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Assessment of High-standard Farmland Construction Effectiveness in Liaoning Province During 2011–2015

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Abstract: At present, the large-scale construction of high-standard farmland in China has improved the quality of cropland and crop production and enhanced the eco-environmental security. To obtain a comprehensive understanding of high-standard farmland construction in Liaoning Province of China during the 12th five-year period (2011–2015), through on-the-spot investigations and remote sensing monitoring, this study assessed the construction effectiveness of ten typical sampling projects in Liaoning Province and then presented practical suggestions. The main conclusions were as follows. 1) The ranges of increase in productivity of the ten sampling projects in Liaoning Province all surpassed the goal of 1500 kg/ha. 2) Among all sampling project areas, the levels of productivity stability of nine sampling projects were higher than that of the surrounding farmland in a severe drought year. However, the productivity stability of the high-standard farmland construction project in Faku County, Yiniupu Town, declined by 1.04% compared with the surrounding farmland. 3) Except for the high-standard farmland construction project in Dengta City, Dengta Irrigation Region, the productivity uniformity of the other nine sampling projects increased by 3.30%–88.10%. 4) Eight of the ten sampling projects belonged to Class 1, and two projects belonged to Class 2, showing that the effectiveness of high-standard farmland construction in Liaoning Province was quite good. There were some suggestions for high-standard farmland construction in the future. All departments should strengthen cooperation and formulate corresponding protection and development strategies suitable for local conditions. Additionally, lasting management mechanisms should also be established. Using remote sensing monitoring to assess the high-standard farmland construction effectiveness during the 12th five-year period could provide experience and decision-making support for high-standard farmland construction in the future.

Keywords: high-standard farmland; remote sensing monitoring; productivity stability; productivity uniformity; Liaoning Province, China

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1 Introduction

High-standard farmland is defined as concentrated and flat, well-equipped, high-yield, and ecologically-sound farmland (Lan, 2016; Chen et al., 2017; Zhao et al., 2017). Plans to construct more than 5.33 million ha of high-standard farmland in 2018 arose from the 13th session of the National People's Congress. Constructing high-standard farmland on a large scale is an important strategy at present and makes good sense for promoting the quality and quantity of cultivated land and ecologically comprehensive management, enhancing national food security, and promoting agricultural modernization and new rural construction (Wang et al., 2013). Although the government of China (GOC) has already issued the basic standards for high-standard farmland construction, there have been few reports about the study of construction standards based on the quality

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evaluation results of high-standard farmland. Liaoning Province is an important commodity grain production base in China. China′s 12th five-year plan period, from 2011 to 2015, refers to the 12th five-year period of China′s national economic and social development. From 2011 to 2015, 413.87 thousand ha of high-standard farmland were constructed in Liaoning. In view of the current implementation of national agricultural comprehensive exploitation and high-standard farmland construction projects, remote sensing monitoring assessments of high-standard farmland, analyses of productivity increases and effectiveness, and summaries of experience and problems need to be carried out quickly. This makes good sense for responding to cropland protection and economic use of land systems, promoting the construction of high-standard farmland during the 13th five-year period (2016–2020), and ensuring national food security (Fan et al., 2016).

In 2011, China’s first high-standard farmland construction specification was established, and research about high-standard farmland began a few years ago. Many scholars have adopted different methods to assess high-standard farmland construction effectiveness. 1) Assessment methods of construction content. Some researchers summarized the construction content of high-standard farmland and then assessed construction effectiveness (Cao, 2016; Deng et al., 2016; Fan et al., 2016). Cao selected a typical high-standard farmland construction project in Fuxin City, Zhangwu County as the study area, summarized the infrastructure construction in the project area as well as the crop productivity increase and per capita income increase of farmers after project construction, and then described some experiences and innovations for high-standard farmland construction (Cao, 2016). 2) Assessment methods of a comprehensive index (Huang et al., 2013; Wang, 2013; Cui and Liu, 2014; Zheng et al., 2014; Jiang et al., 2015; Liu, 2015; Wang et al., 2015; Zhuang, 2016; Sun et al., 2017; Li et al., 2018). Zheng et al. selected nine indicators to analyze the high-standard farmland construction effectiveness in Beiyuan, Linxia County, according to the physical geography, land use, infrastructure and regional development and then divided these project areas into three levels (Zheng et al., 2014). Cui et al. took natural quality conditions, infrastructure and regional development as criteria, used GIS spatial analysis methods, and selected ten indicators to assess the high-standard farmland construction suitability of Beijing, Huairou District (Cui et al., 2014). 3) Methods of model calculation (Cai et al., 2014; Zhao et al., 2016; 2018; Xin et al., 2017). Cai et al. analyzed the social effects of high-standard farmland construction of Baoji City based on the entropy weight method and extension model (Cai and Li, 2014). Xin et al. used the entropy weight method and improved technique for order preference by similarity to an ideal solution (TOPSIS) model to evaluate the social and economic benefits of three high-standard farmland project areas in Chongqing city (Xin et al., 2017).

The above studies show that research on the effectiveness of high-standard farmland construction currently aims at specific project areas. There have been few studies that focused on assessing the high-standard farmland construction effectiveness at the macro scale. Moreover, cropland productivity can be the index that intuitively reflects project construction effectiveness; to date, there have been few studies to explore the change in cropland productivity with the method of remote sensing monitoring and then assess the effectiveness of high-standard farmland construction.

This study selected ten typical sampling projects of farmland in Liaoning Province in China as the study area, converted Net Primary Productivity (NPP) into cropland productivity in the project areas, and then chose three indicators, namely, cropland productivity, cropland productivity stability and cropland productivity uniformity. Through on-the-spot investigations and remote sensing monitoring, we explored productivity changes after high-standard farmland construction and then classified the construction effectiveness of the sampling project areas and put forward practical suggestions. The objective of this study is to fully grasp high-standard construction effectiveness during the 12th five-year period (2011–2015) and then provide experiences and decisions for high-standard location and construction during the 13th five-year period. This is an important measure for ensuring the smooth implementation of high-standard farmland projects, production and increased benefits for farmers and for food security.

2 Materials and Methods

2.1 Study area

In this study, Liaoning Province of China, an important region for grain, oil and vegetable production, was chosen as the study area. Liaoning Province is located in Northeast China and has a large area of cultivated land (6.41 million ha in 2015). It is located at 38°43′18″N–43°29′26″N, 118°50′16″E–125°41′16″E, and contains 14 cities, namely, Shenyang, Dalian, Anshan, Fushun, Benxi, Dandong, Jinzhou, Yingkou, Fuxin, Liaoyang, Panjin, Tieling, Chaoyang and Huludao (Fig. 1). The total area is approximately 14.60 million ha. The terrain of Liaoning Province slopes from south to north and from the east and west to the middle (Currie and Chen, 2001). It is located on the east coast of Eurasia, belonging to the temperate continental monsoon climate zone. There are four equal seasons of spring, summer, autumn and winter. The annual mean temperature is 6℃–11℃, and the annual precipitation is 60–1100 mm (Zhou et al., 2000; Hu et al., 2013). The highest precipitation is in the northeastern provinces. Liaoning has a population of approximately 43.15 million. Cropland and woodland are the major land use types, covering approximately 66.10% of the total area.

From 2011 to 2015, 445 high-standard farmland projects were constructed in Liaoning Province. Sampling projects need to be chosen according to different agricultural, ecological, terrain and climate conditions and should be in the concentrated distribution of cropland. Therefore, Faku County, Liaozhong District, Dengta City and Dawa District in the center of Liaoning Province where the cropland is concentrated and the land is flat and Jianping County in western Liaoning Province that is elevated were chosen as the sampling counties. Each county had two sampling projects; thus, there were a total of ten sampling projects (Fig. 1).

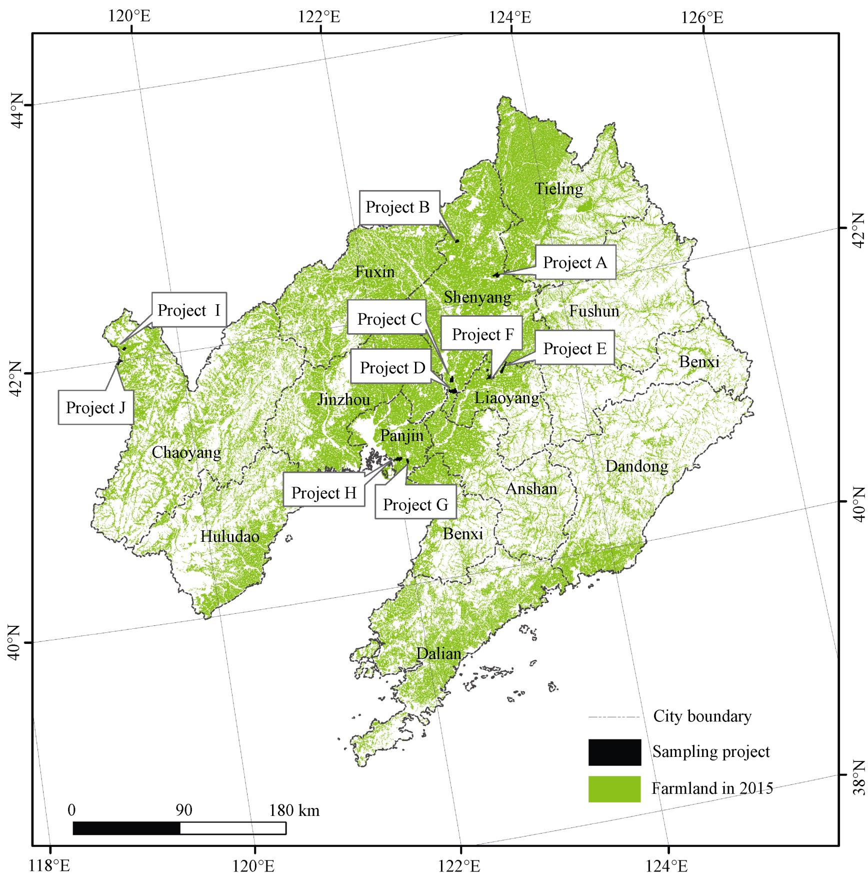

Fig. 1 Locations of the ten high-standard farmland sampling projects in Liaoning Province. Project A: High-standard farmland construction project of Faku County, Yiniupu Town; Project B: High-standard farmland construction project of Faku County, Woniushi Village; Project C: High-standard farmland construction project of Liaozhong District, Liujianfang Town; Project D: High-standard farmland construction project of Liaozhong District, Zhujiafang Town; Project E: High-standard farmland construction project of Dengta City, Dengda Irrigation Region; Project F: High-standard farmland construction project of Dengta City, Tongerpu Town; Project G: High-standard farmland construction project of Dawa District, Tangjia Town; Project H: High-standard farmland construction project of Dawa District, Wangjia Town; Project I: Water-saving and food-increasing project of Jianping County, Heishui Town; Project J: High-standard farmland construction project of Jianping County, Changlong Town

2.2 Data sources

The land use data for 2010 and 2015 used in this study were extracted from the land use database developed by the Chinese Academy of Sciences (with a mapping scale of 1∶100 000) (http://www.resdc.cn/). The land use database was obtained from the manual visual interpretation of Landsat Enhanced Thematic Mapper (ETM) and Operational Land Imager (OLI) images. Through field verification, the interpretation precision was > 94.3%, which satisfies the accuracy requirements for 1∶100 000 mapping. The land use data were classified into six major categories: cultivated land, woodland, grassland, water body, built-up land, and unused land. In this study, cropland data covering the sampling project areas were processed into raster data with a spatial resolution of 30 m.

To take into account the regional differences in natural and climatic conditions, China's cropland is divided into three cropping zones, 12 major zones, and 38 subzones in terms of temperature, water, topography, cropping systems, crop types, and socioeconomic conditions (Liu, 1993; Lu et al., 2013; Xue, 2014). Yan et al. provided a detailed statement to high-, medium-, and low-yield cropland productivity classification within different cropping zones (Yan et al., 2016). In this article，the study area, Liaoning Province, is located in the NO. 31 subzone. Therefore, when the NPP in Liaoning Province is more than 703 g C/m^2, the cropland can be considered as high-yield cropland. When the NPP is less than 556 g C/m^2, the cropland can be considered as low-yield cropland. The cropland where the NPP is between 556 and 703 g C/m^2 can be considered as medium-yield cropland.

The NPP was calculated by the Vegetation Photosynthesis Model (VPM). Among the driven data of the VPM, the Enhanced Vegetation Index (EVI) and Land Surface Water Index (LSWI) were obtained by calculating the Moderate-resolution Imaging Spectroradiometer (MODIS) surface reflectivity product (MOD09AI) (500 m spatial resolution, 8 day temporal resolution) (http://www.edc.usgs.goc/). The meteorological data included temperature, precipitation and radiation data (Xiao et al., 2005; Niu et al., 2016a; 2016b; Luo et al., 2018).

The statistical data included meteorological disaster data for Liaoning Province extracted from China's Meteorological Disaster Yearbook from 2011 to 2015 (China Meteorological Administration, 2012; 2013; 2014; 2015; 2016). Crop planting areas and production data for all counties were extracted from the Statistical Yearbook of Liaoning Province in 2013 (Statistical Bureau of Liaoning, 2014).

2.3 Methods

2.3.1 Calculation of NPP

The NPP in this study was calculated by the VPM. In the VPM, the Gross Primary Productivity (GPP) is first estimated using the following formula:

$$GPP = \varepsilon_g \times FPAR_{chl} \times PAR \quad (1)$$

where ε_g is the light use efficiency (μmol CO_2/μmol photosynthetic photon flux density, PPFD), *PAR* is the Photosynthetically Active Radiation (μmol PPFD), $FPAR_{chl}$ is the fraction of (*PAR*) absorbed by leaf chlorophyll in the canopy, and (Yan et al., 2016).

Light use efficiency (ε_g) is affected by temperature, water and leaf phenology:

$$\varepsilon_g = \varepsilon_0 \times T_{scalar} \times W_{scalar} \times P_{scalar} \quad (2)$$

where ε_g is the maximum radiation use efficiency (μmol CO_2/μmol PAR) and the value of ε_0 is calculated from the Net Ecosystem Exchange (NEE) and incident PAR observed from CO_2 eddy flux tower sites (Yan et al., 2012). $T_{scalar,}$ W_{scalar} and P_{scalar} are the scalars for the effects of temperature, water and leaf phenology, respectively, on the light use efficiency of vegetation.

NPP is estimated as the ratio of autotrophic respiration to GPP. According to the experimental results of respiration rates of wheat, sunflower, sorghum, and soybeans, the ratio of autotrophic respiration to GPP generally remains constant and equal to 0.42 (Gifford, 1995; Luo et al., 1996; Cheng et al., 2000; Albrizio and Steduto, 2003).

Meantime, the spatial resolution of initial NPP is 500 m. To obtain the rates of high-, medium- and low-yield farmland accurately, we changed the spatial resolution of the initial NPP to 30 m by using land use data and EVI data with a 30 m spatial resolution with a downscaling method.

2.3.2 Calculation method of cropland productivity

In this study, we used VPM and MODIS data with a spatial resolution of 500 m to calculate the NPP of Liaoning Province from 2011 to 2015 and then converted NPP into cropland productivity according to the statistical data of actual crop yields in the statistical yearbook.

First, according to the statistical planting area and production of main crops (rice, maize, wheat and soybean) in each county of Liaoning Province in 2013, we calculated the total production of main crops in each county and obtained the per unit yield of the main crops by dividing by the planting area in each county as the cropland productivity. Then, we used the NPP data from 2013 and land use data to calculate the per unit cultivated land NPP of each county. We then set up a regression relationship between the cropland productivity and per unit cultivated land NPP of Liaoning (Fig. 2) and obtained the conversion formula between the NPP and cropland productivity of Liaoning:

$$y = 13.17x + 653.83 \ (R^2 = 0.74) \quad (3)$$

where y is the cropland productivity (kg/ha) and x is the per unit cultivated land NPP (g C/m^2).

2.3.3 Assessment indicators of high-standard farmland

(1) Cropland productivity change

A cropland productivity change refers to the change in the production ability of grain and commercial crops in an area. It is a direct indicator for measuring high-standard farmland construction effectiveness. In this study, changes in cropland productivity before and after high-standard farmland construction indicated the levels of cropland productivity change.

In this study, we used the central NPP in a project as the NPP of the project. We totaled the average annual NPP before and after project construction and then calculated the average annual crop productivity according to formula (4).

$$\Delta P = P_2 - P_1 \quad (4)$$

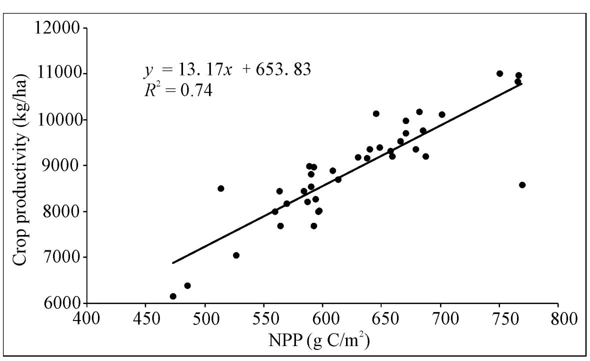

Fig. 2 Conversion between the net primary productivity (NPP) and cropland productivity in Liaoning Province in 2013

where ΔP is the change in cropland productivity, P_2 is the average annual cropland productivity per unit farmland area after project construction, and P_1 is the average annual cropland productivity per unit farmland area before project construction.

In general, when $\Delta P > 1500$ kg/ha, the level of cropland productivity increase can be considered to be good.

(2) Cropland productivity stability change

The cropland productivity stability can reflect the fluctuation range of cropland productivity. It is an important indicator to assess the ability to resist disasters after high-standard farmland construction. In this study, we assessed the rate of change of cropland productivity inside and outside the project areas in a disaster year compared to that in a normal year to measure the capability for disaster resistance after project construction. By referring to China's Meteorological Disaster Yearbook (China Meteorological Administration, 2015), there was a severe drought in Liaoning Province in 2014 between 2011 and 2015. Hence, we chose 2014 as the drought year and 2015 as the normal year and assessed whether the disaster recovery ability had improved after the construction of high-standard farmland projects in Liaoning Province. Outside the ten sampling projects, we selected nine surrounding farmland areas where the productivity was less than 20% of that in the projects as a comparison respectively. If the productivity in the projects in the drought year (2014) (HP_d) was almost the same as in the normal year (2015) (HP_n) and the productivity in the surrounding farmland areas in the drought year (2014) (NP_d) was lower than in the normal year (2015) (NP_n), the cropland productivity stability improved due to the construction of high-standard farmland. The construction of high-standard farmland not only increased the cropland productivity but also improved the capability for disaster resistance. The formula for calculating the level of productivity stability change (SP) is

$$SP = RN - RH \quad (5)$$

$$RN = (NP_n - NP_d) \times 100 / NP_n \quad (6)$$

$$RH = \left(HP_n - HP_d\right) \times 100 / HP_n \quad (7)$$

where RN is the productivity gap between normal and disaster years in the surrounding farmland areas, and RH is the productivity gap between normal and disaster years in the sampling projects.

(3) Cropland productivity uniformity change

Cropland productivity uniformity refers to the degree of uniformity and similarity of the spatial distribution of croplands with different productivity levels. In this study, the rates of the middle- and low-yield farmland areas were considered the indicator of a productivity uniformity change. If the rate of medium- and low-yield farmland decreases in a project area but the rate of high-yield farmland increases, the effectiveness of productivity uniformity of high-standard farmland increases. Smaller rates for the middle- and low-yield farmland combined with more homogeneous high-yield farmland show a clear effect on productivity uniformity.

The formula for calculating the change rate of the middle- and low-yield farmland area is as follows.

$$LP = \left(\frac{L_a}{S_a} - \frac{L_b}{S_b} \right) \times 100\% \quad (8)$$

where LP is the change rate of middle- and low-yield farmland, S_a is the area of cropland in the projects after project construction, S_b is the area of cropland in the projects before project construction, L_a is the area of middle- and low-yield farmland in the projects after project construction, and L_b is the area of middle- and low-yield farmland in the projects before project construction.

(4) Comprehensive assessment

Based on quantitative results of the cropland productivity change, productivity uniformity change and stability change, we divided the high-standard farmland construction effectiveness of the ten sampling projects during the 12th five-year period into three classifications, as shown in Table 1.

3 Results

3.1 Cropland productivity change analysis for the ten sampling projects

The increases in cropland productivity for the ten sampling projects in Liaoning Province were all higher than 1500 kg/ha. Among them, the productivity of four high-standard farmland projects increased from less than 9750 kg/ha to more than 11 250 kg/ha after the project implementation. The maximum productivity was 17 235 kg/ha after project construction (the high-standard farmland construction project of Jianping City, Changlong Town), and the productivity increased 3480 kg/ha, which was the largest among these ten projects. Although the cropland productivity of high-standard farmland construction project of Dengta City, Tongerpu Town (Project F) was less than 7650 kg/ha before project construction, the increase of 2790 kg/ha was large after construction (Fig. 3).

3.2 Cropland productivity stability change analysis for the sampling projects

From section 2.2, 2014 was selected as the drought year, and 2015 was selected as the normal year. We used project G (project of Dawa County, Tangjia Town) as an example (Fig. 4) and selected nine other surrounding farmland areas where the productivity was less than 20% of that in project G, namely, 9090 kg/ha. Then, we analyzed the differences in cropland productivity stability inside and outside the high-standard farmland project in the drought year (2014).

Among the ten sampling projects in Liaoning Province, the level of productivity stability for the nine other surrounding farmland areas in the severe drought year was higher than that for other surrounding farmland areas. After project construction, the irrigation facilities fully covered all farmland in the projects, and the cropswere

Table 1 Classification standard for remote sensing monitoring assessments of high-standard farmland

Classification	Standard
1	Increasing productivity by more than 1500 kg/ha, increasing productivity uniformity and increasing productivity stability can all be satisfied
2	Two conditions can be satisfied among the following: increasing productivity by more than 1500 kg/ha, increasing productivity uniformity and increasing productivity stability
3	Only one condition can be satisfied among the following: increasing productivity by more than 1500 kg/ha, increasing productivity uniformity and increasing productivity stability

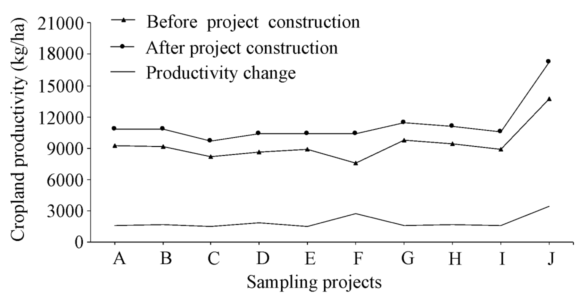

Fig. 3 Cropland productivity change for the ten sampling projects. A–J: the ten high-standard farmland sampling projects shown in Fig. 2.

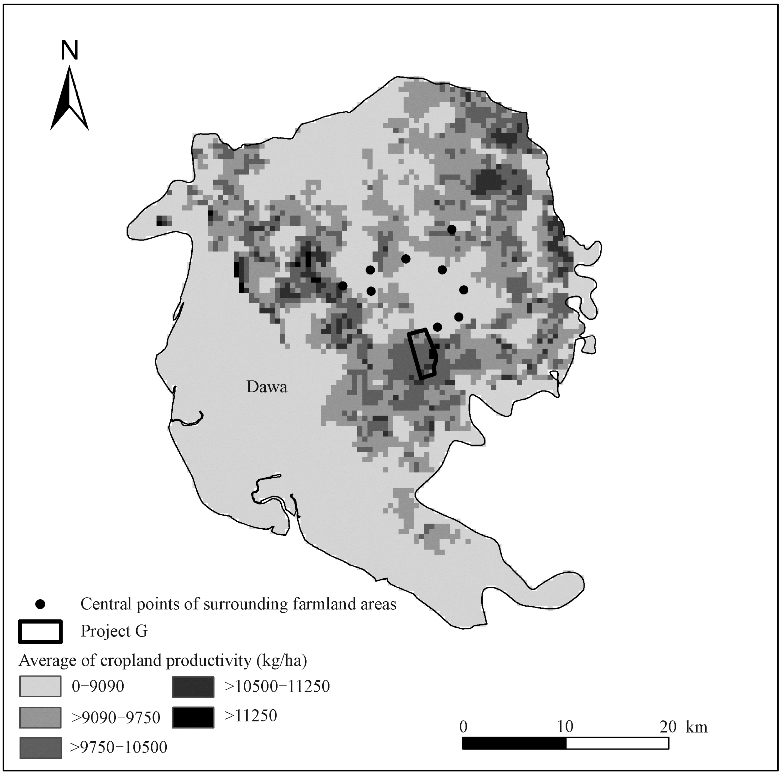

Fig. 4 Distribution of high-standard farmland construction project of Dawa County, Tangjia Town (Project G) and nine surrounding farmland areas

farmlandwere well watered during the drought. This ensured the construction effectiveness of drought resistance for the projects. Among them, the level of productivity stability of the high-standard farmland construction project of Dengta City, Dengta Irrigation Region, was the highest and increased by 16.19% compared with nine other surrounding farmland areas. The second highest increase was observed for the water-saving and food-increasing action project of Heishui Town, Jianping County, for which the level of productivity stability increased by 16.10% compared with other surrounding farmland areas. The only project area where the productivity stability declined was the high-standard farmland construction project of Faku County, Yiniupu Town. The level of productivity stability of this project fell slightly compared with those of other surrounding farmland areas (1.04%) (Table 2).

3.3 Cropland productivity uniformity change analysis of the sampling projects

In this study, we used the changes in medium- and low-yield farmland in the projects as an indicator of the cropland productivity uniformity change after project construction. Taking project D (the high-standard farmland project of Liaozhong District, Zhujiafang Town) as an example, we discussed the change rates of medium- and low-yield farmland in the project after project construction (Fig. 5).

Table 2 Analysis of the cropland productivity stability of the ten sampling projects

Sampling projects	HP_d (kg/ha)	HP_n (kg/ha)	RH (%)	NP_d (kg/ha)	NP_n (kg/ha)	RN (%)	SP (%)
A	10500	10800	2.78	7635	7770	1.74	–1.04
B	10185	10500	3.00	7290	8220	11.31	8.31
C	11580	10875	–6.09	8100	8805	8.01	14.10
D	10425	10905	4.40	7485	7845	4.59	0.19
E	8475	8880	4.56	6645	8385	20.75	16.19
F	12000	12180	1.48	8280	8535	2.99	1.51
G	11625	11955	2.76	6240	6945	10.15	7.39
H	10530	11085	5.01	7170	7665	6.46	1.45
I	11820	11505	–2.67	8025	9270	13.43	16.10
J	13455	14115	4.68	8280	9495	12.80	8.12

Notes: A–J represents the ten sampling projects shown in Fig. 2. The meanings of HP_d, HP_n, RH, NP_d, NP_n, RN and SP have been shown in formulas (5), (6) and (7). '–' represents that the change rate is negative.

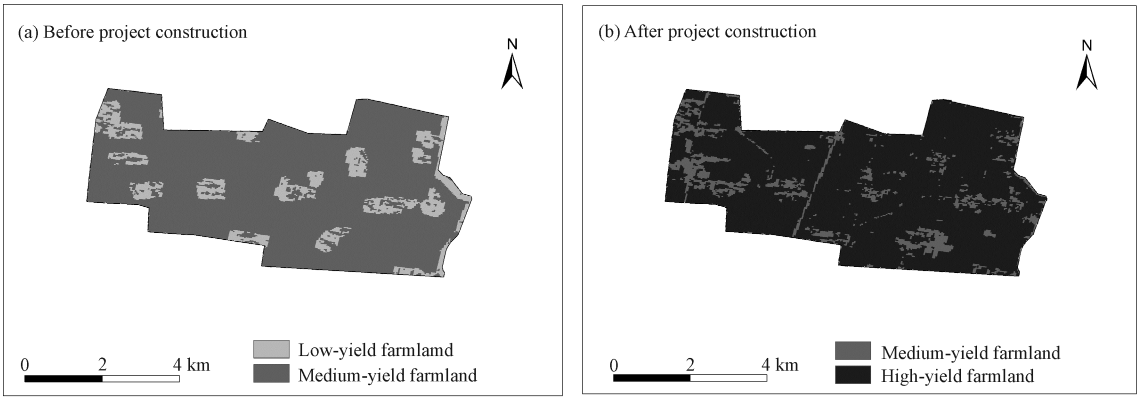

Fig. 5 High-, medium- and low-yield farmland distributions in project D

Middle-yield farmland dominated in project D before construction, while mainly high-yield farmland dominated after construction (Figs. 5a and 5b). Through the construction of high-standard farmland projects, the cropland productivity and its uniformity clearly improved.

Among the ten sampling projects in Liaoning Province, seven consisted of more than 90% medium- and low-yield farmland before project construction. After project construction, the irrigation facilities of the projects fully covered all farmland, and the crop irrigation conditions and levels were the same in the projects, ensuring the construction effectiveness of the cropland productivity uniformity change in the projects. After project construction, the rates of medium- and low-yield farmland of only one project did not decrease, and the rates of medium- and low-yield farmland of three projects fell below 30%. The level of productivity uniformity for nine projects increased by 3.30%–88.10% (Fig. 6).

3.4 Comprehensive assessment of the sampling projects construction effectiveness

The classification results of the construction effectiveness of the ten high-standard farmland sampling projects during the 12th five-year period in Liaoning Province are shown in Table 3.

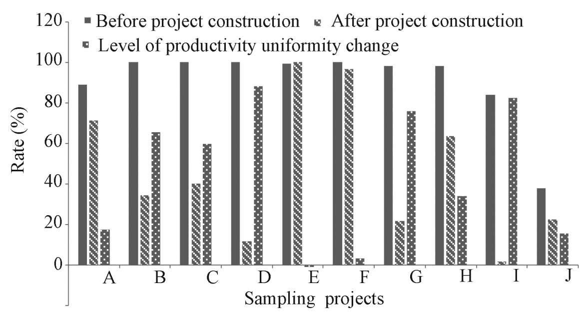

Fig. 6 The rates of medium- and low-yield farmland area of the total sampling project area, and the rates of productivity uniformity change in Liaoning Province, China

Table 3 The comprehensive assessment of the ten sampling projects construction effectiveness

Sampling project	Productivity change (kg/ha)	Productivity stability change (%)	Productivity uniformity change (%)	Classification
A	1650	–1.04	17.50	2
B	1665	8.31	65.50	1
C	1530	14.10	59.70	1
D	1845	0.19	88.10	1
E	1530	16.19	–0.80	2
F	2790	1.51	3.30	1
G	1635	7.39	76.10	1
H	1665	1.45	34.20	1
I	1650	16.10	82.30	1
J	3480	8.12	15.50	1

Notes: A–J represents the ten sampling projects shown in Fig. 2. '—' represents that the change rate is negative.

Eight of the ten sampling projects in Liaoning Province satisfied the conditions of increasing cropland productivity by more than 1500 kg/ha, increasing productivity stability and increasing productivity uniformity. Two sampling project areas, including the high-standard farmland projects of Faku County, Yiniupu Town, and Dengta City, Dengta Irrigation Region, belonged to class 2. The productivity stability of the project in Faku County did not increase. Perhaps this was due to the anomalous conditions for this project. The irrigation method in the Faku County project was groundwater irrigation. Before project construction, there was sufficient water in the paddy fields, so the capability of drought resistance after project construction did not increase. The productivity uniformity of the project in Dengta City did not increase, which may have been because the facilities in the project have not yet come into play.

4 Discussion

4.1 Further verification of cropland productivity stability change

In 2012, some regions, especially the central region, suffered from flooding; in 2015, the entire province suffered from severe drought. To further verify the change in productivity stability after project construction, we considered both flood and drought scenarios. Project G was also taken as an example because it is located in the central region of Liaoning Province. First, to further verify the change in the crop productivity stability in flooding (2012) and normal years (2015), we compared the crop productivity in Project G with that in nine other surrounding farmland areas, and the results are shown in Fig. 7. In Project G, the crop productivity was almost the same in 2012 and 2015 and was higher than that in the nine other farmland areas. However, in the nine other farmland areas, the gaps between crop productivity in 2012 and in 2015 were very large. This indicates that the crop productivity stability in Project G was greater than that in the other farmland areas in the flooding year. The flood in 2012 had no significant effect on the project, but nine other farmland areas were affected significantly by the flood. By constructing high-standard farmland, the crop productivity stability in Project G clearly increased.

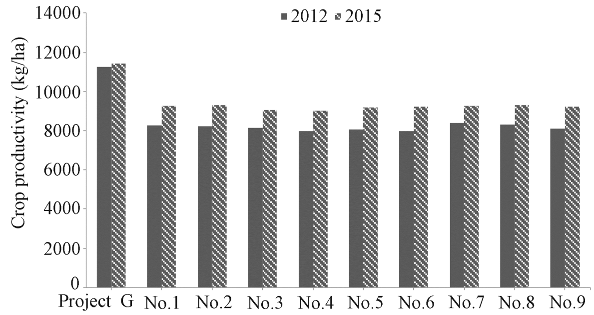

Fig. 7 Crop productivity in Project G and nine other farmland areas in Liaoning Province in 2012 and 2015. No. 1-No. 9: the nine surrounding farmland areas

Second, to further verify the change in crop productivity stability in a drought year (2014) and in a normal year (2015), we compared the crop growth in these two years. Crop growth can be recognized through the EVI of MODIS data. The EVI is close to the average monthly temperature and can accurately represent the growth and change processes of crops in different seasons (Li et al., 2007; Zhao and Li, 2007). We still took Project G as an example, compared the crop growth represented by the average EVI in project G and nine surrounding farmland areas in drought (2014) and normal (2015) years and obtained the Table 4. We see that the crop growth in Project G was clearly better than that in the nine surrounding farmland areas. Moreover, the severe drought in 2014 had no significant effect on the project. For the ninesurrounding farmland areas, the productivity was clearly lower than that in the sampling project regardless of whether it was a disaster year or a normal year, and the change rates of productivity in the disaster year and the normal year were clearly higher than those in the sampling project. The results indicate that the nine surrounding farmland areas were significantly affected by the drought. Therefore, the productivity stability of Project G increased through high-standard farmland construction.

4.2 Suggestions for the design and construction of high-standard farmland

Based on the assessment results of the high-standard farmland construction effectiveness during the 12th five-year period in Liaoning Province, some suggestions are proposed to provide decision-making guidelines for the design and construction of high-standard farmland in the future. Related suggestions are as follows.

Table 4 EVI × 100 of the high-standard farmland projects of Dawa County, Tangjia Town (Project G) and nine surrounding farmland areas (No. 1–No. 9) during the growing period in years 2014 and 2015

Growing period (d)		1	10	20	30	40	50	60	70	80	90	100	110	120
NO.1	2014	19	20	30	39	45	55	63	61	50	32	18	15	8
	2015	22	23	41	56	62	76	79	70	56	45	31	20	12
NO.2	2014	21	22	27	40	44	53	61	62	48	31	17	16	6
	2015	24	25	40	57	59	78	80	69	57	44	20	21	13
NO.3	2014	18	19	31	39	43	52	60	61	51	32	18	14	8
	2015	23	24	38	59	66	75	78	71	54	43	30	19	15
NO.4	2014	20	22	29	40	41	57	62	59	49	33	16	15	9
	2015	25	24	38	49	59	77	80	70	55	45	30	21	13
NO.5	2014	19	22	26	37	39	59	60	60	48	32	14	14	9
	2015	22	26	40	47	58	78	79	69	56	41	31	21	14
NO.6	2014	20	21	23	36	41	60	61	58	51	34	15	17	10
	2015	23	25	38	49	59	79	78	71	54	42	32	20	15
NO.7	2014	18	19	23	39	44	59	59	60	50	35	16	15	9
	2015	22	23	37	53	60	75	81	70	57	44	32	22	14
NO.8	2014	18	21	30	36	47	58	61	61	49	32	18	16	8
	2015	23	25	39	52	60	76	82	69	55	41	34	21	15
NO.9	2014	18	22	29	40	46	56	62	62	49	33	17	16	9
	2015	22	25	41	55	61	77	78	69	55	44	32	20	14
Project G	2014	30	34	54	67	78	95	89	78	62	52	41	32	21
	2015	28	33	57	65	76	97	86	77	61	49	42	30	19

(1) All relevant departments should strengthen their cooperation, use modern agricultural machinery, rely on green and efficient agriculture, and build a modern agricultural staple food production base.

(2) The layout of high-standard farmland projects during the 13th five-year period should be aimed at major grain-producing areas, major grain-producing counties, grain-producing areas, high-yield fields, middle- and low-yield fields with large potential for improvement, new cultivated land resources, ecological limits and other different characteristics, and a customized layout should be implemented based on local conditions.

(3) Responsibility for management and protection needs to be implemented. Long-term management operational mechanisms need to be established to ensure the long-term benefits of construction projects.

5 Conclusions

Assessing the high-standard farmland construction effectiveness in Liaoning Province during the 12th five-year period (2011–2015) could be beneficial for promoting high- standard farmland demarcation and construction in Liaoning in the future and is a good way to ensure increased quality of cultivated land, increased income of farmers and food security. This study employed cropland productivity as the evaluation index of the high-standard farmland construction effectiveness, used the remote sensing monitoring method and finally assessed and classified the construction effectiveness of ten sampling projects considering three indicators: productivity, productivity stability and uniformity.

Cropland productivity for the ten sampling projects in Liaoning Province all increased by more than 1500 kg/ha; the productivity increase range of the high-standard farmland construction project of Jianping City, Changlong Town, was the largest at 3480 kg/ha. Among the ten sampling projects in Liaoning Province, the levels of productivity stability for nine projects in a severe drought year were higher than those for the nine surrounding farmland areas. The ability to resist disasters in the projects significantly improved. The levels of productivity stability of the high-standard farmland project of Dengta City, Dengta Irrigation Region were the highest and increased by 16.19% compared with the nine other surrounding farmland areas. Considering the productivity uniformity, the rates of medium- and low-yield farmland for seven projects were more than 90% before project construction, but the rates for three projects fell below 30% after project construction. The productivity uniformity of only one sampling project did not improve (the high-standard farmland project of Faku County, Yiniupu Town). The levels of productivity uniformity increase for the other nine projects were 3.30%–88.10%. Summarizing the assessment results of three remote sensing monitoring indicators, eight of ten sampling projects in Liaoning Province belonged to Class 1, and two belonged to Class 2. No projects belonged to Class 3. This demonstrates that the construction effectiveness of Liaoning Province during the 12th five-year period was quite good.

However, based on the assessment results of the high-standard farmland construction effectiveness in Liaoning Province, some suggestions still need to be implemented. All departments should strengthen their cooperation in the future, and long-term management operational mechanisms need to be established to ensure the long-term benefits of construction projects.

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