Ecological Benefit Evaluation of Grassland Agriculture in Ecological Fragile Areas —— A Case Study in Dingxi, Gansu Province

WU pei-han ¹², Lin Hui Long¹²*
¹ State Key Laboratory of Grassland Agro-ecosystems, Lanzhou 730070, China
² College of Pastoral Agriculture Science and Technology, Lanzhou University, Lanzhou 730070, China
* Corresponding author: linhuilong@lzu.edu.cn
b1137994260@qq.com

Abstract: Dingxi City of Gansu Province is a typical ecological fragile area and a famous poverty-stricken city in China. Because of its harsh natural environment and traditional farming ideas, economic development there has been slow. With the implementation of "Agricultural Supply-side Reform" in China, some regions have developed grassland agricultural production mode (GAPM) by introducing grass into fields, but there are still many regions that conform to traditional cultivated land agricultural production mode (CLAPM). In order to find out the suitable agricultural production mode for Dingxi City, two production modes, GAPM and CLAPM there were studied. This study used opportunity cost method and alternative engineering method to compare the ecological benefits of the two production modes. The results showed that the values of GAPM to provide products, conserve soil, regulate climate, sequestrate carbon and product oxygen were 479.31 yuan / mu, 483.51 yuan / mu, 1.94 yuan / mu, 394.6 yuan / mu, and 393 yuan / mu respectively, better than CLAPM. Therefore, GAPM in Dingxi City has been effective, indicating a new suitable industrial mode for Dingxi city and other regions with the same requirement of agricultural industry updating.

1. Introduction
Traditional agriculture in China is cultivated land agricultural production mode (CLAPM), whose main ways to expand the production scale are to cultivate grasslands, forests, bushes, etc. [¹], and it is very extensive. However, it has outstanding disadvantages of simple mode and insufficient large-scale planting ability. Grassland agricultural production mode (GAPM) is developed through the introduction of high-quality forage and herbivorous livestock on the basis of traditional CLAPM. Taking the rangeland as the basis, GAPM combines arable land and non-arable land, and the combination of grass, forest, vegetables, and cotton is implemented on arable land. Through technologies like soil rotation and string seeding, soil fertility is enhanced and the productivity of various lands is fully utilized, leading to efficiency improvement [²-⁵]. Therefore, GAPM can simultaneously meet the basic living needs of farmers and output higher economic values.

Grassland agriculture has been a hot topic among Chinese scholars in recent years. Ren et al. proposed to store grain in grass to develop animal husbandry, which can increase farmers' income and
strengthen the production and ecological security of the agricultural system [6]. From the perspective of national feed and grain security, Lu first demonstrated that GAPM can solve conventional disadvantages of CLAPM structure by plant characteristics, then pointed out that GAPM was a new choice for agricultural structure adjustment by economic benefit analysis [7]. Wang et al. studied the relationship between GAPM and social development, indicating that agricultural production contradicted with social development in China, calling for an urgent transformation in agricultural production structure [8]. However, on GAPM and CLAPM, Chinese scholars have made more macro demonstrations of economic benefits while focused less on the structures, economic situations and ecological impacts of the two modes. Therefore, it is significantly important to comprehensively compare the two modes in Dingxi to find out which one performs better in economic and environmental sustainability.

2. Materials and Methods

2.1. Study area
Dingxi City is located in the central part of Gansu Province and at the intersection of the Loess Plateau and West Qinling Mountains, with large undulations, vertical and horizontal mountains. It is in the southern-temperate semi-humid and medium-temperate semi-arid zones, with an average annual temperature of 5.7~7.7 °C, a frost-free period of 122~160 days, an annual average rainfall of 500 mm. The maximum average rainfall from 2013-2017 was 474.8 mm and the minimum 282.5 mm, usually concentrated in July, August, and September, and in the form of heavy rain, torrential rain and hail. The evaporation was much larger than the precipitation, as high as 1400 mm. These features make Dingxi a typical ecologically-fragile area.

2.2. Data collection
The macro data was downloaded from official websites, yearbooks, and industry sectors. Among them, the climate data came from the 2015 Dingxi City temperature and precipitation dataset provided by the Resource and Environmental Science Data Center of the Chinese Academy of Sciences (http://www.resdc.cn); the land type data came from the 2010 geospatial data cloud (http://www.gscloud.cn); crop prices and agricultural industrial conditions came from the 2016 Dingxi Statistical Yearbook, the 2017 Gansu Statistical Yearbook, the 2017 Dingxi Statistical Yearbook, and the 2017 Gansu Development Yearbook; amounts and areas of soil loss were from Water and Soil Conservation Bureau and Water and Soil Conservation Bureau in Tongwei County and Dingxi City.

2.3. Methods
In the analysis of ecological benefits, the opportunity cost method, the alternative engineering method, the shadow pricing method, the carbon tax method, the afforestation cost method, and the market value method were used to calculate GEP (Gross Ecosystem Product) indicators. The calculation methods are shown in Table 1.

| Benefit | Service | Function index          | Evaluation method          | Calculation formula                      |
|---------|---------|-------------------------|---------------------------|-----------------------------------------|
| Ecological | Preventing soil erosion | Preventing topsoil loss | The opportunity cost method | Reduced land erosion area × normal income per unit area |
|         | Conserving soil          | Preventing siltation     | The alternative engineering method | Water and soil loss × reservoir construction cost per water storage |
|         | Adjusting the atmosphere | Preventing nutrient loss | The shadow pricing method | Nutrient loss × fertilizer market price |
|         | Fixing carbon and releasing oxygen | Fixing CO₂ | The carbon tax method | Fixed CO₂ × carbon tax rate |
3. Results
GAPM will impose positive impacts on the ecological environment. As shown in Table 2, the ecological service value per unit area was 4,160.97 yuan/mu (1 ha = 15 mu), 1.73 times that of CLAPM. Among them, the value of agricultural products and conserving soil were relatively high, respectively 1188.5 yuan/mu and 1198.1 yuan/mu, accounting for 28.56% and 28.79% of the total value; the value of fixing carbon and releasing oxygen followed them closely, 877.26 yuan/mu and 881 yuan/mu respectively, accounting for 21.08% and 21.17% of the total value; the lowest value of adjusting the climate was 16.11 yuan/mu, only 0.39% of the total value. Although CLAPM had the function of ecosystem services, its ecosystem service benefit was 2408.61 yuan/mu, far lower than that of GAPM. Among them, the values of agricultural products and conserving soil and water were relatively high, 709.19 yuan/mu and 714.59 yuan/mu respectively, accounting for 29.44% and 29.67% of the total value; the value of fixing carbon and releasing oxygen was 482.66 yuan/mu and 488 yuan/mu respectively, accounting for 20.04% and 20.26% of the total value; the value of adjusting the climate was the lowest, 14.17 yuan/mu, only 0.59% of the total value.

Table 2 The quantity and value of ecological service function of the two agricultural production modes

| Agricultural production mode | Service function                  | Index                          | Functional Value (yuan/mu) | In total (yuan/mu) |
|------------------------------|----------------------------------|--------------------------------|---------------------------|-------------------|
| **GAPM**                     | Providing product                | Agricultural products (kg/mu)  | 3971.65                   | 1188.5            |
|                              | Prevented soil erosion (kg/mu)   | 15940                          | 1188.5                    |
|                              | Reduced siltation (m³)           | 0.4                            | 2.47                      |
|                              | Maintained fertilizer (kg/mu)    | 6.06                           | 7.13                      |
|                              | In total                        | —                              | 1198.1                    |
|                              | Adjusting the climate           | Absorbed heat by transpiration (kJ/mu) | 1.16×10⁵                  | 16.11             |
|                              | Fixing carbon and releasing oxygen | Fixed carbon by plants (kg/mu) | 873.76                    | 877.26            |
|                              |                                 | Released oxygen by plants (kg/mu) | 2382.99                  | 881               |
|                              | Providing product                | Agricultural products (kg/mu)  | 2185.76                   | 709.19            |
|                              | Prevented soil erosion (kg/mu)   | 9900                           | 709.19                    |
|                              | Reduced siltation (m³)           | 0.23                           | 1.43                      |
|                              | Maintained fertilizer (kg/mu)    | 2.89                           | 3.97                      |
|                              | In total                        | —                              | 714.59                    |
| **CLAPM**                    | Adjusting the climate           | Absorbed heat by transpiration (kJ/mu) | 1.02×10⁵                  | 14.17             |
|                              | Fixing carbon and releasing oxygen | Fixed carbon by plants (kg/mu) | 480.87                    | 482.66            |
4. Conclusion
Planting industry, as the basic sector to support social existence and development, has played a particularly important role in the entire agriculture. Dingxi City is both China’s important commodity food production base and a typical semi-arid area where the ecological environment has been deteriorating. Its serious ecological environment status is rather outstanding in the whole China. Therefore, evaluating whether the agricultural production mode reform there has been rational is vitally important. However, the economy is a single indicator, and the pursuit of GDP and food yield per capita only will lead to mistakes. Compared to the developed areas in the south, Dingxi has a lower population density. Therefore, even if the total output is not much, the arable land area per capita is large. However, the food output per unit area is not high. As a result, only the combination of ecology and economy can be reliable, indicating that the agricultural production should also be evaluated from the perspective of ecology.

Through the comparative analysis of the two modes above, in terms of economy and the ecological environment, the following conclusions can be drawn:

In terms of agricultural products, conserving soil, adjusting climate, fixing nitrogen and releasing oxygen, GAPM had higher contribution rates than CLAPM. First, on adjusting climate, the main crop plants grown by GAPM farmers had a longer growth period, which can enhance light energy utility, adjust the climate and improve the ecological environment by transpiration and heat absorption. As for fixing nitrogen and releasing oxygen, GAPM had the powerful advantage of releasing carbon and oxygen. Compared with CLAPM, the greening period and growth period of crops are longer, and the stems and leaves are lusher. GAPM can make full use of solar energy to perform photosynthesis, which will promote the absorption of photosynthesis and improve the efficiency of fixing carbon and releasing oxygen. On conserving soil and water, CLAPM increased the amount of grain farming, reduced vegetation coverage, shortened the time of vegetation coverage, and increased the possibility of soil erosion caused by floods after rain. Although the precipitation does not meet the heavy rain standard, if the time is short and the intensity is high, it will cause natural disasters such as floods, resulting in soil erosion and ineffective soil and water conservation. GAPM contributes to soil and water conservation and reduces soil erosion. In GAPM, alfalfa and other crops turn green earlier in spring, with their roots scattered on the surface of the soil during the growing season, and continue to extend to the depths, which can solidify the topsoil and stabilize the soil layer. Moreover, planting alfalfa and red bean grass will reduce the average annual farming frequency, increase vegetation coverage, enhance rainwater collection capacity, prevent soil erosion, effectively store rainwater, and reduce surface runoff and soil erosion.

Based on the results, in order to promote the agricultural sustainable development and protect the ecological environment from worsening, the following suggestions should be conformed to: Now that GAPM has produced greater ecological benefits than CLAPM, the government should strengthen propaganda and policy support to enable farmers to correctly and completely understand the “grain to feed” reform, then the reform can be carried on better. The government should also accelerate the transition from CLAPM to GAPM and optimize the structure of the agricultural sector, thereby obtaining more benefits both economically and ecologically.

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