Loss of Ecological Value in Farmland during Farmland Conversion: A Case Study of Shaanxi Province

HE Xiao-ying * , **LI Fei**, **GUO Bei**
School of Economics and Management, Xi'an Technological University, Xi'an 710032, China

Abstract We divide the ecological functions of farmland into five types: soil conservation, water conservation, air purification, maintenance of biological diversity, entertainment and culture. Using the direct method of market evaluation, we establish the assessment model, to calculate the ecological service value of various functions, respectively, and then calculate the total loss of ecological value in farmland. Taking the case of Shaanxi Province, we calculate the total loss of ecological value in farmland in Shaanxi Province during the period 2000 –2009 at 6 366.365 3 million yuan. Finally in order to rationally protect farmland, we put forth the following recommendations: correctly understanding the ecological benefit of farmland, and scientifically assessing the value of farmland; optimizing the industrial structure, and promoting intensive use of farmland; taking actions that suit local circumstances, and conducting rational planning of farmland use; strengthening multilateral cooperation, and establishing the common protection accountability mechanism of farmland.
Key words Farmland resources, Ecological value, Direct method of market evaluation

In recent years, the development of China's urbanization is rapid, and considerable farmland is used by non-agricultural sectors. Rapid farmland conversion provides a strong support for China's rapid economic growth, but the reality of vast population and limited farmland in China also raises concerns about the excessive loss of farmland resources. Farmland resources are the material basis for people's survival and development, having various ecological functions, such as air purification, water conservation, climate regulation, maintenance of biological diversity. In addition, farmland resources can provide beautiful landscape, recreation, environmental comfort, and other social benefits. The enormous difference of value between urban land and agricultural land exacerbates conversion of farmland, which is related to the fact that the ecological value of farmland with the external benefits has not been correctly estimated. Therefore, scientific and rational estimation of ecological value of farmland is conducive to the operation of agricultural land, evaluation of farmland conservation benefits, constraint of excessive farmland conversion, urban-rural coordination and social sustainable development.

The literature at home on the ecological value of resources is mainly focused on the assessment of the forest resources and water resources, such as the service value equivalency factor table of the Chinese terrestrial ecosystem developed by Xie Gaodi, *et al*. [1]. Some scholars have made a good attempt at comprehensive computation of the value of farmland, for example, Cai Yinying, *et al*. use contingent valuation method (CVM) to assess the market value and non-market value of farmland in Wuhan City [2]; Wang Jiali, *et al*. propose to internalize the negative external costs of farmland conversion [3]. However, the domestic assessment of the ecological value of agricultural land at present still lacks unified and mature way. Using the direct method of market evaluation and revealed preference approach, we establish the assessment model of farmland ecological value in the process of farmland conversion; take Shaanxi Province as the study object, and assess the loss of ecological value in farmland in the process of farmland conversion, in order to provide the basis of decision making for determining the compensation standards and formulating the relevant policies in the process of circulation of farmland.

1 Establishment of the assessment model of farmland ecological value

In accordance with the classification method of ecosystem services developed by Costanza [4] and Xie Gaodi, *et al*., we divide the ecosystem services of farmland in the study area into five service functions (soil conservation, water conservation, air purification, maintenance of biological diversity, entertainment and culture); then calculate the value of various ecological services, respectively, in order to assess the loss of ecological value in farmland in the process of farmland conversion. It is an assessment method using the value of the most important part to evaluate the overall value, with strong operability.

1.1 Assessment of soil conservation value The conversion of farmland into construction land will leave considerable farmland abandoned. As the green vegetation in farmland no longer exists, the soil layer of the farmland will be completely destroyed, and the farmland will be completely degraded. Therefore, keeping the soil is tantamount to reducing the area of farmland abandoned.

The ecological value of soil conservation in agricultural land ecosystem can be calculated in accordance with restoration and protection cost method, namely, using the costs of land recla-

Received: June 19, 2012 Accepted: July 29, 2012
Supported by Special Scientific Research Project of Shaanxi Provincial Department of Education (11JK0120,).
* Corresponding author. Email: he99@sohu.com

mation and consolidation, and the area of farmland occupied by construction for calculation.

The formula is as follows:

$$V_{waste} = S * P_j \quad (1)$$

where V_{waste} is the ecological value of soil conservation in farmland (yuan); S is the area of farmland occupied by construction (hm^2); P_f is the cost of land reclamation per unit area ($yuan/hm^2$).

1.2 Assessment of water conservation value The water conservation value of soil in farmland is mainly calculated using the shadow project method, namely using the alternative technology to calculate the water conservation value of soil in farmland. Assuming that when farmland is damaged and it can not provide the normal function of the ecological services of water conservation, there is a reservoir whose water conservation function is the same as the substance amount of soil water conservation of vegetation; then the cost needed for constructing the same size reservoir to replace the function of farmland is calculated, and the reservoir cost is the water conservation value of farmland.

The calculation formula is based on the method of Wu Kening, *et al.* [5]:

$$V_{conservation} = S \times R \times \theta \times P \quad (2)$$

where $V_{conservation}$ is the water conservation value of the agricultural land (yuan); P is the shadow price of water conserved (determined by the cost of building storage capacity of reservoir); R is the average rainfall (mm); θ is the runoff coefficient; S is the area of farmland occupied by construction (hm^2).

1.3 Assessment of air purification value Using the farmland's ecological environmental function of carbon fixation and oxygen production, we estimate the air purification value, and the estimation is mainly based on the method of Guo Xia, *et al.* [6]. This part is divided into 2 steps: firstly, calculating the amount of substance of CO_2 absorbed by the agricultural land ecosystem and O_2 supplied by the agricultural land ecosystem; secondly, determining its market price. When calculating the value of carbon fixation and oxygen production, the carbon taxes and the cost of industrial oxygen are regarded as shadow prices, respectively; finally the total value of CO_2 absorbed by the agricultural land ecosystem and O_2 supplied by the agricultural land ecosystem is calculated.

According to the photosynthesis equation ($6CO_2 + 6H_2O—C_6H_{12}O_6 + 6O_2\uparrow$), when the agricultural land ecosystem is in photosynthesis, 180 g $C_6H_{12}O_6$ (carbohydrate) produced can absorb 264 g CO_2, and release 192 g O_2, then 180 g carbohydrate is transformed into 162 g dry matter again. Therefore, from the reaction equation, we derive that 162 g dry matter produced by the ecosystem can absorb and fix 264 g CO_2; extrapolate that 1 kg dry matter produced can absorb 1.6 kg CO_2, and release 1.2 kg O_2.

As to the calculation of the value of CO_2 fixation, we use carbon tax method to calculate the annual value of carbon fixation per unit area. The carbon tax method is to determine the loss of value due to CO_2 emission by imposing charge on CO_2 emission. Using the carbon fixation amount multiplied by one certain carbon tax rate to calculate the value of the ecological environment absorbing CO_2, is a widely used method at present. The calculation formula is as follows:

$$V_{CO_2} = Q_{CO_2} \times 0.95 \quad (3)$$

where V_{CO_2} is the agricultural land ecosystem's value of carbon fixation per unit area; Q is the amount of material fixing CO_2 per unit area; 0.95 yuan/kg is the commonly used standard carbon tax rate in the world.

As to the calculation of economic value of O_2, we adopt industrial oxygen generation method, and O_2 can be obtained through industrial production, therefore, we can determine the value of O_2 supplied annually according to cost of producing goods. The calculation formula is as follows:

$$VQ_2 = Q_{O_2} \times 0.4 \quad (4)$$

where V is the value of O_2 supplied annually by the agricultural land ecosystem per unit area; Q is the amount of material fixing CO_2 per unit area; the industrial oxygen price is 0.4 yuan/kg.

The assessment model of the value of the agricultural land ecosystem fixing CO_2, and supplying O_2. is as follows:

$$V_{purification} = (V_{CO_2} + V_{Q_2}) \times S \quad (5)$$

1.4 Assessment of the value of biological diversity maintenance, entertainment and culture The assessment of value of biological diversity and entertainment is revised based on the ecological value equivalency factor method of Xie Gaodi, *et al.* The equivalency factor of ecosystem service value is the potential ability of relative contribution size of ecological services produced by ecosystem, which is defined as the economic value of natural food yield per year in 1 hm^2 farmland with the national average yield. The equivalency factors of a variety of ecological services can be converted (Table 1) [1]. We convert the weighting factor table into the ecosystem service unit price table. Through the comprehensive comparison and analysis, we make it clear that the economic value of 1 equivalency factor of ecological service value is equal to one seventh of the national average market value of grain yield per unit in the current year.

Table 1 Equivalency factors of the ecological service value of the Chinese farmland ecosystem per unit area

Service function of farmland ecosystem	Equivalency factors of the ecological service value	Service function of farmland ecosystem	Equivalency factors of the ecological service value
Grain production	1	Soil formation and protection	1.47
Gas regulation	0.72	Waste disposal	1.39
Climate regulation	0.97	biological diversity conservation	1.02
Water Conservation	0.60	Entertainment and culture	0.17

Table 1 is equivalency factors of the ecological service value of the Chinese farmland ecosystem per unit area. When the weighting factor is converted into the ecological service unit price, it is also the unit price in the national average state.

When conducting the evaluation of specific areas, due to difference in the regional natural environmental conditions, so it is necessary to conduct certain correction according to the actual situation.

The ecological service value of food production in farmland per unit area is defined as the annual output value of natural food per hm^2 of farmland with average output [7]. The calculation formula is as follows:

$$v = 1/7 \times (T/S_{grain}) \tag{6}$$

where T is the average total grain value in the study period (yuan); S_{grain} is the average planting area of grain in the study period (hm^2); 1/7 means that the natural ecosystem service value is one seventh of the market value of grain per unit area provided by the current farmland per unit area.

Shaanxi Province is a major agricultural province in the western region. According to the annual Shaanxi Statistical Yearbook, by calculation, we get: v = 1 015.14 yuan/hm^2. The national average farmland ecosystem service value per unit area is 884.9 yuan/ hm^2, which is substituted into the value equivalency factors in Table 1 ($P_{biology} = 1.02v$, $P_{culture} = 0.17v$). Thus the corrected farmland ecosystem service value per unit area in Shaanxi Province, the grain production value per unit area is 1 015.14 yuan/ hm^2; the biological diversity conservation value per unit area is 1 035.44 yuan/ hm^2; the entertainment and culture value per unit area is 172.57 yuan/ hm^2.

We get the following calculation formula:

$$V_{biology} = S \times P_{biology} \tag{7}$$

$$V_{culture} = S \times P_{culture} \tag{8}$$

where S is the area of farmland occupied by construction (hm^2); $P_{biology}$ is the corrected unit price of biological diversity maintained by farmland ecosystem service in Shaanxi Province per unit area; $P_{culture}$ is the corrected unit price of entertainment and culture maintained by farmland ecosystem service in Shaanxi Province per unit area.

The loss of total ecological value of farmland in the process of farmland conversion is as follows:

$$V_{total} = \sum_{i=1}^{n} V_i$$

2.1 Current situation of farmland conversion in the study area In recent years, with the western development and the construction of the Guanzhong – Tianshui Economic Zone, the economic development is rapid in Shaanxi Province; the process of industrialization and urbanization is accelerated constantly; the area of farmland occupied by construction is increasing.

In 2009, the area of newly added construction land in Shaanxi Province was about 52 000 hm^2; the area of farmland occupied by construction was 42 300 hm^2, accounting for 81% of the total area of newly added construction land.

The data on farmland occupied by non-agricultural construction can basically reflect the conversion of agricultural land. According to the literature [8], the calculation formula of farmland conversion rate is as follows:

$$\begin{cases} K_i = \sum k_t / n \\ k_t = (Q_t / L_t) \times 100\% \end{cases} \tag{9}$$

where K_i is the average annual farmland conversion rate during the study period; n is the number of inter-annual variation; k_t is farmland conversion rate in year t; Q_t is farmland conversion area in year t; L_t is the area of farmland at the end of year t.

Based on the amount of farmland occupied for construction during the period 2000 – 2009 in Shaanxi Province and the annual farmland area data, we use formula (9), to calculate the annual farmland conversion rate in Shaanxi Province during the period 2000 – 2009 (Table 2).

Table 2 The annual farmland conversion rate in Shaanxi Province during the period 2000 – 2009

Year	Area of farmland used for construction // 10^4 hm^2	Farmland area // 10^4 hm^2	Farmland conversion rate // %
2000	0.388 0	480.044 7	0.081
2001	0.393 3	468.545 3	0.084
2002	0.486 7	450.595 3	0.108
2003	0.513 3	424.184 0	0.121
2004	0.712 7	415.409 3	0.172
2005	0.292 0	408.890 0	0.071
2006	0.625 3	405.823 3	0.150
2007	0.390 7	404.904 7	0.097
2008	0.613 3	405.034 7	0.150
2009	0.599 3	399.690 0	0.140
Mean		0.120	

Data source: Shaanxi Provincial Department of Land Resources

Table 2 shows that the periodic fluctuation of farmland conversion rate is not big on the whole, in 0.08% – 0.14%. Except individual years, the fluctuation of farmland conversion basically increases slightly year by year.

2.2 Assessment of loss of ecological value in farmland in the study area Using formula (1) – (8), we assess the loss of ecological value in farmland during the period 2000 – 2009 in Shaanxi Province, and the results are shown in Table 3.

Table 3 shows that the total loss of ecological value in farmland in the process of farmland conversion during the period 2000 – 2009 in Shaanxi Province is 6 366.365 3 million yuan. In the various parts of ecological value lost, the soil conservation value is 6 017.87.01 million yuan, accounting for 95% of the total loss of ecological value, with the greatest proportion; the air purification value is almost tantamount to water conservation value, 14 2.3648 million yuan and 145.337 7 million yuan, respectively; the biological diversity maintenance value lost accounts for 0.8% of the total loss of ecological value; the share of entertainment and culture value lost in the total loss of ecological value is the smallest.

Shaanxi Province is located in the inland, with a continental monsoon climate, and the ocean water vapor transmission is restricted, so precipitation is not as rich as that of the southeastern coastal regions. In addition, the vegetation is sparse and soil erosion is serious in Loess Plateau, therefore, the soil conservation function and and water conservation function farmland in Shaanxi Province is very important. Through calculation, we know that the ecological value in farmland lost in the process of farmland conversion in Shaanxi Province, is mainly concentrated in soil conservation value and water conservation value, line with the actual situation.

Table 3 Loss of ecological value in farmland in the process of farmland conversion during the period 2000 – 2009 in Shaanxi Province

10^4 yuan

Year	Loss of soil conservation value	Loss of water conservation value	Loss of air purification value	Loss of biological diversity maintenance value	Loss of entertainment and culture value
2000	46 536.24	1 100.91	1 119.97	401.54	66.92
2001	47 208.24	1 116.81	1 136.14	407.34	67.89
2002	58 400.29	1 381.58	1 412.52	506.43	84.4
2003	61 600.30	1 457.28	1 489.92	534.18	89.03
2004	85 560.43	2 024.10	2 059.15	738.27	123.04
2005	35 040.17	828.94	847.51	303.86	50.64
2006	75 040.38	1 775.23	1 814.99	650.73	108.45
2007	46 880.23	1 109.05	1 133.89	406.53	67.75
2008	73 600.37	1 741.16	1 780.16	638.25	106.37
2009	71 920.36	1 701.42	1 739.53	623.68	103.94
Total	601 787.01	14 236.48	14 533.77	5 210.82	868.45

3 Recommendations for irrational farmland protection

The traditional understanding of the value of farmland mainly remains at the value of economic output, ignoring the ecological value of farmland, which is the main reason for underestimation of the value of farmland. Based on the above findings, in the process of China's urbanization and industrialization, we should pay attention to the following aspects to promote the sustainable use of agricultural land.

3.1 Correctly understanding the ecological benefit of farmland and scientifically assessing the value of farmland We should realize the ecological value and impact value of farmland to future generations, have a comprehensive understanding of the ecological value of farmland resources, include the loss of ecological value arising from farmland conversion into the market cost, to reestablish agricultural land resource value assessment system, in order to provide a scientific theoretical basis for the rational pricing of farmland resources, effective compensation and sustainable development.

3.2 Optimizing the industrial structure and promoting intensive use of farmland At present, the industrial structure in Shaanxi Province is basically the resource-consuming structure, highly relying on land resources, taking up a large area of land. Therefore, we should optimize the industrial structure and improve the efficiency of urban land use. At the same time, vigorously developing agricultural science and technology and promoting technological progress is an effective way to improve land productivity, and reduce the pressure of farmland conversion.

3.3 Taking actions that suit local circumstances and conducting rational planning of farmland use In Shaanxi's three different terrain areas, the agricultural land protection and maintenance of ecosystem services should also be adapted to local conditions.

In Loess Plateau, the soil erosion is serious and the bearing capacity of the regional ecological environment is weak. The focus of farmland protection is the protection of resources and environment, therefore, the area should focus on strengthening the construction of ecological protection forest, and implementing the projects of soil and water conservation, returning farmland to grass, returning farmland to forestry.

The Guanzhong region, with flat topography and fertile land, is an important wheat and corn producing area in northern China. The construction of Guanzhong urban group develops by leaps and bounds, therefore, we should strengthen urban construction land use planning, and pay attention to the quantity protection and quality protection of farmland. The urban construction should make full use of idle land, improve the utilization rate of urban land, cut costs, and arrest the trend of dwindling area of farmland.

Qinling and Bashan mountainous area is located in the south of the Qinling Mountains, which has rich animal and plant resources. Therefore, it is necessary to establish nature reserve in this area, strengthen biodiversity conservation, and protect forests and tourism resources.

3.4 Strengthening multilateral cooperation and establishing the common protection accountability mechanism of farmland The farmland reserve resources are insufficient in Shaanxi Province. With the social and economic development, the demand for construction land is increasing ceaselessly, and the contradiction between the protection of arable land and development of construction has become increasingly prominent. Therefore, it is necessary to establish the government-led common farmland protection accountability mechanism supervised by the public, to ensure the ecological and food security.

References

[1] XIE GD, LU CX, LENG YF, *et al.* Ecological assets valuation of the Tibetan Plateau[J]. Journal of Natural Resources, 2003(3): 189 – 196. (in Chinese).

[2] CAI YY, ZHANG AL. Value evaluation of agricultural land resources in Wuhan[J]. Chinese Journal of Ecology, 2007, 26(3): 422 – 427. (in Chinese).

[3] WANG JL, YU ZX. Analysis on farmland conversion and countermeasures of agricultural land protection[J]. Journal of Anhui Agricultural University, 2008, 35(1): 145 – 148. (in Chinese).

[4] COSTANZA R *et al.* The value of the world's ecosystem service and natural capital[J]. Nature, 1997, 387(15): 253 – 260.

[5] WU KN, WANG XL, GUAN XK, *et al.* Study on the change of ecosystem service function value in Zhengzhou suburban[J]. Urban Environment and Ecology, 2007, 20(4): 24 – 27. (in Chinese).

[6] GUO X. Research on value structure and evaluation methods of agrarian land in China[D]. Wuhan: Wuhan University, 2005. (in Chinese).

(To page 41)

regions.

(ii) Establishing economic incentive mechanism of farmland consolidation. We should focus on the central and local financial transfer payment, and establish regional compensation mechanism; improve the distribution system of paid land use fee factor method of new added construction land; explore and establish farmland protection economic compensation mechanism, and fully mobilize the enthusiasm of the local government and farmers for protecting arable land and constructing high-standard basic farmland.

(iii) Exploring the land reclamation incentive mechanism. In accordance with the principle "who invests, who benefits", we should encourage and guide the social capital to participate in land reclamation. Based on the relevant provisions of the *Land Reclamation Ordinance*, we should comprehensively use some ways, such as returning the farmland occupation tax, complementing the farmland indicator incentives and giving financial subsidies, to mobilize the enthusiasm of people who reclaim land, the main body of social investment, land right owners, and the government for participating in land reclamation.

(iv) Improving the land consolidation benefit distribution mechanism. The irrational distribution of land consolidation income and land benefits, results in damage to the interests of farmers, which is the biggest challenge facing land consolidation. The next step we should urgently take is to improve the rural land system, and rationally allocate the land income.

(v) Exploring the marketization mechanism of land consolidation. We should research and explore the market-based funds operation mode of land consolidation; establish diversified investment and financing channels of land consolidation, to form the security system of land consolidation funds dominated by the government funds, attracting funds from society.

3.2.4 The social supervision measures.

(i) Expanding the scope and depth of public participation. The main body of participation should not only include the government and departments involved in planning, but also include the relevant interest groups in the consolidation.

(ii) Improving the working style of planning. We should establish and improve the expert advice system of planning formulation and department coordination system, and strengthen the argument and coordination of the planning.

(iii) Establishing and improving the planning publicity system. After the land consolidation planning is approved, we should increase the transparency of planning implementation, implement "sunshine operation" of land consolidation, and consciously accept the public supervision and management on the planning implementation[8].

3.2.5 The technology management measures.

(i) Improving the technical standard system of land consolidation. We should formulate provincial, municipal and county land consolidation planning, and the special planning rules of land consolidation, land planning and land reclamation.

(ii) Promoting the information-based construction of land consolidation planning management. Based on the "one map" project, we should use 3S technology, to establish the planning database and the planning management information system[9-10].

(iii) Strengthening the building of practitioners and planning team in the land consolidation institutions at all levels.

(iv) Improving the dynamic monitoring and early warning system of land consolidation, and establishing the "monitoring – evaluation – early warning" system of land consolidation planning implementation, to form the system platform of planning – project – supervision.

(v) Establishing the regulatory system for ensuring the implementation of planning.

References

[1] GAO XJ, PENG AH, PENG ZH, *et al*. Problems and countermeasures of rural land integrated consolidation[J]. China Land Science, 2011, 25(3): 4-8. (in Chinese).

[2] YUN WJ, LI C. Land regulation planning[M]. Beijing: Geological Publishing House, 2011: 18-19. (in Chinese).

[3] WANG WM. Multi-dimensional reflections of land use and essence of planning[J]. China Land Science, 2002, 16(1): 4-6. (in Chinese).

[4] ZHANG YA. Study on the rigidity and the flexibility of general land use planning[J]. China Land Science, 2004(1): 24-27. (in Chinese).

[5] LEI P, NAN L. Safeguard measures for operation of land use general planning in Shaanxi Province[J]. Shaanxi Journal of Agricultural Sciences, 2009(3): 151-153. (in Chinese).

[6] DONG ZJ, WU YJ. Modern land use planning in China: theory, method and practice[M]. Beijing: China Land Press, 2008: 385-386. (in Chinese).

(From page 37)

[7] XIAO Y, XIE GD, AN K. [J]. Chinese Journal of Applied Ecology, 2003, 14(5): 676-680. (in Chinese).

[8] XU HZ, GUO ZX. Study on the value loss and spatial difference of farmland non-market during farmland conversion: a case study of Jiangsu Province[J]. Areal Research and Development, 2010(6): 119-123. (in Chinese).

[9] FENG F. The Study on the rural land transfer based on the perspective of the principal part's interests[J]. Journal of Anhui Agricultural Sciences, 2011,39(11): 6770-6771,6774. (in Chinese).

[10] CHEN SC, LI JQ. Research of mechanism on the impact of local governmental competition on farmland conversion[J]. Asian Agricultural Research, 2011,3(1): 104-107,111.

[11] GUO B, MA Y. The contrast and evaluation of the utilization rate of transferable and non-transferable agricultural land in Xi'an[J]. Journal of Anhui Agricultural Sciences, 2010,38(35): 20400-20402. (in Chinese).

[12] HUANG LM, LIU CW. Marginalization of arable land and its correlation with rural labor migration [J]. Asian Agricultural Research, 2010,2(2):6-9.