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Analyzing Macro-Level Ecological Change and Micro-Level Farmer Behavior in Manas River Basin, China

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Abstract: Environmental degradation is closely related to unreasonable land use behaviors by farmers. In this study, participatory rural assessment (PRA) is used to conduct a detailed survey of farmers and plots and to collect relevant natural and social statistics. The accuracy of remote sensing data is verified by comparative analysis, and the change in status of various land use types in each research period is reflected by the change in the dynamic degree and change in range. We examine how farmers' attitudes and behaviors affect environmental degradation, using a sample of 403 farmers in China's Manas River Basin. Due to age, education, income and other differences, farmers' land use behaviors, as well as their attitude toward and feelings about environmental degradation, vary greatly. We found that most farmers considered the environment to be very important to their lives and crop production, but nearly 21% did not know the causes of environmental degradation and nearly 8% did not consider the environmental impacts of their crop production activities. A new model for oasis expansion—land integration—is presented here. This model can increase the area of cultivated land, reduce cultivated land fragmentation, save irrigation water, improve the field microclimate and form a good ecological cycle. Through land transfer, ecological compensation and ecological protection incentives, the government should guide farmers' land use behaviors toward cooperation with the river basin's ecological protection and land use planning.

Keywords: Manas river basin; farmers' land use behaviors; PRA; ecological degradation; land integration

1. Introduction

Arid areas of Northwestern China experience glacier recession, the drying-up of lakes, decreased river runoff, vegetation decline, soil salinization and land desertification [1–4]. Such ecological degradation affects social and economic development and people's livelihoods. Research shows that farmers' decision-making behaviors are major causes of regional environmental deterioration [5–7]. Because farmers are the main sources of agricultural land use, their land use behaviors significantly impact regional ecological environments. Farmers' perceptions of ecological degradation do not entirely depend on environmental conditions but are also influenced by factors including farming years, experience, funds and social networks [8,9].

The Manas River Basin oasis, located on the northern slope of the Tian Shan Mountains, is a typical example of the agricultural irrigation oases found in arid regions of China [10]. Since the 1950s, the exploitation of water and soil in these arid regions has led to the rapid expansion of artificial oases and the shrinking of natural oases [10–12]. This excessive human exploitation of water and land resources has also extensively changed the ecosystem and caused a sharp decline in the ecological service value [4,10,13–15] of the arid basin. Farmers' perceptions of ecological change, as well as their response strategies, are crucial to the sustainable development of the Manas River Basin. However, few studies have examined the relationship between macro-level environmental changes and micro-level farmer behaviors.

At present, farmers' unreasonable land use behaviors are causing serious damage to the environment. Therefore, it is of urgent need to adjust farmers' behaviors. One method of accomplishing this would involve the implementation of land integration in the oasis, i.e., increasing the cultivated land area, increasing crop yield, transferring the agricultural surplus labor force, diversifying farmers' income, reducing population pressure on the environment and building a new pattern of urban–rural integration [11,16–18]. In 2004, Xiazhuangzi village in Sidaohezi—a town in Shawan County—took the lead in land integration, improving the fragmentation of land, promoting a continuous concentration of cultivated land and realizing the large-scale management of cultivated land. Subsequently, farmers in Shihezi, Manas and other places in the Manas River basin have also implemented land integration. However, few reports have covered this.

Therefore, based on the above considerations, the aims of this study are to (1) analyze the relationships between farmers' land use behaviors and environmental degradation; (2) study farmers' feelings about and responses to environmental degradation; (3) put forward a new model of oasis expansion implementing land integration and realizing oasis connotation expansion; (4) guide farmers to adjust their land use behaviors to encourage the harmonious development of the social economy and the ecological environment in the Manas River Basin.

2. Materials and Methods

2.1. Study Area

The Manas River Basin in Xinjiang is situated between 43°5–45°58′ N and 84°42–86°33′ E, originating from the northern side of the Tian Shan Mountains (Figure 1). From south to north, the area features alpine glaciers, forests, meadows, an alluvial fan and alluvial plain and deserts.

The basin experiences a continental arid desert climate, with low precipitation and large differences in precipitation distribution. The total average annual runoff volume from the basin is 22.198×10^8 m^3, the average annual precipitation reaches 115–200 mm, the average annual evaporation is 1500–2100 mm and the average annual temperature is 4.7–5.7 °C. The basin includes Manas County, Shawan County, Shihezi City and 14 farms in the Xinjiang Corps Eighth Division. Xinjiang Production and Construction Corps is a special social organization that integrates the party, government, army and enterprise. It represents a basic implementation of the military organizational system. The company is the basic component of Xinjiang Production and Construction Corps (XPCC) and also the smallest unit of the agricultural economic production of XPCC (for example, the 13th company).

The basin has a total area of 3.135×10^4 km^2, making it the largest artificial oasis on the northern side of the Tian Shan Mountains [4,10,19,20]. In 2017, the basin had a population of 1.11 million; it also had an annual output of 365,000 tons of grain, 382,000 tons of cotton, 369,000 tons of sugar beets, 2.54 million heads of livestock, approximately 125,000 tons of meat and an agriculture and a livestock husbandry output value of greater than CNY 4.21 billion (the data mainly originate from relevant organizations and departments of land, water conservancy, agriculture, and meteorology in Manas County, Shawan County and the eighth division in Xinjiang Production and Construction Corps).

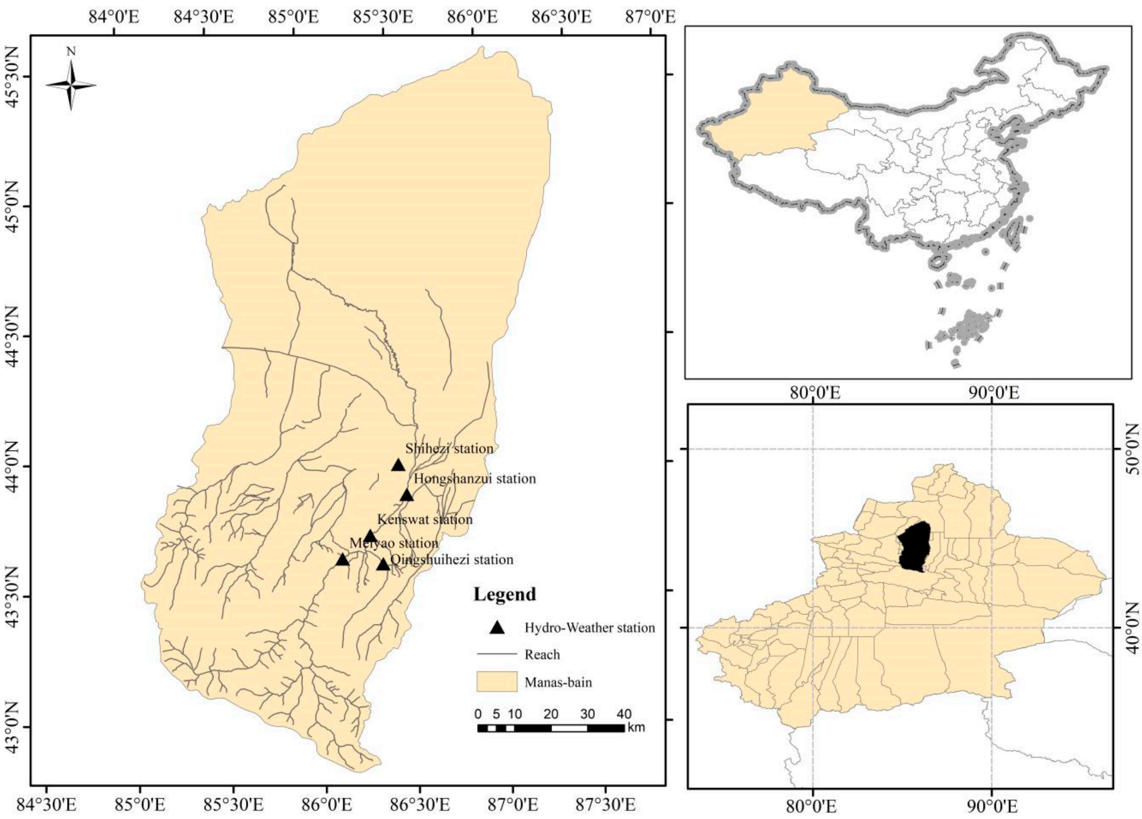

Figure 1. Map of the study area with the administrative division of the Manas River Basin.

There are 13.82 × 10^4 households and nearly 78.65 × 10^4 hm^2 of cultivated land in the Manas River Basin. The oasis of the Manas River Basin is the fourth largest irrigation area in Xinjiang, which plays an important role in agricultural production in Xinjiang. The basin corps is a large-scale, state-owned enterprise which operates self-sufficiently. The basin area is in the stage of agricultural structure adjustment centering on the development of animal husbandry [21]. Compared with the central and eastern regions of China, the economic development of the basin is relatively poor; farmers mainly cultivate crops, and so the farmer's cultural level is generally low. The number of farmers engaged in secondary and tertiary industries is relatively small (no more than 5%), and the proportion of nonagricultural income is also very small. Therefore, farmers heavily depend on the land and the scale and intensity of agricultural production.

2.2. Data Sources and Processing

2.2.1. Land Use Data

In this paper, we selected remote sensing data of the Manas River Basin from the NASA website (https://www.nasa.gov/) [22–26]; data mainly included satellite images from 1958, Landsat Multispectral Scanner System (MSS) images from 1976, and Landsat Thematic Matter/Enhanced Thematic Matter (TM/ETM) images from 1976, 1987, 1998 and 2015. To ensure the reliability of data, the remote sensing images were chosen from the period from August to September of the corresponding year. This is because the period from August to September represents the late summer and early autumn period of Xinjiang, in which the weather is relatively clear and the cloud coverage is low, making it the optimal period to obtain all kinds of ground feature images. Although the spectrum changes greatly over different years, the spectral response of the same feature in the same period is relatively consistent, which ensures the accuracy of images. Cloud pixels were removed from the images via rough and fine geometric corrections, radiometric calibrations, band fusion and mosaicking. The researchers employed eCognition 8.7 remote sensing classification software to conduct multi-scale segmentation and feature extraction with the remote sensing images. The images were visually interpreted relative to high-resolution images from Google Earth, and the interpretation results were corrected by a field investigation, as shown in Figure 2.

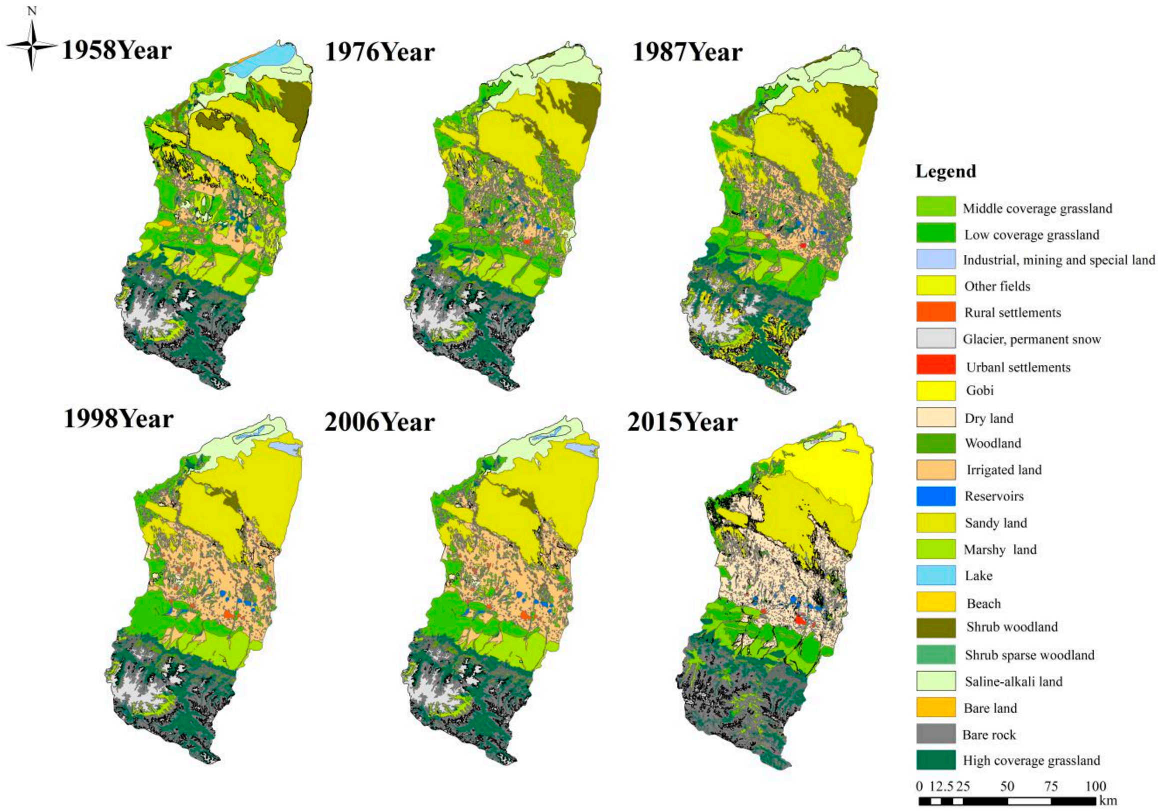

Figure 2. Land use types in the Manas River Basin, 1976–2015.

2.2.2. Questionnaire and Statistics Data

In November–December 2018 and March–April 2019, we developed a large number of questionnaires and interviewed farmers in different areas of the Manas River Basin about their land use behaviors, environmental awareness, feelings and coping styles. Through the data collected from these questionnaires, combined with the abovementioned field survey, systematic statistical analyses were carried out. In this paper, 156 farmers from Jiahezi village, Fengyigong village, Heishawo village and Tupaoying village in Manas County and 254 employees from the 13th company of regiment 121, company 26 of regiment 142 and company 4 of regiment 143 of the Xinjiang Production and Construction Corps were selected as the survey objects, and 420 questionnaires were obtained. The sample in the survey was as follows:

(1) Age and gender of farmers: the age range of the survey was 16–73 years of age; most of the farmers were between 30–55 years old, only 0.62% were under 30 years old, and there were few farmers over 60 years old;
(2) Farmers' education level: 76% of farmers had a junior high school education, and 34% had a level of high school education or above;
(3) Investment in agriculture, animal husbandry or forestry: agricultural inputs were mostly seeds, fertilizer, films and pesticides, while animal husbandry inputs were feed, feeding technology, grassland, etc., and forestry inputs were seedlings, fertilizer, etc.;

(4) Division of upper, middle and lower reaches: the upper reaches belong to the low mountains and hills, representing the ecotone of agriculture and animal husbandry; the middle reaches are the oasis area; and the lower reaches are the desert marginal areas.

2.3. Study Methods

2.3.1. Land Use Change

The land use equation was applied as follows

$$R = (U_b + U_a)/U_a \times 100\% \quad (1)$$

$$K = (U_b - U_a)/U_a/T \times 100\% \quad (2)$$

$$P = \begin{bmatrix} P_{11} & P_{12} & \cdots & P_{1n} \\ P_{21} & P_{22} & \cdots & P_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ P_{n1} & P_{n2} & \cdots & P_{nn} \end{bmatrix} \quad (3)$$

where R is the representative range of land use change, K is the representative dynamic degree of land use change, P is the transfer matrix for calculating land use change, U_a and U_b, respectively, represent the area of a certain land category at the beginning and the end of the study period, and T represents the study period.

2.3.2. Participatory Farmer Evaluation Method

Questionnaire interviews were combined with a plot survey (participatory rural appraisal (PRA)) [27–30]. Under the guidance of village cadres and local insiders, the farmers were interviewed, then, the land parcel survey was carried out. Following the advice of local insiders and farmers participating in the questionnaire survey, a field survey was conducted on the transferred land. The researchers used a global positioning system (GPS), a tape measure, theodolite, shovel and record book to record the area of the plot, crop planting type, irrigation mode, yield, etc. The study investigated a total of 420 farmers. We eliminated 17 incomplete and invalid questionnaires; therefore, 403 valid questionnaires were analyzed.

2.3.3. Comparative Analysis of Land Integration

In order to fully understand and master the implementation of land integration, this paper used the village level LSV (LocaSpace Viewer) remote sensing images with a 0.3 m resolution in 2007 (before the integration) and 2017 (after the integration) to ensure that the accuracy met the requirements. The authors first set up the sample in the field, carried out the experiment to determine the net cultivated land coefficient and compared the land use types of the measured samples with the results of the LSV image interpretation. The similarity between the two was approximately 97%, and the LSV images met the study's requirements. Next, taking seven villages ((Tupaoying Village, Heishawo Village, Fengyigong Village, Jiahezi Village (these four villages are located in different towns of Manas County) and company 13 of corps 121, company 16 of corps 142, company 4 of corps 143 (these three companies are located in the eighth division in Xinjiang Production and Construction Corps)) as research objects, the authors quantified and compared the differences in the change of cultivated land area, irrigation water volume, and crop output value before and after land integration.

3. Results

3.1. Analysis of Farmers' Land Use Behavior

3.1.1. Farmer Demographics

The average age among the 403 interviewed farmers was 44 years, with a range of 16–73 (Table 1). The family unit consisted mainly of four to six members (46%). In many households, two people were part of the labor force (44%). Nearly half of the interviewed farm families (43%) worked at other farms. In response to questions about their degrees of satisfaction, 32% of farmers responded that they were satisfied with their lives, 46% were neutral and 22% were dissatisfied (Table 1).

Table 1. Farmer demographics in the Manas River Basin.

Category		Total	
		Frequency	%
Education	Illiterate or nearly illiterate	36	9
	Elementary school	76	19
	Middle school	152	38
	Senior school	115	29
	College and above	24	5
Occupation	Planting industry	305	75
	Livestock husbandry	64	16
	Service industry	17	4
	Transport service	9	3
	Others	8	2
Family population	<4	164	41
	[4,6]	186	46
	>6	53	13
Labor force	<2	103	26
	=2	176	44
	>2	124	30
Off-farm work	Yes	174	43
	No	229	57
Satisfaction with living	Satisfied	129	32
	Somewhat satisfied	186	46
	Dissatisfied	88	22

3.1.2. Farmers' Land Use Behaviors

Farmers' land use behaviors may largely be defined as the farmers' production and decision-making behaviors concerning agricultural land use. In the Manas River Basin, farmers' rational land use behaviors include the following: amending soil, actively transferring land, implementing land integration, reasonably using water resources, converting farmland to forest or grassland, and improving irrigation and drainage systems. At present, the rapid development of the social economy in the Manas River Basin is also the result of farmers' rational land use. However, due to the lack of farming experience, there are some problems, such as not paying attention to the maintenance of land and inactive agricultural production management. Older farmers have a relatively low education level and rich farming experience. Their livelihood depends on the land, and they pay more attention to land conservation than younger farmers. However, due to differences in environmental awareness, production, operation and income, farmers' unreasonable land use behavior has also intensified environmental degradation.

3.2. Analysis of Farmers' Unreasonable Land Use Behavior

3.2.1. Decline of Natural Forest and Grassland

As can be seen in Figure 2 and Table 2, between 1958 and 2015, the area of high-coverage grassland in the Manas River Basin was reduced from 4154.70 to 3112.10 km^2. The areas of medium-coverage grassland, low-coverage grassland, sparse wood and shrub wood were reduced from 4560.48 to 2694.08 km^2, from 5908.05 to 3816.58 km^2, from 75.85 to 44.78 km^2, and from 1900.98 to 41.44 km^2, respectively. Although the natural forest and grassland increased in some years, the total area has followed a decreasing trend. In addition, the relevant literature indicates that, during the 1950s, mountain forests covered 1500 km^2 of the basin; 38% of these forests have since been harvested. Grassland areas have also decreased due to overgrazing, and vegetation cover has shifted from tall trees and shrubs to low shrubs. For example, the prevalence of reeds has declined by nearly 91%, with only 24 km^2 remaining; only 212 km^2 of desert forest is intact, and the remaining vegetation has been impacted by desertification at a rate of nearly 927 km^2/a.

Table 2. Changes in natural forests and grasslands from 1958 to 2015; unit: km^2.

	1958	1976	1987	1998	2006	2015
High-coverage grassland	4154.70	3943.81	4236.53	3880.37	3480.17	3112.10
Middle-coverage grassland	4560.48	3718.90	2072.89	3242.46	2546.90	2694.08
Low-coverage grassland	5908.05	6145.20	6051.61	4311.64	4384.78	3816.58
Sparse wood	75.85	99.75	136.81	47.02	9.077	44.78
Shrub wood	1900.98	1893.56	1760.42	485.65	530.06	41.44

Deforestation, vegetation destruction and overgrazing patterns by farmers, alongside other such behaviors, are carried out for farmers to make their livelihoods; however, these activities aggravate the degradation of forests and grasslands.

3.2.2. Increased Desertification

The analysis of land use/cover changes revealed that the area of desertification and salinization in the Manas River Basin is increasing, as is the degree of degradation (see Figure 2). At present, most farmland in the basin is irrigated by flood irrigation, which wastes a large amount of water resources. The high-salinity water from Tail Lake frequently exchanges with the groundwater, and groundwater extraction by well drilling is becoming more common, leading to a continuous increase in soil salinization. On the other hand, loose sediment in the Tail Lake area has become a source of sandstorms, and the retreat of lake water has caused the soil of the lake basin has become increasingly salinized The increase in bare area has also led to a greater number of sandstorm days.

According to the results of the remote sensing satellite survey (Figure 2), heavily salinized soil is distributed in the towns of Sidaohezi and Laoshawan, encompassing 136 and 135 farms, respectively, and around Manas Lake in the lower reaches of the study area, with a total area of 2206.01 km^2. Moderately salinized soil is distributed around the severe salinization area and the middle reservoirs (Jiahezi Reservoir, Yuejin Reservoir, Xinhuping Reservoir, etc.), with a total area of 5122.18 km^2. Mildly salinized soil is mainly distributed in the irrigation area and the transition zone between oasis and desert, with an area of 1829.40 km^2. Heavily and moderately salinized soils already make up 7328.19 km^2 of the study area; 80 km^2 of cultivated land has been abandoned because of severe desertification.

To a large extent, the salinization of the basin is caused by man-made secondary salinization. For example, farmers' unreasonable flood irrigation raises the groundwater level, while evaporation in the arid area is at a far greater level than precipitation and the underground mineralized water accumulates salt on the surface via the evaporation of phreatic water.

3.2.3. Decline in Groundwater Levels

In the last 60 years, large-scale water resource development has been carried out in the upper and middle reaches of the basin to accommodate a rapid increase in human population and the economy. This has decreased the levels of surface water coming from the lower reaches of the river. The farms of companies 150, 136 and 121 near the downstream desert zone have difficulty introducing surface water, resulting in the increased desertification of the land. The exploitation of groundwater in the basin has reached 7.29×10^8 m^3, accounting for 58% of the exploitable amount. In the last 40 years, groundwater level in farms of corps 150, corps 121 and corps 136 (these three corps are located in the eighth division in Xinjiang Production and Construction Corps) in the Manas River Basin, and in the marginal zones of other oases, decreased by more than 12 m (Figure 3).

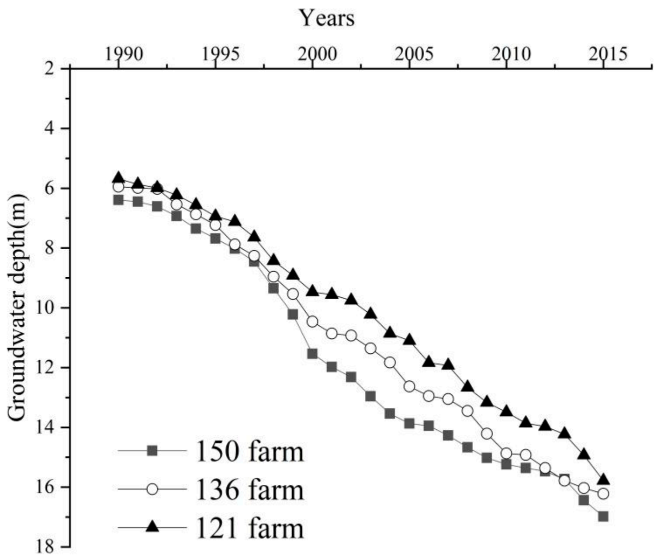

Figure 3. The change in groundwater depth at farms 150, 136, and 121 from 1990 to 2015.

Obviously, because there is insufficient surface water for irrigation, the digging of wells by farmers to irrigate their crops is the direct reason for the decline in the groundwater level.

3.2.4. Changes in the Water System Structure

Since the 1950s, a series of artificial diversion channels has been built in the Manas River Basin, which has obviously changed the basin's water system structure (see Table 3 and Figure 4). For example, from 1958 to 2006, the length of the water system continuously increased. From 1958 to 1976 and from 1987 to 2006, the growth rates were 32.65 and 29.71 km/a, respectively. This shortened—or even cut off—the lower reaches of the Manas River, causing the water quality to deteriorate, decreasing biodiversity and limiting the water supply to grasslands, pastures, the oasis margin and the transitional desert zone [31–34].

Table 3. Length and density changes of streams in the Manas River Basin from 1958–2006.

Manas River Basin	Year				Period Variation		
	1958	1976	1987	2006	1958–1976	1976–1987	1987–2006
Drainage length (km)	4428.06	5015.75	5176.93	5741.5	587.69	161.18	564.57
Water network density (km/km^2)	0.1322	0.1497	0.1546	0.1714	0.0175	0.0049	0.017

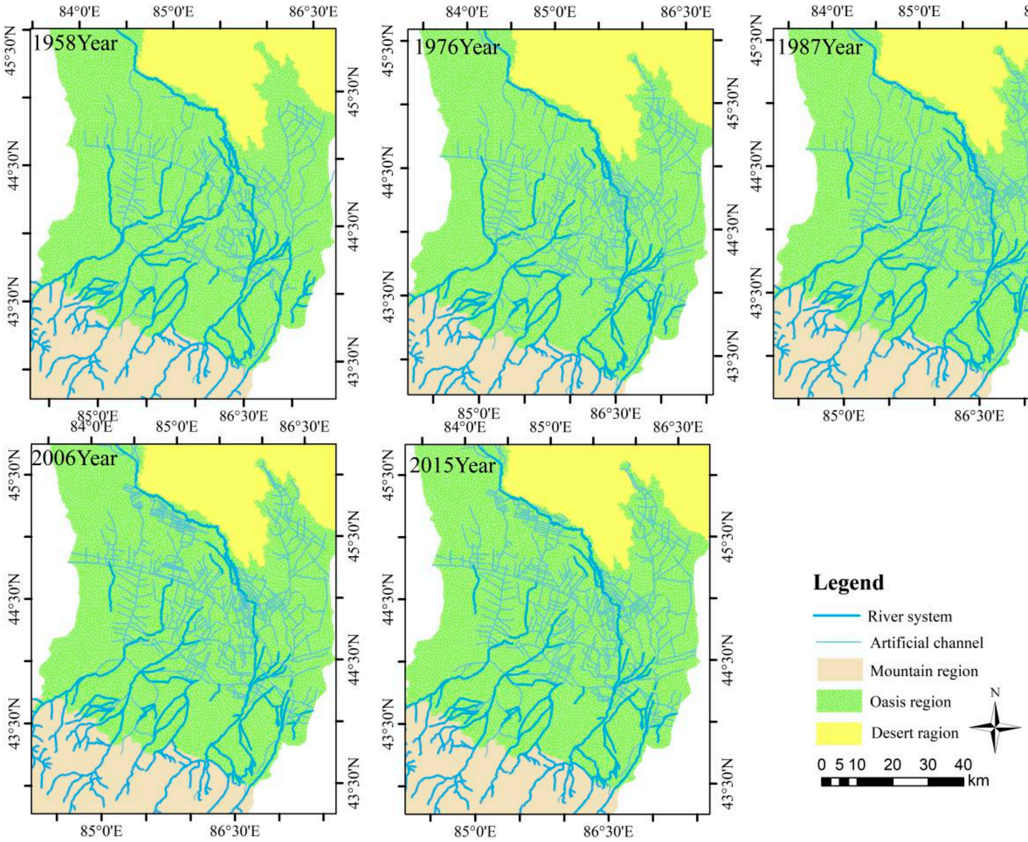

Figure 4. Stream construction of the Manas River Basin from 1958–2015.

With the increase in population and the oasis scale, the demand for and dependence on water resources are increasing. Changes in the water system structure and the shrinkage of Tail Lake are the indirect result of farmers' behaviors.

3.2.5. Population Evolution in the Study Area

From 1978 to 2017, the population of the basin increased from 630,700 to 1,128,500, i.e., almost doubling. The population of Manas, Shihezi and Shawan showed an increasing trend (Figure 5). Through the analysis, the evolution of the population was shown to correspond to the reduction in high-, medium- and low-coverage grassland, sparse wood and shrub wood in the same period as the continuous increase in land desertification and salinization area, the increase in diversion channels and the increase in water demand. The population pressure of the basin is excessive, meaning that the farmers must increase their short-term output and meet their basic living needs by reclaiming wasteland, cutting down forests, destroying vegetation and overgrazing. Although the current behavior for decision-making has already been realized, it is necessary to obtain the necessary commodities from limited resources to ensure the maximization of economic benefits. However, the ecological environment of the oasis is fragile, and the excessive development and utilization of resources by farmers will easily lead to pressure on resources and environmental deterioration, and their land use behavior is obviously unsustainable. For example, due to overgrazing and deforestation, most of the forests and grasslands in the upper reaches of the basin have been degraded. The use of films, pesticides and other white pollution in the central and lower reaches of the region has led to a decline in land quality. Due to mining, reclamation of wasteland and the drilling of wells at the edge of the desert, desertification has been intensified.

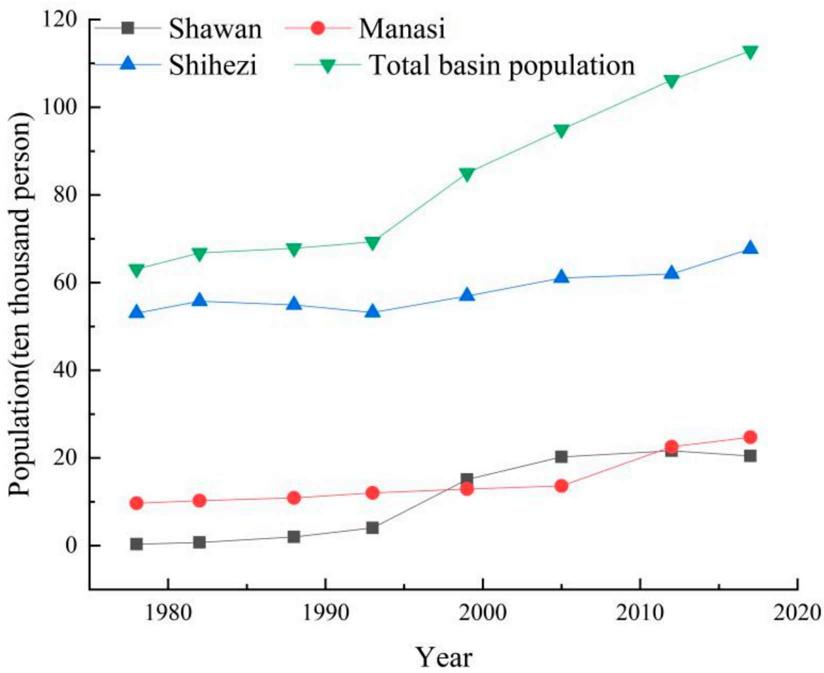

Figure 5. Population evolution in the study area.

3.3. Farmers' Understanding of and Feelings about Environmental Degradation

3.3.1. Effects of Environmental Factors on Farmers' Land Use

Environmental factors have a strong impact on farmers' land use behavior. It can be seen from Table 4 that soil erosion, sandstorm damage, snowstorm and other problems in the cultivated land environment are mostly caused by uncontrollable extreme weather (natural environmental factors). However, the problems of salinization, desertification, forest and grassland degradation and water quality deterioration in cultivated land are obviously caused by human activities. Therefore, the influencing factors are classified into natural environmental factors and human-activity-influenced factors. These two factors affect farmers' land use behavior by different degrees.

Table 4. Ecological factors affecting farmers' land use.

	Category	**Total**	
		Frequency	**%**
Environmental factor	Shortage of water resources	128	32
	Sandstorm	234	58
	Flood	53	13
	Snowstorm	217	54
	Forest degradation	67	17
	Grassland degradation	89	22
	Soil and water loss	164	41
	Water quality deterioration	243	61
	Salinization	325	81
	Desertification	175	43
	Vegetation decay	143	11

3.3.2. Farmers' Awareness of the Causes of Environmental Degradation

In our survey concerning the causes of environmental degradation (Table 5), more than 45% of farmers thought that the leading cause was the loss of natural vegetation, 44% thought that water and soil loss affected the environment, approximately 33% thought degradation was due to the estrepement of land, and 21% were not aware of the causes of environmental degradation.

Table 5. Farmers' awareness regarding the causes of environmental degradation.

Category	Total	
	Frequency	%
Dry weather	94	23
Overgrazing	124	31
Estrepement of land	131	33
Vegetation damage	184	46
Severe water and soil loss	176	44
Unknown	84	21

3.3.3. Farmers' Awareness of Environmental Protection

The survey responses indicated large differences in farmers' awareness of environmental protection (Table 6). When asked whether the environment was important to production and life, more than 70% of farmers thought that it was important, indicating that their awareness of the environment has improved. In total, 65% thought that environmental impacts should be considered when arranging production activities. Compared with ten years ago, about 70% of farmers thought that the local environment had improved. For example, the low mountain and hilly area in the upper reaches correspond to a desert steppe and dry steppe, respectively, and the grassland area tends to be stable because of serious grassland reclamation. In the middle reaches of the oasis, the expansion mode of cultivated land changes from external expansion to internal expansion, which causes the cultivated land area to steadily increase under the premise of protecting the ecological environment; the extension of desertification to the oasis is effectively controlled in the lower desert marginal area, and this was attributed to the strengthened improvement in the ecological environment; in recent years, governments have launched ecological protection projects such as ecological forestry construction, the grain-for-green policy, the conversion of farmland to forest and efficient water-saving ecological agriculture methods in the Manas River Basin. Farmers downstream of the river basin have the strongest feelings regarding ecological improvements in the Manas River Basin. However, the grain-for-green policy was implemented only recently, and its effects are not yet clear. Nevertheless, 27% of farmers occasionally considered environmental influences when carrying out their production activities. Compared with ten years ago, 22% of farmers thought that the environment had not experienced or caused any apparent changes; this indicates that the concepts of production, operation income, and environmental awareness must be addressed by farmers.

Table 6. Farmers' awareness of the environment.

	Category	Total	
		Frequency	%
Is the environment important in crop production and life?	Important	294	0.73
	Unable to judge	86	0.21
	Unimportant	23	0.06
Do you consider your influence on the environment when planning production activity?	Consider	261	0.65
	Consider occasionally	109	0.27
	Do not consider	33	0.08
How does the local environment today compare with that of 10 years ago?	Improved	284	0.70
	No change	86	0.22
	Deteriorated	33	0.08

3.4. Land Integration Analysis

3.4.1. Analysis of Farmland Changes before and after Land Integration

According to Figure 6, after the land integration of seven villages (company), the fields in the sampled area became more obviously regular; the land fragmentation declined; the combination of fields increased the area of cultivated land; the field roads, production roads, and ditches were re-planned; the agricultural irrigation facilities were improved; and the availability of water for irrigation facilities was ensured. Among them, company 4 of corps 143 had the largest new cultivated land rate (8.58%). In general, the new cultivated land rate of each land integration research area was more than 2%. Land integration effectively increased the cultivated land area and improved the land use rate.

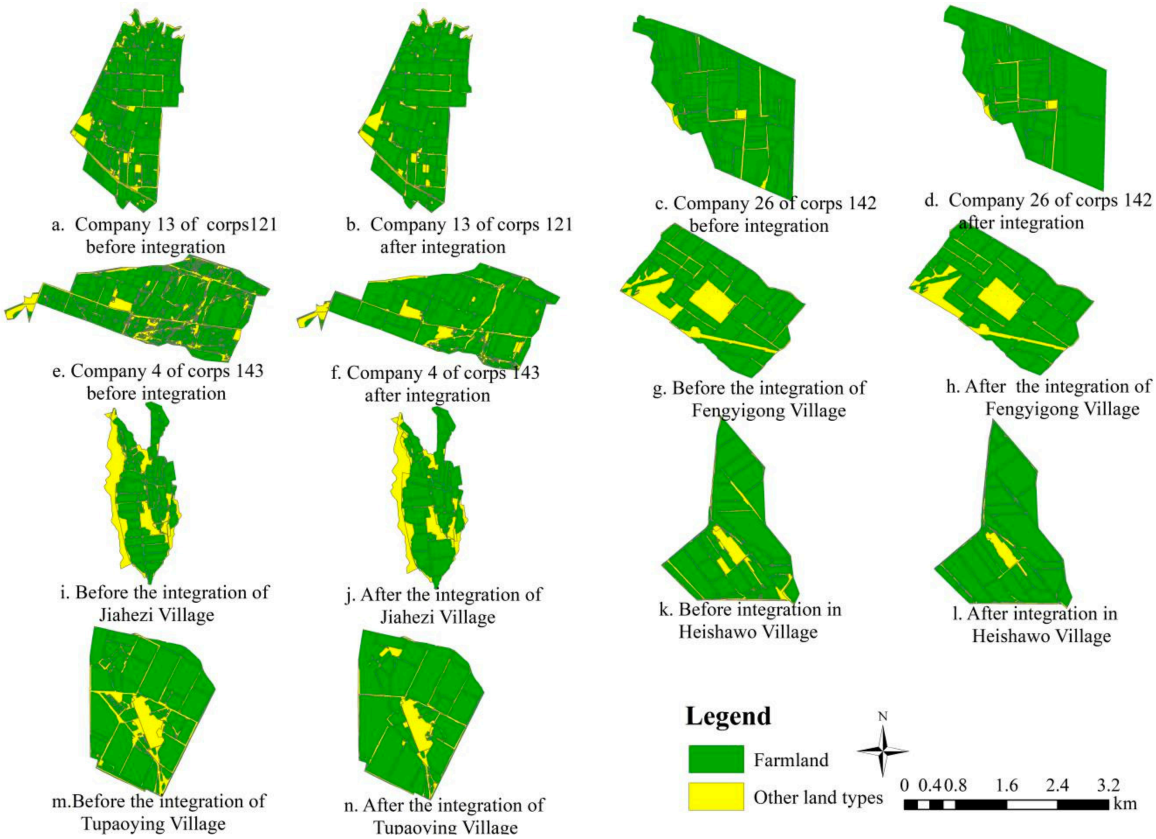

Figure 6. Comparison of seven village teams before and after land integration.

After the land integration of seven villages (companies) (Figure 6), firstly, unnecessary field trails and canals were removed, parts of the wasteland and marginal land were integrated, and the cultivated land landscape became more obviously regular. Secondly, the number of fields decreased significantly, the area of each strip field increased and the area of cultivated land increased significantly. The re-planning of cultivated land, production roads and ditches has improved the agricultural irrigation facilities and guaranteed irrigation water. For example, the cultivated land area of company 13 of regiment 121 increased by 88.29 hm^2, and the new cultivated land rate was 3.14%. After land consolidation, the new cultivated land rate of other villages (companies) ranged from 8.58% to 2.28%. This shows that land integration can effectively increase the cultivated land area and improve the land use rate.

3.4.2. Comparative Analysis of Irrigation Water Changes before and after Land Consolidation

As Figure 7 shows, irrigation water consumption in the seven studied areas declined significantly after land integration over the past 10 years, with an obvious overall trend. The water consumption of Heishawo Village declined most significantly, with a rate of creation of newly arable land of 5.27%. Land integration can not only merge scattered plots, increase the cultivated land area and reasonably adjust the land structure, but can also develop drip irrigation under films over a large area, realize the readjustment and planning of water conservancy facilities and encourage the use of pipeline water delivery for crop irrigation, which can greatly reduce field evaporation and leakage. This both ensures irrigation water consumption and saves irrigation water. Thus, altering patterns of water consumption provides a new method of saving water for irrigation in arid areas.

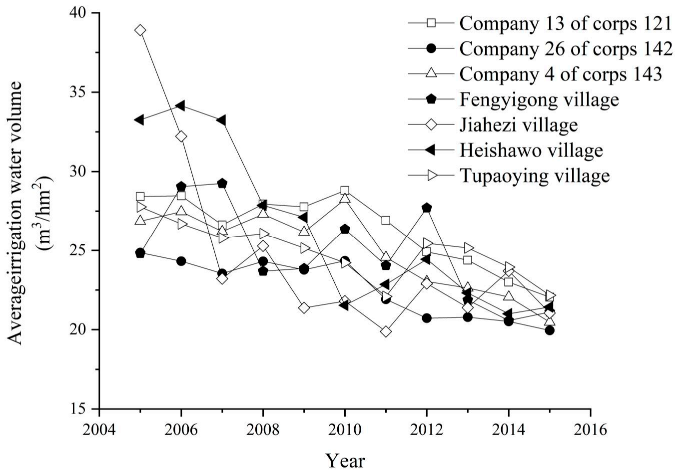

Figure 7. Analysis of irrigation water consumption in the seven sampled villages, 2005–2015.

4. Discussion

The objective of farmers' behavior is utility maximization. The relationship between livelihood and the environment is the core of sustainable development. When people are impoverished, environmental problems cannot be solved. People living merely under conditions of self-sufficiency cannot be required to respect the environment. Therefore, when promoting land integration, we should consider the resource conditions, economic level and various limitations of different regions and actively and steadily carry out land integration work according to local conditions [35]. In this study, farmers made decisions to maximize revenue: when selecting land use types, they first considered how to use limited resources to obtain necessary goods and guarantee maximum economic benefit. Therefore, farmers' behavior toward land use was apparently (relatively) non-sustainable, causing conflict between farmers' behavior and environmental protection.

Extensive oasis expansions, represented by large-scale deforestation and reclamation, overgrazing and the expansion of cultivated lands, have caused the ecological security of oases to decline. However, a large scattered waste land, marginal land and ridge in an oasis can effectively increase the area of cultivated land, improve the use rate of water resources, increase farmers' income, and improve the oasis environment through land transfer and land renovation measures [36–39], allowing oasis agriculture to move towards a more competitive market economy. This is a viable idea for future oasis development.

Land integration is one of the main means to improve and maintain the ecological environment. Land integration is not compulsory for farmers, but it is necessary to guide farmers to actively understand the benefits of land integration (e.g., honestly investigating the land integration model of Shawan). For the surplus labor force after land integration, individual farmers take the lead in terms of setting up cooperatives. The surpluses of farmers take the form of capital, technology, agricultural equipment and land with management rights, and the farmers share dividends at the end of the year. Farmers who lose the right of land management can obtain income for their employees. The government can provide employment training and increase employment posts to increase farmers' incomes and realize the transfer of the rural population to secondary and tertiary industries [40].

Ecosystem management is a comprehensive project, which requires the participation of numerous farmers. The present survey, however, highlights a vast insufficiency in this regard. In the future, ecosystem management must be further publicized, and the environmental awareness of local farmers must be continuously improved. Extension services should also be strengthened in agricultural areas, and water and soil conservation technology must be implemented to serve farmer's needs, improve their knowledge of agricultural technology and enable agricultural production based on local conditions. River basin governments should also guide farmers' land use behaviors to be consistent with the basin's ecological protection and land use planning. This could be accomplished via market regulation, ecological compensation and ecological protection incentives [39,41–43] and would alleviate environmental damage. More importantly, in fragile ecological areas, an ecological red line should be strictly defined and a new pattern of urban–rural integration should be developed [44–46].

5. Conclusions

Generally speaking, farmers around the world have been developing sustainable agricultural systems because they realize that they depend on these resources for their livelihood. However, in times of population pressure, the trend is to take measures to increase short-term production and meet basic needs for land expansion and resource development. In the last 60 years, the population and oasis area of the Manas River Basin has increased, and land use patterns have changed dramatically. These changes have obviously adversely affected the ecosystem, particularly by degrading the forests and grasslands, increasing desertification, diminishing groundwater depth at the oasis margin, changing the water system structure and shrinking Tail Lake. Farmers' unsustainable land use behaviors have been an important factor in the basin's environmental degradation. When farmers' livelihoods conflicted with ecological protection, they prioritized their livelihoods, and their land use behaviors (digging wells, opening wastelands, cutting down forests, damaging vegetation, etc.) intensified ecological degradation.

In the present survey of farmers' environmental awareness and activities, more than 70% of respondents thought the environment was very important, while about 8% did not consider the influence of their production activities on the environment. Approximately 21% of farmers did not know the causes of environmental degradation at all. Such large differences in farmer attitudes and awareness are closely related to the status of the local agroecosystem, as well as to social and economic conditions.

After the implementation of land integration in the seven sampled villages, the cultivated land area increased at an average of 69.80 hm^2, and the average increase rate of cultivated land was 5.03%. The average yield increased by 11.00%, and the farmers' average income grew by 31.65%. The average amount of irrigation water used per hm^2 of farmland decreased significantly (between 5.61 and 17.86 m^3). These points show that land integration in the Manas River Basin effectively increased the scale of the oasis and simultaneously raised the ecological and economic value of the land.

Therefore, implementing land integration is a viable method of oasis expansion for the future. Through this method, farmers can be guided to adjust their land use behaviors to coordinate the development of the social economy and the ecological environment in the basin.

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References

1. Holden, S.; Shiferaw, B.; Pender, J. Non-farm income, household welfare, and sustainable land management in a less-favoured area in the Ethiopian highlands. *Food Policy* **2004**, *29*, 369–392. [CrossRef]
2. Wang, Y.; Liu, Z.; Yao, J.; Bayin, C. Effect of Climate and Land Use Change in Ebinur Lake Basin during the Past Five Decades on Hydrology and Water Resources. *Water Resour.* **2017**, *44*, 204–215. [CrossRef]
3. Yan, J.; Zhang, G.; Deng, X.; Ling, H.; Xu, H.; Guo, B. Does Climate Change or Human Activity Lead to the Degradation in the Grassland Ecosystem in a Mountain-Basin System in an Arid Region of China? *Sustainability* **2019**, *11*, 2618. [CrossRef]
4. Ling, H.; Yan, J.; Xu, H.; Guo, B.; Zhang, Q. Estimates of shifts in ecosystem service values due to changes in key factors in the Manas River basin, northwest China. *Sci. Total Environ.* **2019**, *659*, 177–187. [CrossRef]
5. Huang, X.; Wang, L.; Qian, L. Vulnerability Assessment of Soil and Water Loss in Loess Plateau and Its Impact on Farmers' Soil and Water Conservation Adaptive Behavior. *Sustainability* **2018**, *10*, 4773. [CrossRef]
6. Morris, J.; Gowing, D.J.G.; Mills, J.; Dunderdale, J.A.L. Reconciling agricultural economic and environmental objectives: The case of recreating wetlands in the Fenland area of eastern England. *Agric. Ecosyst. Environ.* **2000**, *79*, 245–257. [CrossRef]
7. Cheng, L.; Zhang, Y.; Sun, H. Vegetation Cover Change and Relative Contributions of Associated Driving Factors in the Ecological Conservation and Development Zone of Beijing, China. *Pol. J. Environ. Stud.* **2020**, *29*, 53–65. [CrossRef]
8. Chowdhury, R.R. Differentiation and concordance in smallholder land use strategies in southern Mexico's conservation frontier. *Proc. Natl. Acad. Sci. USA* **2010**, *107*, 5780–5785. [CrossRef]
9. Thenail, C.; Baudry, J. Variation of farm spatial land use pattern according to the structure of the hedgerow network (bocage) landscape: A case study in northeast Brittany. *Agric. Ecosyst. Environ.* **2004**, *101*, 53–72. [CrossRef]
10. Ling, H.; Xu, H.; Fu, J.; Fan, Z.; Xu, X. Suitable oasis scale in a typical continental river basin in an arid region of China: A case study of the Manas River Basin. *Quat. Int.* **2013**, *286*, 116–125. [CrossRef]
11. Cao, S.; Xia, C.; Yue, H.; Ma, H.; Lin, G. Targeted control measures for ecological restoration in Western Fujian, China. *Land Use Policy* **2018**, *76*, 186–192. [CrossRef]
12. Wossink, A.; Swinton, S.M. Jointness in production and farmers' willingness to supply non-marketed ecosystem services. *Ecol. Econ.* **2007**, *64*, 297–304. [CrossRef]
13. Rufino, M.C.; Verhagen, A.; Hengsdijk, H.; Langeveld, J.W.A.; Ruben, R.; Dixon, J.M.; Giller, K.E. Low-Cost Economic and Environmental Performance Assessment of Farm Households Systems: Application to Mixed Crop-Livestock Systems in the Ethiopian Highlands. *J. Sustain. Agric.* **2008**, *32*, 565–595. [CrossRef]
14. Sierra, R.; Russman, E. On the efficiency of environmental service payments: A forest conservation assessment in the Osa Peninsula, Costa Rica. *Ecol. Econ.* **2006**, *59*, 131–141. [CrossRef]
15. Bannister, M.E.; Nair, P.K.R. Agroforestry adoption in Haiti: The importance of household and farm characteristics. *Agrofor. Syst.* **2003**, *57*, 149–157. [CrossRef]
16. Shi, W. Entropy Analysis of the Coupled Human—Earth System: Implications for Sustainable Development. *Sustainability* **2017**, *9*, 1264. [CrossRef]
17. Olson, K.; Vu, L. Economic efficiency in farm households: Trends, explanatory factors, and estimation methods. *Agric. Econ.* **2009**, *40*, 587–599. [CrossRef]
18. Song, X.; Huang, Y.; Fu, J.; Jiang, D.; Tian, G. Spatial Variability and Ecological Effects of Anthropogenic Activities in a Nature Reserve: A Case Study in the Baijitan National Nature Reserve, China. *Sustainability* **2017**, *9*, 239. [CrossRef]
19. Takemoto, K.; Kajihara, K. Human Impacts and Climate Change Influence Nestedness and Modularity in Food-Web and Mutualistic Networks. *PLoS ONE* **2016**, *11*, e0157929. [CrossRef]
20. Long, H.; Zou, J. Farmland Destroyed by Natural Hazards in China: Spatio-temporal Pattern and IntegratedPrevention and Treatment System. *Disaster Adv.* **2010**, *3*, 592–597.

21. Wang, S.; Tian, Y.; Liu, X.; Foley, M. How Farmers Make Investment Decisions: Evidence from a Farmer Survey in China. *Sustainability* **2020**, *12*, 247. [CrossRef]
22. Palkovacs, E.P.; Kinnison, M.T.; Correa, C.; Dalton, C.M.; Hendry, A.P. Fates beyond traits: Ecological consequences of human-induced trait change. *Evol. Appl.* **2012**, *5*, 183–191. [CrossRef] [PubMed]
23. Li, Y.; Long, H.; Liu, Y. Industrial development and land use/cover change and their effects on local environment: A case study of Changshu in eastern coastal China. *Front. Environ. Sci. Eng. China* **2010**, *4*, 438–448. [CrossRef]
24. Staal, S.J.; Baltenweck, I.; Waithaka, M.M.; de Wolff, T.; Njoroge, L. Location and uptake: Integrated household and GIS analysis of technology adoption and land use, with application to smallholder dairy farms in Kenya. *Agric. Econ.* **2002**, *27*, 295–315. [CrossRef]
25. Long, H.; Zou, J.; Pykett, J.; Li, Y. Analysis of rural transformation development in China since the turn of the new millennium. *Appl. Geogr.* **2011**, *31*, 1094–1105. [CrossRef]
26. Duguma, L.A.; Hager, H. Farmers' Assessment of the Social and Ecological Values of Land Uses in Central Highland Ethiopia. *Environ. Manag.* **2011**, *47*, 969–982. [CrossRef]
27. Li, J.; Zhang, Y.; Qin, Q.; Yan, Y. Investigating the Impact of Human Activity on Land Use/Cover Change in China's Lijiang River Basin from the Perspective of Flow and Type of Population. *Sustainability* **2017**, *9*, 383. [CrossRef]
28. Kangalawe, R.Y.M.; Christiansson, C.; Ostberg, W. Changing land-use patterns and farming strategies in the degraded environment of the Irangi Hills, central Tanzania. *Agric. Ecosyst. Environ.* **2008**, *125*, 33–47. [CrossRef]
29. Liu, Y.; Chen, Y.; Long, H. Regional diversity of peasant household response to new countryside construction based on field survey in eastern coastal China. *J. Geogr. Sci.* **2011**, *21*, 869–881. [CrossRef]
30. Fan, Y.; Jin, X.; Gan, L.; Jessup, L.H.; Pijanowski, B.C.; Yang, X.; Xiang, X.; Zhou, Y. Spatial identification and dynamic analysis of land use functions reveals distinct zones of multiple functions in eastern China. *Sci. Total Environ.* **2018**, *642*, 33–44. [CrossRef]
31. Deng, J.; Hao, W.; Zhang, W.; Han, X.; Li, K.; Feng, Y.; Yang, G. Exploring Farmers' Pro-Ecological Intentions after Ecological Rehabilitation in a Fragile Environment Area: A Structural Equation Modeling Approach. *Sustainability* **2018**, *10*, 29. [CrossRef]
32. Guo, Z.; Dai, X.; Wu, J. Study on land use/land cover change in Jintai and Weibing districts of Baoji city in Western China based on remote sensing technology and Markov method. *J. Appl. Remote Sens.* **2009**, *3*, 033534. [CrossRef]
33. Yao, J.; Liu, Z.; Yang, Q.; Meng, X.; Li, C. Responses of Runoff to Climate Change and Human Activities in the Ebinur Lake Catchment, Western China. *Water Resour.* **2014**, *41*, 738–747. [CrossRef]
34. De Koning, G.H.J.; Benitez, P.C.; Munoz, F.; Olschewski, R. Modelling the impacts of payments for biodiversity conservation on regional land-use patterns. *Landsc. Urban Plan.* **2007**, *83*, 255–267. [CrossRef]
35. Walston, L.J.; Hartmann, H.M. Development of a landscape integrity model framework to support regional conservation planning. *PLoS ONE* **2018**, *13*, e0195115. [CrossRef]
36. Qiao, J.; Yu, D.; Wu, J. How do climatic and management factors affect agricultural ecosystem services? A case study in the agro-pastoral transitional zone of northern China. *Sci. Total Environ.* **2018**, *613*, 314–323. [CrossRef]
37. Liu, Y.S.; Wang, J.Y.; Long, H.L. Analysis of arable land loss and its impact on rural sustainability in Southern Jiangsu Province of China. *J. Environ. Manag.* **2010**, *91*, 646–653. [CrossRef]
38. Su, H.; Wu, J.H.; Tan, Y.; Bao, Y.; Song, B.; He, X. A land use and transportation integration method for land use allocation and transportation strategies in China. *Transp. Res. Part A Policy Pract.* **2014**, *69*, 329–353. [CrossRef]
39. Pan, W.K.Y.; Walsh, S.J.; Bilsborrow, R.E.; Frizzelle, B.G.; Erlien, C.M.; Baquero, F. Farm-level models of spatial patterns of land use and land cover dynamics in the Ecuadorian Amazon. *Agric. Ecosyst. Environ.* **2004**, *101*, 117–134. [CrossRef]
40. Zhang, L.; Li, X. The Impact of Traditional Culture on Farmers' Moral Hazard Behavior in Crop Production: Evidence from China. *Sustainability* **2016**, *8*, 643. [CrossRef]
41. Watson, S.J.; Luck, G.W.; Spooner, P.G.; Watson, D.M. Land-use change: Incorporating the frequency, sequence, time span, and magnitude of changes into ecological research. *Front. Ecol. Environ.* **2014**, *12*, 241–249. [CrossRef]

42. Junge, X.; Lindemann-Matthies, P.; Hunziker, M.; Schuepbach, B. Aesthetic preferences of non-farmers and farmers for different land-use types and proportions of ecological compensation areas in the Swiss lowlands. *Biol. Conserv.* **2011**, *144*, 1430–1440. [CrossRef]
43. Zhou, Y.; Zhang, Y.; Abbaspour, K.C.; Mosler, H.-J.; Yang, H. Economic impacts on farm households due to water reallocation in China's Chaobai watershed. *Agric. Water Manag.* **2009**, *96*, 883–891. [CrossRef]
44. Xue, Y.-J.; Deng, T.; Mao, K. Influencing Factors on the Ecological Protection Behaviors of Entrepreneurial Farmers in Chinese Forest Zones. *Sustainability* **2018**, *10*, 1827. [CrossRef]
45. Long, H.; Liu, Y.; Li, X.; Chen, Y. Building new countryside in China: A geographical perspective. *Land Use Policy* **2010**, *27*, 457–470. [CrossRef]
46. Long, H.; Hellig, G.K.; Li, X.; Zhang, M. Socio-economic development and land-use change: Analysis of rural housing land transition in the Transect of the Yangtse River, China. *Land Use Policy* **2007**, *24*, 141–153. [CrossRef]