Prediction of Farmland Protection Area in County-level Land Use Planning: A Case Study of Mizhi County of Shaanxi Province

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Abstract Taking Mizhi County as an example and the year of 2005 as base period of planning, this paper made a prediction of farmland demand in 2010 and 2020 using grain security method, supply-demand balance method, and trend extrapolation method. In addition, it built a fixed weight combination model to make scientific summary of three prediction results. Finally, it predicted the farmland demand of Mizhi County in 2010 and 2020 will be 40 967 hm^2 and 36 556 hm^2, which can provide basis and reference for determination of farmland protection area in the land use planning.

Key words Land use planning, Farmland protection area, Prediction model, Mizhi County

Farmland is material base guaranteeing national grain security and sustainable development of social economy[1-2]. Zhai Wenxia and Han Binghua stated that reasonable control and improvement of farmland structure is helpful for coordination with industrial structure[3]. To value land highly, use land rationally and protect cultivated land effectively is a national basic policy of China, and to ensure that China's farmland at or above the red line of 120 million hectares relies on scientific determination of farmland protection area in land use planning[4]. The county-level land use planning forms a connecting link between various levels of land use planning, thus making prediction of farmland protection area in county-level land use planning will be of great significance[5]. There are many methods to predict the farmland protection area[6-9]. Taking Mizhi County as an example and the year of 2005 as base period of planning, we made a prediction of farmland demand in 2010 and 2020 using grain security method, supply-demand balance method, and trend extrapolation method. Then, we built a fixed weight combination model to make scientific summary of three prediction results. Finally, we predicted the farmland demand of Mizhi County in 2010 and 2020, in the hope of providing basis and reference for determination of farmland protection area in the land use planning.

1 Overview of the study area and data source

1.1 Overview of the study area Mizhi County (E109°48′45″ – E110°29′28″ and N37°39′26″ – N38°05′22″) is a county in Yulin City of Shaanxi Province. It is 59 km long from east to west and 47 km from north to south, having a total area of 1 173.80 km^2. In the county, major landform is the typical loess landform. Located in north of hilly area of the Loess Plateau, Mizhi County has mild temperate semi-arid continental monsoon climate, with annual average temperature of 8.6℃, extreme highest temperature of 39.6℃, extreme lowest temperature of −31.8℃, mean annual hours of sunshine 2 678.6 hours, and mean annual rainfall of 440.9 mm. Water system in the county belongs to Wuding River (now called Yongding River) system, and total volume of water resource is 71.66 million m^3. In 2005, total population of Mizhi County reached 208 400, local GDP reached 599 million yuan, financial revenue reached 10.75 million yuan, and local financial revenue was up to 8.61 million yuan. Farmers' per capita net income reached 1487 yuan and urban residents' disposable income reached 4 370 yuan. There are 7 towns and 6 townships: Yinzhou Town, Tao Town, Yangjiagou Town, Dujiashigou Town, Shajiadian Town, Yindou Town, Jijiacha Township, Qiaohecha Township, Gaoqu Township, Lizhan Township, Shilipu Township, and Guoxingzhuang Township under the administration of Mizhi County.

1.2 Data source National economic and social development data of Mizhi County were selected from *Statistical Yearbook of Yulin City* and *Statistical Yearbook of Mizhi County* of 1997 – 2006, and statistical data provided by relevant statistical and specialized department. Basic data of land use were selected from dataset of land use changes of Shaanxi Province in 1996 – 2005.

1.3 Study methods

1.3.1 Prediction of farmland protection area based on grain security. The prediction of farmland protection area based on grain security is the minimum farmland protection area guaranteeing regional grain security. Generally, it takes basic demand of local population for grain as objective and predicts area of farmland necessary for protection to satisfy certain self-sufficiency of grain[10]. The calculation formula is as follows:

Farmland demand = (total grain demand / per unit area yield of farmland)/grain-crop ratio = (per capita grain demand × total population × grain self-sufficiency) / (per unit area yield of farmland × multiple crop index)/grain-crop ratio (1)

1.3.2 Prediction of farmland protection area based on supply-demand balance. This method starts from factors influencing changes

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of farmland area and takes satisfaction of demands of national economic development for various types of land and realization of supply-demand balance as purpose[11]. Farmland increase is generally analyzed from land development, land consolidation and land reclamation. Farmland decrease is generally analyzed from construction, ecological restoration, agricultural structural adjustment, and natural disaster, and the prediction of farmland protection area for supply-demand balance can be expressed in following formula:

$$S_n = S_0 - S_1 - S_2 - S_3 - S_4 + S_5 + S_6 + S_7 \quad (2)$$

where S_n signifies the planned farmland supply capacity in the target year, S_0 signifies the farmland area of planning base period, S_1 is farmland area for construction purpose, S_2 is the farmland area for ecological restoration, S_3 is farmland area for agricultural structural adjustment, S_4 is farmland area damaged by natural disasters, S_5 is farmland area increased from land use development, S_6 is farmland area increased from land consolidation, and S_7 is farmland area increased from land reclamation.

1.3.3 Prediction of farmland protection area based on trend extrapolation method. Trend extrapolation is a forecasting technique that can be used to estimate both demand for and supply of human resources. This technique is based on what is called a time series – a set of observations measured at successive points in time (*e.g.*, weekly, monthly, yearly). Usually the most significant underlying characteristic of any data is their trend, mathematically referred to as the slope or average rate of change over a time period. Trend extrapolation is to find out development rules of an event according to past and present data of the event, find out a suitable function curve changes, and accordingly predict future development of the event[12]. According to farmland change trend of Mizhi County, we mainly adopted linear trend model and quadratic curve model to predict the farmland protection area of the target year.

2 Results and analyses

2.1 Prediction of farmland protection area based on grain security

2.1.1 Determination of related parameters.

(i) Per capita grain demand. According to the prediction of *National Medium and Long Term Grain Security Plan* (2008 – 2020), the per capita grain demand of the whole country will be 389 kg in 2010 and 395 kg in 2020.

(ii) Determination of total population. According to the *Overall Urban Planning of Mizhi County* (2009 – 2030) *and the Outline for National Economic and Social Development Planning of Mizhi County*, the total population of Mizhi County is 220 000 in 2010 and 240 000 in 2020.

(iii) Grain self-sufficiency. According to basic ideas of revision of *Outline of National Overall Planning on Land Use* and the white paper *Grain Issue in China* issued by Information Office of the State Council on October 24, 1996, the basic policy of China's grain issue is to realize self-sufficiency based on domestic resources, and the grain self-sufficiency of China should not be lower than 95% in normal years. Considering future grain security of Mizhi County and its strategic position of large agricultural county in Yulin City and combining statistical data of relevant departments, we determined that the grain self-sufficiency of Mizhi County is 95% in both 2010 and 2020, so it can basically realize grain self-sufficiency.

(iv) Per unit area yield of farmland. The per unit area yield, multiple crop index, and grain-crop ratio of Mizhi County in 1997 – 2005 are listed in Table 1.

Table 1 The per unit area yield, multiple crop index, and grain-crop ratio of Mizhi County in 1 – 2005

Year	Per unit area yield kg/hm^2	Multiple crop index//%	Grain-crop ratio//%
1997	609	90.85	81.65
1998	1895	94.56	81.07
1999	555	93.45	77.99
2000	2315	98.35	79.02
2001	932	98.62	73.64
2002	2699	113.12	70.04
2003	1969	115.96	67.10
2004	3724	71.27	100.00
2005	1857	90.14	75.17

According to changes of per unit area yield since 1997, the per unit area yield will be 2450 kg/hm^2 in 2010 and 2724 kg/hm^2 in 2020.

(v) Multiple crop index. According to the *Outline of the Eleventh Five-Year Guideline for National Economic and Social Development of Mizhi County and Outline of the Twelfth Five-Year Guideline for National Economic and Social Development of Mizhi County*, Mizhi County actively builds modern agriculture industrial system, stably develops grain planting industry, strengthens animal husbandry, energetically develops forest and fruit industry, improves vegetable planting industry, actively develops labor migration industry, energetically develops agricultural and sideline product processing industry. In the planning period, the farmland utilization efficiency will further rise. We predict that the multiple crop index of Mizhi County will be 100% and 115% in 2010 and 2020 respectively.

(vi) Grain-crop ratio. The grain-crop ratio is farmland area planting grain to the total sown area of farmland. According to data in Table 1, based on factors such as economic development and agricultural structural adjustment of Mizhi County, we determined that the grain-crop ratio of Mizhi County will be 70% in 2010 and 65% in 2020.

2.1.1 Calculation of the farmland demand based on integrated grain production capacity. According to values of the above parameters, using the formula (1), the farmland demand of Mizhi County will be 47 405 hm^2 and 44 229 hm^2 in 2010 and 2020 separately.

2.2 Prediction of farmland protection area based on supply-demand balance

2.2.1 Prediction of farmland reduction.

(i) Construction. In 1997 – 2005, various types of construction such as urban and rural residential areas, traffic, water conservancy and industrial and mining construction of Mizhi County occupied 566 hm^2 farmland, the annual occupation of farmland is up to 62.8 hm^2. Without considering demand of rapid economic development for farmland, the construction of Mizhi County will occupy 314 hm^2 farmland in 2006 – 2010, and it will occupy 972 hm^2 farmland in 2006 – 2020. Mizhi County always sticks to the principle of protecting and rationally utilizing every parcel of farmland and promoting conserved and intensive use of land. It gets rid of various difficulties and strictly implements the order of farmland area for new construction issued by superior government. Finally, it determined that the farmland of Mizhi County for construction will be 150 hm^2 in 2006 – 2010 and 340 hm^2 in 2006 – 2020.

(ii) Ecological restoration. Since the implementation of the policy of returning farmland to forest, Mizhi County actively responded to the call of the state for building beautiful northwest area. In 1997 – 2005, the total farmland for ecological restoration reached 17435 hm^2. With the ecological restoration focusing on quality and benefit since 2004, the ecological restoration enters steady implementation period and the farmland area for ecological restoration will become slower than in the past.

Table 2 Reduction of farmland in Mizhi County due to ecological restoration in 1997 – 2005

Year	Farmland reduction hm^2	Ecological restoration// hm^2	Ratio %
1997	400	323	80.75
1998	234	148	63.25
1999	563	414	73.53
2000	920	835	90.76
2001	1665	1611	96.76
2002	6596	6412	97.21
2003	6379	6270	98.29
2004	519	460	88.63
2005	1106	962	86.98
Total	18382	17435	86.24

Farmland with slope greater than 25° is major area for returning to forest. In Mizhi County, the farmland with slope greater than 25° takes up 58.56% of the whole farmland area of Mizhi County. Thus, it is not proper to return all such farmland to forest. According to situations of recent years, with policy permits, Mizhi County arranged 500 hm^2 farmland for ecological restoration. In 2006 – 2010, the farmland for ecological restoration will be 2413 hm^2; in 2006 – 2020, the farmland for ecological restoration will be 7 413 hm^2.

(iii) Agricultural structural adjustment. In 1997 – 2005, agricultural structural adjustment of Mizhi Couty occupied 154 hm^2 farmland with annual reduction of 17.2 hm^2. Since Mizhi County will focus on developing highly efficient ecological agriculture in future, the demand of agricultural structural adjustment for farmland will increase. It is predicted that agricultural structural adjustment will occupy 20 hm^2 farmland annually. We determined that the farmland reduction due to agricultural structural adjustment will be 100 hm^2 in 2006 – 2010 and 300 hm^2 in 2006 – 2020.

(iv) Farmland reduction due to natural disasters. Mizhi County is located in typical hilly area of the Loess Plateau. The ground surface is torn to pieces, ridges and loess hills cross with each other. Gullies are widespread. The water loss and soil erosion is serious. In winter, it is cold and the icebound season is long. Natural disasters are of frequent occurrence. In 1997 – 2005, farmland reduced about 237 hm^2 due to natural disasters, with the annual reduction of farmland up to 33.9 hm^2. Considering variability of farmland reduction due to natural disasters, the farmland reduction area is 25 hm^2 annually according to normal years. Therefore, we determined that the farmland reduction area due to natural disasters in 2006 – 2010 will be 125 hm^2 and 375 hm^2 in 2006 – 2020.

(v) Total reduction of farmland area in the planning period. According to the above prediction, the reduction of farmland area in Mizhi County is mainly resulted from construction, ecological restoration, agricultural structural adjustment, and natural disasters. The specific reduction of farmland area is listed in Table 3.

Table 3 Prediction of farmland reduction in Mizhi County in the planning period (unit: hm^2)

Period	Construction land	Ecological restoration	Natural disasters	Agricultural structural adjustment.	Total
2006 – 2010	150	2413	125	100	2875
2011 – 2020	190	5000	250	200	5553
2006 – 2020	340	7413	375	300	8428

2.2.2 Prediction of farmland increase. According to land consolidation planning of Mizhi County in 2010 – 2020, the farmland increase due to land consolidation will be 2454 hm^2 in 2006 – 2020, farmland increase due to land reclamation will be 67 hm^2, and farmland increase due to land development will be 111 hm^2. In total, the farmland increase will be 2631 hm^2 with annual increase of 175 hm^2.

2.2.3 Prediction of farmland protection area. According to analysis of farmland resource potential and factors for increase and reduction, we obtained the farmland increase and reduction situation of Mizhi County in 2010 and 2020 (as listed in Table 4).

From Table 4, the farmland increase will be 877 hm^2 in 2006 – 2010 and the reduction area will be 2 875 hm^2, and the predicted farmland area is 37 615 hm^2; the farmland increase will be 2 631 hm^2 in 2006 – 2020, the reduction area will be 8 428 hm^2, and the predicted farmland area will be 33 826 hm^2.

Table 4 Prediction of farmland area of Mizhi County based on supply capacity of farmland (unit: hm²)

Period	Farmland area of the planning base period	Farmland increase	Farmland reduction	Farmland protection area
2006 – 2010	39613	877	2875	37615
2006 – 2020		2631	8428	33826

2.3 Prediction of farmland protection area based on trend extrapolation method According to farmland changes in 1997 – 2005, we simulated farmland change model using linear trend model and quadratic curve model in the multinomial prediction model, as shown in Fig. 1. We obtained the farmland change model of Mizhi County:

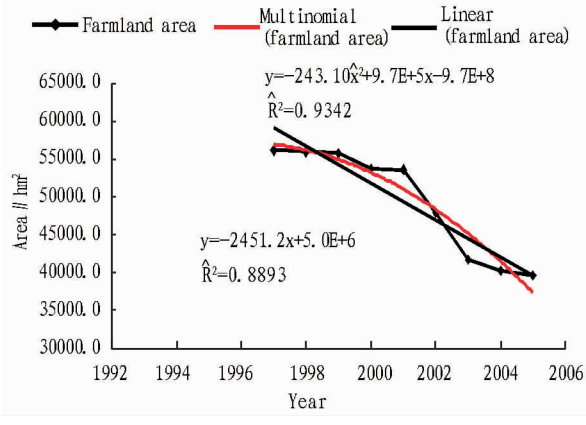

Fig. 1 Prediction of farmland protection area based on trend extrapolation method

Linear trend mode: $y = -2451.2x + 5 \times 10^6$

Quadratic curve model: $y = -243.1x^2 + 970444x - 10^9$

Using the linear trend model, we calculated and obtained farmland area of Mizhi County will be 31 969 hm² and 19511 hm² in 2010 and 2020 respectively.

Using the quadratic curve model, we calculated and obtained the farmland area of Mizhi County in 2010 and 2020 will be 29 889 hm² and 17 045 hm². This prediction result has great difference from agricultural development plan, so it is not included into the statistical data.

2.4 Prediction of the farmland protection area based on combination method The above three methods have various characteristics, but they also have limitation and applicable conditions. If using a single method, the error is great. Therefore, we built a combined prediction model to make more scientific, reasonable and accurate summary of prediction, so as to further increase accuracy, suitability and effectiveness of predicted value. Major points of the combined model lie in determination of single weight coefficient. In this study, we use the fixed weight combined model. The formula is as follows:

$$A = A_1 * K_1 + A_2 * K_2 + A_3 * K_3$$

where A_1, A_2 and A_3 are prediction results of the above three methods, and K_1, K_2 and K_3 are weight coefficient of the above three methods.

Comprehensively considering great-leap-forward development of Mizhi County and its land supply capacity and agricultural development mode, we assigned weight to the above three prediction results. We predicted and calculated farmland area of Mizhi County in 2010 and 2020. The farmland area of Mizhi County will be 40 967 hm² and 36 556 hm² in 2010 and 2020 respectively.

Table 5 Prediction results of farmland area of Mizhi County in 2010 and 2020 (unit: hm²)

Methods	2010		2020	
	Predicted value	Weight	Predicted value	Weight
Prediction based on trend extrapolation method	31969	0.1	19511	0.1
Prediction of farmland demand based on integrated grain production capacity	47405	0.4	44229	0.4
Prediction based on land supply capacity	37615	0.5	33826	0.5
Final value	40966		36556	

3 Conclusions

(i) Using the methods based on grain security, supply-demand balance and trend extrapolation, we made prediction of the farmland protection area of Mizhi County. Using method based on grain security, the prediction result of farmland demand of Mizhi County will be 47 405 hm² and 44 229 hm² respectively; using methods based on supply-demand method, the prediction result of farmland protection area of Mizhi County will be 37 615 hm² and 33 826 hm² in 2010 and 2020 respectively; using the linear trend model based on trend extrapolation, we obtained the farmland area of Mizhi County will be 31 969 hm² and 19511 hm² in 2010 and 2020 respectively; using quadratic curve model, we obtained the farmland area of Mizhi County will be 29 889 hm² and 17 045 hm² in 2010 and 2020 separately.

(iii) Summarizing the three prediction methods, we established a fixed weight combined model and made a prediction of the farmland protection area of Mizhi County. Finally, we obtained the farmland area of Mizhi County will be 40 967 hm² and 36 556 hm² in 2010 and 2020 separately.

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so be equipped in case of the fire. Environmental sanitation mainly consists of toilets and garbage collection sites, which should be arranged in the areas with better accessibility.

4.3.4 Building design. Design of the single building mainly focuses on the details. Deep characterization in details can enrich the building image and motivate people's emotion resonance. Construction of cemeteries mainly depends on some building materials with better durability like stone and concrete and supported by other materials with proper textures and colors in order to show the eternity of cemetery buildings. Sometimes, different kinds of artificial lighting can be equipped to increase or decrease the solemnity. Besides, detailed characterization should reflect the features of traditional and modern funeral culture. Architectural oddments and sculptures can be used to show people's worship to totem and dead people. Personalized epitaphs can be designed to display the "epitaph culture" in the new era.

5 Conclusion

With the soaring of urban population and aged population, demand for urban cemeteries is increasing, thus special planning and designing for the cemetery is of great significance. However, the present cemetery planning and designing lack detailed, systematic and scientific design theories, guidelines and principles. The cemetery is a place where people can show their grief to families, therefore the core of the design is to create a spiritual and emotional atmosphere. It is a pity that the planning of most cemeteries do not reflect the importance of spiritual culture, but over emphasize physical forms. Therefore, a urban cemetery compiling system which can guide the healthy development of cemetery construction is in urgent demand.

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