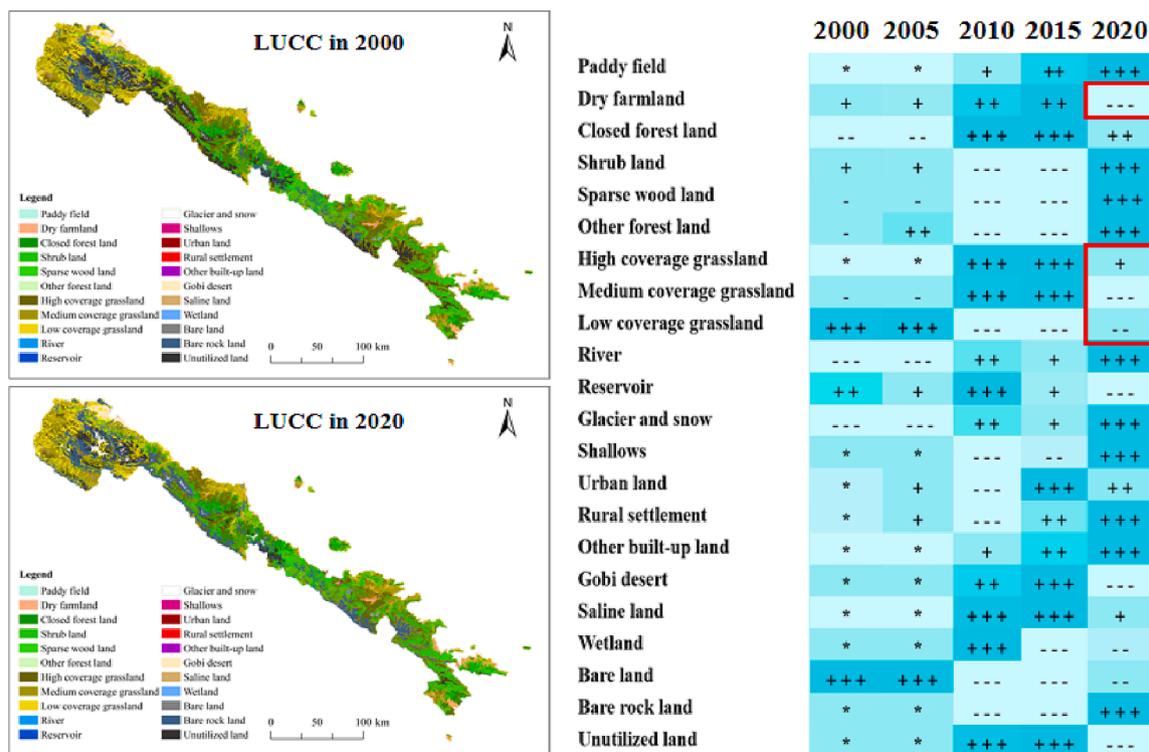
Fig. 2. Temporal variation of LUCC in the Qilian Mountains.

grassland and farmland provisioning services.

3.3. Regional key ecosystem and provisioning services in Qilian Mountains

3.3.1. Land use and cover change in grassland and farmland ecosystems

From the perspective of spatial distribution (Fig. 5), the grassland ecosystem is the most widely distributed, accounting for about 45% of the entire study area, mainly distributed between 1600 and 5200 m above sea level, and the grassland area changes mainly in low-altitude river valleys and western mountainous areas. From 2000 to 2010, the grassland area showed an increasing trend, increasing about 1.2%. The main growth area was the western mountainous area, which was mainly related to the grassland reward and subsidy policy at this stage. The grassland area was generally stable from 2010 to 2015. However, from 2015 to 2018, the grassland area decreased by about 1% due to grazing activities, mainly in the western mountainous areas. From 2018 to 2020, the degraded grassland was gradually restored, and the grassland area increased by about 0.45% during this period. From 2000 to 2020, the grasslands in the Qilian Mountains showed an overall improvement and

partial degradation. The western region is an unstable grassland ecosystem, which is highly vulnerable to climate change and human activities.

Farmland is the third largest ecosystem in the Qilian Mountains. Although the area accounts for only about 2% of the study area, the change in the farmland ecosystem is related to the stability and development of regional people's livelihood and well-being. From spatial distribution (Fig. 6), farmland is mainly distributed in the eastern and central river valleys and piedmont plains, closely related to the more precipitation in the eastern region, the flatter terrain, and the larger population. Concerning the time series from 2000 to 2015, the area of farmland increased by 923.2 ha, showing a more significant relationship with rural population increase. However, from 2015, the farmland area began to decrease, with about 1057.6 ha in five years. We have noticed that the project of returning farmland to forests and grasslands has been carried out at this stage. At the same time, urbanization has accelerated, and the agricultural labor force has decreased, intensifying the abandonment of cultivated land.
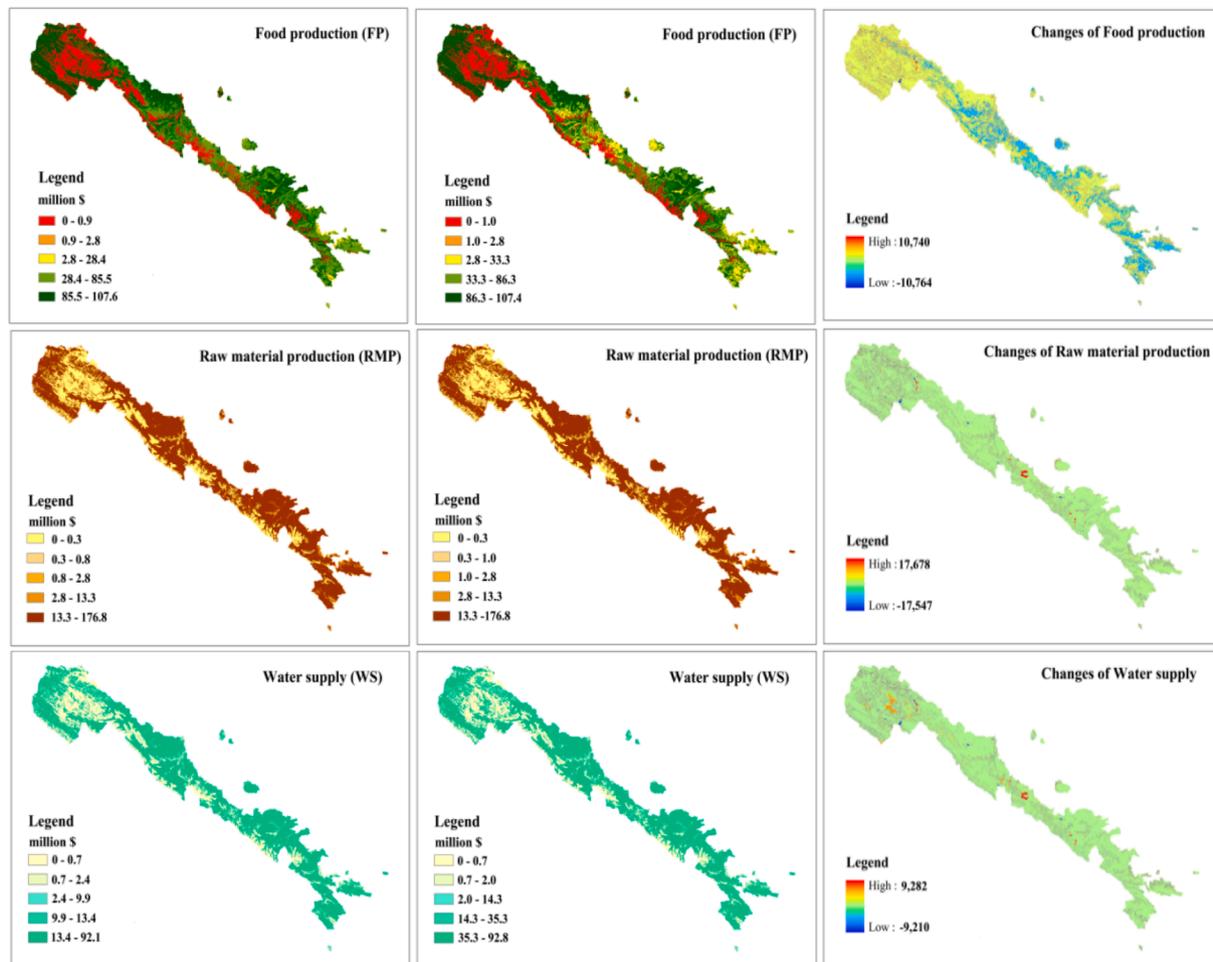
Fig. 3. Spatial distribution and changes of Provisioning services (FP, RWP, WS) in the study area. The left column shows the spatial distribution of ecosystem service value in 2000, the middle shows the spatial distribution of ecosystem service value in 2020, and the right shows the changes of ecosystem services from 2000 to 2020.

3.3.2. Temporal changes of grassland and farmland ecosystem provisioning services

The value of grassland provisioning services is about US $ 550 million per year, and the overall trend is increasing from 2000 to 2020, with a total increase of US $ 249 million in the past 20 years (Fig. 7). Food production (FP), raw material production (RMP), and water supply (WS) contributed about 55%, 29%, and 16%, respectively. FP generally increased from 2000 to 2020, with an average annual output value of about US $ 300 million. On the other hand, RMP and WS varied significantly compared to FP, decreasing by US $ 440,000 and US $ 120,000 from 2015 to 2018. In addition, we found that LUCC significantly affected the provisioning services value of grassland. For example, FP, RMP, and WS all increased significantly with the increase of grassland area from 2000 to 2015, and from 2015 to 2018, the grassland in the study area was degraded, and the production function and water production function of the grassland was affected, which led to a downward trend in FP, RMP, and WS. In general, grassland provisioning services change plays a crucial role in regional ecological protection and economic development.

The provisioning services value of farmland is about US $ 160 million per year, and the overall trend is increasing from 2000 to 2020, an increase of about US $ 67.35 million compared with 2000, of which FP, RMP, and WS contributed 91.2%, 8.3% and 0.5%, respectively. We found that although FP showed an increasing trend as a whole, after 2010, it showed a decreasing trend year by year. The analysis found that the continuous reduction of farmland area resulted in lower FP.

3.3.3. Spatial changes of grassland and farmland ecosystem provisioning services

The grassland ecosystem provides human beings with food, medicine, and raw materials for industrial and agricultural production and maintains the material and water cycle of life (Cheng et al., 2021). We found that the food production capacity of grassland in the Qilian Mountains is higher than that of raw material production and water supply, which is mainly caused by the conversion of grassland into livestock products. The annual income brought by livestock products accounts for 69.5% of the total income of Qilian mountains farmers and herdsmen. From the perspective of space (Fig. 8), the grassland productivity of Tianzhu County in the east of the Qilian Mountains is higher, with an average annual production of 9.19 million kg of beef and mutton, which is mainly related to the high-quality grassland and suitable climate in this region. The second is Sunan County in the west of the Qilian Mountains due to its vast land and sparse population, and relatively rich grassland resources, the annual output of beef and mutton is about 8.88 million kg. Therefore, the rational and scientific management of grassland resources should be strengthened.

From the perspective of the provisioning services of the agro-ecosystem, the primary food production in the Qilian Mountains is wheat, potato, barley, rapeseed, which account for 91% of farmland provisioning services, and the annual income brought by agricultural products accounts for 28.5% of the total income of farmers and herdsmen. From the perspective of space (Fig. 8), Minle county and Shandan County in the central Qilian Mountains have higher farmland production capacity (58.5% and 29.7%, respectively). Therefore, the region
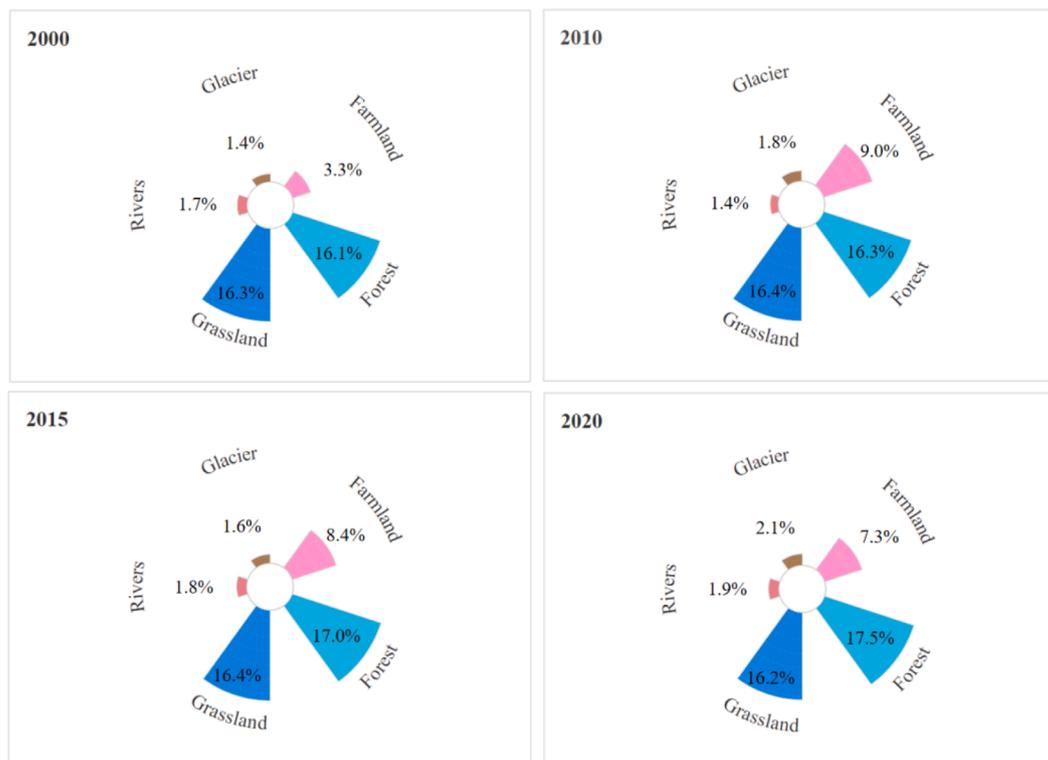
Fig. 4. Provisioning services in Qilian Mountains from 2000 to 2020. The length of each petal expresses the proportion of Provisioning services in each year.

should focus on protecting and utilizing cultivated land resources to prevent the degradation of cultivated land resources.

4. Discussion

4.1. Drivers of changes in provisioning services

According to our research, the grassland and farmland ecosystems in the Qilian Mountains have changed in recent 20 years, showing different degrees of impact at different stages, which leads to instability in the provisioning services of grasslands and farmland. Previous studies have shown that the close relationship between land use patterns and ecosystem services is mainly reflected in the differences in individual ecosystem services of different land-use types (Costanza et al., 2014; Fu et al., 2013). For example, the farmland ecosystem focuses on food production's service function (Russo et al., 2018), and the grassland ecosystem focuses on the service function of raw material production. The transformation of land use patterns is often affected by climate change and human activities, more evident for farmland and grassland ecosystems (Yang et al., 2022). The farmland and grassland ecosystems are the main contributors of food and raw materials in the Qilian Mountains. Changes in the provisioning services of farmland and grassland are related to the survival of nearly 700,000 people (Yang et al., 2022; Ding et al., 2018). Therefore, we focus on the relationship between farmland and grassland provisioning services, climate change, and human activities and further optimize the utilization and management of farmland and grassland.

Changes in land use lead to changes in the value of individual ecosystem services, affecting the total value of ecosystem services (Li et al., 2021). The results show that the provisioning services of farmland were significantly correlated with changes in farmland area ($R^2 = 0.93$). Since 2015, the area of farmland has decreased by 1057.6 ha, and the value of provisioning services has decreased by US $ 24.33 million, which indicates that the provision of farmland ecosystem services was largely dependent on LUCC.

Meanwhile, there is also a significant positive correlation between the provisioning services of farmland and the total rural population, agricultural labor force, and urbanization rate ($R^2 = 0.66$, $R^2 = 0.69$, and $R^2 = 0.54$, respectively), which means that the development of urbanization accelerates the reduction of the rural population and intensifies the abandonment of cultivated land (Fig. 9). At the same time, we are concerned that the project of returning farmland to forest and grassland in the Qilian Mountains has also led to the reduction of farmland provisioning services since 2010 (Yang et al., 2022). In addition, from the perspective of climate change, precipitation and temperature changes have no significant impact on the provisioning services of farmland. Therefore, it can be said that LUCC caused by human activities is the main driving factor for reducing farmland provisioning services.

As a traditional farming and pastoral area in Qilian Mountains, animal husbandry has been the leading industry for regional development in history (Yang et al., 2022). The provisioning services of grassland ecosystems are directly related to regional well-being (Ding et al., 2018). The study found that from 2000 to 2020, grassland provisioning services showed an overall increasing trend, with a total increase of US $ 249 million in 20 years. Combined with the data interpreted by remote sensing, it was found that the grassland ecosystem in the study area showed the characteristics of overall improvement and partial degradation. The correlation test found a significant positive correlation between the provisioning services of grassland and the change of grassland area ($R^2 = 0.91$), which further indicated that the change of grassland area determined the ability of provisioning services. Since 2000, the output of beef, mutton, and green fodder has increased year by year, and there is a significant positive correlation with grassland provisioning services ($R^2 = 0.77$ and $R^2 = 0.89$), which indicates that the service function of grassland raw material production is also increasing year by year. Previous studies have shown that grassland ecosystems are more sensitive to climate change (Liang et al., 2016). The Qinghai-Tibet Plateau and Northwest China have experienced significant warming and humidification (Liang et al., 2016; Yang et al., 2021). The increase
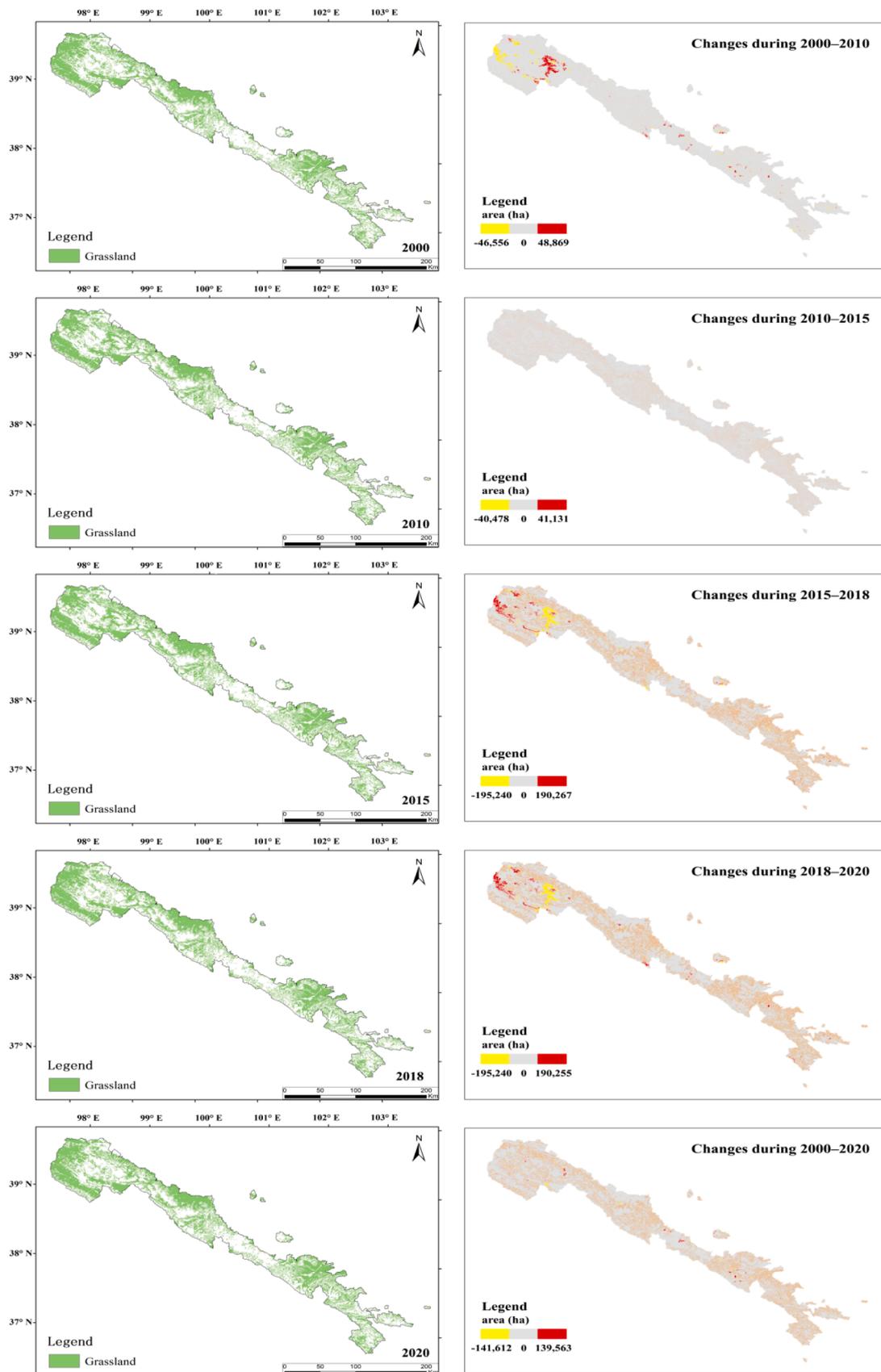
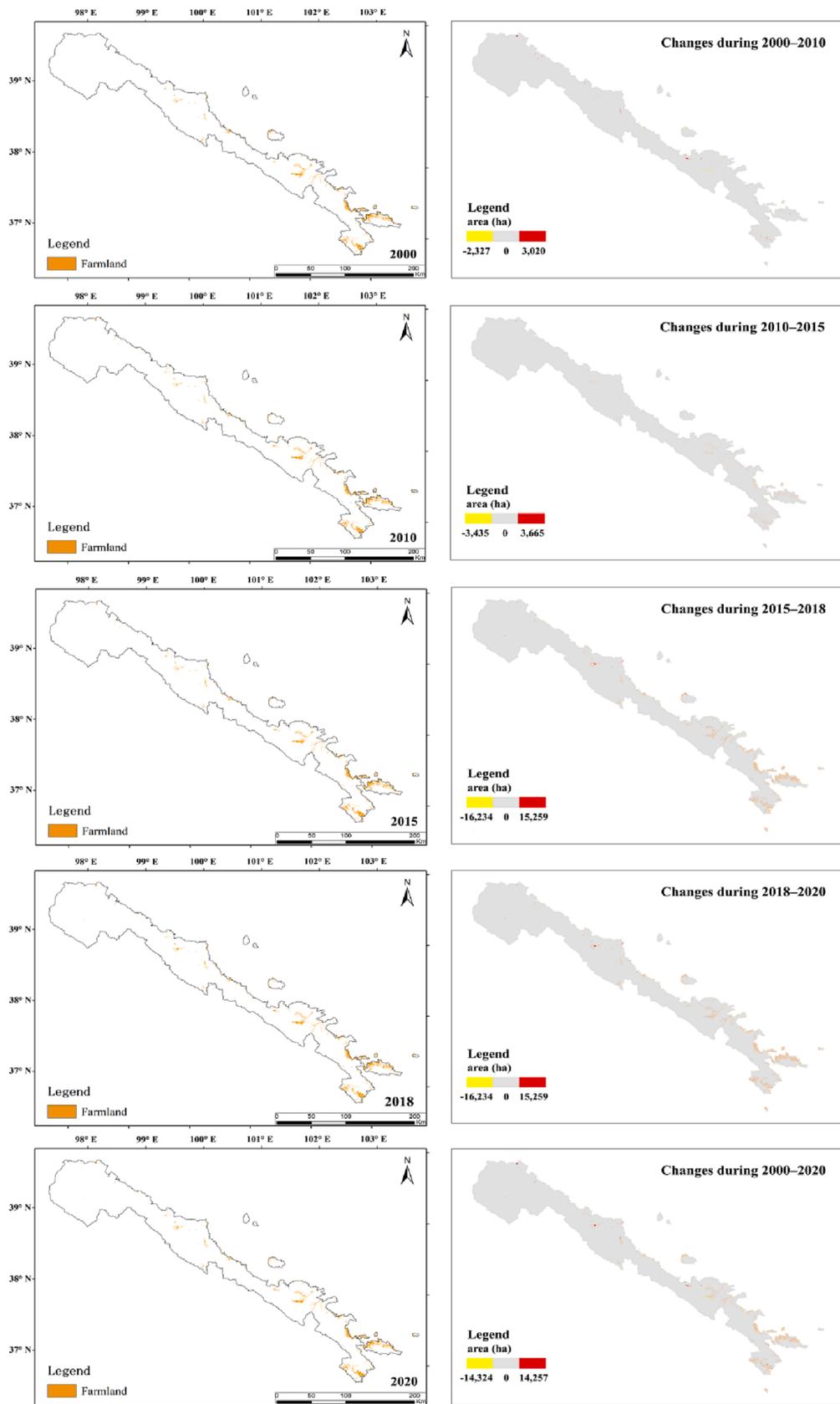**Fig. 5.** The change of grassland ecosystems in the Qilian Mountains.

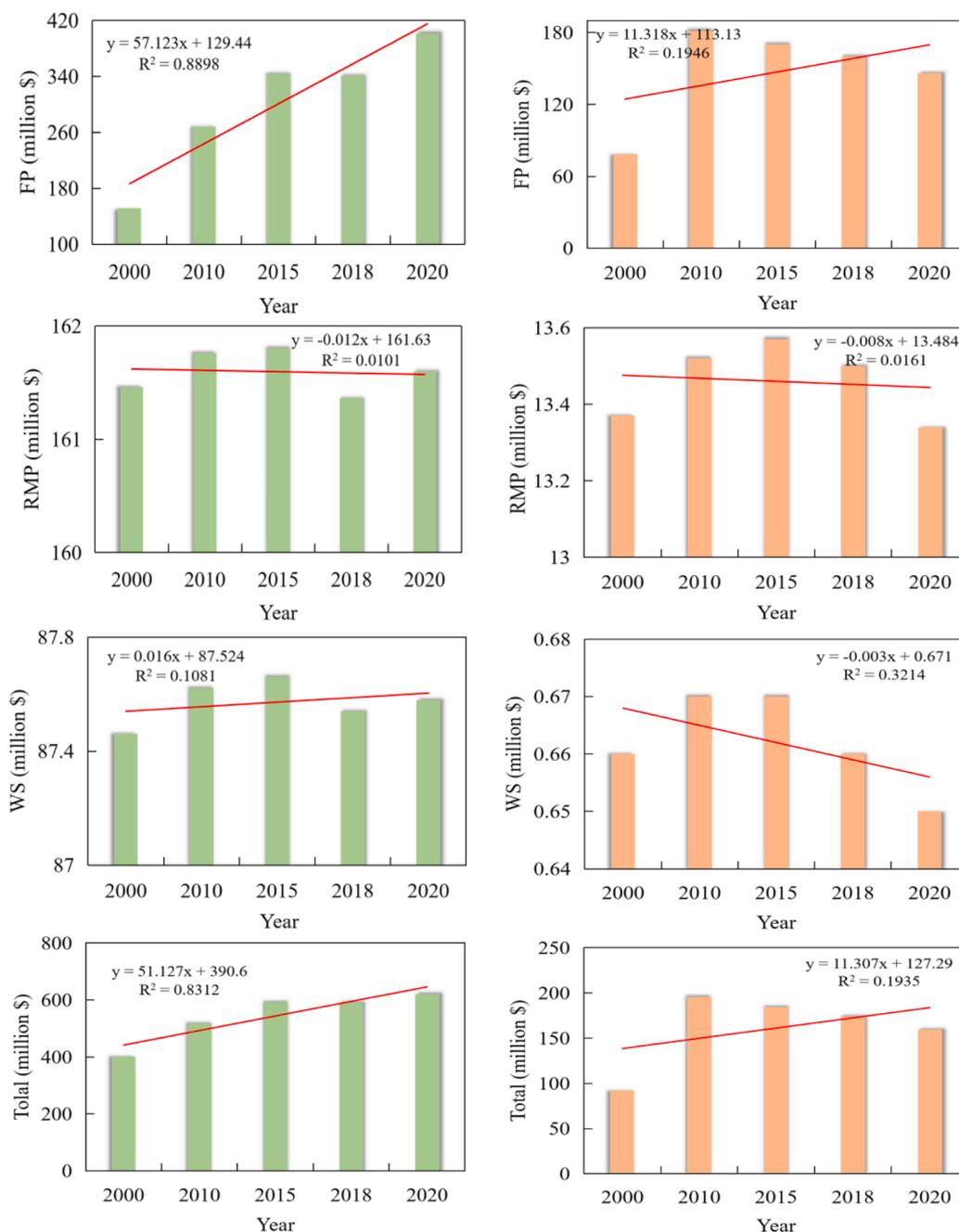**Fig. 6.** The change of farmland ecosystems in the Qilian Mountains.

Fig. 7. Changes in Provisioning services of grassland and farmland ecosystems. Grassland ecosystem on the left and farmland ecosystem on the right. Note: FP: Food production, RMP: Raw material production, WS: Water supply.

in precipitation is conducive to developing forest and grassland ecosystems (Shi et al., 2006; Wang et al., 2008). Through the correlation test, we found a significant positive correlation between the provisioning services of grassland and precipitation in the Qilian Mountains ($R^2 = 0.78$), which indicates that the increase of precipitation will effectively improve the raw material production and water supply service capacity of grassland. In addition, at the policy level, we found that the period from 2015 to 2018 was mainly due to the implementation of large-scale greening projects and ecological resettlement projects in the Qilian Mountains, which significantly increased the grassland area and ecosystem service capacity (Ding et al., 2018).

To sum up, in our results, LUCC leads to significant changes in provisioning services. In terms of driving factors, LUCC caused by human activities is the main driving factor for reducing farmland provisioning

services. Human activities mainly caused changes in grassland provisioning services, and precipitation changes played a catalytic role.

4.2. Sustainable development countermeasures of provisioning services

LUCC may imply significant changes in ecosystem provisioning services or their interactions. In this study, LUCC at different stages leads to increases and decreases in the provision of grassland and farmland ecosystem services and further affects farmers' and herdsmen's benefits, which are directly related to the sustainable development of regional animal husbandry and agriculture. China's rural areas have wholly entered the "rural revitalization" stage, and ecological protection and people's well-being have been promoted to the level of national development strategies (Zhou et al., 2020). Therefore, it is necessary to use
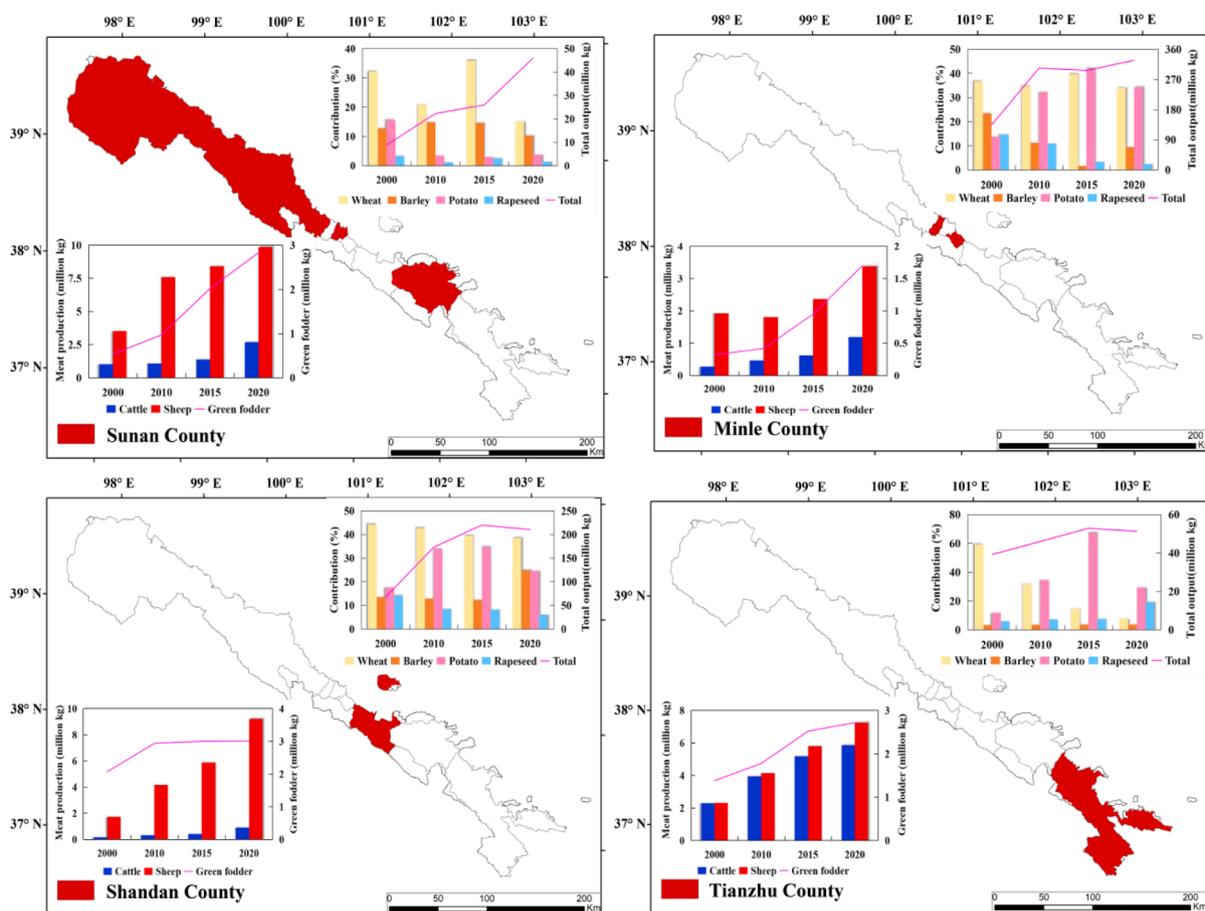
Fig. 8. Spatial changes of grassland and farmland ecosystem Provisioning services.

the existing land resources for mountainous areas fully. Therefore, under the current policy system of ecological protection and people's livelihood development in the Qilian Mountains, we propose sustainable development strategies for grassland and farmland provisioning services (Fig. 10).

Concerns on improving the provisioning services value of grassland, firstly, it is necessary to scientifically implement the ecological restoration project of degraded grassland according to local conditions and adhere to the principle of "mainly natural restoration, supplemented by artificial restoration". For the eastern Qilian Mountains, due to abundant precipitation, the implementation of artificial ecological restoration projects is conducive to grassland restoration. However, for the arid western Qilian Mountains, due to the lack of water resources, manual intervention is not significant, and it is easy to cause waste of resources. Therefore, it is necessary to reduce human intervention and implement natural restoration in grassland-enclosed areas. In addition, local governments need to have a correct understanding of the value of grasslands. Our investigation found that afforestation has been carried out on grasslands in some areas to improve forest coverage (Fig. 10). However, the relatively poor soil and arid environment reduce the survival rate of afforestation and further damage the grassland ecosystem. Secondly, as a traditional animal husbandry area, the annual income brought by animal husbandry accounts for 70.5% of the total income of farmers and herdsmen in the Qilian Mountains. From 2015 to 2018, overgrazing led to severe grassland degradation, and the policy of grazing prohibition in recent years has accelerated the restoration of the grasslands. Therefore, it is first necessary to change the way of animal husbandry and change the extensive grazing to house feeding and rotation grazing, which can reduce the degradation of grassland and increase the income of herdsmen. Then, vigorously develop smart animal husbandry and digital

animal husbandry. Technology empowerment makes the breeding industry more efficient and extends the industrial chain of animal husbandry. To establish a circular economy industrial chain such as breeding of characteristic varieties, artificial grassland construction, scientific breeding, and comprehensive utilization of manure, and establish a new information-based model for the whole process from breeding, epidemic prevention, processing, and market sales to promote high-quality and sustainable developing animal husbandry in the Qilian Mountains.

LUCC caused by human activities is the main driving factor for reducing farmland provisioning services. Firstly, to increase the control of abandoned arable land, the government has introduced a policy of incentives and subsidies to promote the restoration of abandoned arable land and make full use of the existing arable land resources. Secondly, carry out "precision agriculture". Precision agriculture has been adopted by farmers in many countries, with more significant popularity in the United States, Canada, Australia, and Europe (Isgin et al., 2008; D'Antoni et al., 2012; Barnes et al., 2019). Precision agriculture technology (PAT) is at the core of the fourth agricultural technology revolution (Klerkx and Rose, 2020; Lezoche et al., 2020), which accurately adjusts various farming methods through spatial and temporal differences in environmental conditions and crop yields, optimizes water, fertilizers, seeds, pesticides, quantity, quality and timing to obtain the highest yield and maximum economic benefits, and to protect the agro-ecological environment and land resources (Tian, 2014) This is a gradual process for the Qilian mountains with relatively backward agricultural levels. Therefore, it is necessary to actively develop engineering equipment technology, improve sowing technology, fertilization technology and water-saving irrigation technology, improve the quality of agricultural products, reduce production costs, improve resource utilization, and
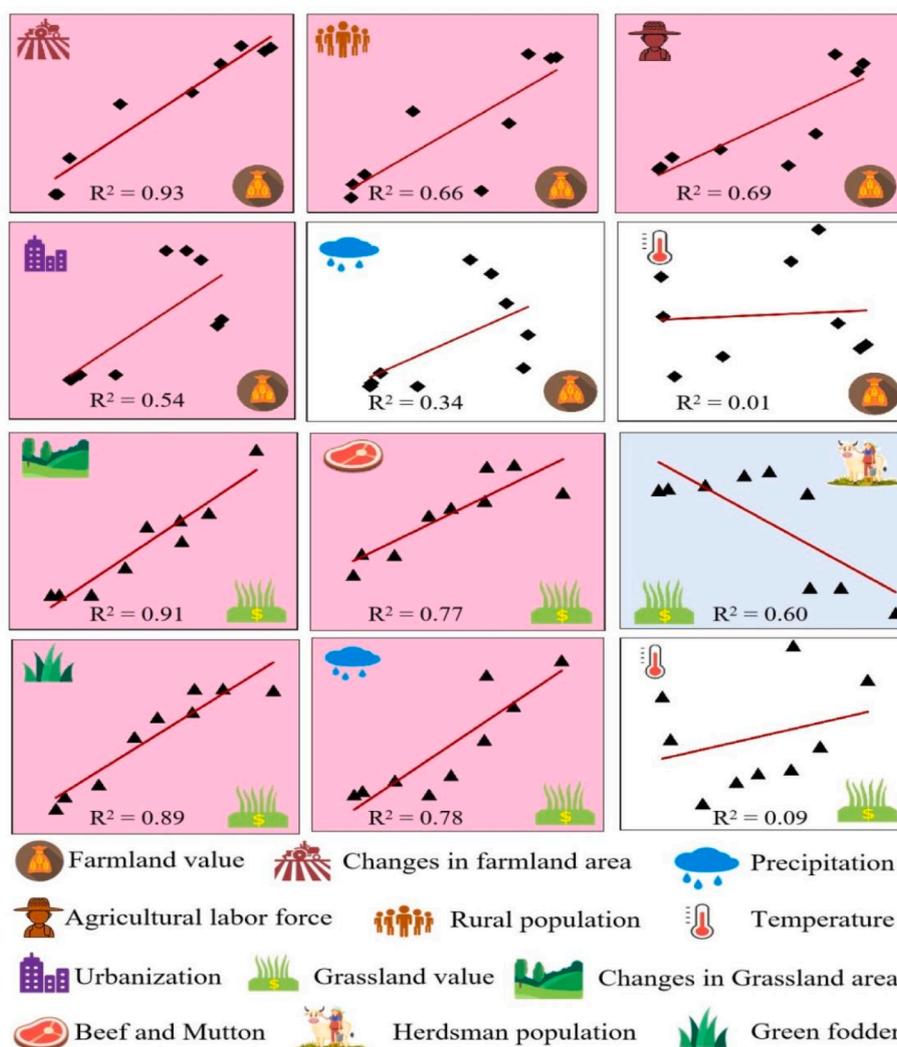
Fig. 9. Relationships between farmland and grassland provisioning services and climate change and human activity factors. The significant correlations (P < 0.05) were overlaid by red (positive) and blue (negative) shadings. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

make agriculture enter the sustainable development track. Thirdly, to introduce incentive and subsidy policies to reduce the loss of agricultural labor, attract migrant workers back to rural areas to develop industries, increase the area of practical arable land, improve the efficiency of land resource utilization, and promote the large-scale operation of farms and the development of modern agriculture and rural tourism.

4.3. Improve the capacity of the ecosystem provisioning services

How to effectively improve the ecosystem provisioning services capacity of traditional agricultural and pastoral areas, we believe that the work should be carried out mainly from the following aspects (Fig. 11).

Firstly, improve the ecosystem provisioning services capacity from the ecological space. The natural ecological space refers to the territorial space with natural attributes and the leading function of providing ecological products or services, such as forests, grasslands, wetlands, rivers, lakes, etc. The production mode must be changed and the development intensity must be strictly controlled to improve utilization efficiency and benefit. At the same time, we should strengthen the protection of the ecosystem, implement major ecological restoration projects, and enhance the production capacity of ecological products. Secondly, improve the ecosystem provisioning services capacity from

the perspective of industrial layout. Accelerate the formation of a green development mode and lifestyle, and minimize the resource consumption, pollution emission intensity and total amount of production activities. At the same time, we need to strictly abide by the upper limit of resource utilization and the red line of ecological protection, and adhere to the policy of giving priority to conservation and protection. Thirdly, improve the ecosystem provisioning services capacity from the development of ecological industries. Green development is an important part of the construction of ecological civilization. Therefore, we should actively develop green agriculture, leisure agriculture, manor agriculture and sightseeing agriculture to increase the supply of green organic agricultural products. At the same time, we should develop ecological industry and accelerate industrial transformation and upgrading, so as to maximize the benefits of ecological service products. Then, improve the ecosystem provisioning services capacity from the perspective of ecological technology. We should open up channels for the transformation and industrialization of scientific and technological achievements, and improve the collaborative innovation platform of "production, learning, scientific research and practical application". Support enterprises to carry out scientific and technological innovation, and develop and expand a number of innovative enterprises. Actively promote environmental protection technologies such as water recycling, reduction of heavy metal pollution, substitution of toxic and harmful
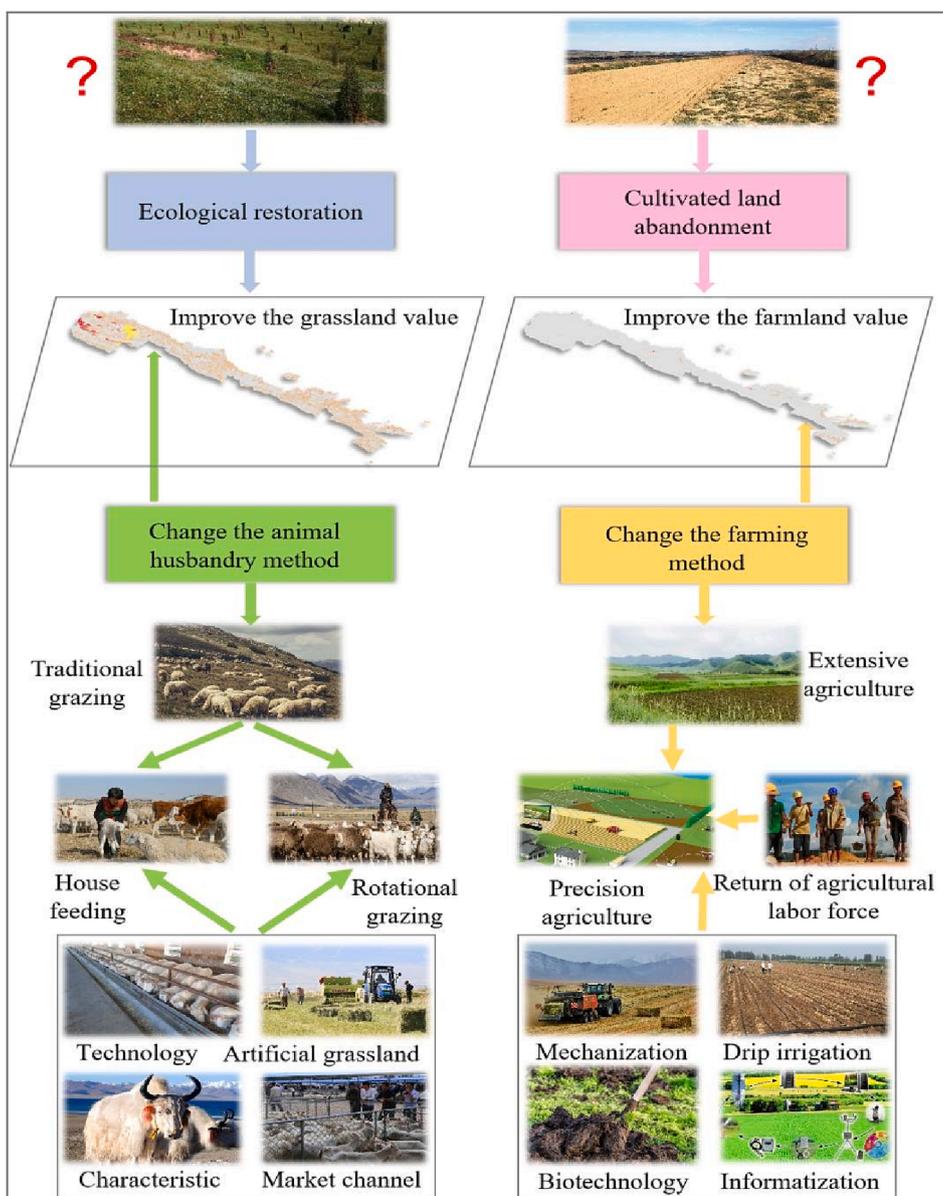
Fig. 10. The development strategy of "Ecological Husbandry + Precision Agriculture (EHPA)".

raw materials, desulfurization, denitration and dust removal, and realize green production. Finally, improve the ecosystem provisioning services capacity from the perspective of ecological policy system. We will implement the performance appraisal of ecological and environmental protection objectives, accelerate the construction of an environmental governance system with the government as the leading role, enterprises as the main body, and social organizations and the public as the participants, and promote the modernization of the governance system and governance capacity in the field of ecological environment.

4.4. Limitations and future perspectives

In terms of research methods, our research mainly refers to the evaluation methods of ecosystem service value of Costanza et al. (2014) and Xie et al. (2015), but the methods have differences in ecosystem classification, parameter selection, etc., which may lead to different evaluation results. Meteorological data are collected from meteorological stations, with difficult to obtain in high-altitude areas. Therefore, the construction of meteorological field stations and data collection will be carried out in the future, which will help further to clarify the driving

factors of ecosystem value assessment. The LUCC data used in this study were obtained from the interpretation of remote sensing images with a resolution of 30 m × 30 m. Although higher resolution LUCC data could provide more accurate results, especially in highly fragmented mountain regions, the data used met our needs. In addition, research should consider comparing this assessment method for ecosystem services with other assessment methods and models. Future research may assess the cultural value of ecosystem services, such as scenic beauty (Schirpke et al., 2013), which is an essential component of ecosystem services in the Qilian Mountains.

5. Conclusions

We assessed the provisioning services of grassland and cropland ecosystems in the Qilian Mountains in 2000–2020 at different temporal and spatial scales and discussed how to change with the LUCC in the Qilian Mountains. In general, we found that: (1) Grassland and farmland ecosystems are the essential service providers in the Qilian Mountains, and the economic benefits of livestock products provided by grassland and agricultural products from farmland accounted for 70.5% and
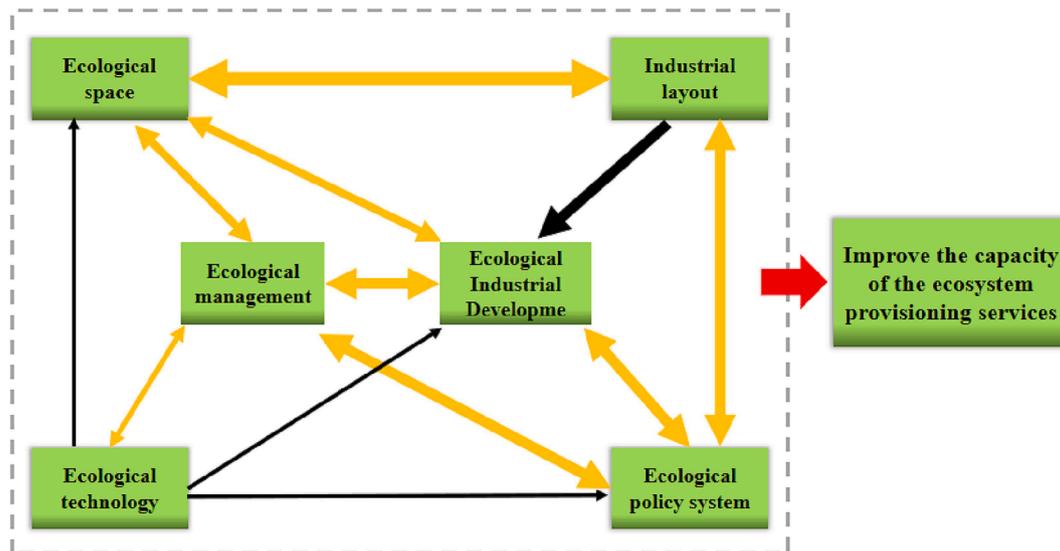
Fig. 11. Improve the capacity of the ecosystem provisioning services.

29.5% of the total income of farmers and herdsmen, respectively. (2) However, in the past 10 years, the contribution of grassland and farmland ecosystems to provisioning services has decreased by 0.2% and 1.7% respectively. The reduction of contribution will directly affect the capacity to provisioning services, which is not conducive to regional development. (3) Human factors such as policy system change, urbanization process and ideological change are the main driving factors for the change of provisioning services in traditional agricultural and pastoral areas, and climate change has played a certain role in promoting. (4) In order to effectively improve the supply and service capacity of grassland and farmland ecosystems, we put forward the development strategy of "Ecological Husbandry + Precision Agriculture". Scientifically restore degraded grasslands, change the way of animal husbandry, increase the control of abandoned farmland, issue reward and subsidy policies, attract migrant workers to return to rural areas to develop industries, improve the utilization efficiency of land resources, and promote the revitalization and development of modern agriculture and animal husbandry and rural areas. (5) For effectively improving the ecosystem supply and service capacity of traditional agricultural and pastoral areas. We believe that we should work together from five aspects: ecological space, industrial layout, ecological industrial development, ecological technology and ecological policy system to achieve systematic cooperation in "Production, Learning, Scientific research and Practical application".(5) Sustainable strategies and policies should be considered to improve the provisioning services capabilities, such as scientifically restoring degraded grasslands, changing the way of animal husbandry, increasing control of abandoned cultivated land, carrying out "precision agriculture", introducing incentive and subsidy policies, attracting migrant workers back to rural areas to develop industries, improving land resource utilization efficiency, and promote modern agriculture and animal husbandry and rural revitalization.

Declaration of competing interest

Data and materials can be obtained by contacting the corresponding authors if needed.

CRediT authorship contribution statement

Haijiang Yang: Visualization, Writing – original draft, Data curation, Resources, Investigation, Formal analysis, Validation, Software, Methodology, Conceptualization. **Xiaohua Gou:** Funding acquisition, Project administration, Supervision. **Bing Xue:** Validation. **Jing Xu:** Data curation, Resources. **Weijing Ma:** Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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