land

MDPI

Article

Agricultural Transformation and Its Impact on Ecosystem Services and Human Well-Being in Peri-Urban Areas: The Case of Xi'an, China

Zhongxue Zhou [1], Xiaofang Liu [1], Bijun Zheng [1], Guy M. Robinson [2,3] and Bingjie Song [2,*]

[1] School of Geography and Tourism, Shaanxi Normal University, Xi'an 710062, China; zhouzhx@snnu.edu.cn (Z.Z.); liuxiaof@snnu.edu.cn (X.L.); zhengbj@snnu.edu.cn (B.Z.)
[2] Department of Geography, Environment and Population, School of Social Sciences, University of Adelaide, Adelaide 5005, Australia; guy.robinson@adelaide.edu.au
[3] Department of Land Economy, University of Cambridge, 16-21 Silver Street, Cambridge CB3 9EP, UK
* Correspondence: bingjie.song@adelaide.edu.au

Abstract: There is a gap in understanding the relationships between the transformation of agricultural landscapes, ecosystem services and human well-being in the peri-urban fringe of major cities worldwide. In this paper, we use semi-structured interviews, perception surveys, social surveys and field mapping to examine linkages between agricultural and landscape transition, ecosystem services and human well-being in five sample villages in Xi'an metropolitan zone, China. The results indicate that: (1) Agricultural change has increased landscape fragmentation, with a shift from grain to more profitable horticulture and nursery production. The farming system is more diversified and exhibits a multifunctional character. (2) This transformation has had a significant impact on the character of the agroecosystem. (3) The agricultural transformation towards greater multifunctionality has increased the supply of ecosystem services, including tourism-related activities, potentially improving human well-being. (4) Different combinations of activities in the sample villages were evaluated with respect to a well-being index, indicating the importance of combining horticulture and tourism. (5) Linkages identified between agricultural transformation, ecosystem services and human well-being may have significant implications for potential approaches within future studies.

Keywords: agricultural transformation; ecosystem services; human well-being; peri-urban; Xi'an metropolitan zone (XMZ)

Citation: Zhou, Z.; Liu, X.; Zheng, B.; Robinson, G.M.; Song, B. Agricultural Transformation and Its Impact on Ecosystem Services and Human Well-Being in Peri-Urban Areas: The Case of Xi'an, China. *Land* **2022**, *11*, 110. https://doi.org/10.3390/land11010110

Academic Editor: Nica Claudia Caló

Received: 17 November 2021
Accepted: 4 January 2022
Published: 10 January 2022

1. Introduction

A peri-urban area (PUA) is a dynamic transition zone between the city and the countryside, often affected by urban sprawl. Currently, rapid global urbanization, especially in Africa and Asia [1], is producing the expansion of many urban agglomerations and affecting the nature of PUAs [2,3]. This is changing agroecological landscapes on a global scale [4], for instance, consuming a large amount of productive cropland [5,6] and natural areas [7] and converting it to built-up land, also transforming agricultural systems [8–10], leading to loss of biodiversity [6] and degrading the ecological capacity of the landscape. The capacity of ecological supporting and regulating services has been severely weakened. PUAs are crucial in terms of providing ecosystem services (ES) to metropolitan areas [11,12], but economically, socially and ecologically sustainable development have been profoundly impacted by the changes to the landscape [13,14]. For instance, the decrease in open space around the city [15] and the degradation of landscape ecological security in PUAs have impeded sustainable agriculture and put grain production and food security at risk [16,17].

In recent years, PUAs have undergone substantial physical and non-physical changes (e.g., social change) through urban expansion, giving rise to various studies, especially by scholars in the field of urban and regional research [18,19]. This research has focused on the development and transformation of urban and peri-urban agriculture. Some scholars have discussed the concepts and characteristics of agricultural transformation, proposing that this is best represented in changes of land use, planting structure and agricultural practices [20,21]. The driving forces of change mainly reflect urban market demand for agricultural products [22,23], socioeconomic factors, policy-related factors, location-based factors [24] and farmers' behaviour [25]. In many countries, peri-urban agriculture has shifted from monoculture to more integrated farming systems, with moves towards diversified cropping to support livelihoods [26] that are not only economically appealing but also socially inclusive and environmentally friendly [27].

Some research has focused on the influence of urbanization on land use/cover (including agricultural land) in PUAs [28–31], examining changes in landscape pattern and ecosystem structure [32,33], for instance, the loss of large amounts of cropland [34] or peri-urban open space (primarily by conversion to built-up land) [16] and the increased fragmentation of the landscape through greater land-use diversity. These changes are mainly driven by structural, functional and institutional forces [35], including population growth and economic (e.g., increased income, development of the tertiary industry sector, road construction), political, social, ecological and environmental factors [36].

Other research has evaluated peri-urban agricultural multifunctionality and agroecosystem services [37–40]. Research has noted the diverse functions of urban agriculture [41,42], providing a variety of ES [43] but also producing many negative services [44–46]. There has also been a focus on the impact of land-use change on ES in PUAs. Some scholars suggest that agricultural land use (or agricultural transformation) has had a significant influence on ES [47–49]. For instance, the different cropping patterns of agriculture can have different effects on the ecological environment (e.g., eutrophication, soil acidification and toxicity of water and land ecosystems) [50]. In China, the transformation from traditional crops in PUAs to mixed fruit production accompanied by tourism has produced significant changes in agroecosystem services [8]. Simultaneously, some research has also argued that the diminishing of peri-urban open spaces or the increase in built-up land have negatively influenced ES [51,52]. Research indicates that landscape change in PUAs has led to trade-offs and synergies of ES in agroecosystems [53], suggesting that the increased availability of economic and social services comes at the cost of supporting and regulating services [51].

Some research has focused on the relationship between landscape pattern, ES and human well-being, with studies suggesting that there is a relatively strong coupling. This suggests that the livelihoods of residents in PUAs often depend on landscape diversity and the supply of ES [54,55]. The relationship between ES and human well-being varies under different agricultural transformation models, but they are both positively correlated with agricultural output and negatively correlated with agricultural net income [56].

There has been relatively little research on the social and ecological effects of agricultural transformation and the linkages between ES and human well-being. Specifically, the changes in PUAs have been associated with fragmented landscape structures and associated with rapidly growing socioeconomic structures [57,58]. These have numerous physical, social, economic and environmental consequences, and to meet the challenges posed in those areas requires a comprehensive understanding of related socioeconomic and ecological dimensions [35]. From the perspective of complex human-land relationships, there is a need for more case studies on the relations between agricultural landscape, ES and human well-being in PUAs, including the use of novel and relevant methods of analysis. Analysis needs to develop insights into the relationship between agricultural transformation, ES and human well-being across economic, social and ecological aspects of development to seek sustainable development paths in PUAs.

The majority of global urban agglomerations, especially in developing countries, are densely populated and highly economically clustered, with declining amounts and quality of natural landscape, ecological status and agricultural land [10,25]. The types and structure of agricultural landscape, which play a key role in providing and maintaining ES, have changed greatly with rapid urbanization, representing the transformation of agricultural planting structure, agricultural production and farming mode, farming technology [59–61] and farmers' livelihoods [36]. What are the processes and modes of agricultural transformation in PUAs? How do these modes influence the agricultural landscape, ES and human well-being? What kind of transformation mode is more suitable to generate sustainable development? These are fundamental questions closely related to the 'coupling relation' between agricultural transformation, ES and human well-being.

This paper aims to: (1) develop a comprehensive analytic framework relating to agricultural transformation, ES and human well-being in PUAs; (2) propose rural-scale assessment indicators of human well-being; and (3) analyse the process of agricultural transformation and its impacts on ES and human well-being in Xi'an metropolitan zone and develop greater understanding of ES and well-being effects in PUAs.

2. Material

2.1. The Study Area

The Xi'an metropolitan zone (XMZ) is located in the centre of the Guanzhong Plain in Northwest China. The central city of Xi'an covers approximately 14,958 km^2 of land area, with population of 18.7 million in 2019. Annual daily temperatures range from −1.3 °C to 26 °C, and annual rainfall is between 522 mm and 729 mm. The area has one of the most important agricultural product bases in China, especially for temperate fruit and grain production.

Since the 1990s, the growth of the XMZ has accelerated the transformation from traditional grain cultivation in the PUA to diversified modern agriculture. There have been significant changes in the agricultural landscape, including loss of productive farmland [17]. Grain has been replaced by horticulture, especially orchard fruit, grapes, kiwifruit and nurseries, including flowers, trees and nursery crops. This has resulted in changes in ES and human well-being, which are investigated herein by focusing on five villages representing different aspects of the agricultural transformation, with a dominant focus on grain production and other specialisations: Duling (fruit and tourism), Hongfeng (vegetables), Huangliangxin (flowers), Huojian (grain and vegetables) and Yueyang (grain). The process of agricultural transformation in the five villages is described in Table 1. Their location is shown in Figure 1.

Table 1. Typical village profiles.

Village	Population	Land Area (ha)	Agricultural Land (ha)	Agricultural Income as a % of Household Income	Agricultural Transformation Process
Huangliang xin	2648	118.9	103.3	80	Around 1990, wheat and corn were planted as the main crops (accounting for more than 90% of farmland). Vegetables have been introduced since 2000, with flowers grown from 2015. In 2020, the crops mainly comprised grain and flowers.
Yueyang	3000	419.4	286.7	80	Since the 1990s, grain has been planted continuously. Grain dominates the farmland (96% share of total farmland), with just a small amount of vegetables and trees.
Duling	1520	75.6	57.3	45	Before 1990, wheat, corn and other grain crops were dominant. After 1990, there was a gradual shifting to cherries and grapevines. Together with surrounding villages, a cherry-picking leisure park was created, with an associated tourism businesses. In 2016, Bailucang tourist village and scenic spots were

					established, and tourism recreation services expanded. Agriculture is dominated by fruit and tourism.
Hongfeng	3614	784.3	391.9	55	Around 2000, grain crops (wheat, corn) accounted for 99% of farmland. In 2005, a rotation of vegetables and grains was apparent. In 2010, more than 50% of farmland was planted with a variety of vegetables. After 2015, the area under grain gradually decreased with further shifts to vegetables and land mainly planted with cabbages and organic cauliflowers.
Huojian	4962	420.7	353.3	60	Before 2000, wheat and corn occupied nearly all farmland. After 2010, some farmers began to grow vegetables, seedlings, flowers and other crops, and there was a flower estate created, engaging in tourism. At present, agriculture is equally dominated by grain and vegetable crops.

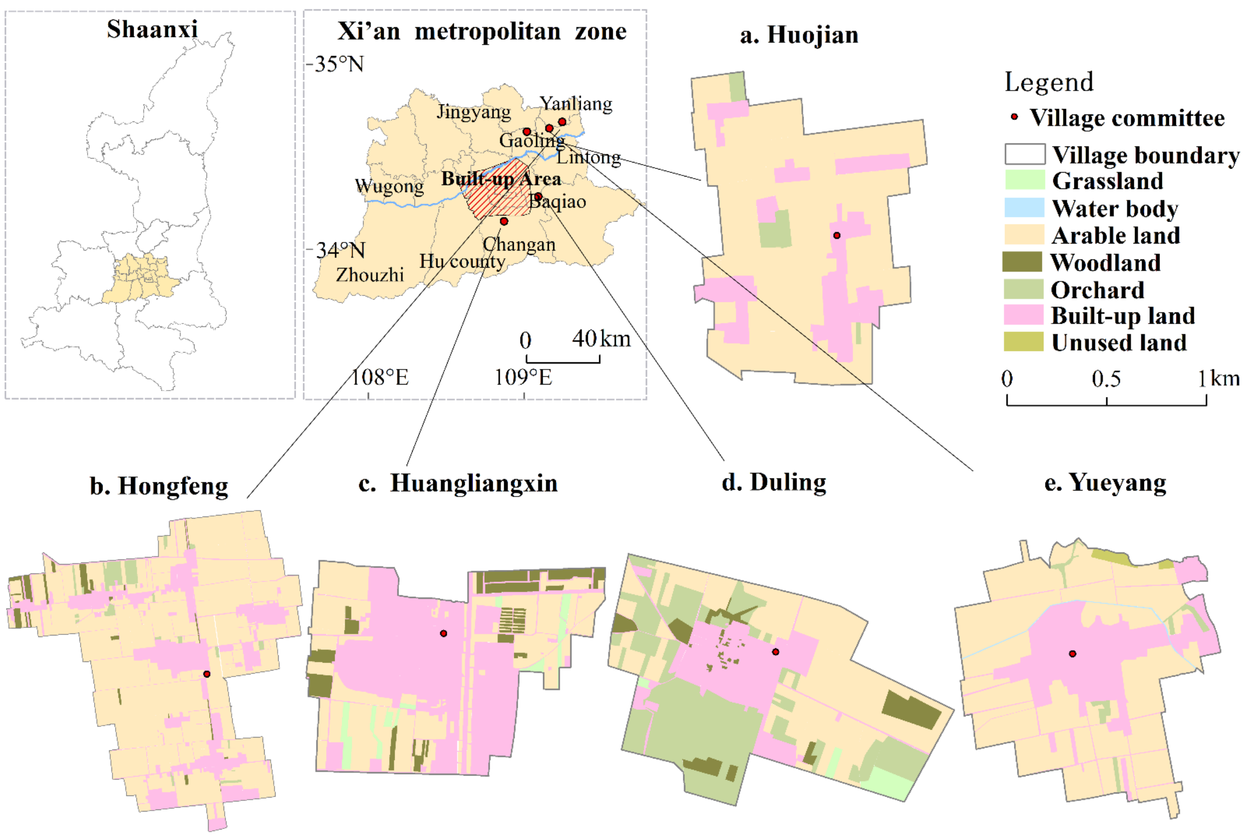


Figure 1. Location of five typical villages in Xi'an Metropolitan Zone and their land use in 2020.

2.2. Methods and Data Sources

2.2.1. Remote Sensing Interpretation and Field-Mapping Method

Data for base maps of the five villages are provided by Landsat 8 OLI TIRS images for 2020, downloaded from http://earth explorer.usgs.gov/ (accessed 1 November 2021). In August 2017 and October 2021, field interviews and field mapping were used to create agricultural planting maps for 2000. A map of agricultural planting in 2020 was completed by interpreting Landsat 8 OLI TIRS images plus field investigation. Land use was classified into seven categories, including arable land, orchard, woodland, grassland, built-up land, water body and unused land. The agricultural planting types were divided into seven categories, including grain, beans, vegetables, melons, fruit trees, flowers and seedlings.

2.2.2. Semi-Structured Interviews and Questionnaire Survey

We employed semi-structured interviews to investigate details of the agricultural transformation process in the five villages, including changes in agricultural practices and household lifestyles. Information on population, land area, agricultural input and output, agricultural product sales, and social and cultural status of the villages was also gathered. A questionnaire was designed to investigate villagers' perception of human well-being in 2000 and 2020, respectively, and a scale method was used to quantify these perceptions. All semi-structured interviews and questionnaire surveys were completed in October 2021. More than 20 farmers and their households were surveyed in each village, with a total of 108 farmers (and households), and 90% of questionnaires were fully completed.

2.2.3. Assessment Methods of Ecosystem Services

Comprehensively taking into consideration natural geographical conditions, agricultural types and characteristics of changes in agricultural production and operation, five ES were selected: economic production, pro-environmental services, carbon sequestration and oxygen release, water conservation, and tourism and leisure services. These services were investigated with regard to evaluating the value and change of agroecosystem services in different periods. The evaluation and spatial models employed are as follows.

(1) Economic-production services

Economic-production services refer to the total economic output of various agricultural products provided by the agroecosystem for human use/consumption. The value was assessed by the total output value of grain, fruit, vegetables, melons and livestock products [62].

$$V_1 = \sum \alpha \times \beta \times \gamma \quad (1)$$

where V_1 represents the value of economic-production services provided by agriculture; α represents the area of different agricultural types; β represents the yield per unit area of different agricultural types; and γ is the price of different agricultural products.

(2) Air-purification services

Air-purification services refer to the dust retention, absorption of harmful gases and sterilization functions by the natural and agricultural landscape. The evaluation formula is as follows [30].

$$V_2 = \sum_{i=1}^{n} \sum_{j=1}^{m} \alpha_{ij} \beta_j \gamma_i \quad (2)$$

where V_2 represents the value of pro-environmental services, α_{ij} represents the value of absorption or purification of the *j*-th pollutants (including SO_2, NO_X, HF and dust) per unit area of the *i*-th agricultural type; β_j represents the cost of treatment of the j-th pollutants per unit mass (β_j is assigned by 0.6 yuan/kg, 0.63 yuan/kg, 0.87 yuan/kg and 0.15 yuan/kg for each pollutant, respectively); and γ_i is the area of the i-the agricultural type [63].

(3) Carbon sequestration and oxygen-release services

Carbon sequestration and oxygen-release services refer to crops, fruit trees and other vegetation absorbing carbon dioxide and releasing oxygen through photosynthesis.

$$V_{c3} = 1.63 \times NPP_i \times R_c \times P_c \quad (3)$$

$$V_{c4} = 1.19 \times NPP_i \times P_{o_2} \quad (4)$$

where V_{c3} and V_{c4} refer to the amount of fixed C and released O_2, respectively, per unit area of the *i*-th agricultural type; NPP_i refers to the net primary productivity of the i-th agricultural type; P_c is the value of unit C, taking 260.9 yuan/t; R_c is the content of C element in CO_2 (27.27%); and P_{o_2} is the price of O_2 (376.47 yuan/t) [10].

(4) Water-conservation services

Water-conservation services refer to the functions of crops, fruit trees and other vegetation to regulate precipitation, enhance infiltration and inhibit evaporation, evaluated by the soil storage capacity method.

$$V_5 = P_1 + P_2 \tag{5}$$

$$P_1 = W \times C \tag{6}$$

$$W = \rho \times h \times p \times S_i \tag{7}$$

where V_5 represents the total value of water-conservation services in the research area; P_1 is the supply value of water conservation provided by cultivated land; W is the amount of water conserved by cultivated land; C is the average cost of a construction reservoir (0.67 yuan /m^3); ρ is the soil bulk density (equal to 303 kg/m^3, according to the experimental test of soil at depth 10 cm and 20 cm); h is the soil depth, taking 0.2 m of ploughed layer; p is soil water content; and S_i represents the area of different agricultural types [10].

$$P_2 = (Q_1 + Q_2 + Q_3) \times C \tag{8}$$

$$Q_1 = r \times l_i \times S_i \tag{9}$$

$$Q_2 = f_i \times q_i \times S_i \tag{10}$$

$$Q_3 = h \times k_i \times S_i \tag{11}$$

where P_2 represents the total value of water conservation by woodland, orchard and grassland; Q_1 is the amount of water intercepted by the forest canopy; Q_2 is the water holding capacity of the litter layer; Q_3 is soil water storage; l_i is the canopy interception rate of the i-th vegetation type; r is precipitation; f_i is the dry weight of the litter layer of the i-th vegetation type; q_i is the saturated water absorption rate of the i-th vegetation type; k_i is the non-pore porosity of the i-th vegetation type; and C is the average cost of a construction reservoir.

(5) Tourism and leisure services

Tourism and leisure services refer to the functions of sightseeing, recreation and leisure provided by the agricultural landscape.

$$V_5 = \sum V_j \times S_j \tag{12}$$

where V_5 represents the total value of tourism and leisure services; V_j is the service-value coefficient per unit area of the *j*-th landscape; and S_j is the area of the j-th landscape [10].

2.2.4. Human Well-Being Assessment Methods

Human well-being refers to the life conditions under which people feel good and satisfied, including safety, health, good social relations, freedom of choice and action, and basic material needs required to maintain a high quality of life [64]. Human well-being is complex and dynamic and includes multiple dimensions for which measurement indicators vary greatly, as developed by different scholars. Hu et al. proposed an index of human well-being including three dimensions, namely basic needs, health and safety, and spiritual needs, with a total of 12 indicators [65]. Liu et al. put forward a three-dimensional index composed of economic, social and environmental development based on ecosystem provision services, cultural services and regulatory services [66].

In this paper, human well-being at the village scale is defined as the sense of well-being generated by farmers who are improving their living standards, ecological environment and mental state through agricultural activities. Developing a suitable index of human well-being at the village scale can effectively measure the impact of the agricultural transition process on ES and human well-being. The selected evaluation index comprises five dimensions, covering quality of life, health and safety, capacity of sustainable development, good social relations, and social freedom and justice, with 30 indicators (Table 2).

Table 2. Index and weightings for human well-being.

Dimension	Items	Indicators	Weights
Maintain a high quality of life	Income	Agricultural income (10^3 yuan)	0.0332
		Agricultural resource supply	0.0334
	Farmer occupation	Occupation satisfaction	0.0332
	Allowance policy	Agricultural allowance satisfaction	0.0332
	Subsistence resource	Domestic water security	0.0333
		Fuel and its supply	0.0333
	Cultural leisure	Cultural facilities and services	0.0334
		Cultural and entertainment	0.0332
	Social security	Social security	0.0333
Health and safety	Physical health	Convenience to seek medical treatment	0.0333
		Life expectancy	0.0335
	Mental health	Psychological pressure	0.0327
	Agricultural security	Risk of agricultural practice	0.0332
	Living safety	Water quality	0.0334
		Food diversification	0.0334
		Beautiful residential environment	0.0334
		Clean air quality	0.0334
		Sewage and waste disposal	0.0333
		Village public security	0.0337
Capacity of sustainable development	Traffic	Traffic convenience	0.0334
	Medical care	Medical resources and facilities	0.0334
	Education	Education facilities and resources	0.0334
	Debt burden	Family debt burden	0.0333
	Confidence in rural development	Confidence in rural and agricultural development	0.0331
Good social relationship	Family relationship	Family reunion	0.0335
	Neighbourhood relationship	Harmonious neighbourhood relationship	0.0335
		Villager cohesion	0.0335
Freedom and justice	Social justice	Knowlege of village key decision making	0.0333
		Allowance satisfaction	0.0332
		Independent decision making of farmers	0.0335

Information relating to the indicators was obtained using semi-structured interviews and a questionnaire survey conducted with randomly selected farmers. This focused on access to resources, satisfaction with agricultural production and subsistence, economic income level, ecological and environmental pollution, social fairness and justice, as well as farmers' satisfaction and desire.

The perception was quantified by scale, based on five levels, namely extremely dissatisfied, unsatisfactory, neutral, satisfied and extremely satisfied. For statistical indicators, values were also divided into five different ranks, e.g., annual agricultural income, namely <30, 30–80, 80–150, 150–200 and >200 thousand yuan. The index of human well-being and the indices of each dimension were evaluated by the comprehensive evaluation method. Weightings were determined by the entropy method and analytic hierarchy process (AHP) and passed the consistency test.

$$S = \sum_{j=1}^{n} W_j \times S_j \quad (13)$$

where S represents the overall score of human well-being; n is the number of indicators; j is a single indicator of human well-being; W_j is the weight of indicators; and S_j is the standardized score of indicator j.

2.3.5. An Analysis Framework of Linkages between Agricultural Transformation, Ecosystem Services and Human Well-Being

In PUAs, land use, economic development, social value and lifestyle are deeply influenced by the nearby city, forming a complicated regional human-land system with complex interactions between the urban and the rural. In analysing a PUA, we need to investigate:

1) The characteristics of economic development (especially the agricultural economy), sociocultural and physical geographical environment (via semi-structured interview and questionnaire survey), identifying the crucial causal relationships within the human-land system.
2) The nature of the agricultural transformation, examining the characteristics and driving factors of agricultural landscape change, focusing on changes in agricultural land use, crop types and practices.
3) Ecosystem characteristics: the types, structure and pattern of local ecosystems (especially agroecosystems).
4) Analysis of changes to ES, identifying major ecosystem services and evaluating and analysing changes in ES.
5) Human well-being assessment. Define human well-being and determine measurement dimensions, select the indicators and quantitatively evaluate.
6) Analyse the linkages between ES and human well-being (Figure 2).

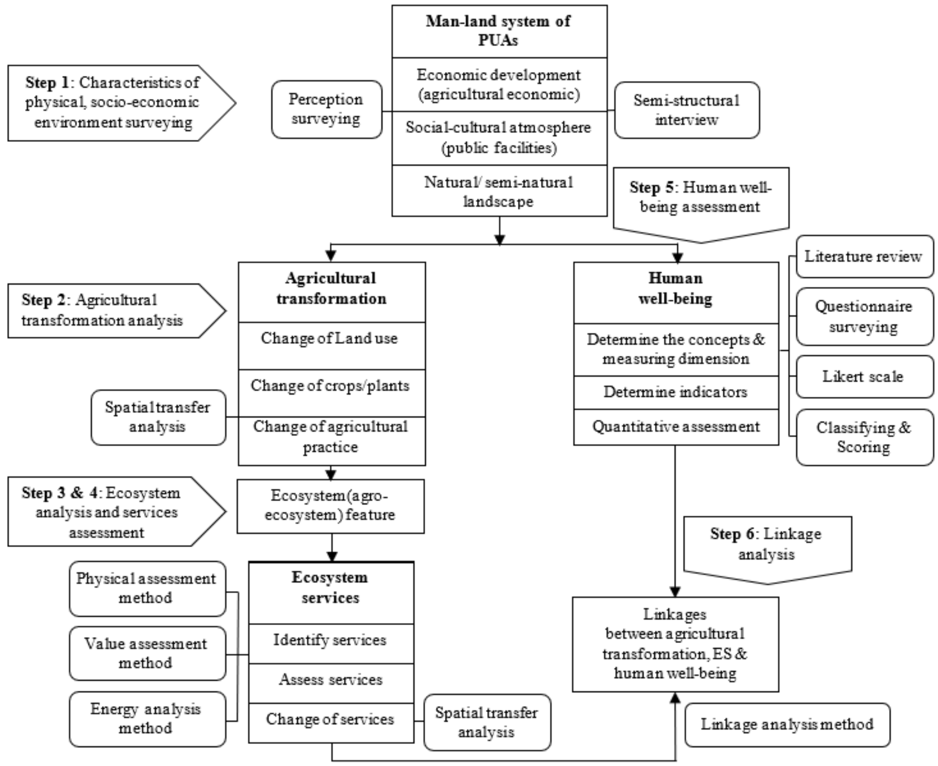


Figure 2. A linkage analysis framework between agricultural transformation, ES and human well-being in PUAs.

3. Results

3.1. Agriculture Transformation Analysis

3.1.1. Changes to Agricultural Land Use

Table 3 shows that changes in agricultural land use varied across the five identified land use types. From 2000 to 2020, the areas under orchards and built-up land increased by 196.3% and 25.2%, respectively, in Yueyang (grain to grain), while arable land, woodland and grassland decreased, with the area of arable land decreasing by 3.6%, mainly through construction of recreational facilities and road network. In 2020, land use was dominated by arable land (285.8 ha) and built-up area (118.3 ha), accounting for 68.1% and 28.2% of the total land area, respectively. In the past 30 years, Yueyang has maintained its focus on grain crops, and as of 2020, the area under grain crops accounted for two thirds of the total agricultural land.

In Duling (grain to fruit/tourism), in 2000, there was 63.4 ha of arable land, or 83.8% of the total land area. The remainder was built-up land and a few orchards. By 2020, arable land had been reduced to 28.4 ha, a decrease of 55.2%, mostly converted to gardens, grassland, woodland and built-up land. A small part of the arable land was converted to a tourist development. Orchards (especially cherries) occupied 17.8 ha, and new grassland and woodland accounted for 9.1 ha and 5 ha, respectively. The built-up area had increased by 26.2%. With the rapid growth of orchards in the past 20 years, fruit production, dominated by cherries and grapes, has become a major part of the local agricultural sector, combining fruit production with rural tourism.

Hongfeng has moved slowly from grain to vegetable production. In 2000, it was dominated by arable land (377.6 ha), accounting for 78% of the total area, followed by 88.3 ha of built-up land, with a few orchards, water and grassland. By 2020, arable land (now dominated by vegetables) had decreased by just 3.9%, still accounting for 74.9% of total land, while built-up land increased by 13.9% to 100.6 ha, newly developed woodland occupied 9.5 ha and a few orchards survived.

Table 3. Land use from 2000 to 2020 (ha).

		Arable Land	Woodland	Grassland	Orchard	Water	Built-Up Land	Unused Land	Total Land
Yueyang	2000	296.6	0.3	7.5	2.7	5.5	94.5	12.3	419.4
	2020	285.8	0	0	8	2.7	118.3	4.6	
	Change (%)	−3.6	−100.0	−100.0	196.3	−0.9	25.2	−62.6	
Duling	2000	63.4	0	0	0.1	0	12.2	0	75.7
	2020	28.4	5	9.1	17.8	0	15.4	0	
	Change (%)	−55.2	0.0	0.0	17,700.0	0.0	26.2	0.0	
Huojian	2000	372.8	0	0	6.5	0	41.4	0	420.7
	2020	324.6	0	0	12.1	0	84	0	
	Change (%)	−12.9	0.0	0.0	86.2	0.0	102.9	0.0	
Hongfeng	2000	377.6	0	1.5	11.6	5.4	88.3	0	484.4
	2020	362.8	9.5	0	11.5	0	100.6	0	
	Change (%)	−3.9	0.0	−100.0	−0.9	−100.0	13.9	0.0	
Huangliangxin	2000	82	0.2	0	0	8.3	28.4	0	118.9
	2020	45.9	10.4	4.4	0	0	58.2	0	
	Change (%)	−44.0	5100.0	0.0	0.0	100.0	104.9	0.0	

Huojian has transitioned from grain to a mixture of grain and vegetables. Arable land and built-up land occupied 324.6 ha and 84 ha, respectively, accounting for 77.2% and 20.0% of the total area. Compared with 2000, arable land decreased by 12.9%, and built-up land and orchards increased by 102.9% and 86.2%, respectively.

In 2000, in Huangliangxin, arable land occupied 82 ha, and built-up land occupied 28.4 ha, accounting for 68.9% and 23.9% of the total area, respectively. With a move towards flower growing, by 2020, the area of arable land had been reduced by 44%, and built-up land had expanded by 104.9%, while 12.5 ha of land was newly developed for nurseries and flowers.

Generally, arable land was the dominant land-use type in these five villages in 2000, occupying at least two thirds of the total area, followed by built-up land (varying from 9.9% to 23.8%). Since 2000, arable land has gradually decreased, while urban development has swept across the area like a wave, increasing the amount of built-up land, although it is being held at bay in Huangliangxin and Hongfeng by the move to orchard production, converting grain cultivation to fruit trees, flowers and seedlings, or from low economic output to high-economic benefit, raising farmers' incomes with farm diversification and a move away from reliance on grain for income. Land-use conversions are ongoing, creating a more fragmented landscape. However, the increases in urban built-up land, the decreases in cropland and the changes of agricultural type have all led to decreases in landscapes providing ES.

3.1.2. Changes of Agricultural Types

The agricultural structure in XMZ changed greatly from 2000 to 2020 (Table 4 and Figure 3). However, in Yueyang, wheat, maize and other grain crops are still dominant, at around 284 ha, accounting for 96.6% of agricultural land, with a decline in area of just 2.8% in 20 years. Vegetable planting decreased by 60.1%, and apple orchards increased by 8 ha, replacing natural grassland, some vegetables and a little arable land converted to apple orchards. Large areas of grain planting have been maintained, with a small number of farmers switching to fruit and vegetable cultivation. Grain cultivation has become mechanised, and there has been adoption of new agricultural techniques, new crop species and organic fertilizer, resulting in higher yields and production efficiency.

Table 4. Changes in agricultural land use (ha, %).

		Grain	Apple	Vegetable	Apricots & Plums	Melons	Grapes	Cherries	Peaches	Beans	Flowers	Agricultural Land Area (ha)
Yueyang	2000	292.1	2.1	4.5	0.5	0	0	0	0	0	0	299.3
	2020	284	8	1.8	0	0	0	0	0	0	0	293.8
	Change (%)	−2.8	281.0	−60.0	−100.0	0.0	0.0	0.0	0.0	0.0	0.0	
Duling	2000	63.3	0.1	0.03	0	0.03	0	0.04	0	0	0	63.5
	2020	30.4	0	1.7	0	0	7.7	18.4	0	0	0	58.2
	Change (%)	−52.0	−100.0	5566.7	0.0	−100.0	100.0	45,900	0.0	0.0	0.0	
Huojian	2000	333.1	6.5	39.7	0	0	0	0	0	0	0	379.3
	2020	160.6	11.3	164.9	0	0	0	0	0	0	0	336.8
	Change (%)	−51.8	73.8	315.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Hongfeng	2000	360.3	1.9	17.3	3.2	0	0	0	6.5	0	0	389.2
	2020	109.9	0	242.5	1.1	10.7	8.5	0	1.6	0	0	374.3
	Change (%)	−69.5	−100.0	1301.7	−65.6	100.0	100.0	0.0	−75.4	0.0	0	
Huangliangxin	2000	79	0	0.3	0	0	0	0	0	2.7	0	82
	2020	45.9	0	0	0	0	0	0	0	0	10.5	56.4
	Change (%)	−41.9	0	−100.0	0	0	0	0	0	−100.0	100.0	

In Duling, grain crops were dominant in 2000 (99.6% of agricultural land) but have gradually been converted to fruit production allied to tourism. Wheat and maize plantations have been reduced by 52% since 2000, being converted to cherries, vineyards, woodland and forage crops. The area of grapes and cherries increased significantly, reaching 26.1 ha, accounting for 44.9% of agricultural land. Cherry production often features pick-your-own (PYO) operations plus sightseeing activities to attract tourists from Xi'an. Cherry and grape production, combined with PYO, are highly profitable. Less labour is needed to grow fruit and grapes, releasing some farmers to commute to the city for work.

In Hongfeng, the area of grain crops accounted for 92.6% of the agricultural land in 2000 but had gradually changed to vegetables, melons and fruit (67.6% of the agricultural land) by 2020, forming a mixed agricultural mode combining vegetables, grain and fruit. In 2020, the area of grain planting had dropped to 109.9 ha, accounting for about 29% of the agricultural land, and vegetable planting was up to 242.5 ha and 64.8% of the agricultural land. Compared with 2000, the area of grain crops decreased by 69.5%, mainly being converted to vegetables and vineyards. Fruit production shifted from peaches, plums and apples to grapes, but orchards remained stable overall (−3%). At present, vegetables, melons and fruit are mainly planted in greenhouses, with facilities to achieve large-scale production. As part of the largest melon production base in XMZ, the diverse fruit production largely supplies the urban market of Xi'an.

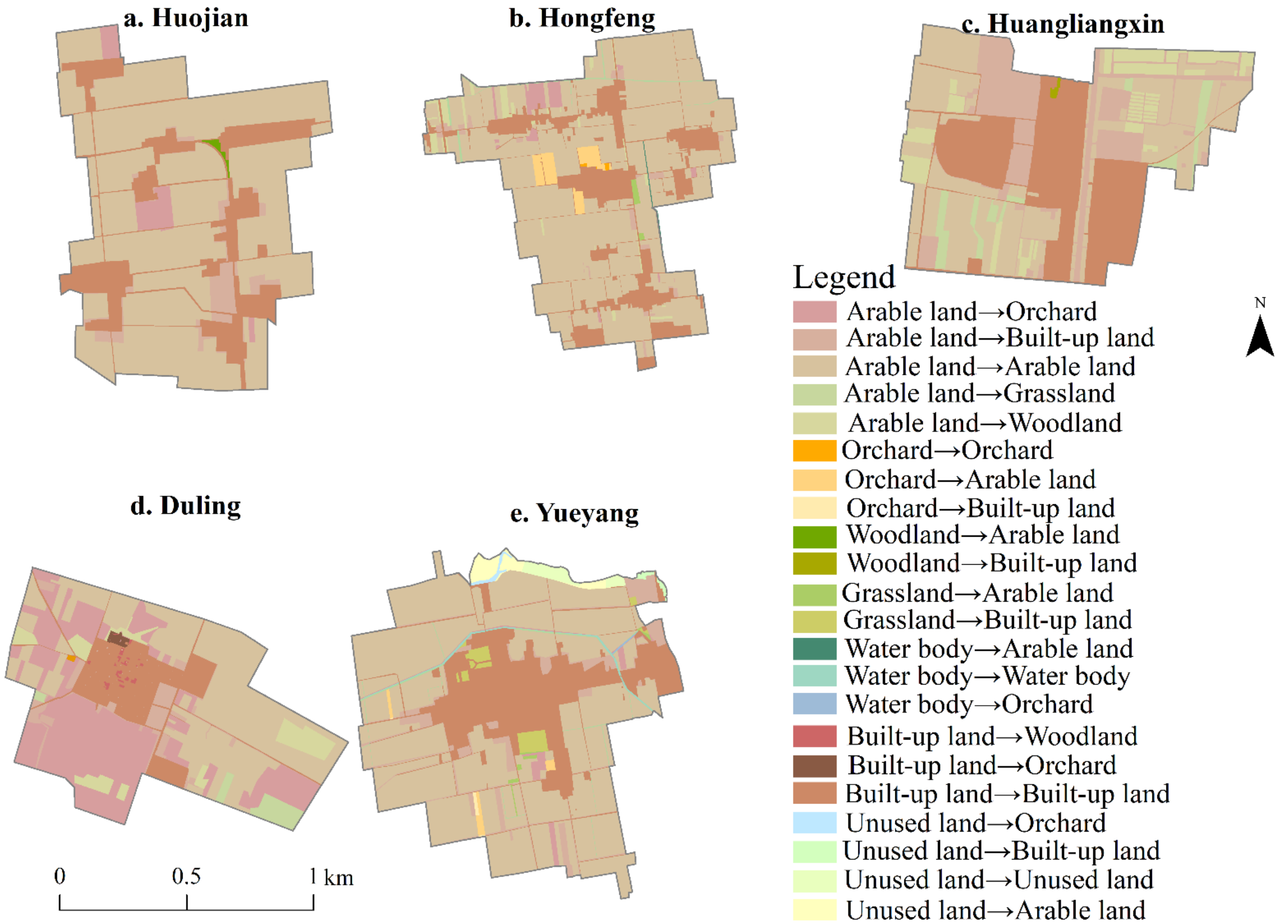


Figure 3. Land-use conversion between 2000 and 2020. In the legend, "Arable land→Orchard" means the conversion of arable land to orchard.

In Huojian, the area of grain crops accounted for 87.8% of agricultural land in 2000, shifting to grain and vegetable cultivation (47.7% and 49.0% of agricultural land, respectively) in 2020. The areas of grain planting decreased by 51.8%, and vegetable planting increased by 3.2 times. At present, Huojian is part of the vegetable-production base of Xi'an city. Vegetables are produced in greenhouses with a range of crops (mainly cabbage, tomato and celery) and high yields, supplying Xi'an city.

Huangliangxin changed from wheat, maize and bean planting in 2000 to both grain and flowers in 2020. The area under grain decreased by 41.9%, converted to flowers (+10.5 ha) and accounting for 18.5% of agricultural land. Flowers growing in Huangliangxin has developed into part of Xi'an's Qinling Flower World (a flower breeding centre and market) due to its neighbouring location. At present, flower planting in greenhouses is mainly operated by gardening companies with high input and a few farmers belonging to the company (Figure 4).

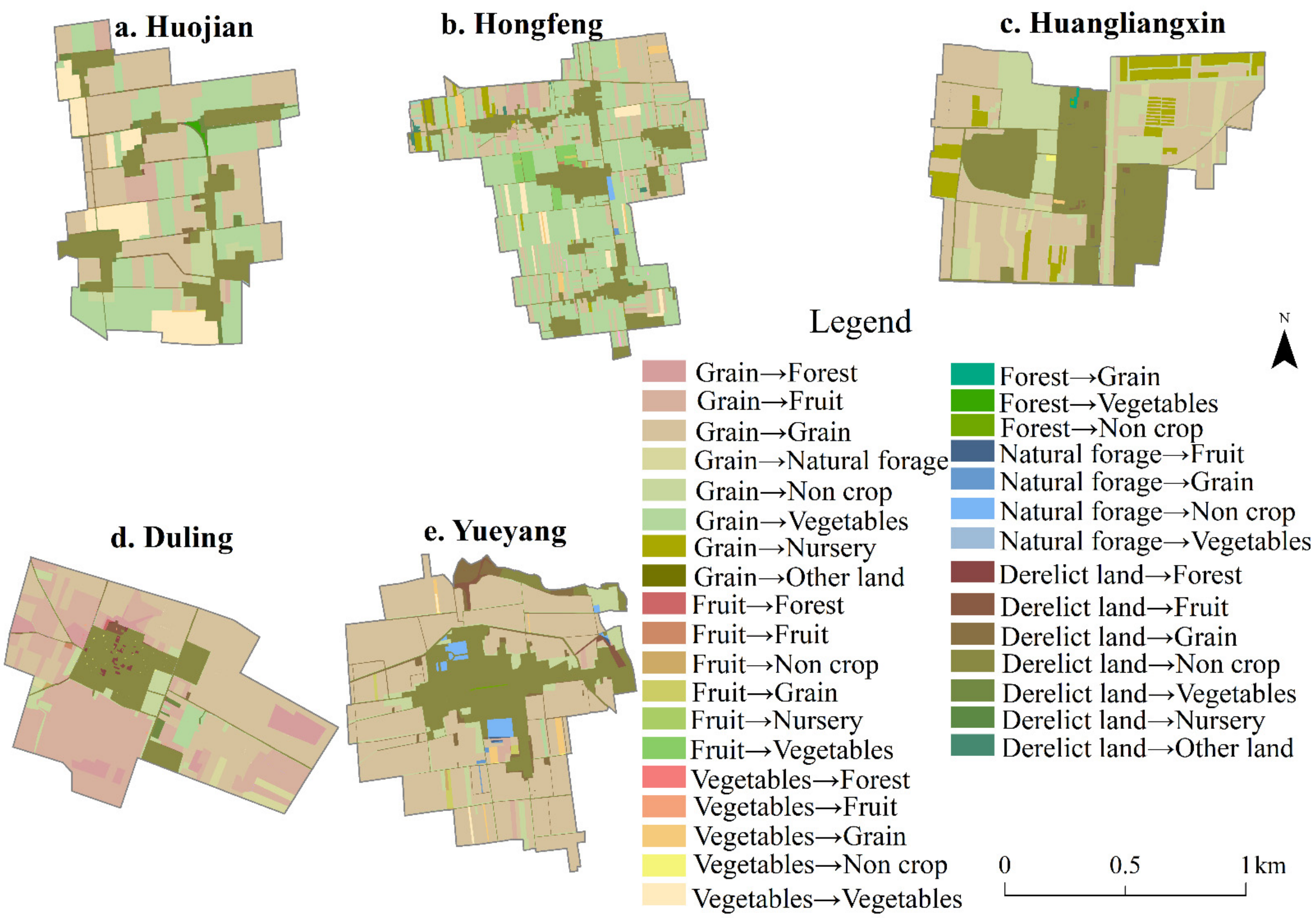


Figure 4. The conversion of agricultural planting patterns between 2000 and 2020. In the legend, "Grain→Forest" means the conversion of grain planting to forest.

Overall, among the five kinds of transformation, the maintenance of grain production is part of the Guanzhong high-quality production belt of high-yielding wheat and summer maize. There have been some changes in grain species since 2000, as well as in yields, cultivation practices and input, with more spatial clustering and higher efficiency, though only generating low income for farmers. Changes favouring fruit, tourism and vegetables have led to changes to the agricultural landscape. Fruit and tourism have brought economic benefits to farmers, accelerating the shift from grain toward greater diversification and higher incomes. In contrast, shifts to flower growing have largely not generated higher returns due to farmers' low participation.

3.2. Changes to ES

Driven by urban expansion, the urban market, government regulation and capital investment in XMZ, the agricultural transformation has propelled changes of land use and landscape pattern, with significant impacts on ES. We used the value-assessment method to measure ES and their changes in five typical agricultural transition villages (Figure 5, Table 4).

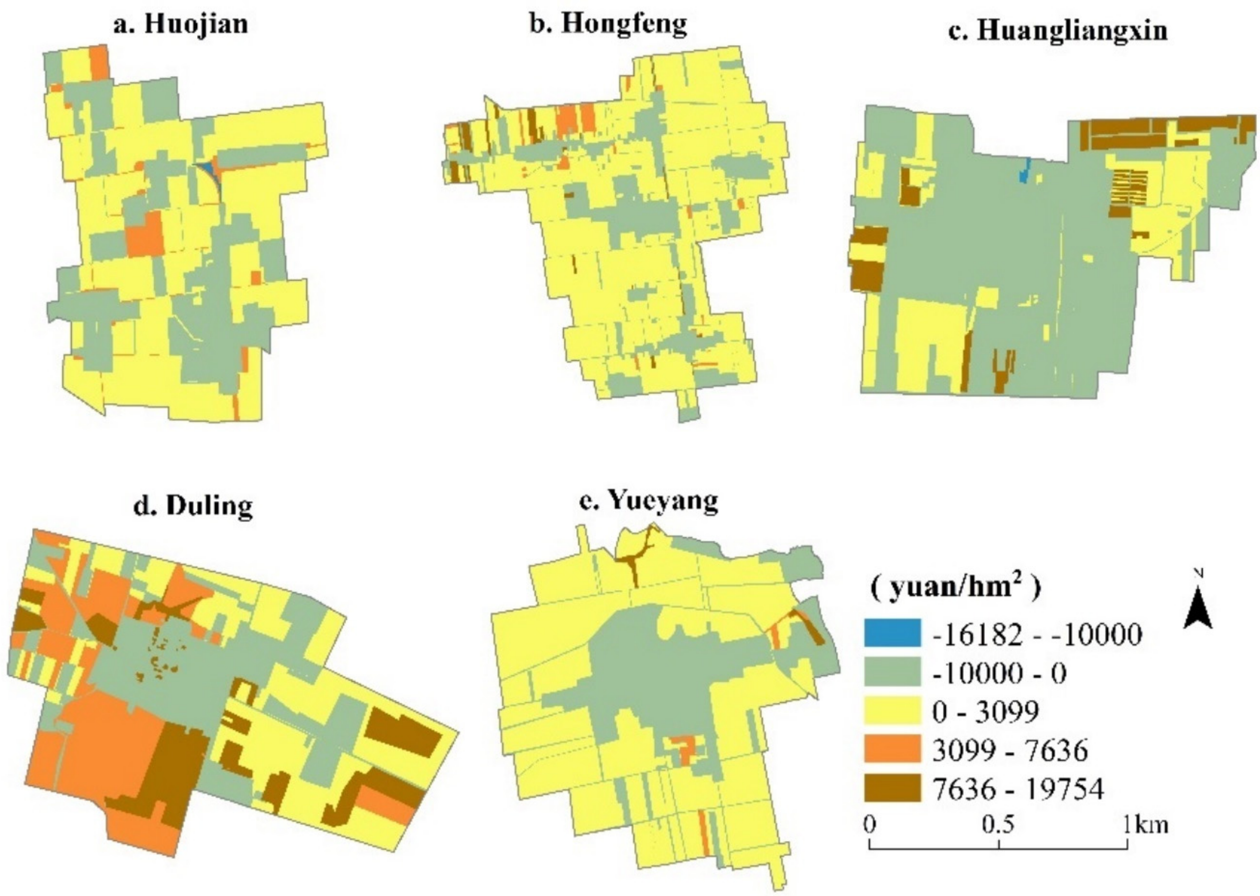


Figure 5. Changes in the values of ES.

From 2000 to 2020, the total value of ES supplied to agriculture in Yueyang, which remained focused on grain, increased from 5.8×10^5 yuan to 5.9×10^5 yuan (+1.7%.) In terms of ES, the values of carbon sequestration and oxygen release decreased from 5.0×10^5 yuan to 4.7×10^5 yuan (−6%). Although other ES accounted for a small proportion of the total services, they all showed an increasing trend, with tourism and leisure services increasing 4.8 times, mainly due to the growth of urban residents visiting the area. Economic-production services increased by 50% due to increased yields. Water-conservation services and air-purification services increased by 25% and 50%, respectively. In part, this is due to high planting density, application of fertilizer, healthy crops and new tillage technology, which are all beneficial to interception of precipitation and absorption of air pollutants by crops and fruit trees. For instance, no-tillage technology for some plots is conducive to soil interception of precipitation, and mechanical tillage for most plots is helpful for soil water storage.

In Duling, the move from grain to fruit and tourism since 2000 has significantly increased the total ES value from1.2×10^5 yuan to 3.1×10^5 yuan (+158.3%). Tourism and leisure services increased by more than 69 times. Water-conservation and air-purification services also rose by 56.6 times and 17.9 times, respectively. Carbon sequestration and oxygen-release services increased marginally, mainly due to dwarf cherry trees and tree pruning. Additionally, grapes as a perennial liana, compared with grain crops, have higher potential carbon sequestration and oxygen-release services. The development of fruit production mixed with tourism and leisure also improved the economic-production services of the agricultural landscape (+2.6 times).

The total value of ES in Huojian, where vegetable growing was adopted, increased from 7.3 × 10^5 yuan in 2000 to 7.6 × 10^5 yuan in 2020 (+4.1%). Tourism and leisure services increased from 0.11 × 10^5 yuan to 0.6 × 10^5 yuan (+5.5×) due to farming and picking activities. Compared with grain production, vegetables have higher density and coverage, which are conducive to precipitation interception. Water-conservation services increased from 0.14 × 10^5 yuan to 0.3 × 10^5 yuan (+2.14×). The output and price of vegetables were much higher than those of grain, and economic-production services increased by 2.2x, while carbon sequestration and oxygen-release services decreased by 18.7%.

From 2000 to 2020, the total value of ES in Hongfeng increased from 7.7 × 10^5 yuan to 1.03 × 10^6 yuan (+33.8%) as vegetable production rose. Both tourism and leisure services and water-conservation services increased more than fourfold, while economic-production services and air-purification services increased by 3 times and 2.5 times, respectively, and carbon sequestration and oxygen-release services decreased by 10.8%.

The total value of ES in Huangliangxin, where flowers were introduced, increased from 1.5 × 10^5 yuan in 2000 to 2.9 × 10^5 yuan (+93.3%). Compared with grain, flowers have higher output and economic value, as well as high ornamental value, attracting a large number of tourists. Economic-production services and tourism and leisure services increased by 19 times and 3 times, respectively. Air-purification services and carbon sequestration and oxygen-release services decreased by 40% and 35.7%, respectively.

3.3. Changes in Human Well-Being

Sample characteristics are as follows (Table 5): more than 59% of sampled farmers were over 50 years old in each village, more than 88% residing in parts of the village officially designated as 'rural', and over 83% were engaged in agricultural activities. The majority of farmers were familiar with the development of agriculture in their village over the past 20 years, and all provided their perceptions of well-being and how they had changed since 2000. The majority of farmers (85.7%) had a high school education or below, indicating relatively low levels of education. The average annual agricultural income per household was less than 80,000 yuan (US$ 12,514) for 79.6% of households. More than half of household income across the villages came from non-agricultural sectors.

It can be seen that among the five villages, human well-being improved from 2000 to 2020. Duling (fruit/tourism) had the largest increase (+30.6%). Huangliangxin (flowers), Hongfeng (vegetables) and Huojian (grain/vegetables) also improved (+25.5%, +24.0% and +18.4%, respectively), while Yueyang, which retained its focus on grain, only improved by 7.0% (Table 6).

According to the scores for the five dimensions of human well-being (Table 7), Duling experienced a high level of improvement in all the five dimensions of human well-being, with the capacity of sustainable development, (+57.1%) and freedom/justice (+40.0%) with the largest increases. Increased sustainable-development capacity can be attributed to the improvements in local transportation and medical and health resources, the convenience of selling agricultural products, and ease of access to schools and the hospital. The score of farmers' perceptions rose by more than 60%. The farmers' satisfaction with the household debt burden and rural and agricultural development improved by 34%. Knowledge of events in the village and perception of fairness of subsidies increased by 73.5% and 54%, respectively, as part of perceived improvement of freedom and justice. The dimensions of maintaining a high quality of life and health and safety also increased by more than 22.2%, mainly due to improvement of water security (+56%), cultural facilities and social security (+35%). Satisfaction with social security, food diversification, quality of the residential environment and convenience when seeking medical treatment rose by 35%. Satisfaction with family cohesion (members stay together, workers do not leave home and live in the city for work) and neighbourhood cohesion increased by 36%, suggesting a degree of social harmony. However, satisfaction with agricultural income, supply of resources, life as a farmer, governmental subsidies and air quality rose only slightly, and satisfaction with risks encountered in farming declined.

Table 5. Characteristics of sampled farmers and their households.

Feature	Classification	Duling		Hongfeng		Huangliangxin		Huojian		Yueyang	
		n	%	n	%	n	%	n	%	n	%
Gender	Male	9	37.5	7	33.3	11	50	9	60	8	50
	Female	15	62.5	14	66.7	11	50	6	40	8	50
Age (years)	<30	1	4.2	4	19	1	4.5	2	13.3	2	12.5
	30–50	4	16.7	7	33.4	6	27.3	6	40	7	43.8
	50–60	7	29.1	5	23.8	7	31.8	5	33.3	3	18.7
	>60	12	50	5	23.8	8	36.4	2	13.4	4	25
Educational experience	High school and below	22	91.7	17	81	21	95.5	11	73.3	13	81.3
	Junior college degree and above	2	8.3	4	19	1	4.5	4	26.7	3	18.7
Household income from agriculture (1000 yuan/yr)	<30	12	50	10	47.6	6	27.3	6	40	5	31.3
	30–80	7	29.2	7	33.3	12	54.5	6	40	6	37.5
	80–150	2	8.3	2	9.5	1	4.5	1	6.7	2	12.5
	150–200	2	8.3	1	4.8	2	9.2	1	6.7	1	6.2
	>200	1	4.2	1	4.8	1	4.5	1	6.6	2	12.5
Profession	Crop planting	21	52.5	16	44.4	17	51.5	13	56.5	13	48.1
	Livestock	0	0	1	2.8	0	0	0	0	0	0
	Tertiary services	14	35	13	36.1	15	45.5	8	34.8	5	18.5
	Corporate staff	3	7.5	1	2.8	0	0	1	4.3	4	14.8
	Government staff	2	5	1	2.8	0	0	0	0	3	11.1
	Private factory owner	0	0	4	11.1	1	3	1	4.4	0	0
	Others	0	0	0	0	0	0	0	0	2	7.5
Place of residence	Dwell in village	22	91.7	17	81	21	95.5	14	93.3	13	81.3
	Occasionally dwell in village	2	8.3	2	9.5	1	4.5	0	0	3	18.7
	Live in city	0	0	2	9.5	0	0	1	6.7	0	0
Total number (people)		24		21		22		15		16	

Table 6. Values of and changes to ES.

		Air Purification (10^5 Yuan)	Carbon Sequestration and Oxygen Release (10^5 Yuan)	Water Conservation (10^5 Yuan)	Tourism and Leisure (10^5 Yuan)	Economic Production (10^5 Yuan)	Total Value (10^5 Yuan)
Yueyang	2000	0.2	5	0.08	0.06	0.4	5.8
	2020	0.3	4.7	0.1	0.3	0.6	5.9
	Change (%)	50.0	-6.0	25.0	400.0	50.0	1.7
Duling	2000	0.03	1.1	0.01	0.01	0.08	1.2
	2020	0.6	1.2	0.4	0.7	0.2	3.2
	Change (%)	1900.0	9.1	3900.0	6900.0	150.0	166.7
Huojian	2000	0.3	6.2	0.14	0.11	0.6	7.3
	2020	0.3	5.04	0.3	0.6	1.3	7.6
	Change (%)	0.0	−18.7	114.3	445.5	116.7	4.1
Hongfeng	2000	0.4	6.5	0.2	0.2	0.6	7.7
	2020	1	5.8	0.9	0.9	1.8	10.3
	Change (%)	150.0	−10.8	350.0	350.0	200.0	33.8
Huangliangxin	2000	0.05	1.4	0.02	0.01	0.1	1.5
	2020	0.03	0.9	0.02	0.03	1.9	2.9
	Change (%)	−40.0	−35.7	0.0	200.0	1800.0	93.3

Table 7. Change in human well-being scores between 2000 and 2020.

	Duling	Hongfeng	Huangliangxin	Huojian	Yueyang
2000	4.9	5.0	5.1	4.9	5.7
2020	6.4	6.2	6.4	5.8	6.1
Change (%)	30.6	24.0	25.5	18.4	7.0

Hongfeng, which has adopted a vegetable-growing village, also saw increases in sustainable-development capacity (+37.5%) and health and safety (29.4%), mainly attributable to increased satisfaction with transportation conditions (+62%) and medical (+37%) and educational resources (+33%) (Table 8). Significant improvements were noted for convenience of medical treatment, diversity of food, natural environment and sewage, and waste treatment, but satisfaction with local social relations only rose slightly (+7.13%). Similarly low increases were recorded for family reunion, neighbourhood relations (+4%) and agricultural income (+6.5%). Hence, it was perceived that social cohesion of the village had not changed in the past 20 years.

Table 8. Composite scores for human well-being.

		Maintain High-Quality Life	Health and Safety	Sustainable Development	Good Social Relationship	Freedom and Justice
Duling	2000	1.4	1.8	0.7	0.5	0.5
	2020	1.7	2.2	1.1	0.8	0.7
	Change (%)	21.4	22.2	57.1	60.0	40.0
Hongfeng	2000	1.3	1.7	0.8	0.7	0.5
	2020	1.7	2.2	1.1	0.7	0.6
	Change (%)	30.8	29.4	37.5	0.0	20.0
Huangliangxin	2000	1.3	1.7	0.9	0.7	0.5
	2020	1.6	2.3	1.2	0.8	0.7
	Change (%)	23.1	35.3	33.3	14.3	40.0
Huojian	2000	1.2	1.7	0.8	0.6	0.5
	2020	1.6	1.9	1	0.7	0.6
	Change (%)	33.3	11.8	25.0	16.7	20.0
Yueyang	2000	1.6	1.9	0.9	0.7	0.6
	2020	1.8	1.9	1.1	0.7	0.7
	Change (%)	12.5	0.0	22.2	0.0	16.7

Huangliangxin, where farmers are growing flowers, has also seen an increase in sustainable-development capacity (+33.3%) and health and safety (+35.3%). Perceived satisfaction increased for a range of indicators: psychological stress (+1.7 times) traffic conditions (+58%), access to hospital, life expectancy, living environment, sewage disposal and village public security (>35%). However, farmers' satisfaction with agricultural work, water quality and air quality increased by less than 8%, and satisfaction with agricultural risk and agricultural income fell by 13.4% and 5.5%, respectively.

Sustainable-development capacity (+25.0%) and maintaining a high quality of life (+33.3%) increased in the grain- and vegetable-growing village of Huojian. Farmers' satisfaction with traffic conditions, medical resources and educational facilities and resources increased at least by 35%, as did satisfaction with domestic water security, agricultural resource supply and government subsidies (>38%). On the other hand, satisfaction with agricultural work, cultural and recreational activities, confidence in agricultural development, village cohesion and agricultural decision-making was not significantly improved (<8.5%). Meanwhile, scores for psychological stress (−16%), agricultural risk (−32%) and life expectancy all decreased.

Among the five dimensions of evaluation of human well-being, in grain-producing Yueyang, the largest increase was in satisfaction with sustainable-development capacity (+22.2%). This is mainly attributable to perceived improvement in medical resources, transportation conditions, and educational facilities and resources (+20% to 26%). Satisfaction with other well-being dimensions is relatively low (less than 12%). Due to mechanisation of grain planting, farmers' satisfaction with agricultural production methods has increased. In contrast, their satisfaction with water quality (−21%), agricultural risk (−11%), air quality, family reunion, villager cohesion and knowledge of village events declined.

Of the five villages, Duling showed the greatest improvement in human well-being and was substantially better than the remaining grain-producing village, Yueyang. Duling's move into fruit production combined with tourism has increased agricultural incomes and has been associated with improved transportation facilities, health care and social relations, reducing the household debt burden and improving sustainable-development capacity, social freedom/justice, and health and safety of the village. Flower growing in Huangliangxin has increased agricultural incomes, contributing to alleviation of household debt burden, improving health care, rural social security, and physical and mental health.

In Hongfeng, where there has been a substantial move to vegetable growing, agricultural incomes have improved more than in Huojian, where the move towards vegetable production is less developed. In Hongfeng, there were also improvements to farmers' physical health, leisure culture, agricultural security, public security, social freedom and justice—all higher than in Huojian, generating greater perceived self-confidence in the former village. In Yueyang, agricultural incomes still rely primarily on grain production, resulting in low scores for most indicators of human well-being.

The deterioration of the ecological environment leads to change in residents' happiness, which attracts the attention of the government. Strengthening the construction of the new countryside and changing the appearance of villages indirectly affect the structure and type of crops and, ultimately, feedback into the change of ecosystem service values.

3.4. The Linkages between Ecosystem Services and Human Well-Being

In the five study villages there are correlations between ES and human well-being (Figure 6), with agricultural transition leading to improved ES and human well-being. From 2000 to 2020, the total value of ES barely rose (+2.5%) where grain production remained dominant, and the well-being of the grain farmers also only increased slightly (+7.6%). Where grain production was combined with vegetables, the total value of ES increased by 19.1%, and the welfare of farmers also increased by the same amount. Where vegetables were dominant, in Hongfeng, a similar increase in the value of ES was recorded (+19.6%), but well-being was higher (+24.2%). In stark contrast, flower growing in Huangliangxin increased the value of ES more than twelve-fold, and the well-being score of farmers by 26.3%. In Duling, the move to fruit and tourism produced a large increase in ES (+170%), with human well-being rising by 32.5%.

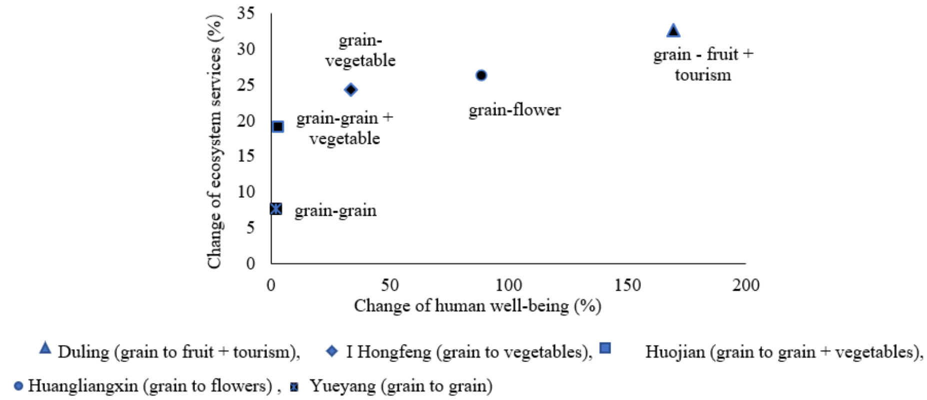
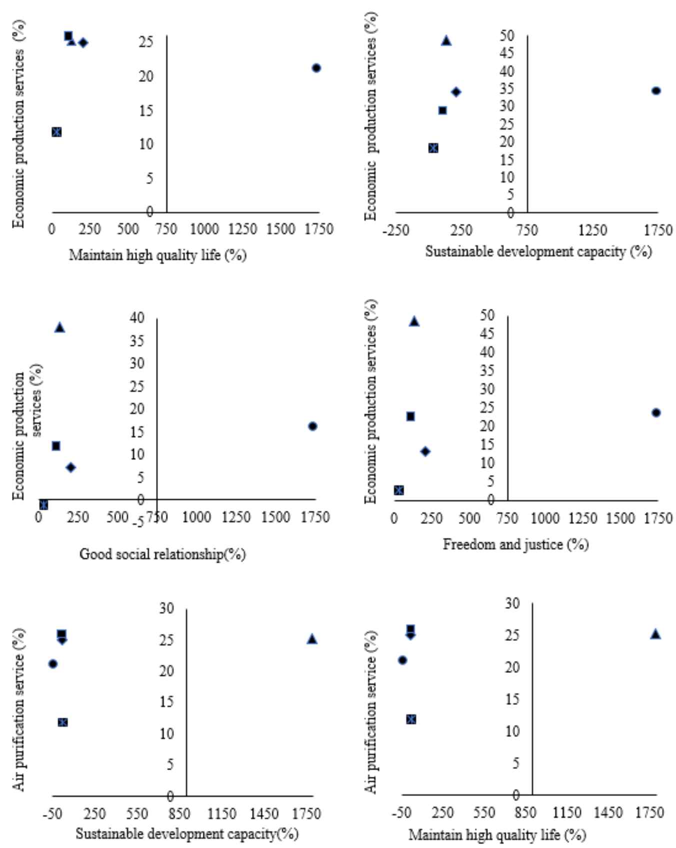


Figure 6. Changes in ES and human well-being.

Figure 7 shows the relationship between changes in agroecosystem services and human well-being in the five villages from 2000 to 2020. Flower production is associated with rising quality of life and sustainable-development capacity, good social relations, social freedom and justice. Meanwhile, the expansion of orchards has improved air-purification services and water-conservation services, resulting in higher sustainable-development capacity, higher quality of life, health and safety and other well-being dimensions. Retaining grain production has made only small contributions to the improvement of ES and human well-being. Where grain and vegetables have been combined, benefits have occurred to economic development and ecological services, such as water conservation and air purification, as well as quality of life and sustainable development.



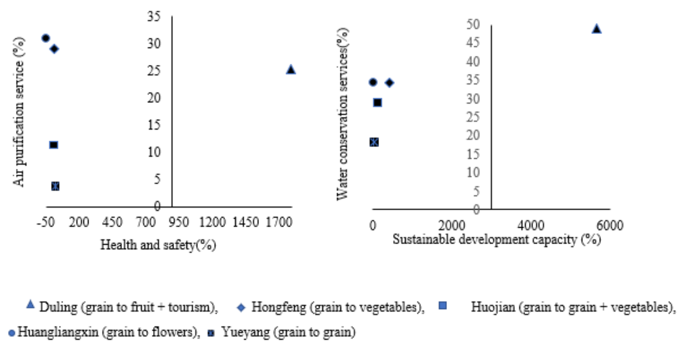


Figure 7. Relations between changes to ES and human well-being under different agricultural transformation modes.

In general, there have been positive impacts on both ES and human well-being, but they vary considerably among the sample villages. Introduction of fruit, vegetables and tourism have had the most significant effect on the improvement of ES and human well-being. Continued reliance primarily on grain has had little effect on the improvement of ES and human well-being.

4. Discussion and Conclusions

4.1. Discussion

Urbanization overwhelmingly drives and reshapes agricultural landscapes and has profound impacts on the relationships between economic, social and ecological development in PUAs. To date, most studies on PUAs have focused mainly on land use and the agricultural landscape, peri-urban agriculture and its multifunctionality, as well as ES. However, research on agricultural transformation and its social-ecological effects, as well as the relationship between ES and human well-being is scarce [67,68]. There is still a great gap in understanding the coupling relations between agricultural (or landscape) transformation, ES and human well-being, especially considering the full range of economic, social and ecological issues in PUAs. Using semi-structured interviews, perception surveys, social surveys and field mapping, we examined the linkage mechanisms and an analytic framework for the agricultural transition between 2000 and 2020, focusing on ES and human well-being (see Figure 8). Five villages representing different types of agricultural transition in the PUA of XMZ were selected as examples of the process of agricultural transformation. Changes to ES and human well-being and the relations between agricultural transformation, ES and human well-being were analysed. The results show that examining the relations between agricultural transition, ES and human well-being can contribute to understanding of the people-land dynamic.

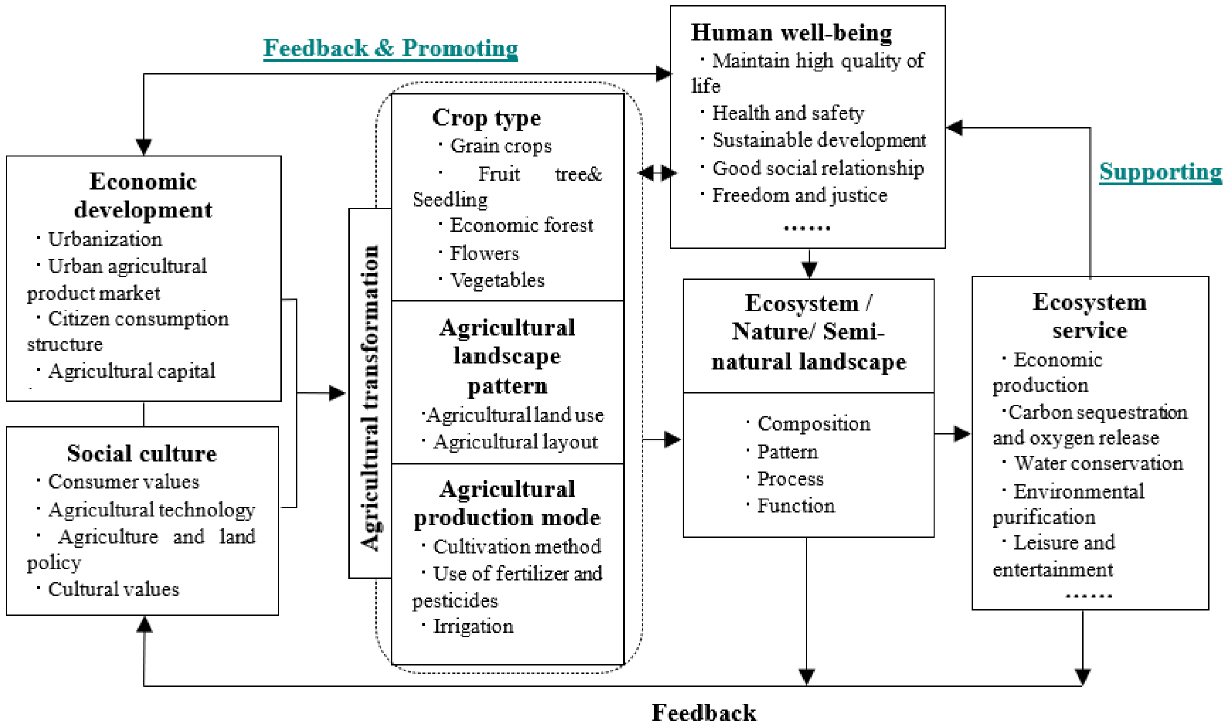


Figure 8. Linking mechanism of agricultural transition, ES and human well-being.

Comparing the five villages, moves from grain to a more diversified and mixed agriculture have changed the appearance of the agricultural landscape and produced an increase in ES supply capacity, especially the improvement of tourism and leisure services and economic-production services. The total capacity of agroecosystem services has increased, mainly due to the improvement of tourism and leisure services, economic-production services and water-conservation services. However, where grains have remained more important, the total supply capacity of ES has only grown slightly. Moves from grain to vegetables have led to a decline in carbon sequestration and oxygen-release services, while water conservation, tourism and leisure, and economic-production services have grown slightly. Transformations from grain cultivation to fruit production and tourism have improved all five ES. The shift from grain cultivation to flowers/nursery has significantly reduced air purification and carbon sequestration and oxygen-release services. Generally, the different ecological characteristics of grain crops, fruit trees, nursery plants, flowers, vegetables and grass have resulted in different supply capacities for the various ES. The modernisation of farming technology and agricultural practices [69], the changing choice of crops, and the introduction of greenhouse facilities have all lead to changes in crop and vegetation growth, planting structure, spatial patterns (including land use) and the diversity and stability of agroecosystems, resulting in changes in the ES of agriculture.

Overall, the results indicate that moves from traditional grain cultivation to cash crops with greater economic benefits (such as vegetables and fruit trees), mixed with tourism, have improved human well-being. However, the four villages with the most changes in production reported increased agricultural risks and concerns about agricultural income and agricultural work. This seems to be mainly due to unstable urban markets, with significant price fluctuations, compared with that for grain. Moreover, the cost of producing vegetables, flowers, fruit and other cash crops is high, and the produce is often difficult to store. Risk from changing weather patterns was also reported [70]. Farmers earned less than those working in the secondary and tertiary sectors, and the perception was that farm work is harder. In general, there was satisfaction with transportation and medical resources, especially with the former, reflecting implementation of the "village to village project" across the country, beginning in 1999, significantly improving transportation in rural areas. Paradoxically, farmers complained about poor air quality due to emissions from cars. The deterioration of the ecological environment leads to changes in residents' well-being, which has aroused the attention of the government. The 'construction of new countryside' has been strengthened, changing the appearance villages and indirectly affecting the structure and type of agricultural planting, ultimately feeding back to the changes in the value of ES.

In general, both ES and human well-being improved in the study area since 2000, especially where grain production has given way to either orchards and tourism or to vegetables. For instance, in Duling, tourism and leisure services increased by more than 69 times, and the services of water conservation and air purification improved by 56.6 times and 17.9 times, respectively, because of the large-scale development of fruit and tourism, mainly focusing on grapes and cherries. Shifting from traditional grain production to grapes and cherries can reduce the deep turning of soil, and the roots of fruit trees can intercept more water than those of crops, while fruit trees have large leaf areas and a long growing period. The greater the continued reliance on grain, the less the improvement in ES and human well-being. Fruit and vegetables provide more ES than traditional food crops [71]. The traditional grains are herbaceous crops, such as wheat, maize and soybean, with low-growing plants, small leaf areas and short growing periods. Ploughing the soil and removing weeds requires provision of ES, e.g., carbon sequestration and oxygen release, water conservation and improved air quality. Fruit trees, nursery crops and vegetables (in multiple rotation in greenhouses), with tall plants, high coverage, large leaf area and long growing periods, generate more ES, as well as greater economic production capacity, including when combined with tourism [72]. Differences in ES in the five villages reflect crop selection, planting structure, and growing period of the plants, which all vary between trees (fruit trees, seedlings), shrubs (such as grapes, shrubs and flowers) and herbs (vegetables, wheat, maize). Therefore, the impact of agricultural transformation on ES and human well-being depends significantly on the composition of the agricultural landscape [12,69]. Although retention of grain production in the study area had little impact on ES or human well-being, its contribution to food security remains extremely important (similar to that reported in other research [73,74]), as recognised in policies supporting basic farmland protection since 1998 and the construction of 'high standard' farmland since 2011, which were implemented nationwide in order to ensure grain supplies. Hence, there remains a large area of grain planting in the PUAs of XMZ. The five agricultural transformation processes, namely, "grain to grain", "grain to grain + vegetable", "grain to vegetables", "grain to flowers" and "grain to fruit + tourism" and their impacts on ES and human well-being can be regarded as five prototypes of the linkages occurring in PUAs. These reflect the different change processes and development trends of agriculture, ES and human well-being and are also in line with their commercial nature (e.g., high profitability, local fresh food trade and food processing) and offering a high level of ecological services (e.g., shaping of cultural landscape, recycling of urban biodegradable waste, improving individual and public well-being, closer contact with nature and visual amenity) [75].

The research shows that a key driver of agricultural transformation is the urban market. From the farmers' perspective, decision making on the selection of crops and planting structure is chiefly regulated by market mechanisms , and the potential economic benefits, for instance, the input and output of agricultural production, the relations between supply and demand of agricultural products in the urban market, as well as labour costs for different crops. Government policies have also been important, relating to urban-agglomeration planning, agricultural and land-use planning, and agricultural subsidies [26], for instance, the spatial distribution of different peri-urban agricultures or specialization were arranged by government planning. Distance to central Xi'an has influenced loss of agricultural land to construction of real estate, factories and roads. Locations closest to the city have suffered the greatest loss of farmland. The creation of agricultural parks (government-funded agricultural development zones) has also helped determine the intensity of agricultural production, shaping the adoption of modern agricultural practices and new agricultural technology. However, although there are at least 14 such parks in XMZ, there is none in the five sample villages.

The analytic framework proposed in this paper provides a framework for analysing the people-land system and its economic, ecological and social components. It has been employed herein to analyse the relationships between landscape transition, ES and human well-being.

However, the transformation in PUAs is very complicated, often marked by the shifting of agricultural structure, the conversion of land use, the opportunities for farmers seeking part-time or full-time work, migration into cities and the changes of livelihoods or lifestyles detaching from agriculture, cultural traditions and identities related to the rural environment [36]. These all will result in the alteration of rural society and possibly also the improvement of human well-being. Especially at the village scale, the income of farmers earned from non-agricultural jobs and/or working in cities has had an important impact on their well-being. Thus, to determine the indicators of human well-being and the selection of key ES, including analysing the relationship between them, should clarify the linkages with agricultural development and landscape, choosing indicators that have relatively strong relations to the ecosystem and its services.

When the framework is further applied in similar PUAs, it needs to determine the concept and main aspects of agricultural transformation, identifying the key ecosystem services of agriculture and selecting the suitable evaluation indicators of human well-being according to the characteristics of local agroecosystems and the stage of social and economic development. In the analysis of the relation between the ecosystem services of the agricultural landscape and human well-being, urban agriculture (such as courtyard agriculture) can also be included, as it may play an important role in the improvement of human well-being in PUAs.

Further analysis can extend understanding of the substantial land-use changes occurring by considering in more detail the range of decisions being made by farmers, village leaders and local officials as they respond to changing market conditions and government policies and pay more attention to assessment of broader society in PUAs. This would inject a behavioural component into the analysis to complement the portrait of change in the dynamic PUA developed herein.

In our analysis, five key ES were selected by comprehensive consideration of natural geographical conditions, agricultural types, changes in agricultural production and operation mode, regional agricultural planting structure and crop types. If the analysis was developed further, we would be able to cover more agroecosystem services and also consider several disservices in agricultural practices, e.g., non-point pollution by chemical fertilizers and pesticides, usage of large amounts of water in irrigation [46,71] and farm management being key to the crop selection, water resource utilization, agrochemical toxicity and even economic output [69]. Further analysis will also need to address farmers' behaviour, agricultural practices, agricultural and planning policies, and the lure of income in urban-based employment.

4.2. Conclusions

(1) Agricultural transition in the PUA of XMZ has involved a shift in the rural economy away from grain towards fruit and vegetables, with some additional involvement of farmers in tourism.
(2) Agriculture has become more diverse and multifunctional, generating higher incomes as part of the moves away from grain but with a more fragmented landscape in which farmland is increasingly threatened by urban sprawl.

(3) There are notable differences between our five sample villages based on the nature of their evolving specialisations. The transformation towards multifunctional agriculture increased the supply of ES, especially through the increase in tourism and leisure activities and economic-production services.
(4) Increases in total ES were most closely associated with the introduction of orchards, vegetables and tourism. The combination of orchards and tourism also contributed most to improved human well-being in the five villages. This reflected both increased income to farm households and improvements in quality of life associated with better provision of schools, medical services, welfare provision and road links to the city.

Author Contributions: Conceptualization, Z.Z.; Methodology, Z.Z, B.Z. and X.L.; Software, X.L.; Formal analysis, Z.Z., B.Z. and X.L.; Investigation, B.Z. and X.L.; Writing—original draft preparation, Z.Z., B.Z. and X.L.; Writing—review and editing, G.M.R. and B.S.; Visualization, B.Z. and X.L.; Supervision, Z.Z. and G.M.R.; Funding acquisition, Z.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the National Natural Science Foundation of China [grant number 42071280].

Institutional Review Board Statement: Formal ethics approval was not required by the funding body or the host academic institution.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data from the interviews and surveys are deemed private and confidential.

Conflicts of Interest: There are no conflicts of interest.

References

1. UN Habitat. *World Cities Report 2020: The Value of Sustainable Urbanization*; United Nations Human Settlements Programme (UN Habitat): Nairobi, Kenya, 2020.
2. Artmann, M.; Sartison. K. The role of urban agriculture as a nature-based solution: A review for developing a systemic assessment framework. *Sustainability* **2018**, *10*, 1937.
3. Dadashpoor, H.; Malekzadeh, N. Driving factors of formation, development, and change of spatial structure in metropolitan areas: A systematic review. *J. Urban Manag*. **2020**, *9*, 286–297.
4. Seto, K.C.; Fragkias, M.; Güneralp, B.; Reilly, M.K. A meta-analysis of global urban land expansion. *PLoS ONE* **2011**, *6*, e23777.
5. d'Amour, C.B.; Reitsma, F.; Baiocchi, G.; Barthel, S.; Guneralp, B.; Erb, K.H.; Haberl, H.; Creutzig, F.; Seto, K.C. Future urban land expansion and implications for global croplands. *Proc. Natl. Acad. Sci. USA* **2017**, *114*, 8939–8944.
6. Solecka, I.; Sylla, M.; Świąder, M. Urban sprawl impact on farmland conversion in a suburban area of Wroclaw, Poland. *IOP Conf. Ser. Mater. Sci. Eng.* **2017**, *245*, 72002.
7. Inostroza, L.; Tábbita, J.H. Informal urban development in the Greater Buenos Aires area: A quantitative-spatial assessment based on households' physical features using GIS and principal components analysis. *Procedia Eng.* **2016**, *161*, 2138–2146.
8. Song, B.; Robinson, G.M.; Zhou, Z. Agricultural transformation and ecosystem services: A case study from Shaanxi Province, China. *Habitat Int*. **2017**, *69*, 114–125.
9. Su, S.; Wang, Y.; Luo, F.; Mai, G.C.; Pu, J. Peri-urban vegetated landscape pattern changes in relation to socioeconomic development. *Ecol. Indic*. **2014**, *46*, 477–48.
10. Zhou, Z.; Li, M. Spatial-temporal change in urban agricultural land use efficiency from the perspective of agricultural multi-functionality: A case study of the Xi'an metropolitan zone. *J. Geogr. Sci*. **2017**, *27*, 1499–1520.
11. Banos, A.; Abrantes, P.; Rocha, J.; Kristensen, S.B.P.; Busck, A. Agricultural land fragmentation analysis in a peri-urban context: From the past into the future. *Ecol. Indic*. **2019**, *97*, 380–388.
12. Lee, Y.; Ahern, J.; Yeh, C.T. Ecosystem services in peri-urban landscapes: The effects of agricultural landscape change on ecosystem services in Taiwan's western coastal plain. *Landsc. Urban Plan*. **2015**, *139*, 137–148.
13. James, S.W.; O'Neill, P.M. Planning for peri-urban agriculture: A geographically-specific, evidence-based approach from Sydney. *Aust. Geogr*. **2016**, *47*, 179–194.
14. Nicholls, E.; Ely, A.; Birkin, L.; Basu, P.; Goulson, D. The contribution of small-scale food production in urban areas to the sustainable development goals: A review and case study. *Sustain. Sci*. **2020**, *15*, 1585–1599.
15. Spyra, M.; Kleemann, J.; Furst, C. Protection of peri-urban open spaces at the level of regional policy-making: Examples from six European regions. *Land Use Pol*. **2021**,*107*, 105480.

16. Elhadary, Y.A.E.; Samat, N.; Obeng-Odoom, F. Development at the peri-urban area and its impact on agricultural activities: An example from the Seberang Perai region, Penang State. *Agroecol. Sustain. Food Syst.* **2013**, *37*, 834–856.
17. Yu, D.; Wang, D.Y.; Zhou, Y.H. Decreased landscape ecological security of peri-urban cultivated land following rapid urbanization: An impediment to sustainable agriculture. *Sustainability* **2018**, *10*, 394.
18. Dadashpoor, H.; Ahanib, S. Land tenure-related conflicts in peri-urban areas: A review. *Land Use Pol*. **2019**, *85*, 218–229.
19. Hedblom, M.; Andersson, E.; Borgström, S. Flexible land-use and undefined governance: From threats to potentials in peri-urban landscape planning. *Land Use Pol*. **2017**, *63*, 523–527.
20. Gullino, P.; Battisti, L.; Larcher, F. Linking multifunctionality and sustainability for valuing peri-urban farming: A case study in the Turin Metropolitan Area (Italy). *Sustainability* **2018**, *10*, 1625.
21. Long, H.; Zou, J.; Li, T. Study on the characteristics and territorial types of rural transformation development: The case of "Southern Jiangsu-Northern Shaanxi" transect. *Geogr. Res*. **2012**, *31*, 495–506.
22. Robinson, G.M.; Song, B. Transforming the peri-urban fringe in China: The example of Xi'an-Xianyang. *Sustainability* **2018**, *10*, 3932.
23. Vandercasteelen, J.; Beyene, S.; Minten, B.; Swinnen, J. Cities and agricultural transformation in Africa: Evidence from Ethiopia. *World Dev*. **2018**, *105*, 383–399.
24. Ustaoglu, E.; Williams, B. Determinants of urban expansion and agricultural land conversion in 25 EU countries. *Environ. Manag*. **2017**, *60*, 717–746.
25. Wadduwage, S. Drivers of peri-urban farmers' land-use decisions: An analysis of factors and characteristics. *J. Land Use Sci.* **2021**, *16*, 273–290.
26. Thanh, B.N.; Le, V.; Minh, N.A.; Nguyen, M.N.; Trung, N.H. Drivers of agricultural transformation in the coastal areas of the Vietnamese Mekong Delta. *Environ. Sci. Policy* **2021**, *122*, 49–58.
27. Yang, Z.; Hao, P.; Liu, W.; Cai, J. Peri-urban agricultural development in Beijing: Varied forms, innovative practices and policy implications. *Habitat Int*. **2016**, *56*, 222–234.
28. Ayele, A.; Tarekegn, K. The impact of urbanization expansion on agricultural land in Ethiopia: A review. *Environ. Socio-Econ. Stud*. **2020**, *8*, 73–80.
29. Mallinis, G.; Koutsias, N.; Arianoutsou, M. Monitoring land use/land cover transformations from 1945 to 2007 in two peri-urban mountainous areas of Athens metropolitan area, Greece. *Sci Total Environ*. **2014**, *490*, 262–278.
30. Ouyang, Z.; Wang, R. Ecosystem services and their economic valuation. *World Sci-Tech. R D* **2000**, *5*, 1006–6055.
31. Paul, S.; Saxena, K.G.; Nagendra, H.; Lele, N. Tracing land use and land cover change in peri-urban Delhi, India, over 1973–2017 period. *Environ. Monit. Assess*. **2021**, *193*, 52.
32. Ashiagbor, G.; Amoako, C.; Asabere, S.B.; Quaye-Ballard, J.A. Landscape transformations in rapidly developing peri-urban areas of Accra, Ghana: Results of 30 years. *Open Geosci*. **2019**, *11*, 172–182.
33. Perez-Campana, R.; Valenzuela-Montes, L.M. Nodes of a peri-urban agricultural landscape at local level: An interpretation of their contribution to the eco-structure. *J. Environ. Plan. Manag*. **2018**, *61*, 406–429.
34. Pribadi, D.; Pauleit, S. The dynamics of peri-urban agriculture during rapid urbanization of Jabodetabek Metropolitan Area. *Land Use Pol*. **2015**, *48*, 13–24.
35. Dadashpoor, H.; Ahani, S. Explaining objective forces, driving forces, and causal mechanisms affecting the formation and expansion of the peri-urban areas: A critical realism approach. *Land Use Policy*. **2021**, *102*, 105232.
36. Perez-Belmont, P.; Lerner, A.; Mazari-Hiriart, M.; Valiente, E. The survival of agriculture on the edge: Perceptions of push and pull factors for the persistence of the ancient chinampas of Xochimilco, Mexico City. *J. Rural Stud*. **2021**, *86*, 452–462.
37. Bogunovic, I.; Viduka, A.; Magdic, I.; Telak, L.J.; Francos, M.; Pereira, P. Agricultural and forest land-use impact on soil properties in Zagreb Periurban Area (Croatia). *Agron. J.* **2020**, *10*, 1331.
38. Calzolari, C.; Tarocco, P.; Lombardo, N.; Marchi, N.; Ungaro, F. Assessing soil ecosystem services in urban and peri-urban areas: From urban soils survey to providing support tool for urban planning. *Land Use Pol*. **2020**, *99*, 105037.
39. Huang, S.; Chen, Y.; Kuo, F.; Wang, S. Emergy-based evaluation of peri-urban ecosystem services. *Ecol. Complex*. **2011**, *8*, 38–50.
40. Rigby, D.; Woodhouse, P.; Young, T. Constructing a farm level indicator of sustainable agricultural practice. *Ecol. Econ*. **2001**, *39*, 463–478.
41. Boody, G.; Vondracek, B.; Andow, D.A.; Krinke, M.; Westra, J.; Zimmerman, J.; Welle, P. Multifunctional agriculture in the United States. *Bioscience* **2005**, *55*, 27–38.
42. Song, B.; Robinson, G.M. Multifunctional agriculture: Policies and implementation in China. *Geogr. Compass*. **2020**, *14*, e12538.
43. Zhou, T.; Vermaat, J.E.; Ke, X. Variability of agroecosystems and landscape service provision on the urban-rural fringe of Wuhan, Central China. *Urban Ecosyst*. **2019**, *22*, 1207–1214.
44. Russo, A.; Escobedo, F.J.; Cirella, G.T.; Zerbe, S. Edible green infrastructure: An approach and review of provisioning ecosystem services and disservices in urban environments. *Agric. Ecosyst. Environ*. **2017**, *242*, 53–66.
45. Swinton, S.M.; Lupi, F.; Robertson, G.P.; Hamilton, S.K. Ecosystem services and agriculture: Cultivating agricultural ecosystems for diverse benefits. *Ecol. Econ*. **2007**, *64*, 245–252.
46. Zhang, W.; Ricketts, T.; Kremen, C.; Carney, K.; Swinton, S. Ecosystem services and dis-services to agriculture. *Ecol. Econ*. **2007**, *64*, 253–260.

47. Islam, G.; Islam, A.; Shopan, A.A.; Rahman, M.; Lazar, A.; Mukhopadhyay, A. Implications of agricultural land use change to ecosystem services in the Ganges delta. *J. Environ. Manage*. **2015**, *161*, 443–452.
48. Stenchly.; Waongo, A.; Schaeper, W.; Nyarko, G.; Buerkert, A. Structural landscape changes in urban and peri-urban agricultural systems of two West African cities and their relations to ecosystem services provided by woody plant communities. *Urban Ecosyst*. **2019**, *22*, 397–408.
49. Torquati, B.; Giacchè, G.; Tempesta, T. Landscapes and services in peri-urban areas and choice of housing location: An application of discrete choice experiments. *Land* **2020**, *9*, 393.
50. Cui, J.; Yan, P.; Wang, X.; Yang, J.; Li, Z.; Yang, X.; Sui, P.; Chen, Y. Integrated assessment of economic and environmental consequences of shifting cropping system from wheat-maize to mono-cropped maize in the North China Plain. *J. Clean Prod*. **2018**, *193*, 524–532.
51. Zhou, ZX.; Robinson, GM.; Song, BJ. Experimental research on trade-offs in ecosystem services: The agro-ecosystem functional. spectrum. *Ecol. Indic.* **2019**, *106*, 105536.
52. Chakraborty, S.; Avtar, R.; Raj, R.; Minh, H. Village level provisioning ecosystem services and their values to local communities in the peri-urban areas of Manila, The Philippines. *Land* **2019**, *8*, 177, 1–18.
53. Manners, R.; Varela-Ortega, C.; The role of decision-making in ecosystem service trade-offs in lowland Bolivia's Amazonian agricultural systems. *Ecol. Econ.* **2018**, *153*, 31–42.
54. Montoya, D.; Haegeman, B.; Loreau, M. Trade-offs in the provisioning and stability of ecosystem services in agroecosystems. *Ecol. Appl.* **2019**, *29*, e01853.
55. Christopher, D.; Kendal, D. Values and attitudes of the urban public towards peri-urban agricultural land. *Land Use Pol*. **2013**, *34*, 80–90.
56. Reng, T.; Zhou, Z. Influence of agricultural structure transformation on ecosystem services and human well-being: Case study in Xi'an metropolitan area. *Acta Ecol. Sin.* **2019**, *37*, 2553–2365.
57. Pili, S.; Grigoriadis, E.; Carlucci, M.; Clemente, M.; Salvati, L. Towards sustainable growth? A multi-criteria assessment of (changing) urban forms. *Ecol. Indic.* **2017**, *76*, 71–80.
58. Dadashpoor, H.; Azizi, P.; Moghadasi, M. Analyzing spatial patterns, driving forces, and predicting future growth scenarios for supporting sustainable urban growth: Evidence from Tabriz metropolitan area, Iran. *Sustain. Cities Soc.* **2019**, *47*, 101502.
59. Langemeyer, J.; Madrid-Lopez, C.; Mendez, G.V. Urban agriculture—A necessary pathway towards urban resilience and global sustainability? *Landsc. Urban Plan*. **2021**, *210*, 104055.
60. Rolf, W.; Diehl, K.; Zasada, I.; Wiggering, H. Integrating farmland in urban green infrastructure planning. An evidence-based synthesis for informed policymaking. *Land Use Pol*. **2020**, *99*, 104823.
61. Viana, C.M.; Freire, D.; Abrantes, P.; Rocha, J.; Pereira, P. Agricultural land systems importance for supporting food security and sustainable development goals: A systematic review. *Sci. Total Environ*. **2021**, *806*, 150718.62.
62. Zhang, B.; Zhou, Z. Impact of land use change on agro-ecosystem services in Qinba Mountain area: A case study of Hanzhong Basin. *J. Shaanxi Norm. Univ.* **2020**, *48*, 21–31.
63. Li, M.; Zhou, Z. Positive and negative ecosystem services evaluation and its spatial pattern analysis on urban landscape: A case study of Xi'an City. *Acta Geographica Sinica* **2016**, *71*, 1215–1230.
64. Reid, W.V.; Mooney, H.A.; Cropper, A. *Millennium Ecosystem Assessment. Ecosystems and Human Well-Being: Synthesis*; Island Press: Washington, DC, USA, 2005.
65. Hu, Z.; Yang, X.; Yang, J.; Yuan, J.; Zhang, Z. Linking landscape pattern, ecosystem service value, and human well-being in Xishuangbanna, southwest China: Insights from a coupling coordination model. *Glob. Ecol. Conserv*. **2021**, *27*, 1583.
66. Liu, L.; Wu, J. Ecosystem services-human wellbeing relationships vary with spatial scales and indicators: The case of China. *Res. Conserv. Recycl.* **2021**, *172*, 105662.
67. Schultner, J.; Dorresteijn, I.; Manlosa, A.; Wehrden, H.; Hylander, K.; Senbeta, F.; Fischer, J. Ecosystem services from forest and farmland: Present and past access separates beneficiaries in rural Ethiopia. *Ecosyst. Serv.* **2021**, *48*, 101263.
68. Wheeler, R.; Lobley, M. Managing extreme weather and climate change in UK agriculture: Impacts, attitudes and action among farmers and stakeholders. *Clim. Risk Manag.* **2021**, *32*, 100313.
69. Verhagen, W.; van der Zanden, E.H.; Strauch, M.; van Teeffelen, A.J.; Verburg, P.H. Optimizing the allocation of agri-environment measures to navigate the trade-offs between ecosystem services, biodiversity and agricultural production. *Environ. Sci. Policy*. **2018**, *84*, 186–196.
70. Chami, E.; Daccache, A.; Moujabber, M. What are the impacts of sugarcane production on ecosystem services and human well-being? A review. *Ann. Agric. Sci*. **2020**, *65*, 188–199.
71. Fisher, C.; Gayer, C.; Kurucz, K.; Riesch, F.; Tscharntke, T.; Batáry, P. Ecosystem services and disservices provided by small rodents in arable fields: Effects of local and landscape management. *J. Appl. Ecol.* **2017**, *55*, 548–558.
72. Murray, I.; Jover-Avella, G.; Fullana, O.; Tello, E. Biocultural heritages in Mallorca: Explaining the resilience of peasant. landscapes within a Mediterranean Tourist Hotspot, 1870–2016. *Sustainability* **2019**, *11*, 1926.
73. Montanaro, G.; Xiloyannis, C.; Nuzzo, V.; Dichio, B. Orchard management, soil organic carbon and ecosystem services in. Mediterranean fruit tree crops. *Sci. Hortic.* **2017**, *217*, 92–101.

74. Aubry, C.; Manouchehri, N. Urban agriculture and health: Assessing risks and overseeing practices. *J. Field Actions* **2019**, *20*, 108–111.
75. Sroka, W.; Bojarszczuk, J.; Satoła, L.; Szczepanska, B.; Sulewski, P.; Lisek, S.; Luty, L.; Zioło, M. Understanding residents' acceptance of professional urban and peri-urban farming: A socio-economic study in Polish metropolitan areas. *Land Use Pol*. **2021**, *109*, 105599.