CONSTRUCTION STANDARD OF FARMLAND LANDSCAPE PATTERN IN CHINA BASED ON PRECISION AGRICULTURE

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Abstract: Precision agriculture is an important choice for the future agriculture. It is the base for precision agriculture development to change the state of small-scale farmland production and weak agricultural foundation in China gradually. Combined with the poorness of village in China, the variation of farmland and the dominance of small-scale peasant economy, this paper analyzed the adaptability of farmland landscape pattern to precision agriculture based on literatures and farmland landscape survey. With the requirements of precision agricultural production, this paper put forward the standards on cultivated field scale and shape, farmland corridor structure, cultivated field matrix and farmland landscape protection in order to make farmland landscape suitable for precision agriculture and to provide references for the sustainable development of precision agriculture in China.

Keywords: precision agriculture, farmland landscape, agricultural mechanization, agricultural modernization

1. INTRODUCTION

Farmland landscape pattern is the product of long-term integration of nature, society and agricultural production technology, which shows variable natural, cultural and technical characteristics. With the deepening of

ecological civilization conception, the scientific development concept makes a higher demand of farmland landscape pattern, and protecting and improving rural farmland landscape have become the historical responsibility in agricultural modernization construction. Precision agriculture with sustainable development is the core of agricultural modernization construction. It requires more to farmland landscape pattern than the mechanized simply agriculture, which can be seen not only in field size, shape and leveling degree, but also in the structure of farmland landscape pattern. Obviously, the farmland landscape pattern suitable for agricultural mechanization is just the basis of sustainable precision agriculture. However, the small scale fields, low level of agricultural mechanization and poor facilities in China have hindered the construction of precision agriculture. It is necessary to rebuild the existing farmland landscape pattern objectively.

2. TRADITIONAL FARMLAND LANDSCAPE PATTERN AND EXISTING PROBLEMS

After a long-time historical vicissitudes, farmland landscape pattern characterized with “Well field” was formed. The long-term petty-farmer management and private ownership of property right in feudal society made the field scale small and the boundary irregular. Autarkical or half-autarkical small-scale family farming lacks the ability to resist the nature disaster. Before the foundation of New China, the farming scale formed in rural areas in China. But because of the scattered highly land use right, the agricultural productivity was very low, it was so hard to irrigate in dry days or to drain in rain days that farmers relied on the nature, which caused wasted land and field full of weed. For example, in Baoding County in Hebei province, each farming family had an average area of 1.05hm^2, and each was cut into 20 pieces. And in Wuxi County in Jiangsu province, each farming family had an average area of 1.05hm^2, and each was cut into 15 pieces.

Before the Rural Producer's Cooperative was established, the area of private land owned by farmers was often small, which was composed of small scattered fields and narrow pieces. After 1949, farmland was centralized. In 1955, the Cooperative Movement was developed quickly and the "1956-1967 National Agricultural Development Outline (Draft)" was issued which made "Reclaiming wasteland, expanding cultivated land area" as one of the important goals (General Administration of Land use, 1956). To eliminate one field inserting, wedging, far from and replaced by another field, it is necessary to make the farmland centralized and the shape regular, which adapt to the requirement of production. Therefore, the planning and project “Square field and strip field” were carried out in plain areas, and the

planning and project "Terrace field" were carried out in mountainous areas. Meanwhile, farmland was centralized and regulated, soil was improved, and ancillary field roads, sheltered belts and irrigation channels were constructed, which all laid the foundation for the initial formation of intensive farmland landscape pattern.

The traditional mode of agricultural technology also selects species and monitors soil fertility on regional scale and accumulates the cultivation and management measures suitable for local conditions, which are recommended to farmers. In fact, even in the same field, there are obvious space-time distribution differences of crop growth conditions and yield on and below the ground, including crops diseases, insects and weeds in the fields, which always happen in the form of patch in an area and then gradually spread and change in time and space. That farmers divide cultivated land into small pieces was restricted to the emotional knowledge to crop growth environment and yield spatial variation. Thus, production management experience of "Traditional precision farming" was formed. However, it is impossible to form large-scale productivity because of the supportive lack of quantitative researches of modern scientific methods and modern engineering means (Chen Deen et al., 2008).

(1) Scattered land property right and small-scale cultivated field

The implementation of the household contract responsibility system in the mid-1980s reduced the average operation scale of each farming family (Zhao Yanwen et al., 2007). In Yangzhong of Jiangsu, the total area of farmland patches decreased 3% from 1999 to 2004, while the number of patches increased to 369, 73.8 patches increased each year on average. The patch density increased from 8.07 patches per km^2 in 1999 to 9.48 in 2004 (Li Xintong et al., 2000).

The scale of agricultural production based on the unit of farming family is often small, and the fertilizer and management levels of different farmers are differences, and soil nutrients in fields change greatly in space. Therefore, it is difficult to draw a spatial distribution map of soil with sub-meter precision and to make variable rate fertilizer precisely (Chen Fang et al., 2006). Since the division state caused by the household contract responsibility system is definitely not suitable for the development of precision agriculture, it is necessary to reform the land management mode (Lei Yu et al., 2007).

(2) Extensive management and low efficient use of resources

The effective utilization rate of water resources is only 45% in China, while 50%-70% in developed countries. It's an important direction for agricultural resource use to fertilize precisely according to soil moisture condition in fields and to increase water utilization rate to the greatest extent. The utilization rate of chemical fertilizer in China is also quite low, between 30% and 40%. And the loss rate of nitrogen reaches up to 70%-80%. The

chemical fertilizer waste is very serious, which caused many environmental issues. To implement precision agriculture and to fertilize precisely according to the soil nutrients will save greatly the usage of chemical fertilizer and reduce investment (Liu Yanxuan et al., 2007).

(3) Weak protection and biodiversity

Agricultural civilization in China shows the bright shine. In the course of thousands-year development, rural ecological civilization with different regional characteristics has formed. But in the process of farmland construction and development, people emphasized on the intensive use of farmland but ignored the protection of agro-ecosystem, which caused the crop variety and planting patterns single. To emphasize pesticides and chemical fertilizer but to ignore ecological treatment and straw back into field caused the biodiversity declined sharply and the stability of agro-ecosystem weakened.

In short, resources in China are limited, and the contradiction between human and land is obvious, and natural disasters happen frequently, and there is too much draught, barren and saline-alkali soil. Therefore, the overall condition of agricultural production is poor. And it's hard to meet the requirements to support the practice and management of modernized agriculture by information technology, to decide the input on the crop based on the soil properties as well as temperature, humidity, light and other factors, to diagnose cultivated land and growing way of crops in quantity and real-timely, to improve soil productivity and to realize precision agriculture with high quality, high yield, low consumption and environmental protection (Lei Weiwei et al., 2008; Zhao Wei et al.,2008; Wang Maohua,1999; Zhao Chunjiang et al.,2003). Obviously, it is necessary to rebuild the existing farmland landscape pattern.

3. CULTIVATED FIELD SCALE AND SHAPE

Agricultural mechanization requires proper scale and shape of cultivated field to improve the efficiency of agricultural machine operation and to reduce the degree of damage to the soil structure. Precision agriculture supported by mechanization has higher requirements on the scale and shape of cultivated field, and the requirements under different agricultural operation methods differ.

3.1 Scale and shape of cultivated field in plain areas

The scale of farmland operation in China is small. The level of agricultural mechanization is low. There is still a long road of development

process to implement wide-area precision agriculture. Plain area is flat, densely populated, has complete infrastructure relatively and is basically able to adapt to agricultural mechanized operation after long-term farmland construction. It's the best area to develop precision agriculture in advance recently. It corresponds with national conditions of China to develop precision agriculture in large-scale farms and plain areas with large-area crop production.

(1) Scale and shape of cultivated field with mechanized operation

Mechanized operation can exert the mechanical efficiency only if fields meet the requirements of machine operation. Precision agriculture makes following requirements to cultivated field:

Cultivated field scale: Precision agriculture was put forward to adapt to the sustainable development of crop production system with highly intensive and scale degree. And the marginal effect is positively related to operation scale. In addition, precision agriculture such as sampling and testing soil is clearly inappropriate to the situation of plot operation in China, which makes the accuracy declined. Therefore, cultivated field should be in proper scale to meet the need of precision agricultural production. The length is designed to bring machines into full play. Generally, the longer the field is, the fewer the time that the agricultural machines turn is and the higher the efficiency is. Considering the requirements of irrigation, drainage and windbreak, the field length in plain areas is commonly 500m-800m; the field width is multiple of that of machine operation, 200m-400m, and the ratio between perimeter and area is controlled within $60m/hm^2$-$300m/hm^2$. Taking fertilizing wheat as an example, according to the analysis of economic benefit, the minimum area of cultivated field, which is appropriate for technical practice of precision agriculture and feasible economically is $85.6hm^2$ (Li Shicheng et al., 2007). High agricultural mechanization promotes the appropriate scale of land operation.

Scale of paddy field is smaller than that of dry land. In terms of precision agricultural management, the field area is $0.5hm^2$ to $1.5hm^2$.

Cultivated field shape: In order to set good conditions for machine operation, the field shape should strive to be regular and take rectangular and square as the best followed by right-angle trapezoid and parallelogram. And the worst are irregular triangles and arbitrary polygon. The patch shape index should be close to 1. And the field orientation should be good for machine operation, generally the north and south (Bao Haijun et al., 2002).

(2)Scale and shape of labor-intensive cultivated field

To save resources and to improve the efficiency of resources use are both the mission of labor-intensive agriculture. And precision agriculture provides it with technical support.

Scale and shape of labor-intensive agriculture for industrial production should be in accordance with the production process. Cultivated area of agriculture taking plastic warm shed and energy-saving sunlight greenhouse as main facility has reached nearly $20.0\times10^4 hm^2$ in China, which is No.1 in the world. Nevertheless, there is still a large gap about the whole level of facility production between China and developed countries, which can be seen on poor facilities, low technical contents, poor control of light and temperature, especially computer management difficult to support. Thus, agriculture can not be regarded as precision cultivation and needs to construct supported facilities in accordance with the production process.

Scale and shape of open-air labor-intensive cultivated field should adapt to characteristics of the labor. Generally speaking, the area should not be too large and the pattern should not be too complex. It can be divided by the field roads based on mechanized cultivated field to meet the requirements of labor operation.

3.2 Scale and shape of cultivated field in hilly areas

The landform is obviously undulated in hilly area. Except flat farmland in valley, most farmland is terrace field. Low agricultural mechanization and high cost of precision cultivation make it an area difficult to develop precision agriculture. Although the hilly area is unsuitable for development of precision agriculture temporally, it's still feasible to exert some functions of precision agriculture in this area gradually. Under the precondition of keeping the stability of regional ecosystem, scale and shape of farmland in hilly area can be set by the slope. Terrace fields are developed based on road system or irrigation and drainage channel system as framework. The direction should follow the contour, and the shape should be square, rectangular or trapezoidal and the area should be 5hm2-6hm2.

4. STRUCTURE OF FARMLAND LANDSCAPE

With the development of modern agriculture, agricultural mechanization promoted the intensive use of farmland. Small and scattered patches (such as forest land, shelterbelts, channels, grassland) disappear largely from modern agricultural landscape. In the past 58 years, in order to increase agricultural production, a lot of farmland corridors were eliminated and the farmland scale was expanded continually, which caused the great changes of farmland landscape (Croxton et al., 2002). With the increase of agricultural mechanization, field marginal zone reduced sharply, for example, the density of shelterbelts and channels reduced (Cœur et al., 2002). Field roads for

small agricultural tools, people and livestocks will be consolidated into farmland. Some other field roads will be widened to be suitable for large agricultural machines. And farmland patch scale surrounded by wide corridors will be expanded. Water resources amount is a key factor to determine the structure of precision farmland landscape corridors.

(4) Structure of farmland corridors in water-short area

Water-saving irrigation is an important measure for sustainable development in water-short area. Precision irrigation is apparently out of what channels can do. It needs laying water pipes and supported water-saving facilities.

Dry farming area: Considering saving water, in order to reduce occupied land, it is necessary to fix up the drainage channels as underground pipes when laying water delivery pipes. In the areas with large surface runoff, drainage or stain, lateral canals and some field ditches can be reserved properly. In the area with wind damage, protection forest should be laid out according to the requirements of wind precaution. Production road should be laid out according to the requirement of production in accordance with channels, pipes and protection forest.

Paddy farming area: The composition of paddy field corridors is basically as the same as that of dry field corridors. Water delivery should adopt pipes, and drainage should adopt open ditches, and protection forest should be laid out according to the requirements of disaster prevention.

(2) Structure of farmland corridors in water-rich area

In water-rich area, paddy field is the main part of farmland. And the core of precision agriculture is fertilizer, control of plant diseases and insect pests and field management. The requests to structure of corridor are land saving and supported facilities.

(3)Composition of farmland marginal line

Intensive farmland is usually to cultivate uniformly in a large area of land. Due to great spatial variability of land, single uniform farming results in land degradation and low efficiency of protection measures. Precision agriculture can protect soil and reduce environmental hazards on the basis of continuing high-yield (Bai Yi, 2007). Therefore, between fields and water channels establishing permanent vegetation zone along and level to the sides of fields can hold up and slow down the runoff, improve infiltration, reduce the water pollution of chemical substances on the lower reaches of the stream and protect farmland ecological security.

(4)Cultivated field matrix

Cultivated field matrix mainly contains soil conditions, land leveling degree and farming method. Soil is the site of material, energy and information exchanges for crops. Soil conditions are mainly texture and fertility. Soil with poor texture needs soil improvement design and

fertilization design. Surface soil thickness is highly related to the yield of crop. In the construction of precision agriculture, surface soil should be protected (Wu Fei et al.,2006). Land leveling degree directly impacts intensive cultivation, irrigation, drainage, crop ventilation and photosynthesis, which aim to flatness. Farming method is mainly rotation method, which aims to raise productivity through crop rotation.

Field leveling height should adapt to local conditions, invest less, and be proper for irrigation and drainage and mechanized cultivation. The elevation design of farmland that harvests even in flood or dry seasons with small undulating landform and thick soil should be determined mainly in accordance with the requirements of fill and excavation volumes; the elevation design of sloping field with large undulating landform and thin soil should not only consider leveling earthwork volume but also try to meet the requirements of irrigation and drainage facilities according to landform features; the elevation design of low bottomland should also take requirements of water level into consideration, and the elevation after leveling should be 0.2m higher than annual flood level. For the farmland with high water level, the field elevation should be designed 0.8m higher than annual ground water level (Fu Meichen et al., 2007). Inner height differences of paddy field should be controlled within 3cm

(5)Protection and development of farmland landscape

Through study of relationship between farmland yield and production input and field scale, Indra Roschewitz et al. said that farmland with a high degree of production specialization has larger area of field, less kind of crops, higher yield of crop and more input, while farmland with complex landscape has lower yield, higher biodiversity and less input. So they thought that the idea that simple landscape structure was good to improve the intensity of land use may be misleading (Roschewitz et al., 2005). And many countries take farmland corridor as an important part of rural cultural heritage and protect it to enhance the tourism value of rural landscape.

Farmland use in China is mainly in the form of plot. What are considered is confined in the inside plot. Even though external conditions are considered, they are mainly connected with essential infrastructure related to direction of land use, and it is hard to take the harmony of regional rural landscape. Different places have their unique landscape and culture, which forms rural landscapes with different characteristics. At present, farmland consolidation in the purpose of intensive operation in China is difficult to break existing pattern, which caused landscape machine-made. Precision farmland consolidation project should not only meet the demands of precision agriculture but also pay attention to protecting local traditional landscape, and highlight the specialty of local landscape and reflect local cultural connotation.

5. CONCLUSIONS

Precision agriculture based on agricultural mechanization and 3S technology, which integrates modern electronic information technology, decision-making support for crop cultivation management and agricultural engineering equipment technology, has been recognized as the most advanced agricultural technology in the 21st century, which is being demonstrated and promoted globally by the leading of the USA. In 1994, Chinese scientists started to care about precision agriculture. But restricted by conditions, precision agriculture was not paid much attention to until the beginning of the 21st century and included in 863 national schemes. Meanwhile, demonstration zones were established in Beijing and Heilongjiang (Sui Changling et al., 2005). At present, precision agriculture is in the stage of experiment, demonstration and development. Compared with developed countries, there is still a large gap on technology level, operation management and economic benefit. It is necessary not only to break through technology but also to create production conditions. Therefore, it's an inevitable developing trend of agriculture in China to change the style of petty-farmer management, to turn decentralized management to centralized management gradually, to rebuild farmland landscape pattern constantly on scale and shape of cultivated field, farmland production facilities and farmland matrix in order to adapt to the requirements of future development of precision agriculture.

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