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The Effects of Rural Settlement Evolution on the Surrounding Land Ecosystem Service Values: A Case Study in the Eco-Fragile Areas, China

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Abstract: General declines in ecosystem service values (ESV) are acknowledged worldwide; however, rather few studies have quantitatively analyzed the interrelationship between changing rural settlements and values of ecosystem services. This study used the county of Tongyu in West Jilin Province, China, as a case study to analyze how changing rural settlements impact the values of ecosystem services on surrounding land in the eco-fragile areas during 1997–2010. Quantitative analytical techniques mainly include the buffer analysis and an ecosystem services valuation. The results show that as the area of rural settlements increased in 1997–2010, the structure of land ecosystems had changed significantly during this time period, causing a change in ESV that was observed with a decline by 1.87 billion yuan and above 20%. The degradation of grasslands, wetlands, and water areas, as well as the farmland reclamation, were the main drivers of the decreases in ESV. The effects of the increased rural settlements on the distribution and variation of ESV were larger than the decreased rural settlements, especially the new rural settlements whose effect was largest, and the effect of changing rural settlements on the values of ecosystem services on the surrounding land was significant in proximity to these settlements. In conclusion, the effects of rural settlement evolution on the natural environment were obvious in the eco-fragile areas. Thus the encroachment of rural settlements still requires enhanced supervision in land management practices, and the scale and spatial distribution of rural settlements should be befittingly allocated in the eco-fragile areas to reduce the disturbance to the ecosystem.

Keywords: rural settlements; spatial evolution; eco-fragile areas; ecosystem service; Tongyu County; ESV; benefit transfer

1. Introduction

The concept of ecosystem services began in the early 1970s, referring to the ecological conditions and ecological processes through which the natural ecosystem and its components maintained and satisfied the natural environment ecosystem condition and the relevant effects for human survival [1]. Ecosystem services have a high, or even incalculable, value and are closely related to human well-being by maintaining human production capacity and living standards, as well as protecting human health [2–4]. However, human activities will affect the natural ecosystem and its services through changing the land-use structure and spatial pattern, then changing the land cover [5–9]. Additionally, human actions sometimes have externalities, which are not internalized by individual economic agents because policies and markets do not discourage them from acting in their own self-interest. Hence, in the tradeoff of economic development and environmental sustainability, the effects of human activities on ecosystem services cannot be ignored. With the in-depth studies on ecosystem service valuation, the study tends to change from multi-discipline research to interdisciplinary and cross-disciplinary studies, meanwhile, the research angle is turning to more problem-oriented approaches [10–13]. At present, there are such case studies in which the variations in ecosystem service values associated with land-use changes due to demographic factors, urbanization, economic conditions, and different scale policies are assessed [6,8,14–22]. The case studies of land planning, land evaluation, and land management containing ecosystem services research also begin to appear, but the policies primarily for the changes in ecosystem services are still lacking, especially in eco-fragile areas [23–28].

Rural residential construction activity is one of the ways to transform the natural environment, and directly determines the spatial pattern and intensity of human activities. It has direct and indirect effects on the natural ecosystem, which is more obvious in eco-fragile areas. For example, residential construction activity is often accompanied by farmland reclamation, deforestation, or grassland degeneration, and the decreases of semi-natural land and natural land constrain the ecosystem capacity in providing ecosystem services, and will result in damage to the quality of the ecological environment under long-term conditions [29]. However, ecosystem services are mostly produced in a "supply-side logic"; wilful neglect of the adverse effects of human activities on the ecosystem services tends to lead to the deterioration of the natural environment, while the rural development projects considering the value of ecosystem services can provide opportunities for sustainable ecosystem [30]. Consequently, the ecosystem services valuation in eco-fragile areas are vital to protect the local environment and sustain the regional ecosystem. It is an inevitable trend to integrate ecosystem services into land management practices, and land management practices also require this kind of knowledge. In the existing studies, the unit area value coefficient method is one of the effective methods for ecosystem services valuation at present [31–34]. Therefore, this study used the county of Tongyu in the ecologically fragile region of West Jilin Province as a case study to quantitatively calculate and comparatively analyze the values of ecosystem services within three different-sized buffers of four changing types of rural settlements during the years 1997–2010. Furthermore, this study investigated how changing rural settlements impact the values of ecosystem services on the surrounding land in the ecologically fragile areas, providing empirical research of the benefit transfer study [35], as well as scientific references for decision-making in terms of land-use planning and land management.

2. Materials and Methods

2.1. Study Area and Data Sources

2.1.1. Study Area

Tongyu County, locating in the western Songliao Plain and the Southwestern Jilin Province, is one of the most saline-alkali areas in the world, and was selected as an example to evaluate the effect of rural settlement dynamics on change patterns in land ecosystems. Tongyu County extends from 44°13′ N to 45°16′ N latitude and from 122°02′ E to 123°30′ E longitude, covering an area of 8496 km^2 and includes 16 townships (Figure 1). Tongyu is flat and about 160 meters above sea level, and its terrain generally decreases in elevation from west to east. The county belongs to Baicheng City and is in an area dominated by a northern temperate continental monsoon climate. In the past 50 years, the climate of Tongyu County has developed towards a trend of drought, resulting in the imbalanced structure of the ecological system and the decline in the ecological function, as well as serious problems of land desertification and grassland degradation. With the most obvious phenomena observed in persistent droughts since the 1980s, resulting in a large reduction in water area, the surface water area decreased from 3.52% in 1989 to 3.16% in 2001. The natural wetland area was 1330 km^2 in the 1960s, reducing to 690 km^2 in the 1980s, and decreasing to 360 km^2 after 2000 [16,36].

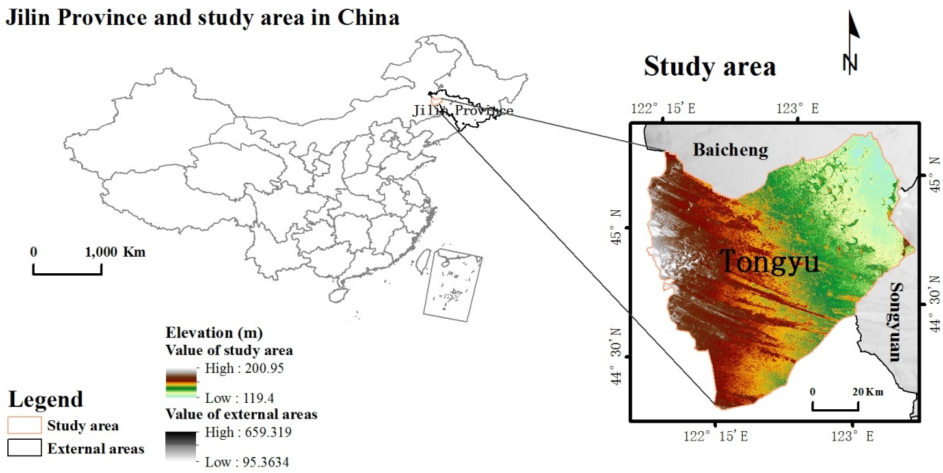

Figure 1. Location and elevation of the study area.

2.1.2. Data Sources

Data sources used in this study include the first national land survey data (present land-use map) for Tongyu County in 1997 and the national land change survey database for Tongyu County in 2010, and socioeconomic and demographic data were obtained from the Jilin Statistics Yearbook and Baicheng Statistics Yearbook, such as the demographic data and local GDP. The process of vector data includes: (1) land-use map from the first national land survey in 1997, of which the scale was 1:50,000, was vectored and processed to obtain the land-use database for Tongyu County in 1997; (2) to unify the scale and coordinate systems of multi-period data, the vector data in 2010 was projected and processed according to the scale and coordinate system of the first national land survey; and (3) vector data for rural settlement areas and other land-use types were extracted from databases obtained from (1) and (2).

National land survey data has its own land classification system in China, and the first national land survey in 1997 used a special land classification system designed in its technical specifications for investigation. The land change survey in 2010 adopted the land classification system implemented since 2007. Nevertheless they could be linked and consistently classified through a professional comparison table. Referring to the land classification system of the Chinese Academy of Sciences, and considering the land degradation in the study area, alkali land and wetland were independent from unused land in this study [37,38]. Thus, the land-use types were eventually classified into Farmland, Forest, Grassland, Water area, Construction land, Unused land (i.e., desert), Alkali land and Wetland (i.e., marshland) in study area.

Li et al. used the Western Jilin Province as a case study to explore the effects of population density changes on ecosystem services values, with the result showing that lower population density correlated with higher values of ecosystem services per unit area, and their value coefficients of ecosystem services were derived in a detailed research report on the ecological environment in Western Jilin [39]. Tongyu, is located at the southwestern corner of Western Jilin Province and has the same geographical conditions and natural environmental conditions with Western Jilin, according to the idea of benefit transfer [35], the value coefficients from Li's study for Western Jilin could be applied to Tongyu County.

2.2. Methods

2.2.1. Classification of the Rural Settlement Evolution and Selection of the Typical Patches

From the changes in the total area of rural settlements, rural settlements could be classified into increased rural settlements, invariant rural settlements, and decreased rural settlements. Rural settlement patches, like the naturally-formed village, means rural settlement plots whose borders are enclosed within building plots and other lands for farmers' lives. At the scale of the rural settlement patches, increased rural settlements could be divided into new and larger ones, and decreased rural settlements could be divided into smaller and vanished ones. The relevant description can be seen in Table 1.

Table 1. Evolution types of rural settlements.

	Types	Descriptions	Patch Number	Sample Number
1	New patch	the patch which is non-existing in 1997, but emerging in 2010	191	82
2	Larger patch	the patch which is existing in 1997, and larger in 2010	408	69
3	Invariant patch	the patch which is existing in 1997, and invariant in 2010	/	/
4	Smaller patch	the patch which is existing in 1997, and smaller in 2010	252	43
5	Vanished patch	the patch which is existing in 1997, but vanished in 2010	31	31

In this study, the rural settlement patch was used as the basic study unit. We compare the late patches of rural settlements (2010) with original ones (1997), and the result showed that there were 191 new patches, 408 larger patches, 252 smaller patches, and 31 vanished patches in Tongyu during this study period. The typical patches of different rural settlement evolution types were picked up to explore the action mechanism of different changing rural settlements on the ecosystem service values. The area of new patches varied from less than 10,000 m^2 to more than 270,000 m^2, and new patches with larger scales will be more stable and have a stronger effect on the nature. Thus we selected the new patches whose areas are larger than 50,000 m^2. The larger patches and smaller patches are relatively rich and have different changes, and the patches with greater changes had the more obvious disturbance to the environment. Thus, we selected the patches whose changing areas are larger than 150,000 m^2. The vanished patches are relatively rare, and we selected all of the vanished patches. As shown in Figure 2, the typical patches are distributed throughout the study region in order to reduce the effect of locational factors on the results. According to the typicality and the number of different rural settlement patches, 82 new patches, 69 larger patches, 43 smaller patches, and 31 vanished patches were selected as typical samples.

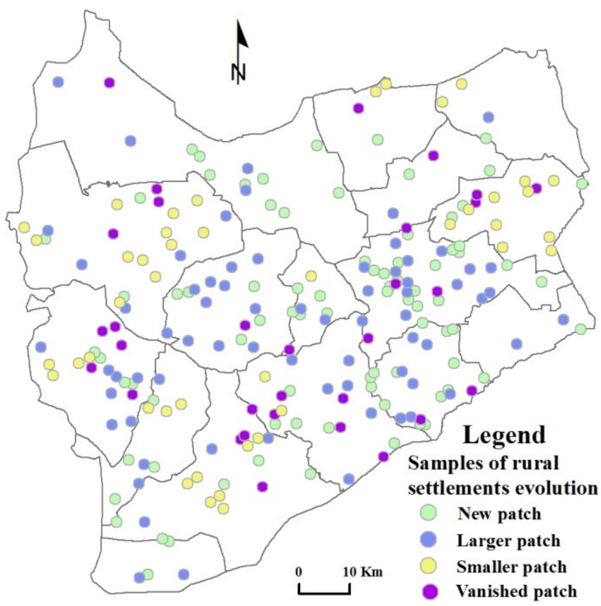

Figure 2. Spatial distribution of the typical patches of changing rural settlements.

2.2.2. Buffer Analysis

Buffer analysis is automatically setting up a certain width range of buffer polygons around the geographical entity, its basic idea is creating a spatial object and determining its neighborhood whose scale is determined by the neighborhood radius R, where R is a constant [40,41]. The neighborhood radiuses R in this study were 1 km, 3 km and 5 km, all buffer polygons of each rural settlement evolution type with different-sized neighborhood radiuses were draw out and used for statistical analysis of the land ecosystem service valuation, as well as its changes.

The area of each land-use type within the same-sized buffers around a rural settlement evolution type would be summed first, then the differences in the total area of each land-use type over the buffers between 1997 and 2010 can be obtained.

2.2.3. Ecosystem Services Valuation

According to the modified unit area value coefficient of Western Jilin in existing research [39] (Table 2), ecosystem service values (ESV) within three different-sized buffers are, respectively, calculated as:

$$\mathrm{ESV} = \sum_{i=1}^{n} VC_i \times A_i \quad (1)$$

where VC_i and A_i represent the ecosystem service value coefficient and the total area of land-use type i within the same-sized buffers around a rural settlement evolution type, respectively (yuan/ha, ha), and n is the number of land-use types.

For comparative analysis, the areas of different buffers were extracted, and the land ecosystem service value of unit land area ($\overline{\mathrm{ESV}}$) in a certain buffer zone is calculated as:

$$\overline{\mathrm{ESV}} = \mathrm{ESV}/S \quad (2)$$

where ESV represents the total ecosystem service value within the same-sized buffers around a rural settlement evolution type, and S represents the total area of corresponding buffers.

Table 2. Ecosystem services value per unit area of different land ecosystems in Western Jilin (yuan·ha^{-1}·yr^{-1}) [1].

	Forest	Grassland	Farmland	Wetland	Water Area	Alkali Land	Unused Land
Gas regulation	2663	722	425	1593	0	311	0
Climate regulation	2055	812	756	15,131	407	350	0
Water conservation	2435	722	510	13,715	18,033	311	27
Soil formation & protection	2968	1760	1240	1513	9	759	18
Waste disposal	997	1182	1393	16,087	16,087	510	9
Biodiversity protection	2481	984	603	2212	2203	424	301
Food production	76	271	850	266	89	117	9
Raw material	1979	45	85	62	9	19	0
Entertainment & cultural	974	36	8	4911	3840	16	9
Total	16,627	6535	5870	55,489	40,676	2819	371

[1] Construction land is considered to be valueless and is not listed in this study.

3. Results

3.1. Changes in the Land Ecosystem Service Values, 1997–2010

3.1.1. Changes in the Structure of Land Ecosystem

In 1997, the area of grassland was 2563 km^2, accounting for about 30% of the total land area of Tongyu County. Hence, the grassland occupied the largest proportion in the land ecosystem, followed by farmland (25%) and forest (20%). The area of wetland was small. In 2010, the area of farmland was 4003 km^2, accounting for about 47% of the total land area of Tongyu County. Hence, farmland occupied the largest proportion in the land ecosystem, followed by forest (18%) and alkali land (17%). The areas of wetland and unused land were small. In 1997, farmland and grassland were the major land-use types in Tongyu, demonstrating that Tongyu County was mainly a farming pastoral transitional zone. In 2010, the regional characteristic was weakened, and farmland became the predominant land-use type.

As shown in Figure 3, in 1997–2010, the sizes of farmland and alkali land increased greatly, whereas the areas of other system types decreased, so the structure of the land ecosystem was significantly changed. Farmland increased by 1889 km^2 with a significant increase in the proportion, the area of alkali land increased significantly and increased by about 570 km^2, the area of grassland decreased by 1420 km^2 with an obvious decrease in the proportion, and areas of water decreased by about 456 km^2 and unused land was also reduced.

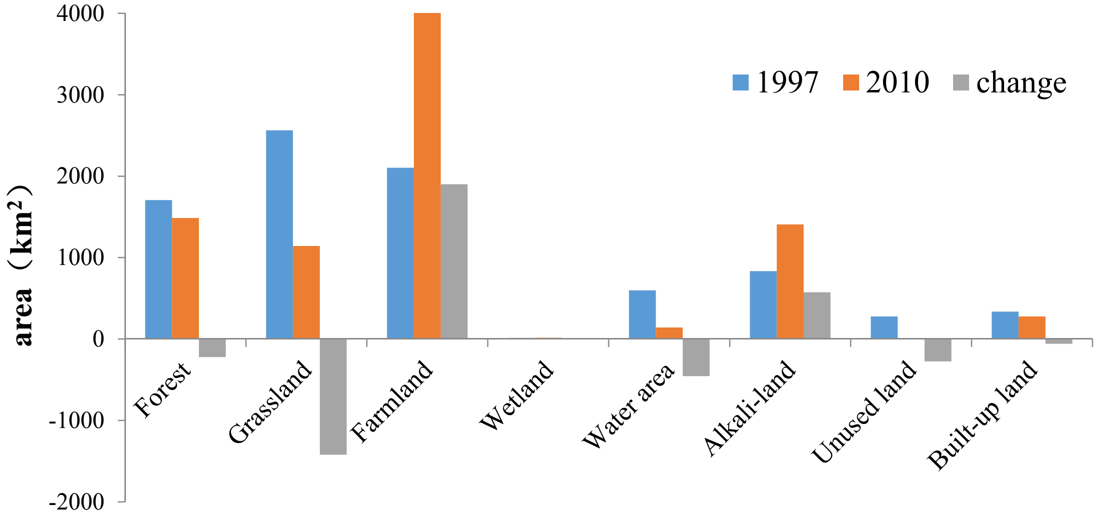

Figure 3. Changes in the land-use area in Tongyu, 1997–2010.

3.1.2. Changes in Total Values of Land Ecosystem Services

As shown in Table 3, the total ESV of Tongyu decreased by about 1.87 billion yuan in 1997–2010, with a pronounced decline of about 22.03%. In 1997, ESV of Tongyu was primarily comprised of forest and water areas (about 60%), and the ESVs of alkali land, wetland, and unused land were small. In 2010, approximately 70% of the ESV was comprised of forest and farmland, and the ESVs of wetland and unused land were small. During this time period, the ESVs of water, grassland, and unused land were significantly reduced, with reductions of 1.856 billion yuan (about 76%), 928 million yuan (about 55%), and 10 million yuan (about 99%), respectively. Meanwhile, the ESVs of farmland and alkali land increased significantly, with an increase of 1.115 billion yuan (about 90%) and 162 million yuan (about 69%), respectively. However, the ESVs of other land ecosystem types had changed very little.

Table 3. Changes in various land ecosystem service values in Tongyu, 1997–2010 (million yuan, %).

	1997		2010		Change in ESV	Variability of ESV
	ESV	Percentage	ESV	Percentage		
Forest	2838	33.39	2470	37.27	−368	−12.95
Grassland	1675	19.70	747	11.27	−928	−55.42
Farmland	1235	14.53	2350	35.47	1115	90.29
Wetland	74	0.87	87	1.31	13	17.12
Water area	2433	28.62	576	8.70	−1856	−76.30
Alkali land	235	2.77	397	5.99	162	68.83
Unused land	10	0.12	0	0.00	−10	−99.01
Total	8499	100	6627	100	−1873	−22.03

3.2. Effects of Rural Settlement Evolution on Land Ecosystem Service Values

3.2.1. Changes in the Land Ecosystem Services Values Surrounded Different Changing Types of Rural Settlements

As shown in Figure 4, the effects of different changing rural settlement types on the variations of land ecosystem service values were different. The reductions of the ESVs on surrounding land of various rural settlement evolution types from large to small were basically as follows: The new patch > the larger patch > the smaller patch > the vanished patch, demonstrating that the increased rural settlements had larger effects on the variations of land ecosystem service values than the decreased rural settlements and the new rural settlements had the largest effect. These influencing characteristics in the 1-km buffer zones were the most obvious. As the buffer distance increased, the differences of reductions in ESVs between increased rural settlements and decreased rural settlements had narrowed, indicating this effect characteristic had gradually weakened. Within the 3-km and 5-km buffers, the value change surrounding smaller rural settlements was still larger than the vanished rural settlements. However, the value change within the buffers of new smaller rural settlements was slightly less than the larger rural settlements, which was inconsistent with the 1-km buffer zone.

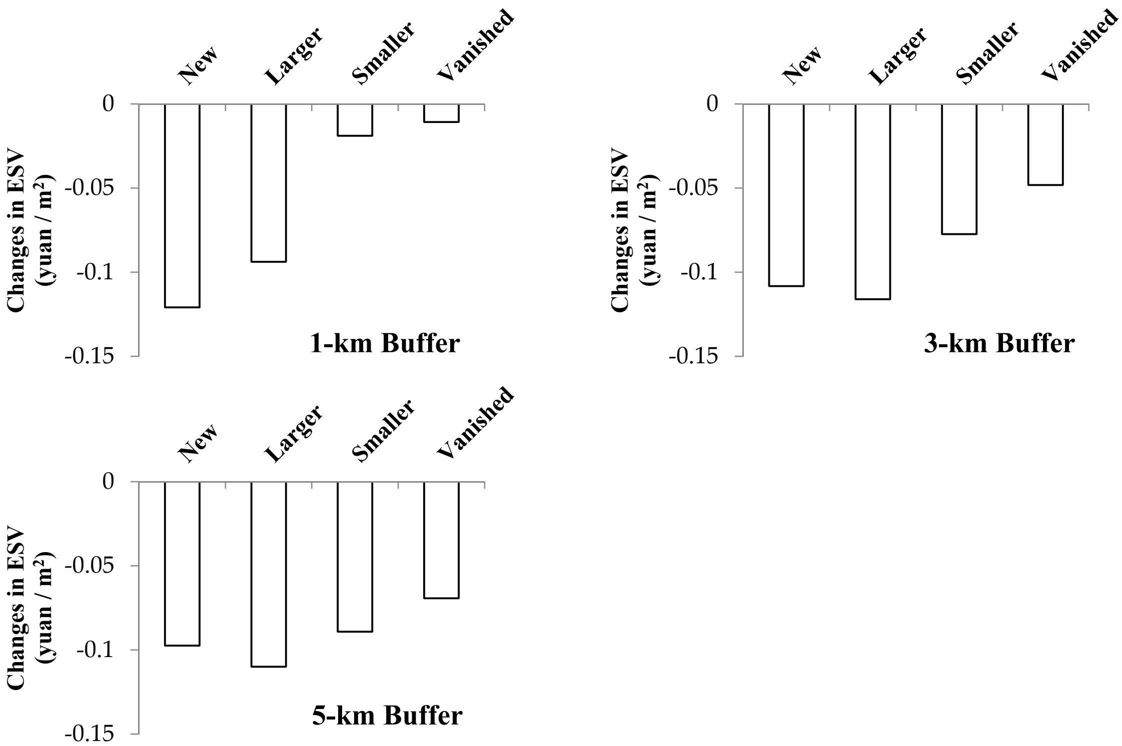

Figure 4. Changes in land ecosystems services values on surrounding land of different changing types of rural settlements.

3.2.2. Changes in the Land Ecosystem Services Values within Different-Sized Buffers

As shown in Figure 5, the effects within different-sized buffers of various rural settlement evolution types on the reductions of land ecosystem service values were significantly different. The changing trends of land ecosystem services values were basically consistent in various buffer ranges for each type of decreased rural settlements, while different for the two increased rural settlements. The reductions of the ESVs on surrounding land within different-sized buffers of decreased rural settlements from large to small were basically as follows: The 5-km buffers > the 3-km buffers > the 1-km buffers. For the new patches, changes in the land ecosystem services values were greatest in 1-km buffers and smallest in 5-km buffers. For the larger patch, changes in the land ecosystem services values were greatest in 3-km buffers and smallest in 1-km buffers. The differences of the changes in ESVs in different-sized buffers of rural settlements indicated that the functionary mechanism of different changing types of rural settlements were quite different, and effects of changing rural settlements on ESVs have risen in proximity to rural settlements.

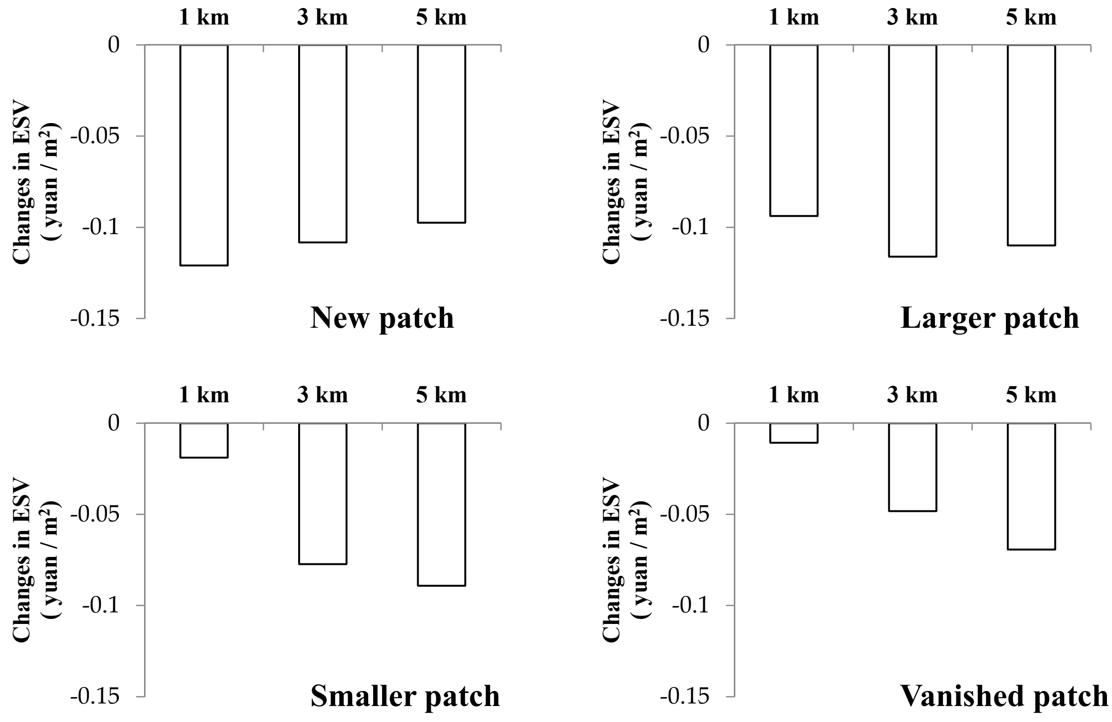

Figure 5. Changes in land ecosystem services values within different-sized buffers.

3.2.3. Effect Mechanisms of the Rural Settlement Evolution on Variations in ESV

It is a common phenomenon for 1-km buffer zones and the whole study area that the forest and grassland shifted into farmland, and that the grassland degraded to alkali land, which is the principal reason for the declines of ESV. As shown in Figure 6, the transition probability showed two main characteristics of land transition surrounding the rural settlements; one was the forest, grassland, water area, and unused land, as well as alkali land reclaimed to farmland, while the other was grassland, water areas, and farmland degraded to alkali land, jointly resulting in the dramatic reduction in ESV.

However transformation between different land-use types was complex in the study area. The areas of other land converted into farmland in the buffer zones of two increased rural settlements were much larger than the decreased rural settlements, with a larger variability in the buffer zones of new rural settlements than the larger rural settlements. The alkali land was converted into grassland in the region surrounding the decreased rural settlements, while this characteristic of land transition does not exist in the region surrounding the increased rural settlements. The reduction of ESV due to land transition ranged from large to small as: The new rural settlements > the larger rural settlements > the smaller rural settlements > the vanished rural settlements.

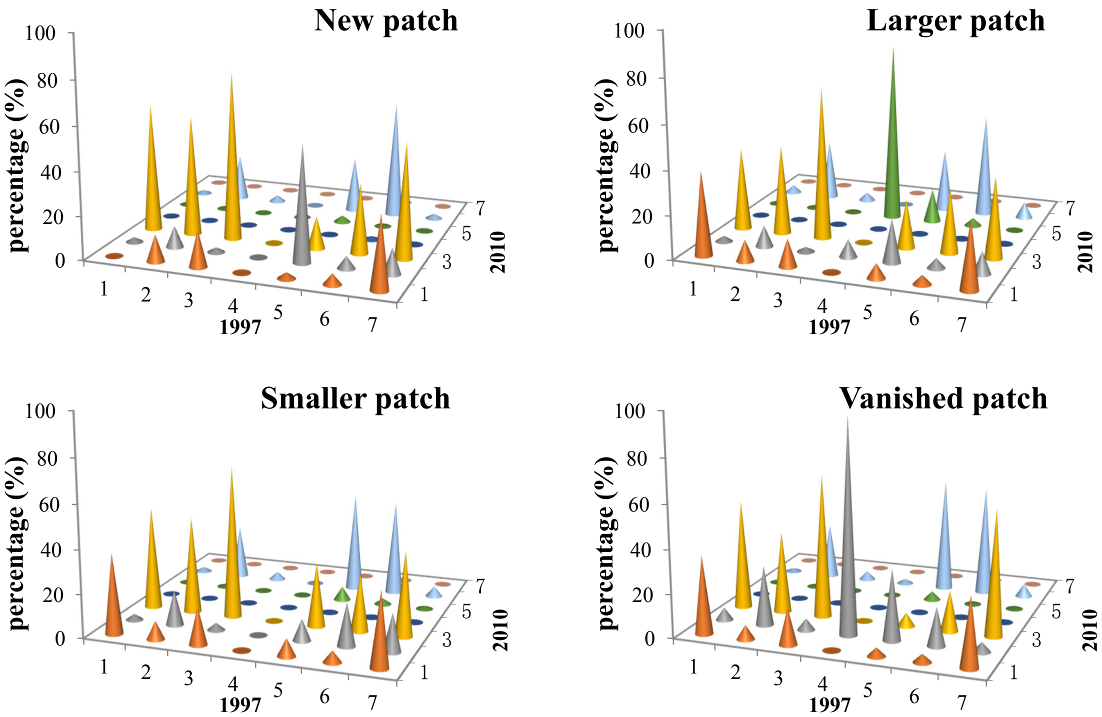

Figure 6. Transition proportions of land ecosystem in the buffer zones of various rural settlements evolution types. 1: forest, 2: grassland, 3: farmland, 4: wetland, 5: water areas, 6: alkali land, 7: unused land, 8: construction land.

4. Discussion

During the study period, total population and agricultural population increased from 340,500 and 240,400 people to 366,100 and 248,800 people in 1997–2010, respectively. The total population and agricultural population increased by approximately 2000 and 650 people every year, respectively. With the increase of rural population, the total rural settlements in Tongyu showed an increasing trend. The total area of rural settlements in Tongyu increased from 186.07 km^2 in 1997 to 210.28 km^2 in 2010, with an annual increase of 1.86 km^2 and a dynamic degree of 1%. Furthermore, increases of rural settlements in Tongyu were mainly located in the regions with good geographical conditions and economic conditions near Kaitong Town, whereas increases and decreases of rural settlements coexisted in other areas. Rural settlement evolution was not only guided by social economic factors, such as economic and demographic changes, but also subjected to the natural environment condition. Therefore, the spatial evolution was not very even in the study area. There was obviously a great deal of synergy between the spatial distribution of rural settlements and the population density, economic level, and geographic conditions. In the regions with larger population density, higher income, and better location conditions, rural settlements increased significantly and had a more concentrated distribution.

Prolonged droughts since the 1980s had resulted in a large reduction in water areas by about 456 km^2, and about 20% of the water area and 15% of the wetlands changed to alkali land in 1997–2010. Grassland, the largest part of the land ecosystem in 1997, decreased by about 1420 km^2, and about 25% of grassland changed into alkali land during 1997–2010. The increasing utilization intensity and unfavorable natural factors jointly changed the natural environment of ecological fragile areas, resulting in a significant reduction of natural land and a very serious land saline-alkalization in Tongyu [38,42], The reductions of grassland and water area, as well as the increase of alkali land, demonstrated the ecological degradation in the study area. Farmland increased by 1889 km^2, resulting in the study area changing from a farming pastoral transitional zone to an agricultural leading region.

The demands of land for grain in the agglomeration region of rural settlements were large, which caused the other kinds of land-use types to be changed into farmland. Nearly 50% of the farmland in Tongyu in 2010 was transformed from forest, grassland, and unused land. With the population growth and economic development, a large scale of ecological lands transformed into productive lands, resulting the reduction of ecosystem services values, which was an inevitable trend for human survival and development [15,43].

During the past 13 years, the ESV in Tongyu decreased by about 1.87 billion yuan and more than 20%, reflecting the deterioration of the natural environment under human activities in the ecologically fragile areas. According to the ecosystem service valuation theory and the related calculation, the substantial increases in farmland and alkali land caused a reduction of about 1.80 billion yuan in ESV, and the substantial decreases in water area and grassland led to a decline of about 1.65 billion yuan in ESV, thus, the degradation (saline-alkalization) of grassland, wetland, and water areas, as well as farmland reclamation, were the major causes of the decreased land ecosystem service values in the study area. Farmland reclamation is due to the direct interference of human activities on the ecosystem, while the degradation of grassland, wetland, and water areas may be the deterioration of the natural environment, or may be indirectly due to human disturbance to the ecological environment. For the development of human beings and to feed a growing population, human activities will inevitably have an impact on the natural system, but the deterioration of the ecological environment, in turn, will have a significantly negative impact on human production and life. Now, the decline in ecosystem service values is already a global phenomenon [42,44], so we must raise awareness of ecological protection and environmental protection. Under the circumstances of ecological degradation, it is necessary to restrict the transformation of other land to farmland.

Even though the potentially neutralizing influence of positive land use changes with negative effects on rural settlement sprawl on ecosystem services may exist [45], the reductions in land ecosystem service values around the increased rural settlements were greater than the decreased rural settlements, i.e., the increases of rural settlements resulted in a greater reduction in ESV in the surrounding land, which indicated that the expansion of rural settlements had a more significant impact on the surrounding ecosystem. However, the rural residential area increased significantly in the study area, especially in regions with a better location and economic conditions, so enhanced supervision over the influence of rural settlement expansion on the ecosystem is required in the future. With the increased distance to rural settlements, the disturbance of human activities on land ecosystems had weakened, which led to the effects of the changing rural settlements on the ESVs being more significant in proximity to rural settlements. Effects of new rural settlements on the ecosystem service values are obvious, but the new rural settlement patches are usually unstable ones before their scales became big enough. In land-use planning and land-use practices, especially in the cases with the rural population outflow, avoiding the small new rural settlements and the appropriate reduction of the original rural settlements could be considered. If increasing the area of rural settlements to accommodate the growing rural population is inevitable, expanding the scale of the original rural settlement patches and the centralized living mode should be selected first in order to reduce disturbances to the ecological system.

The land-use vector data used in this study was derived from national land survey data whose accuracy was improved by field investigation. Thus, the uncertainty of valuation of land ecosystem services due to the digitalization error in quantifying the area of each land-use patch is small. Even so, there were still some shortcomings in this study. For example, the value coefficients were the subjective assessments of the provision of natural capital and value of ecosystem services, but the differences that exist in people's perceptions of values of ecosystem services varied in different research regions and scales [46]. West Jilin Province is a typically eco-environmentally vulnerable area, and the research of West Jilin Province by Li et al. [39] emphasized ecological and environmental protection, so value coefficients of natural and semi-natural land were higher than other artificial or agricultural land-use patches. However, these kinds of value coefficients were applicable for this study but not necessarily applicable to other areas. In the multi-temporal study on dynamic values of ecosystem services, there is a hypothesis that value coefficients were supposedly unchanged during this study period. This is convenient for actual calculation, however, it will cause errors. Additionally, the value coefficients of land ecosystem services are often more meaningful for detecting land cover changes than for considering the time values of the capital. Therefore, this study used the same value coefficient in the evaluation of two-period land ecosystem services to examine the effects of changing rural settlements on land ecosystem services.

5. Conclusions

In the study area, the total scale of rural settlements increased in the period of 1997–2010. Meanwhile the increases and decreases of rural settlements coexisted in the space, and rural settlements significantly increased in the regions with good locational conditions and economic conditions. In 1997–2010, there was a substantial increase in farmland in Tongyu, while about 25% of the grasslands, 20% of the water areas, and 15% of the wetlands changed into alkali lands. The changes in the land ecosystem structure (i.e., conversion between different land use types) due to the human factors and natural factors jointly led to the total value of ecosystem services decreasing by as much as about 1.87 billion yuan and more than 20%, reflecting gradual deterioration processes of the natural environment under human activities in the ecologically fragile regions. Additionally, the major reduction of ESV was due to the farmland reclamation, as well as the degradations of grassland, wetland, and water areas.

Changing rural settlements had significant impacts on changes in ESV in the ecological fragile regions. The effects of increased rural settlements on ESV were greater than the decreased rural settlements, and the ESV on the surrounding land of new rural settlements reduced the most. The characteristics of effects have risen in proximity to the rural settlements. Therefore, in the practices of rural land-use planning and land management, as well as ecosystem protection in the future, the scale and spatial pattern of rural settlements should be optimized to reduce the effects of the encroachment of rural settlements on the ecosystem services, especially in the ecologically fragile areas. Meanwhile, enhanced supervision is needed over the impacts of rural settlement evolution on ecosystem services.

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