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Comprehensive benefit evaluation and influencing factors analysis of high-standard farmland construction in Shaanxi Province,China

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Abstract: Cultivated land is a vital resource for human survival and development, playing a crucial role in maintaining harmony between humans and land and safeguarding food security. The Chinese government has always attached great importance to the protection of cultivated land resources and implemented strict policies for this purpose. Among these initiatives, the construction of high-standard farmland, as an innovative measure, aims to improve the quality of cultivated land, enhance its production capacity, and optimize the farmland ecological environment. This is to meet the demand for cultivated land resources driven by socio-economic development and promote the sustainable and healthy development of agriculture.Taking 101 counties (districts) in Shaanxi Province as the research object, this study collects relevant data on high-standard farmland construction over the ten-year period from 2012 to 2021. The entropy weight method, spatial autocorrelation model, GeoDetector model, and fixed-effect model are employed to evaluate the comprehensive benefits of high-standard farmland construction.The results indicate that the comprehensive benefits showed an overall upward trend during the research period, with the spatial distribution gradually optimizing from north to south and presenting significant spatial agglomeration characteristics. The key factors influencing the spatial differentiation of comprehensive benefits include the share of the total output value of agriculture, forestry, animal husbandry, and fishery, the proportion of rural residents' per capita disposable income, regional economic density, local fiscal budget expenditure, average annual precipitation, and total grain output. Moreover, there are non-linear enhancement and two-factor enhancement interactions among these factors, with obvious regional differences.This study reveals the temporal and spatial evolution laws and key driving factors of the comprehensive benefits of high-standard farmland construction in Shaanxi Province, providing a scientific basis for accurately improving the quality of regional high-standard farmland construction and promoting the sustainable development of agriculture.

Keywords: high-standard farmland construction; comprehensive benefit evaluation; GeoDetector; fixed-effect model

1. Introduction

The construction of high-standard farmland has significantly broadened farmers' income channels by improving infrastructure, upgrading the farmland quality, and improving output efficiency, and has become an important hand in promoting rural revitalization and realizing common prosperity. In 2022, China has built a cumulative total of 1 billion acres of high-standard farmland. In 2023, 45 million acres were newly built, adhere to the new construction while the transformation and upgrading of high-standard farmland, and concentrate on building concentrated contiguous areas, drought and flood protection, water-saving and efficient, stable and high-yield, eco-friendly high-standard farmland.Shaanxi Province is expected to complete the construction of 21.94 million acres of high-standard farmland in 2025 and build 26.17 million acres of high-standard farmland in 2030 cumulatively. However, as completed farmland still has outstanding problems such as the ineffectiveness of increasing farmers' income, the imperfect post-construction management and care mechanism leading to land abandonment, the frequent occurrence of natural disasters leading to the damage of engineering facilities, and the lack of effective integration with measures of good seeds, good laws, good opportunities and good systems leading to the pollution of agricultural surface sources. After the completion of high-standard farmland, how to use its effectiveness, economic benefits and ecological benefits of a comprehensive evaluation, in order to ensure that the implementation of high-standard farmland policy has become the current urgent need to solve the real problem.

In the face of the dual challenges of population growth and limited resources, ensuring food security has become the primary task of governments. By optimizing the land use structure and upgrading the infrastructure level of farmland such as irrigation, drainage and soil fertility, the construction of high-standard farmland effectively enhances the stability and risk-resistant capacity of food production, providing a solid guarantee to fundamentally solve the problem of food self-sufficiency. On this basis, the construction of high-standard farmland also promotes the diversified development of the rural economy, provides more employment opportunities for farmers, helps reduce the phenomenon of returning to poverty due to natural disasters or market fluctuations, and guarantees the basic quality of life and dignity of farmers, reflecting the concept of decent work. At the same time, as agricultural productivity improves, the rural economy is energized, injecting new momentum into overall economic growth. More importantly, the construction of high-standard farmland, as an important part of agricultural modernization, is closely linked to the goal of sustainable development. It not only reduces the excessive use of chemical fertilizers and pesticides and protects the ecological environment, but also promotes the recycling of agricultural resources, laying a solid foundation for the realization of a green, low-carbon and recycling model of modern agricultural development. Therefore, the construction of high-standard farmland is not only an effective means of guaranteeing national food security and preventing the return of poverty, but also an important way to promote the comprehensive, coordinated and sustainable economic and social development, and to enhance the people's health and well-being, and its far-reaching significance should not be ignored.

This paper relies on the output data of high-standard farmland, quality data of high-standard farmland, environmental data of high-standard farmland and economic data of high-standard farmland in the latest high-standard farmland construction counties in Shaanxi Province to construct a comprehensive benefit analysis framework of high-standard farmland construction in terms of "output capacity, farmland quality, ecological environment and economic benefits". The entropy weight method is used to determine the comprehensive benefit value of high-standard farmland construction counties and districts in Shaanxi Province, and the spatial autocorrelation model is used to analyze the spatial agglomeration

characteristics of high-standard farmland construction, and finally, the GeoDetector and panel data model are used to analyze the spatial differentiation of the comprehensive benefit of high-standard farmland construction and the influencing factors of the changes of the comprehensive benefit.

2.Literature Review

2.1 Research on High-standard Farmland Construction

Since 2008, with the official implementation of High-standard Farmland Construction Standard (NY/T2148-2012) and High-standard Basic Farmland Construction Standard (TD/T1033-2012), scholars have conducted in-depth research on high-standard farmland construction from different perspectives. For example, Liu Xinwei conducted a study on the challenges and existing progress in the construction of high-standard farmland, and put forward a series of countermeasures and suggestions, including the formulation of implementation plans, improvement of work mechanisms, innovation of fund management methods, and improvement of relevant systems(Liu X, 2013). Ma Xingqiao analyzed the current situation and problems faced in the construction of high-standard farmland in the southeast region from the construction standards and evaluation norms of high-standard farmland. It also combined a case study on the construction model of high-standard farmland in Jiaxing City, Zhejiang Province, and put forward policy recommendations related to the construction of high-standard farmland as well as its management after completion(Ma X.Q., 2023). Huang Yujiao emphasized that the construction of high-standard farmland needs to focus not only on hardware construction, but also on software construction, suggesting that the construction of high-standard farmland should be combined with the construction of new rural areas and integrated into the construction of new rural areas(Ma X.Q, 2023). Guo Beibei argued that comprehensive risk factors such as climate and disasters should be taken into account as the main basis for determining the areas for high-standard farmland construction(Yang Z.H,2014).

Domestic scholars evaluate the benefit level of high-standard farmland construction mainly by constructing a comprehensive index system with selecting appropriate evaluation methods, which is a built-up evaluation mode. The more commonly used methods include double difference method, approximation of ideal point method, multi-factor comprehensive analysis method, principal component analysis method and so on. Liu Peng chose the high-standard farmland construction project in Zhoutang Town, Suizhou County, East Yu Plain District as the research object, and established a set of evaluation models by combining the obstacle degree model and hierarchical analysis method in order to explore the constraints faced by the construction of high-standard farmland and the specific construction content in depth(Liu P., 2023). In terms of the effect of the implementation of high-standard farmland policy, Ma Xiaoyan mainly evaluated the effect of policy implementation around the efficiency of capital utilization(Ma X.Y., 2020), Xiong Bingyao evaluated the effect of the policy implementation in a typical region from a regional perspective(Xiong B.Y., 2016), and Hu Xinyan empirically examined the effect of the high-standard farmland construction policy on the total grain output(Hu X.Y., 2022), while Cai Jie(Cai J., 2014)and Liu Chunfang (Liu C.F., 2018) valuated the social and ecological effects of high-standard farmland construction based on the entropy weighted topological model and the InVEST model, respectively, and Liang Zhihui utilized the difference model DID to conduct a study to analyze the effect of high-standard farmland construction on causal effect of farmland construction on fertilizer reduction and its mechanism of action(Liang Z.H., 2021).

Taken together, at present, the research of domestic scholars on the construction of high-standard farmland is divided into two stages: pre-construction and post-construction, with the former stage mainly focusing on the study of suitability and selection of assessment methods; and the latter stage focusing on the study of benefit assessment and the factors affecting the level of benefits. The post-construction benefit assessment builds an evaluation system by selecting evaluation indexes, and then evaluates the benefit level with the help of a model, in which the benefits are mainly focused on the economy, grain yield

increase, project construction performance, etc., and less consideration is given to the ecological and economic benefits. However, in the construction of high-standard farmland, the benefits generated should be considered comprehensively, and the comprehensive impact of the comprehensive benefits on the region should be analyzed. In addition, in the current study, the selection of research objects is mostly concentrated in the city and above, and there are fewer studies on the high standard farmland in the county, which is precisely the precise area that can truly reflect the effectiveness of the implementation of regional policies.

2.2 Research on High-standard Farmland Construction in Shaanxi Province

Located in the middle reaches of the Yellow River, Shaanxi Province spans three major geomorphological units: the Loess Plateau in northern Shaanxi, the Guanzhong Plain, and the Qinba Mountains in southern Shaanxi. As the primary grain-producing region in Northwest China, it boasts approximately 43 million mu (about 2.9 million hectares) of arable land, with the Guanzhong Plain serving as a crucial national base for commercial grain production. According to the 2019 "National Arable Land Quality Grade Announcement" issued by China's Ministry of Agriculture and Rural Affairs, the region's higher-quality farmland is predominantly concentrated in the Guanzhong area, while southern Shaanxi slightly exceeds the provincial average, and northern Shaanxi has the lowest quality. To achieve dual improvements in both quantity and quality of high-standard farmland across the province, scholars have proposed region-specific solutions tailored to local conditions, creating a unique development model for high-standard farmland in Shaanxi(Han Qunzhu,2020). For example, irrigation technologies have been introduced in northern Shaanxi to address drought, water scarcity and soil erosion(Zhang Haiou, 2021), while southern Shaanxi, with superior production conditions, promotes the vigorous development of organic and green agriculture(Huang Lei, 2020). However, challenges persist in the province's high-standard farmland construction, including substandard construction standards, an incomplete system, insufficient awareness of agricultural carbon sequestration, inadequate implementation of modern agricultural practices, low overall production efficiency, and misalignment between modern construction models and industrial integration(Li Liurong, 2025).

3. Index and Methods

3.1. Index

3.1.1. Index of high-standard farmland comprehensive benefit evaluation

This study selects relevant indicator data from counties and districts in Shaanxi Province over the ten-year period from 2012 to 2021 for comprehensive evaluation. The selection of indicators is mainly based on the National Master Plan for High-Standard Farmland Construction and the Specifications for the Evaluation of High-Standard Farmland Construction to ensure consistency with policy requirements. Meanwhile, it draws on mature research results from scholars, screening high-frequency indicators that have undergone empirical verification to avoid blindness in indicator innovation. A comprehensive benefit evaluation index system is constructed from four aspects: output capacity, farmland quality, ecological environment, and economic benefits.

In terms of output capacity, high and stable yield, drought and flood are the key to judge its high and low. The commonly used cultivated area affects the overall quantity of output, the grain unit area directly affects the output per unit of cultivated area, and the total output value of agriculture, forestry, animal husbandry and fishery measures the value of output yield. Therefore, this study selects these three indicators to evaluate the output capacity of each county and district in Shaanxi Province, which is consistent with the quantitative

requirements for "output capacity" specified in the Specifications for the Evaluation of High-Standard Farmland Construction.

In terms of farmland quality, the quality of cultivated land can be summarized as the sum of the material productivity of cultivated land and the quality of the cultivated land environment. The area of protected agriculture reflects the level of modern supporting facilities for farmland, the area under mechanical harvesting indicates the degree of application of agricultural mechanization, and the total power of agricultural machinery measures the efficiency of farmland operations. Therefore, these three indicators—area of protected agriculture, area under mechanical harvesting, and total power of agricultural machinery—are selected to evaluate the quality benefits of high-standard farmland in Shaanxi Province.

In terms of the ecological environment, the National Master Plan for High-Standard Farmland Construction proposes promoting the development of resource-saving and environment-friendly agriculture. While the application of chemical fertilizers can increase agricultural output, it also alters the biological properties of soil. Continuous application of chemical fertilizers leads to a decrease in soil organic matter content, which in turn pollutes soil and water sources and endangers the environment. PM2.5 is a key indicator affecting air quality; green plants can not only absorb PM2.5 but also increase atmospheric oxygen content. These two indicators have strong regional pertinence, addressing regional issues such as sandstorms in northern Shaanxi and agricultural pollution in the Guanzhong Plain. Therefore, the application amount of agricultural chemical fertilizers and the annual average PM2.5 concentration are selected for ecological environment evaluation.

In terms of economic benefits, it is crucial whether the construction of high-standard farmland can effectively drive local farmers to increase their income and regional economic development. This study evaluates the economic benefits from rural residents' per capita disposable income, gross regional product, and the added value of primary industry, aiming to explore the actual social and economic benefits of the implementation of high-standard farmland construction in counties and districts in Shaanxi Province.The 11 indicators characterizing the output capacity, farmland quality, ecological environment, and economic benefits of annual high-standard farmland construction in Shaanxi Province were divided layer by layer to establish a comprehensive benefit evaluation index system for high-standard farmland construction (Table 1).

Table1. High-standard farmland comprehensive benefit evaluation index system.

Objective layer (A)	Guideline layer (B)	Indicator layer (C)	Unit	Attribute
Evaluation of comprehensive benefits of high standard farmland construction	Output capacity (B1)	Common cultivated land area	Hectare	Positive
		Grain output per unit area	(tons/ha)	Positive
		Gross output value of agriculture, forestry, animal husbandry and fishery	million yuan	Positive
	farmland quality (B2)	Area occupied by facility agriculture	Hectare	Positive
		Machine harvesting area	Hectare	Positive
		Total power of agricultural machinery	Million watts	Positive
	Ecological environment (B3)	Agricultural Fertilizer Application	tons	Negative
		Average annual PM2.5 value	(μg/m3)	Negative
	Economic Benefits	Gross Regional Product	million yuan	Positive

	(B4)	Per capital disposable income of rural residents	Yuan	Positive
		Value added of primary industry	million yuan	Positive

3.1.2. Index of the influencing factors of high-standard farmland comprehensive benefit evaluation

The comprehensive benefit of high-standard farmland construction is affected by many factors. Based on the principles of science, comprehensiveness and feasibility, we refer to the existing studies(Chen S.L., 2022), and analyze the spatial differentiation of the comprehensive benefits of high-standard farmland construction in Shaanxi Province and the influencing factors of the changes of the comprehensive benefits by selecting indexes from the two major aspects of nature and social economy (Table 2).

Table2. The influencing factors of high-standard farmland comprehensive benefit evaluation index system.

Variables	Data description
Comprehensive benefits of high-standard farmland construction	Calculated in the previous section
Total population at the end of the year (x1)	County Statistical Yearbook (10,000 people)
Average annual temperature (x2)	ERA5-Land raster processed data (°C)
Average annual precipitation (x3)	ERA5-Land raster processed data (m)
Local budget expenditures (x4)	County Statistical Yearbook (m)
Population productivity (x5)	Gross regional product/total population at the end of the year (million yuan/person)
Effective irrigated area (x6)	County Statistical Yearbook (ha)
Regional economic density (x7)	GDP/area of region (million yuan/square kilometer)
Permanent basic farmland protection ratio (x8)	Area of permanent basic farmland protection/area of commonly cultivated land
Cultivated land area per capital (x9)	Area of commonly cultivated land/total population at the end of the year (ha/million people)
Intensity of fertilizer use (x10)	Discounted agricultural fertilizer/total grain production (t)
Share of total output value of agriculture, forestry, animal husbandry and fishery (x11)	Gross output value of agriculture, forestry, animal husbandry and fishery/gross regional product
Total power of machinery per unit of cultivated land (x12)	Total power of agricultural machinery/area of commonly cultivated land (tens of millions of watts/ha)
Disposable income per rural resident as a percentage (x13)	Disposable income per rural resident/(Disposable income per rural resident + Disposable income per urban resident)
Total grain output (x14)	Statistical yearbook of cities (counties) (tons)

Sown area of grain crops (x15)	County statistical yearbook (thousands of hectares)

3.2. Methos

3.2.1. Hierarchical analysis

Hierarchical analysis is a multi-objective decision analysis method, proposed by Saaty, a professor at the University of Pittsburgh, USA, in the mid-1970s. The method combines qualitative and quantitative analysis to help decision makers in a systematic decision-making process. A judgment matrix is constructed by hierarchizing the problem and setting multiple objectives, comparing factors at each level and judging their importance(Lin Z., 2019).

3.2.2. Entropy weight method

Entropy weight method is an objective method for determining the weights of multiple indicators, which evaluates the degree of variation based on the information entropy of the indicator data by normalizing the original data, and then assigns weights based on this. This method is usually used in multi-indicator comprehensive evaluation system to avoid the bias influence of subjective factors on weight assignment(Li F.F.,2023).

3.2.3. GeoDetector model

The core concept of the GeoDetector model is to test the correlation between explanatory variables and dependent variables by analyzing the consistency of their spatial distribution. If the explanatory variables are closely related to the dependent variables, their spatial distributions tend to be similar. The model consists of four basic models, which are risk detector, factor detector, ecological detector and interaction detector. The factor detector is used to reveal the explanatory power of the determinants on the explanatory variables, while the interaction detector reveals whether the two explanatory variables interact on the explanatory variables. In contrast to traditional regression models, geographic detector models are able to deal with categorical independent variables without taking into account multicollinearity among explanatory variables. In this study, the factor detector and interaction detector were used to reveal the strength of influence factors on the spatial differentiation of the comprehensive benefits of high-standard farmland construction. Among them, the factor detection model is as follows:

$$FD = 1 - \frac{1}{n\delta^2}\sum_{h=1}^{L} n_h \delta_h^2 \quad (1)$$

Where: the FD ranges from 0 to 1, indicating the explanatory power of each factor on the spatial divergence of the comprehensive benefits of high-standard farmland construction, and the larger the FD is, the stronger the explanatory power of the factor is. n and nh denote the sample size in the whole region and sub-level region,$\delta^2$and$\delta_h^2$the variance of the corresponding coordination degree. The number of L natural breaks clustering hierarchies.

The interaction detector aims to assess whether factor N and factor M have enhanced or weakened effects on the comprehensive benefits of high-standard farmland construction when they act together. Its assessment principle is to first calculate the q-value q(N) of factor N and the q-value q(M) of factor M on Y respectively, then calculate their joint q(N∩M) values under interaction, and finally compare them, and the judging criteria are shown in Table 3.

Table3. Judgment basis and type of interaction.

Judgment basis	**Interaction**
q(N∩M)<Min(q(N),q(M))	Nonlinear weakening

Min(q(N),q(M))<q(N∩M)<Max(q(N),q(M))	One-factor nonlinear weakening
q(N∩M)>Max(q(N),q(M))	Two-factor augmentation
q(N∩M)=q(N)+q(M)	Independent
q(N∩M)>q(N)+q(M)	Nonlinear augmentation

3.2.4 Panel data model

Based on the results of the previous study, the factors affecting the comprehensive benefits of high-standard farmland construction are further identified. Panel data models are used to analyze the effects of the respective variables on the dependent variable in panel data, and there are generally three forms to choose from. Mixed estimation model (POOL), fixed effect model (FE), and random effect model (RE). The mixed estimation model assumes that regardless of any individual or cross-section, there are no differences between individuals and no significant differences between time terms. For some omitted variables, the random effects model assumes that the error term and the explanatory variable are uncorrelated, whereas the fixed effects model assumes that they are correlated and adds an intercept term to the model that is correlated with the explanatory variable and varies across individuals or time. The model is defined as follows:

$$Y_{it} = \alpha + X'_{it}\beta + u_{it}(i = 1,2,\cdots,\ N; t = 1,2,\cdots,\ T) \quad (2)$$

Above is the mixed estimation model definition. Where Y is the explanatory variable, α is the intercept term, X_{it} is a k × 1 order column vector of explanatory variables, β is a k × 1 order column vector of regression coefficients, and u_{it} is the random error term. N denotes the number of individuals in the panel data and T denotes the length of time in the panel data.

$$Y_{it} = \alpha_i + X'_{it}\beta + u_{it}(i = 1,2,\cdots,\ N; t = 1,2,\cdots,\ T) \quad (3)$$

$$Y_{it} = \gamma_t + X'_{it}\beta + u_{it}(i = 1,2,\cdots,\ N; t = 1,2,\cdots,\ T) \quad (4)$$

$$Y_{it} = \alpha_i + \gamma_t + X'_{it}\beta + u_{it}(i = 1,2,\cdots,\ N; t = 1,2,\cdots,\ T) \quad (5)$$

Above is the definition of the fixed effects model. Where Eq.(3) is the individual fixed effects model, αi denotes a random variable that varies with the individual but not with time; Eq.(4) is the point-in-time fixed effects model, γ_t is a random variable that varies with respect to X_{it} ; Eq.(5) is the individual point-in-time dual fixed effects model, which denotes that for different cross-sections and individuals there are different intercept models. In this paper, we explore the influence of the selected indicators on the comprehensive benefits of high-standard farmland construction when both time and individuals are fixed, so we choose the double fixed-effects model.

The difference between the random effects model and the fixed effects model lies in the definition of individual differences, assuming that the differences between individuals are random, the individual and time effects are uncorrelated with all explanatory variables, and its heterogeneity intercept is reflected in the randomized perturbation terms(Hu X., 2024).

4. Results

4.1. High-standard farmland comprehensive benefit evaluation

4.1.1. Output capacity evaluation

Regarding the output capacity of high-standard farmland construction, the counties with higher evaluation results include Jingyang County, Wuqi County, Suide County and Meixian County; and the counties with lower evaluation results include Weicheng District, Changwu County, Xunyang County and Zhenping County. The mean value of the evaluation result of each county and district is 0.063, and this result is mainly affected by the size of cultivated land area and unit area yield. On the whole, the average level of output capacity of high-standard farmland construction in Shaanxi Province during the past 10 years was not high, but the output capacity after the construction of high-standard farmland showed a trend of continuous improvement. In recent years, as the construction of high-standard farmland continues to advance, land leveling has led to more effective utilization of cultivated land area, coupled with the continuous improvement of planting technology and management level, which has led to a gradual increase in output per unit area, thus promoting the improvement of output capacity. The continued development of this trend has made important contributions to agricultural production and food security in Shaanxi Province, and has also brought new opportunities for farmers to increase their income and rural economic development.

4.1.2. Farmland quality evaluation

Regarding the farmland quality , the counties and districts with higher evaluation results are Dingbian County, Anse District, Hantai District, Huazhou District, etc., and the counties and districts with lower evaluation results are Lantian County, Weicheng District, Zhenping County, and Dali County. The average value of farmland quality assessment results in all counties and districts is 0.072, slightly better than the output capacity but still relatively low. Farmland irrigation, drainage and reasonable layout of country roads all affect agricultural mechanization, which can improve the farmland quality while increasing the efficiency of agricultural production, including ploughing, planting, fertilizing, irrigating and harvesting links. For example, mechanized tillage can realize land loosening and deep ploughing, promote soil aeration and root extension, which is conducive to crop growth and root development. The construction of high-standard farmland includes the improvement of field roads and farmland irrigation and drainage facilities, but the construction and mechanized application of these facilities involves a series of issues related to topography, funding, and interests, so the complex decision-making and negotiation process affects the speed of construction and improvement. Through the rational layout of farmland irrigation, drainage and country roads of high-standard farmland construction, combined with the application of agricultural mechanization, the farmland quality can be further improved, and the quality and yield of crops can be promoted.

4.1.3. Ecological environment evaluation

Regarding the ecological environment, the counties and districts with higher evaluation results include Zhashui County, Shenmu City, Jingbian County, Ningqiang County, etc., while the counties and districts with lower evaluation results include Zhenping County, Jintai District, Zizhou County, and Suide County. The average value of the ecological environment assessment results of each county and district is 0.123, which is only second to the evaluation results of economic benefits. The ecological environmental protection of high-standard farmland construction mainly focuses on soil erosion, gale sand and dust or other ecological problems to develop farmland protection and ecological environmental protection. Shaanxi Province, in response to this ecological environment problem, actively carries out biological measures, chooses to plant herbaceous economic plants with high survival rate or plant protection forest grasses to improve soil and water conservation ability and flood control

ability in the loess hill and gully area of northern Shaanxi and the mountainous and hilly area of southern Shaanxi, so as to improve the farmland protection forest system.

4.1.4. Economic benefits evaluation

In terms of economic benefits, the counties and districts with higher evaluation results include Baishui County, Hancheng City, Yanliang District, Fu County, etc., and the counties and districts with lower results include Zizhou County, Zhenping County, Baihe County, Mili County, etc., and the average value of the economic benefit evaluation results of all counties and districts is 0.180, which is the highest in the evaluation of the guideline layer of the comprehensive benefits of high-standard farmland construction. Improvement of economic benefit is one of the main objectives of high-standard farmland construction, which generally refers to the increase of agricultural production income and profit brought by the construction of high-standard farmland, which is directly related to the sustainable development of agricultural production. Therefore, in the comprehensive benefit evaluation, economic benefit is often regarded as a core indicator interacting with indicators of ecological environment, farmland quality or other aspects, which together constitute the overall assessment system of high-standard farmland construction. Since the construction of high-standard farmland, land that was originally scattered and of different sizes has gradually been leveled, and the mechanized operation of field roads after repair has helped to reduce the labor costs of farmers in the process of planting, harvesting, fertilizing, etc., while the yield of grain per unit area has been increased, which has improved the income of farmers. These direct economic benefits are often the most obvious in the evaluation system. The disposable income of farmers in all counties and districts has gradually increased, and the added value of the primary industry and the gross regional product have also shown an increasing trend, indicating that the construction of high-standard farmland has brought about an increase in the level of the individual income of farmers and an increase in the efficiency of agricultural production.

4.1.5. Comprehensive benefit evaluation

On the basis of establishing the weights of each criterion layer, the comprehensive weights and standardized values are used to calculate the average annual comprehensive score of the counties and districts of Shaanxi Province with high-standard farmland construction. Since the calculated values are all between (0, 1], they are all divided into 5 levels, if the results of the benefits of each guideline layer are in (0,0.2], it is considered very poor, (0.2, 0.4] that the comprehensive benefits are poor, (0.4,0.6] that the comprehensive benefits are average, (0.6.0.8] that the comprehensive benefits are better, and (0.8, 1] that the comprehensive benefits are very good. The results show that the average value of the comprehensive benefit of high-standard farmland construction in all counties and districts of Shaanxi Province during the period of 2012-2021 is 0.438, and the results are between (0.4, 0.6], and the comprehensive benefit of high-standard farmland construction is average. It can be seen that the construction of high-standard farmland in Shaanxi Province has achieved certain results in various counties and districts, but there is still a large space for improvement.

4.1.6. Spacetime benefits evaluation

During the study period, the comprehensive benefits of high-standard farmland construction in Shaanxi Province experienced changes from planning and implementation, early construction, mid-construction, and late construction. High-standard farmland construction as a whole achieved remarkable results, and the comprehensive benefit evaluation results as a whole experienced a change from very poor to better. Shaanxi Province, after ten years of construction and management of high-standard farmland course, the quality of arable land has been significantly improved, and the output of grain and agricultural products has been significantly increased. Through the management of water sources,

planting structure adjustment, and the improvement of rural mechanized road network and other measures, on the one hand, it reduces the pressure of agricultural production on the environment, and on the other hand, it helps to promote large-scale operation of agriculture, and facilitates transformation of the agricultural industry to modernization, specialization and branding, and improves the market competitiveness of agricultural products. market competitiveness, drive rural collective income and realize common prosperity(Figure 1).

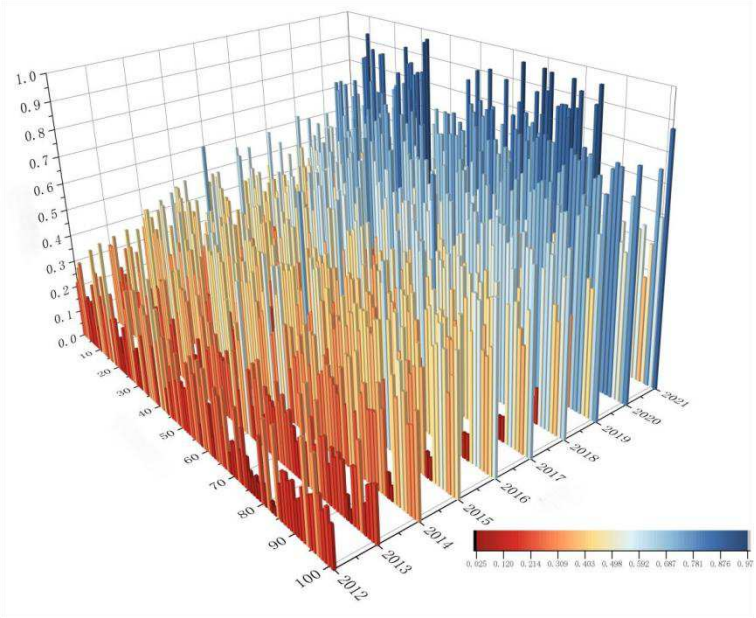


Figure 1. Comprehensive benefits of high-standard farmland construction in 101 counties and districts of Shaanxi Province.

4.2. The influencing factors of high-standard farmland comprehensive benefit evaluation

4.2.1. Factor detection analysis

Detection metrics	Q-statistic	p-value
Total population at the end of the year (x1)	0.029	0.287
Average annual temperature (x2)	0.045	0.163
Average annual precipitation (x3)	0.078	0.040
Local budget expenditure (x4)	0.079	0.048
Population productivity (x5)	0.037	0.978
Effective irrigated area (x6)	0.060	0.144
Regional economic density (x7)	0.089	0.007
Permanent basic farmland protection ratio (x8)	0.010	0.962
Cultivated land area per capital (x9)	0.029	0.750
Intensity of fertilizer use (x10)	0.034	0.641
Share of agriculture, forestry, livestock and fisheries GDP (x11)	0.120	0.002
Total mechanical power per unit of cultivated land (x12)	0.016	0.652
Rural per capital disposable income share (x13)	0.105	0.047
Total grain production (x14)	0.068	0.030
Sown area of grain crops (x15)	0.049	0.379

Table4. Factor detection results.

In order to reveal more clearly the spatial characteristics of the factors detecting the comprehensive benefits of high-standard farmland construction as well as the subsequent GeoDetector analysis, the above indicators are graded using the natural breaks to classify the factors, and each independent variable is divided into 5 grades. The factor detector in the GeoDetector model was utilized to measure the intensity of the influence of each influence factor on the spatial differentiation of the comprehensive benefits of high-standard farmland construction. The indicators were analyzed by factor detector separately with the evaluation results of the comprehensive benefits of high-standard farmland construction in Shaanxi Province, and the corresponding Q statistics were obtained (Table 4).

According to the detection results, Six factors, including the share of the total output value of agriculture, forestry, animal husbandry, and fishery, and the proportion of rural residents' per capita disposable income, are the core driving factors.

4.2.2. Interaction detection analysis

Using the interaction detector, we can explore the degree of influence of the two two factors on the comprehensive benefits of high-standard farmland construction in Shaanxi Province counties and districts when they work together, and the results of the interaction detection are shown in Figure 2.

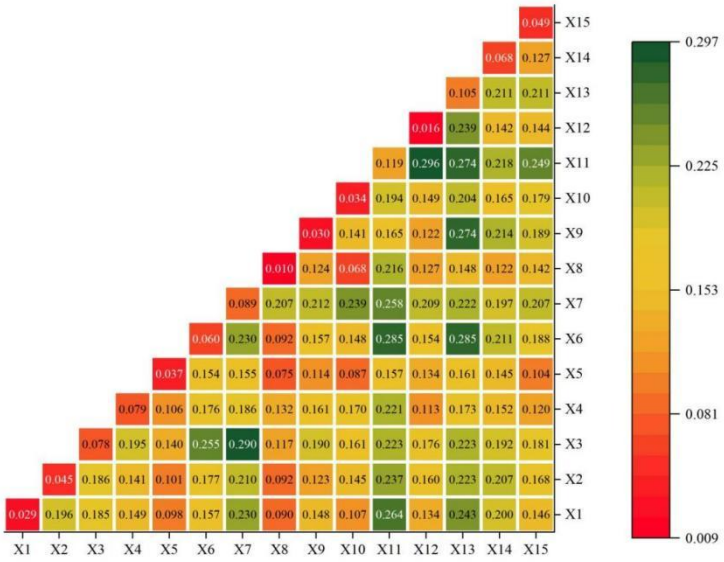


Figure 2. Interaction detection results of all factors.

The results show that there is a certain degree of interaction between the factors affecting the comprehensive benefits of high-standard farmland construction, and their values are between 0.009 and 0.297. Overall, the degree of interaction's influence on spatial differentiation exceeds that of individual influencing factors acting alone.

Interaction detection of the main explanatory power factors, plotting the main influence factor interaction (Figure 3), and further analyzing the interaction of the main influence factors. The results show that the interaction detection results are all higher than the single-factor results, and the three highest ones are the interaction between average annual precipitation (X3) and regional economic density (X7), the share of total output value of agriculture, forestry, animal husbandry and fishery (X11) and the share of per capital disposable income in rural areas (X13), and the interaction between regional economic density (X7) and the share of total output value of agriculture, forestry, animal husbandry and fishery (X11) with the detector results of 0.290, respectively, 0.274, and 0.258. The lowest interaction value is between local

budget expenditure (X4) and total grain production (X14) with a detector result of 0.152. Other factor interaction detections ranged from 0.186 to 0.223.

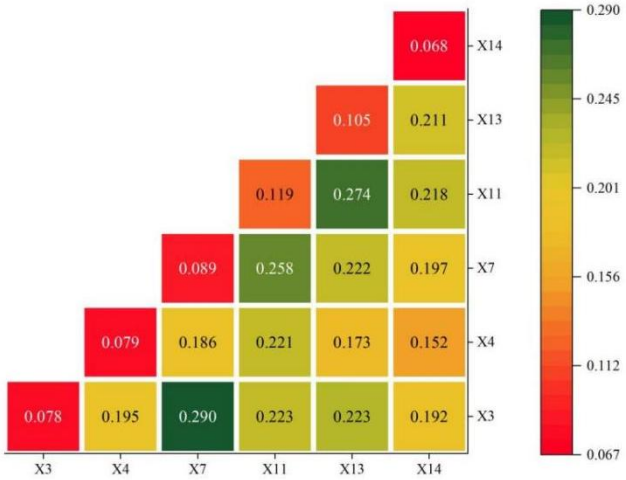


Figure 3. Main effect factor interaction.

Further summarizing the results of the main factor interaction detector (Table 5), it was found that there are two types of interaction between the influencing factors: two-factor-enhanced and nonlinear-enhanced, and there are no factors that are independent of each other. The influence of any two factor interactions is greater than the influence of factors acting alone. Specifically, there is a two-factor enhancement relationship between the local financial budget expenditure (X4) and the proportion of rural per capital disposable income (X13) and total grain output (X14), i.e., the interaction effect of the two factors on the comprehensive benefits of high-standard farmland construction is greater than the independent influence of a single factor but less than the sum of the two. For example, the influence q-statistic of (X4∩X13) reaches 0.173; followed by the influence q-statistic of (X4∩X14) is 0.152, both of which are higher than the influence of a single factor on the spatial differentiation of the comprehensive benefits of high-standard farmland construction but smaller than the influence of the sum of single factors. The rest of the factors have an enhanced relationship with each other, i.e., the interaction of two factors is greater than the sum of the independent influence of individual factors on the spatial differentiation of the comprehensive benefits of high-standard farmland construction. For example, the influence q-statistic of (X3∩X7) is 0.290, indicating that among the factor interactions, the interaction of average annual precipitation and regional economic density plays a dominant role in the spatial differentiation of the comprehensive benefits of high-standard farmland construction in Shaanxi Province. In addition, the interactions of any two of all the influencing factors on the spatial differentiation of the comprehensive benefits of high-standard farmland construction in Shaanxi Province are mutually enhancing, which further confirms that the spatial differentiation of the construction of high-standard farmland is the result of the combined effect of multiple factors. However, there are significant differences in the interaction between factors. Specifically, the combined effect of average annual precipitation, regional economic density, the proportion of total output value of agriculture, forestry, animal husbandry and fishery, and the proportion of per capital disposable income in rural areas is higher than that of the combined effect among other factors.

Table 5. Interaction of main influence factors.

H	N+M	Results	Factor	Interpretatio

				n
X3∩X4=0.195	X3(0.078)+X4(0.079)	H>N+M	Average annual precipitation, local budget expenditures	Non-linear enhancement
X3∩X7=0.290	X3(0.078)+X7(0.089)	H>N+M	Average annual precipitation, regional economic density	Nonlinear enhancement
X3∩X11=0.223	X3(0.078)+X11(0.119)	H>N+M	Average annual precipitation, share of gross output value of agriculture, forestry, livestock and fishery industries	Non-linear enhancement
X3∩X13=0.223	X3(0.078)+X13(0.105)	H>N+M	Average annual precipitation, share of rural disposable income per capital	Non-linear enhancement
X3∩X14=0.192	X3(0.078)+X14(0.068)	H>N+M	Average annual precipitation, total grain production	Non-linear enhancement
X4∩X7=0.186	X4(0.079)+X7(0.089)	H>N+M	Local budget expenditure, regional economic density	Nonlinear enhancement
X4∩X11=0.221	X4(0.079)+X11(0.119)	H>N+M	Local budget expenditures,the agriculture, forestry, animal husbandry and fishery gross output value share	Non-linear enhancement
X4∩X13=0.173	X4(0.079)+X13(0.105)	H>Max(N, M)	Local budget expenditures,rural disposable income per capital	Two-factor augmentation
X4∩X14=0.152	X4(0.079)+X14(0.068)	H>Max(N, M)	Local budget expenditures, total food production	Two-factor augmentation
X7∩X11=0.258	X7(0.089)+X11(0.119)	H>N+M	Regional economic density,percentage of gross output value of agriculture, forestry, livestock and fishery	Non-linear enhancement
X7∩X13=0.222	X7(0.089)+X13(0.105)	H>N+M	Regional economic density,rural disposable income per capital as a percentage of	Non-linear enhancement
X7∩X14=0.197	X7(0.089)+X14(0.068)	H>N+M	Regional economic density, total food production	Non-linear enhancement
X11∩X13=0.274	X11(0.119)+X13(0.105)	H>N+M	Share of total output value of agriculture, forestry, animal husbandry and fishery, share of rural per capital disposable income	Non-linear enhancement
X11∩X14=0.218	x11(0.119)+x14(0.068)	C>N+M	Share of gross output value of agriculture, forestry, animal husbandry and fishery, total grain production	Non-linear enhancement
X13∩X14=0.211	X13(0.105)+X14(0.068)	C>N+M	Share of rural per capital disposable income, share of total grain production	Non-linear augmentation

4.2.3. Analysis of regression results

In order to explore the direction and extent of the influence of the above factors on the comprehensive benefits of high-standard farmland construction in 101 counties and districts in Shaanxi Province in the past 10 years, based on the balanced panel data in this paper, the mixed model (POOL), fixed effect model (FE), random effect model (RE) are applied to regression analysis, and the regression results are shown in Table 6. From the R-squared, it can

be seen that the fixed effect and random effect models are more reliable in terms of goodness of fit, and the mixed model is not applicable to this study. Further Hausmane's test was conducted to compare the difference between the fixed effect model and the random effect model to determine whether there is individual heterogeneity, and the results showed that P=0.001<0.05, so the random effect model was rejected and the fixed effect model was finally selected.

Table 6. Test of factors affecting the comprehensive benefits of high-standard farmland construction.

Variables	Model 1	Model 2	Model 3	Model 4
	FE	FE	POOL	RE
Share of gross output value of agriculture, forestry, livestock and fishery	0.000*** (-4.96)	0.058* (-1.91)	0.035** (-2.12)	0.174 (-1.36)
Rural disposable income per capital as a percentage of	0.000*** (13.19)	0.000*** (5.93)	0.000*** (4.74)	0.000*** (3.81)
Regional economic density	0.118 (1.57)	0.181 (1.35)	0.540 (0.61)	0.569 (0.57)
Local budget expenditures	0.000*** (9.58)	0.002*** (3.15)	0.000*** (13.48)	0.000*** (3.58)
Average annual precipitation	0.000*** (12.13)	0.000*** (6.73)	0.000*** (8.07)	0.000*** (5.34)
Total grain production	0.000*** (3.78)	0.150 (1.45)	0.682 (-0.41)	0.823 (-0.22)
Total population at the end of the year		0.040** (-2.08)	0.000*** (-7.24)	0.000*** (-3.85)
Average annual temperature		0.471 (0.72)	0.000*** (4.83)	0.002*** (3.11)
Population productivity		0.000*** (4.51)	0.709 (-0.37)	0.437 (0.78)
Effective irrigated area		0.000*** (4.39)	0.183 (1.33)	0.037** (2.09)
Permanent basic farmland protection ratio		0.105 (-1.64)	0.000*** (4.92)	0.062* (1.87)
Cultivated land area per capital		0.078* (1.78)	0.000*** (5.78)	0.001*** (3.32)
Intensity of fertilizer use		0.017** (-2.42)	0.171 (1.37)	0.234 (-1.19)
Total mechanical power per unit of cultivated land		0.005*** (2.89)	0.488 (0.69)	0.140 (1.48)
Area sown in grain crops		0.018** (-2.41)	0.259 (-1.13)	0.000*** (-3.70)
Constant term (constant)	0.000*** (-13.85)	0.000*** (-9.52)	0.000*** (-4.46)	0.000*** (-4.20)
N	1010	1010	1010	1010
R2	0.526	0.567	0.567 0.304	0.517

Note: *, **, and *** represent estimates that are significant at the 10%, 5%, and 1% levels, respectively, and t-values of regression coefficients are in parentheses.

Model 1 explores the specific effects of the main factors affecting the spatial differentiation of the comprehensive benefits of high-standard farmland construction on the comprehensive benefits. The results, except for regional economic density, the other five main factors have a

significant impact on the comprehensive benefits of high standard farmland construction, all of which are significant at the 1% significance level. Among them, the t-value of the total output value of agriculture, forestry, animal husbandry and fishery is negative, indicating that its corresponding regression coefficient is significantly lower than zero at the level of significance, i.e., the comprehensive benefit of high-standard farmland construction decreases with the increasing proportion of the total output value of agriculture, forestry, animal husbandry and fishery during the period of study. The proportion of rural per capital disposable income, local budget expenditure, average annual precipitation, and total grain production then positively affect the comprehensive benefits of high-standard farmland construction. Model 2 adds sown area of grain crops, fertilizer use intensity and other variables on the basis of model 1. The results show that after adding other influencing factors, the main factors are significant except for the total grain production, which has no significant effect on the comprehensive benefits of high-standard farmland construction. In addition, population productivity, effective irrigated area, per capital cultivated area, and total power per unit of cultivated machinery significantly and positively affected the comprehensive benefits of high-standard farmland construction at the 1%, 1%, 10%, and 1% significance levels, respectively. Increases in both population productivity and total power per unit of cultivated land machinery will improve labor productivity, reduce labor costs, and increase the output capacity of high-standard farmland. Effective irrigated area of arable land is an important means for high-standard farmland to improve the quality and output capacity of farmland, while per capital arable land area is a quantitative guarantee for national food security. The total population at the end of the year, the intensity of fertilizer use, and the sown area of grain crops all negatively affect the comprehensive benefits of high-standard farmland construction at the 5% significance level, on the one hand, the population reduction may face the problem of labor shortage, which seriously affects the efficiency of farmland construction and agricultural production, and on the other hand, the excessively high intensity of chemical fertilizer use negatively affects the soil and and the environment, and destroys the farmland quality and the ecological environment. Sustainability. The sown area of food crops negatively affects the comprehensive efficiency of high-standard farmland construction, considering whether agricultural resources are unevenly distributed or other constraints.

Table7. Test of factors influencing the comprehensive benefits of high-standard farmland construction in different regions.

Variables	(1) Northern Shaanxi	(2) Southern Shaanxi	(3) Guanzhong region
Percentage of total output value of agriculture, forestry, animal husbandry and fishery	0.308 (1.04)	0.127 (-1.57)	0.236 (-1.20)
Rural disposable income per capital as a percentage	0.001*** (3.88)	0.000*** (4.29)	0.024** (2.33)
Regional economic density	0.085* (1.80) (1.80)	0.076* (-1.85)	0.514 (0.66)
Local budget expenditures	0.299 (1.06)	0.000*** (4.39)	0.000*** (6.10)
Average annual precipitation	0.555 (0.60)	0.072* (1.87)	0.000*** (7.24)
Total grain production	0.510 (0.67)	0.810 (0.24)	0.012** (2.60)
Total population at the end	0.544	0.778	0.464

of the year	(-0.61)	(0.28)	(-0.74)
Average annual temperature	0.941	0.048**	0.000***
	(0.07)	(-2.07)	(3.79)
Population productivity	0.059*	0.028**	0.000***
	(1.98)	(2.32)	(5.75)
Effective irrigated area	0.022**	0.062* (-1.95)	0.000***
	(2.45)	(-1.95)	(6.81)
Ratio of permanent basic farmland protection	0.326	0.184	0.364
	(1.00)	(-1.37)	(0.92)
Cultivated land area per capital	0.609	0.394	0.012**
	(0.52)	(0.87)	(2.60)
Fertilizer use intensity	0.430	0.118	0.011**
	(-0.80)	(-1.61)	(-2.64)
Total mechanical power per unit of cultivated land	0.243	0.110	0.290
	(-1.20)	(1.65)	(1.07)
Area sown in grain crops	0.433	0.558	0.001***
	(-0.80)	(-0.59)	(-3.51)
Constant term (constant)	0.001***	0.041***	0.000***
	(-3.59)	(-2.15)	(-4.79)
N	250	280	480
r2	0.414	0.731	0.694

Note: *, **, and *** represent estimates significant at the 10%, 5%, and 1% levels, respectively, and t-values of regression coefficients are in parentheses.

Due to its geographic location and historical and cultural characteristics, Shaanxi Province is known as Northern Shaanxi, Southern Shaanxi, and Guanzhong. Among the 101 counties and districts surveyed, there are 25 in northern Shaanxi, 28 in southern Shaanxi, and 48 in Guanzhong, and we continue to use the fixed effect model to analyze the factors and differences affecting the comprehensive benefits of high-standard farmland construction in the three regions. The results show (Table 7) that in northern Shaanxi, there are fewer factors affecting the comprehensive benefits of high-standard farmland construction, mainly rural disposable income per capital as a percentage, regional economic density, population productivity, and effective irrigated area, which positively affect the comprehensive benefits of high-standard farmland construction at a significance level of 1%, 10%, 10%, and 5%, respectively. The factors affecting the comprehensive benefits of high-standard farmland construction in 28 counties and districts in southern Shaanxi were more than those in northern Shaanxi. Rural per capital disposable income, local budget expenditure, average annual precipitation, population productivity all positively affect the evaluation results of the comprehensive benefits of high-standard farmland construction in southern Shaanxi, and the effects of rural per capital disposable income and local budget expenditure are particularly significant. Regional economic density, average annual temperature, and effective irrigated area negatively affect the comprehensive benefits of high-standard farmland construction at 10%, 5%, and 10% significance levels, respectively. Higher regional economic density indicates that land resources are under greater pressure, affecting the input and priority use of high-standard farmland construction, southern Shaanxi mainly planted rice, walnuts, chestnuts, the growth of these crops has a range of temperature requirements, the temperature is too high but not conducive to crop growth. At the same time, southern Shaanxi rainy to humid subtropical climate is dominated, and then increase the irrigation area instead of adding a burden for the comprehensive benefits. Guanzhong region has 48 research counties and districts, rural per capital disposable income, local budget expenditure, average annual precipitation, total grain production, average annual temperature, population productivity,

effective irrigation area, per capital cropland area all positively affect the comprehensive benefits of the construction of high-standard farmland at least 5% significance level, only the intensity of chemical fertilizer use and the sown area of grain crops two factors significantly negatively affect the comprehensive benefits of the construction of high-standard farmland. Only two factors, fertilizer use intensity and grain crop sowing area, significantly negatively affect the comprehensive benefits of high-standard farmland construction. Comparison found that, whether in southern Shaanxi, northern Shaanxi or central Guanzhong, the ratio of disposable income per capital in rural areas and the productivity of the population significantly and positively affect the comprehensive benefits of high-standard farmland construction, which demonstrates that, in different regions, the promotion of economic development and labor force resources for the construction of high-standard farmland has a universal role, and it can provide an important support for improving the comprehensive benefits of high-standard farmland construction. Secondly, the effective irrigated area has a significant positive effect on the comprehensive benefits of high-standard farmland construction in northern Shaanxi and Guanzhong, and shows a significant negative effect in southern Shaanxi, and the average annual precipitation only has a significant effect on southern Shaanxi and Guanzhong. This reflects the differences in water resource utilization, climatic conditions, and agricultural development patterns in different regions as well as the different levels of demand and reliance on irrigation facilities in different regions. Finally, the influence of local financial budget expenditure, per capital cultivated land area and fertilizer use intensity on the comprehensive benefits of high-standard farmland construction also reflects regional differences. The influence of local financial budget expenditure on the comprehensive benefits of high-standard farmland construction is more significant in southern Shaanxi and central Guanzhong, and the influence of per capital cultivated land area and fertilizer use intensity is significant in central Guanzhong. The development of high-standard farmland construction cannot be separated from the government support, which requires the northern Shaanxi region to effectively transform the budget expenditure into the actual input of high-standard farmland construction, Guanzhong region is densely populated and land resources are tense, increasing the per capital arable land area is more significant to improve the comprehensive benefits of high-standard farmland construction, and at the same time, it is more important to reduce the hazards of fertilizers on the soil and water sources, and to protect the ecological balance of the soil.

4.2.4. Robustness test

Referring to related scholars' research and combining with the content of this study, replace the explanatory variables(Zheng J., 2022), and substitute the main factor explanatory variables with one period lag into the model to re-test the regression. As shown in the table, "A" indicates the test results after replacing the explanatory variables, and "B" indicates the test results of the main factor explanatory variables lagged one period. Specific robustness test results as shown in Table 8, the sign direction of the coefficients of each variable and the significance of the basically unchanged, indicating that the empirical analysis model and variable settings are reasonable, and the regression analysis results have the reliability and accuracy.

Table 8. Robustness test.

Variables	**FE**		**(1) Northern Shaanxi region**		**(2) Southern Shaanxi region**		**(3) Guanzhong region**	
	A	B	A	B	A	A	A	B

Percentage of gross output value of agriculture, forestry, livestock and fisheries	0.113 (-1.60)	0.224 (-1.22)	0.574 (0.57)	0.947 (0.07)	0.107 (-1.67)	0.315 (-1.02)	0.441 (-0.78)	0.944 (-0.07)
Rural disposable income per capital as a percentage of	0.000*** (4.38)	0.000*** (6.21)	0.001*** (3.83)	0.012** (2.72)	0.001*** (3.65)	0.000*** (6.27)	0.940 (0.08)	0.044** (2.07)
Regional economic density	0.260 (1.13)	0.195 (1.30)	0.376 (0.90)	0.022** (2.45)	0.013** (-2.66)	0.000*** (-5.44)	0.344 (0.96)	0.109 (1.63)
Local budget expenditures	0.001*** (3.35)	0.001*** (3.43)	0.073* (1.88)	0.758 (0.31)	0.006*** (2.97)	0.000*** (4.84)	0.000*** (4.20)	0.000*** (6.74)
Average annual precipitation	0.000*** (5.32)	0.000*** (7.97)	0.724 (-0.36)	0.916 (-0.11)	0.043** (2.13)	0.001*** (3.77)	0.001*** (3.77) (3.77)	0.000*** (3.94)
Total grain production	0.307 (1.03)	0.016** (2.46)	0.712 (0.37)	0.318 (1.02)	0.756 (0.31)	0.605 (0.52)	0.050** (2.02)	0.050** (2.01)
Total population at the end of the year	0.076* (-1.79)	0.047** (-2.02)	0.437 (-0.79)	0.169 (1.42)	0.789 (0.27)	0.242 (-1.20)	0.964 (0.04)	0.434 (-0.79)
Average annual temperature	0.133 (1.51)	0.200 (-1.29)	0.946 (-0.07)	0.229 (-1.24)	0.441 (-0.78)	0.680 (0.42)	0.001*** (3.52)	0.249 (-1.71)
Population productivity	0.000*** (5.92) (5.92)	0.002*** (3.26)	0.187 (1.36)	0.149 (1.49)	0.035** (2.22)	0.005*** (3.09)	0.000*** (6.16)	0.027** (2.29)
Effective irrigated area	0.001*** (3.39)	0.000*** (5.53)	0.082** (1.81)	0.002*** (3.47)	0.261 (-1.15)	0.417 (0.82)	0.000*** (4.47)	0.000*** (6.46)
Ratio of permanent basic farmland protection	0.059* (-1.91) (-1.91)	0.294 (1.05)	0.868 (0.17)	0.023** (2.43)	0.062* (-1.95)	0.690 (0.40)	0.216 (1.26)	0.165 (-1.41)
Cultivated land area per capital	0.318 (1.00)	0.229 (1.21)	0.510 (-0.67)	0.000*** (4.36)	0.632 (-0.48)	0.181 (-1.37)	0.001*** (3.60)	0.020** (2.40)
Fertilizer use intensity	0.064* (-1.87)	0.099* (-1.66) (-1.66)	0.368 (-0.92)	0.989 (0.01)	0.071* (-1.88)	0.475 (-0.72)	0.067* (-1.88) (-1.88)	0.012** (-2.63)
Total mechanical power per unit of cultivated land	0.031** (2.18) (2.18)	0.398 (0.85)	0.244 (-1.19)	0.048** (-2.08)	0.033** (2.24)	0.234 (1.22)	0.596 (0.53)	0.909 (0.11)
Area sown in grain crops	0.039** (-2.10)	0.000*** (-5.62)	0.425 (-0.81)	0.625 (-0.50)	0.473 (-0.73)	0.442 (-0.78)	0.003*** (-3.12)	0.000*** (-6.51)
Constant term (constant)	0.000*** (-4.42)	0.000*** (-5.00)	0.009*** (-2.84)	0.043** (-2.14)	0.029** (-2.30)	0.000*** (-4.65)	0.046** (-2.05)	0.023** (-1.21)

N	1010	1010	250	250	280	280	480	480
R2	0.451	0.604	0.343	0.497	0.675	0.797	0.569	0.663

Note: *, **, and *** represent estimates that are significant at the 10%, 5%, and 1% levels, respectively, and t-values for regression coefficients are in parentheses.

5. Discussion

Based on the GeoDetector model and fixed-effects model, this chapter reasonably selects the panel data at county and district level in Shaanxi Province, and at the same time analyzes the results of the comprehensive benefits of high-standard farmland construction measured in the previous chapter to explore the spatial differentiation of the comprehensive benefits of the construction of high-standard farmland and the influencing factors of the changes of the comprehensive benefits in Shaanxi Province.

5.1 The Operational Logic of Key Influencing Factors

The proportion of total output value of agriculture, forestry, animal husbandry and fishery, financial budget expenditure, and average annual precipitation are important factors affecting the spatial differentiation of comprehensive benefits of high-standard farmland construction. Generally speaking, counties and districts with rich agricultural resources have a higher proportion of gross output value of agriculture, forestry, animal husbandry and fishery, and the government's investment in agricultural development is relatively high, such as the expenditure on agricultural subsidies, insurance, and agricultural science and technology, so it is easy to form spatial aggregation. However, according to the data in Table 6, the share of the total output value of agriculture, forestry, animal husbandry, and fishery is negatively correlated with comprehensive benefits. This is because the proportion of agriculture, forestry, animal husbandry, and fishery in some regions of Shaanxi Province is excessively high, resulting in a single industrial structure and low added value. Consequently, while output has increased, benefits have not improved, which means that the construction of high-standard farmland in Shaanxi Province is in urgent need of supporting industrial upgrading.

In addition, the spatial differentiation of the comprehensive benefits of high-standard farmland construction in Shaanxi Province is also affected by the main factors such as average annual precipitation, total grain output, and the proportion of effective rural per capital disposable income. That is, the spatial differentiation of the comprehensive benefits of high-standard farmland construction is also affected by the differences between counties and districts in the factors of natural environment, regional economic development, and agricultural share. In the real production activities, it is often difficult for a single factor to individually have a greater impact on the comprehensive benefits of high-standard farmland construction, due to the complexity of the real situation and the synergistic nature of resource allocation of the interaction between the various factors can better reflect the impact of the spatial variation of its comprehensive benefits. For example, precipitation and effective irrigation area directly affect the growth and yield of crops, but there are differences in precipitation or other natural environments among counties and districts, and when interacting with economic, social and policy factors, they can improve or deteriorate the ecological environment of farmland, thus affecting the spatial variation of the comprehensive benefits of the construction of high-standard farmland. At the same time, precipitation itself will also change over time, requiring policy measures to actively adjust resource allocation to promote economic and social development, thus affecting the spatial differentiation of the comprehensive benefits of high-standard farmland.

Among the main factors affecting the spatial differentiation of the comprehensive benefits of high-standard farmland construction, except for the regional economic density and total grain production, the other items significantly affect the evaluation results of the

comprehensive benefits of high-standard farmland construction. Further analyzing the results of the main factors affecting the comprehensive benefits among different regions in Shaanxi Province, such as northern Shaanxi, southern Shaanxi and central Guanzhong, it is found that the ratio of rural per capital disposable income has a significant and positive influence on the results of the comprehensive benefits of high-standard farmland in the three regions. The average annual precipitation and local budget expenditures have a significant impact on the southern Shaanxi and Guanzhong regions, and have no significant impact on the northern Shaanxi region. In addition, other factors, such as population productivity, effective irrigated area, total mechanical power per unit of arable land, and sown area of grain, also significantly affect the comprehensive benefits of high-standard farmland construction, but there are some differences in the results for the three regions of southern Shaanxi, northern Shaanxi, and central Guanzhong. Robustness test results for the above influencing factors show that the significance and direction of most factors basically did not change, indicating that the regression results have a certain degree of reliability. The government should adjust the agricultural support policy according to the climate change to adapt to the changing environment, ensure the sustainable utilization of resources, and improve the comprehensive benefits of high-standard farmland construction with reasonable inputs.

5.2 Research Contributions

The findings of this study are consistent with the conclusions of previous scholars, confirming that financial investment, irrigation facilities, and mechanization level are the core driving factors for high-standard farmland construction. However, this study reveals a negative correlation between the share of the total output value of agriculture, forestry, animal husbandry, and fishery and comprehensive benefits. The main reason for this discrepancy lies in the differences in the industrial structure of the research regions: a high proportion of agriculture, forestry, animal husbandry, and fishery in developed eastern regions indicates a high level of scale and branding, while in some counties and districts of Shaanxi Province, which are still in the traditional agricultural stage, a high proportion reflects the lag in industrial transformation. This suggests that the evaluation of high-standard farmland construction benefits should be combined with the regional industrial development stage and cannot be generalized.

6. Conclusions

This paper takes 101 counties (cities and districts) in Shaanxi Province as the research unit, and relies on the data representing the output, quality, ecological environment, and economic benefits of farmland after high-standard farmland construction, such as the status of arable land resources, the changes of natural resources and environment, and the policy input elements, etc., during the ten-year period between 2012 and 2021, and adopts hierarchical analysis and entropy weight method to establish the comprehensive weights and evaluate the comprehensive benefits of high-standard farmland construction using the entropy weight method. Using hierarchical analysis and entropy weight method to establish the comprehensive weights and assess the comprehensive benefits after the construction of high-standard farmland by entropy weight method, analyze the time and space changes of the comprehensive benefits and the spatial correlation test. According to the analysis results, the geographic detector model and fixed effect model are established to test the influencing factors and analyze the factors of the spatial variation of the comprehensive benefits and the factors of the resultant changes. Finally, from the analyzed results and the results of influencing factors, the strategies and suggestions to improve the comprehensive benefits are proposed, and the conclusions obtained are as follows:

(1) Among the 101 research units in Shaanxi Province, the evaluation results of output capacity and farmland quality are lower than those of ecological environment and economic benefits. Output capacity is the lowest while economic benefits are the highest. The average annual comprehensive benefits of counties and districts were concentrated at the "average level", with about one-fifth of the counties and districts having comprehensive benefits of less than 0.4, mainly in Yulin and Ankang, and to a lesser extent in other cities as well.

(2) During the study period, the comprehensive benefits of high-standard farmland construction in all counties and districts in Shaanxi Province generally show an increasing trend with the change of years. From 2012 to 2023, as the two years of the implementation of high-standard farmland construction planning during the study period, the comprehensive benefits were mostly in very poor or poor grades, ranging from 0.1 to 0.3. 2014-2016 is the early stage of high standard farmland construction during the study period. Most of the results of comprehensive benefits of high standard farmland construction in most counties and districts are mostly between 0.3 and 0.5, rising faster. 2017-2019 is in the middle and late stage of high standard farmland construction during the study period. More counties and districts with high standard farmland construction during the three-year period have comprehensive benefits rising to the average level. In 2020, which is the year of acceptance of the planning stage of high-standard farmland construction and the late stage of high-standard farmland construction during the study period, the number of counties and districts at the average level decreases, and most counties and districts have been at a better level of comprehensive benefit, with the number reaching 71.

(3) The spatial distribution of comprehensive benefits has changed significantly, showing an evolution trend of 'optimization from north to south' with the advancement of high-standard farmland construction.

(4) In response to the changes in the spatial distribution of the comprehensive benefit results, the spatial autocorrelation test of the comprehensive benefit during the study period indicates that the evaluation results of the comprehensive benefit of high-standard farmland construction in Shaanxi Province show a certain degree of spatial clustering effect, and there is a certain degree of similarity or correlation of the comprehensive benefit between different counties and districts. Before 2019, the counties and districts with high and high aggregation are mainly in northern Shaanxi, and after that, they are concentrated in southern Shaanxi. The regions with obvious high and low aggregation are mainly in Guanzhong and southern Shaanxi, such as Huanglong County, Zhen'an County and Foping County. There are fewer counties with obvious low-high aggregation, including Heyang County and Lantian County. The counties and districts with low-low aggregation are mainly concentrated in southern Shaanxi, such as Pingli County, Hanbin District and Lantian County.

(5) Through the GeoDetector model and fixed-effects model, it is found that there are six factors that have relatively large influence on the spatial differentiation of the comprehensive benefits of high-standard farmland construction, which are the percentage of total output value of agriculture, forestry, animal husbandry and fishery, the percentage of per capital disposable income of the rural population, the density of the regional economy, the local financial budget expenditure, the average annual precipitation, and the total grain production, and their interaction detection has a non-linear enhancement and two-factor enhancement relationship, and there is no independent or mutual diminution of their roles. In addition, except for regional economic density and grain production, the other factors of the main influence factors also significantly affect the comprehensive benefits, but the results differ in different regions of southern Shaanxi, northern Shaanxi and central Guanzhong.

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Figure legends

Figure 1. Comprehensive benefits of high-standard farmland construction in 101 counties and districts of Shaanxi Province.

Figure 2. Interaction detection results of all factors.

Figure 3. Main effect factor interaction.

Competing interests

The authors declare no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Data availability

The datasets analyzed in this study have been uploaded and are available as supplementary materials associated with this article.

Informed consent

This article does not contain any studies with human participants performed by any of the authors.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- AnalysisoftheInfluencingFactorsofHighstandardFarmlandConstructioninShaanxiProvince.xlsx
- CalculationofCountylevelComprehensiveBenefits.xlsx
- RegressionDataofInfluencingFactors.xlsx
- SupplementaryFactorsofInfluencingFactors.xlsx