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Assessing the Role of Policies on Land-Use/Cover Change from 1965 to 2015 in the Mu Us Sandy Land, Northern China

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Abstract: Policy has long been considered one of the major driving forces for land-use/cover change. However, research on the interactions between land-use/cover change (LUCC) and relevant policies remains limited. The agropastoral ecotone is a typical area of policy implementation and LUCC. Therefore, this study integrates the use of multisource and multiresolution remote sensing and topographic and field-based datasets for the case of the Mu Us Sandy Land (MUSL) in northern China. The research aim was to quantify LUCC from 1965 to 2015 and describe the relationship between policy changes and land-use types during three stages: the stage of the Great Cultural Revolution, the stage of the modernization of the economy, and the stage of the Great Ecological Project. The results indicated that land use was affected by different national policies because of the national approach to land use during different periods. In the stage of the Great Cultural Revolution, the amount of cultivated land increased, and the environment deteriorated under the influence of leftists. In the stage of the modernization of the economy, vegetation coverage improved after the initial damage, and cultivated and artificial surfaces also increased. In the stage of the Great Ecological Project, cultivated land and unused land decreased, and woodland and sparse vegetation increased with the implementation of the Grain for Green Project (GGP). However, cultivated land increased but wood land and sparse vegetation decreased significantly by the end of the GGP. The coverage of artificial surfaces increased and grasslands decreased due to the encroachment of artificial surfaces into grasslands.

Keywords: policy; land-use/cover change; agropastoral ecotone; Mu Us Sandy Land

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1. Introduction

Since land-use/cover change (LUCC) studies began in the early 1990s, governments and organizations around the world have implemented many projects at different spatial scales, as for example the Land-Use and Cover-Change project and the Global Land Project (GLP) [1]. The processes and driving forces of LUCC have played an indispensable role in the study of global change and regional human-land relationship [2–4]. Currently, human factors, such as population, society, economy, technology, policy, etc., are the major driving force in shaping LUCC, although geomorphic structure and climatic conditions may constrain LUCC in the world [5,6]. Numerous extensive studies on human factors forced on LUCC have been carried out [7–10]. However, the majority of them focus on the influence of population, society, and economy on LUCC, and policy factors have received little attention than other factors due to their slow and subtle influence on LUCC. Some policies can affect land-use change directly and rapidly; for example, changes in land tenure (the Household

Responsibility System (HRS) in China) have direct impacts on land use. Other policies can indirectly affect land use through economic and population factors; for example, changes in population policy (family planning in China) have indirect effects on land use through increasing population. Liu et al. [7] argued that the main driving forces contributing to land-use change were the national macro-policy, regional development policies and socioeconomic development in China during the early 21st century. In conclusion, researchers have gradually recognized the important role of policy in LUCC and considered it as one of the major driving forces for LUCC [1,11,12].

The agropastoral ecotone in northern China is extremely fragile and has a poor environmental carrying capacity, low self-restoration ability and high sensitivity to external disturbance [1]. During the past few decades, improper land use has presented a serious ecoenvironmental problem in the agropastoral ecotone, including grass degradation, groundwater decline, shrinking wetlands, soil erosion, and sandy desertification [11]. These problems have threatened the sustainability of local economic growth and social development. Thus, partial ecological problems have evoked concern on the part of the national government. Since 1979, several momentous government policies led by central and local government have been conducted to deter sandy desertification and land degradation. For example, in 1979, the Three-North Shelterbelt Project (TNSP) was implemented and played a significant role in promoting afforestation in the agropastoral ecotone. Then, the phenomena of overcultivation, overgrazing, and overcutting were controlled following the implementation of the allocating pasture to smallholdings policy. Furthermore, two other policies, the Aerial Seeding Afforestation Project and the Grain for Green Project (GGP), also decreased the effects of overgrazing. Those policies were also meaningful to effectively combat land sandy desertification and promote vegetation restoration in the agropastoral ecotone [13]. According to the published literature, the majority of studies have focused on those policies and the responses to LUCC [14–18] designed to protect the ecological environment. However, the government has also implemented other policies, such as the Great Leap Forward movement and the "Emulating Da-Zhai on Agriculture" campaign, which have had negative impacts on the ecological environment. But, the available studies are limited about those policies. Therefore, given the diversity of policies with respect to land use, more research is needed to focus on the influences of different policies on LUCC over decadal scales [1]. In China, the government has issued different policies at different periods since the reform of the socialist economic system in the 1960s (Figure 1). Land use had been affected by these policies, which encompass land, environment, economy, population, and other matters. Based on the different policies implemented in different periods, policy changes have had various impacts on LUCC in the agropastoral ecotone. In this paper, three stages are defined based on change of national policy and the focus of these policies: the stage of Great Cultural Revolution (1965–1978), the stage of the modernization of the economy (1978–2000), and the stage of the Great Ecological Project (post-2000).

The Mu Us Sandy Land (MUSL) is located at the agropastoral ecotone of northern China [19]. The MUSL still experiences the threat of aeolian desertification caused by inappropriate land-use practices during the past few decades [20]. Therefore, the MUSL has become the focal point of new national policies. Many researchers have focused on the relations between aeolian desertification and policies from 1980 to 2010 [21–25]. However, few analyses have paid attention to the response of land use to government policies over longer timescales, particularly to the periods before the reform and liberalization policy (1965–1978) and after the accomplishment of the GGP (2010–2015). Because the earliest Landsat satellite was launched in 1972, there was a lack of long-term satellite data available from the same source. Assessment of long-term LUCC using multisource remote sensing data is an effective method, but is also a great challenge in the MUSL. Therefore, studying LUCC and analyzing the driving forces of national policies using multisource remote sensing data from 1965 to 2015 is vital for government administrators to understand in-depth the process of LUCC and the relationship between LUCC and policy in order to formulate policies that are better-suited to local conditions in the MUSL.

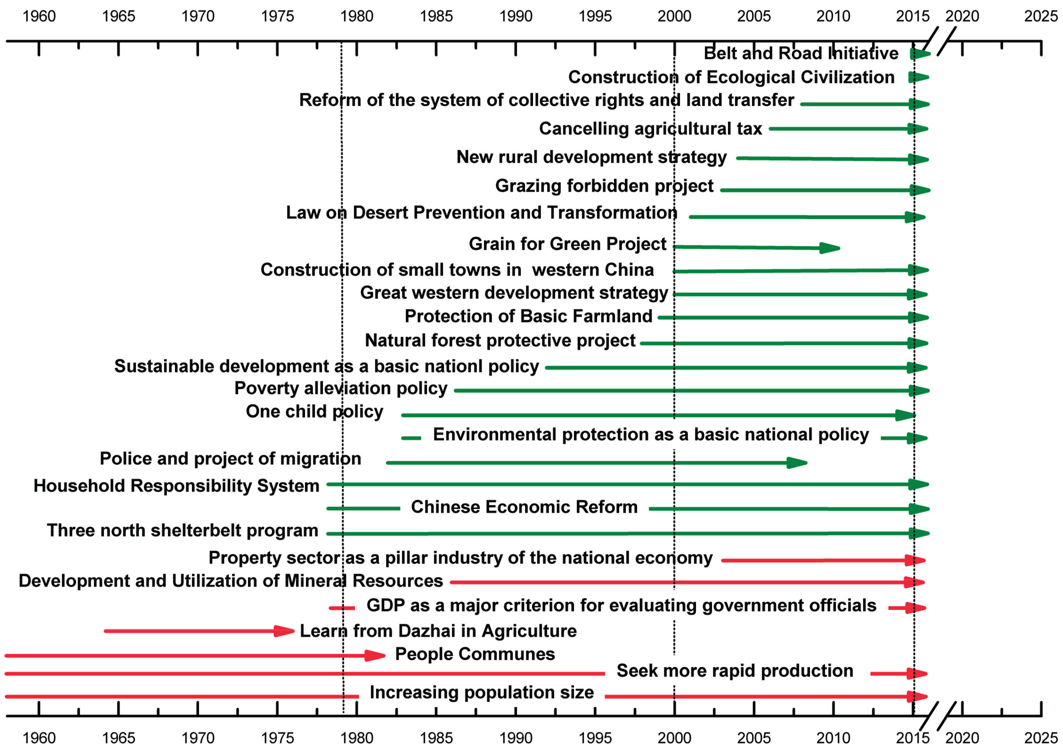

Figure 1. China's major policies affecting LUCC in the agropastoral ecotone during the period 1958–2016 (green arrows mean that the policies have been beneficial to environmental and economic sustainability in the agropastoral ecotone; red arrows mean that the policies have been harmful to environmental and economic sustainability in the agropastoral ecotone; and the dotted lines indicate the three policy stages).

In this study, we used multisource satellite images to determine long-term LUCC in the MUSL and attempted to address the following points: (1) the process of LUCC in the MUSL from 1965 to 2015; and (2) the relationship between LUCC and different government policies from 1965 to 2015 in the study area.

2. Materials and Methods

2.1. Study Area

The MUSL is located at the border of Shaanxi Province, Ningxia Hui Autonomous Region and Inner Mongolia Autonomous Region (106°58′–110°35′ E, 37°28′–39°48′ N) and the area of study is approximately 48,288 km^2 (Figure 2). Land-use/cover types are dominated by grassland and unused land. The MUSL is the transitional zone between the Ordos Plateau and the Loess Plateau, and the elevation is 950–1600 m. The study area is also the transitional zone between semiarid and semi-humid in China. The climate type varies from middle temperate to warm temperate. The annual mean temperature ranges from 6.0 to 8.5 °C and the mean annual precipitation increases from above 250 mm in the northwest to 400 mm toward the southeast, about 60–80% of which falls in summer [26]. Those conditions affect the distribution of water resources, vegetation, and soil. In addition, the region is an important energy and mineral base in China. Because of the special geographical position, the activities of agriculture, animal husbandry, and mining are common practice in the MUSL. However, the ecosystem in the MUSL is a fragile and complex system. Once the regional ecosystem is destroyed, a timely recovery will be difficult. Various policies, including ethnic, ecological protection, and land policies, have been implemented and there have been profound impacts on land-use/cover in the MUSL.

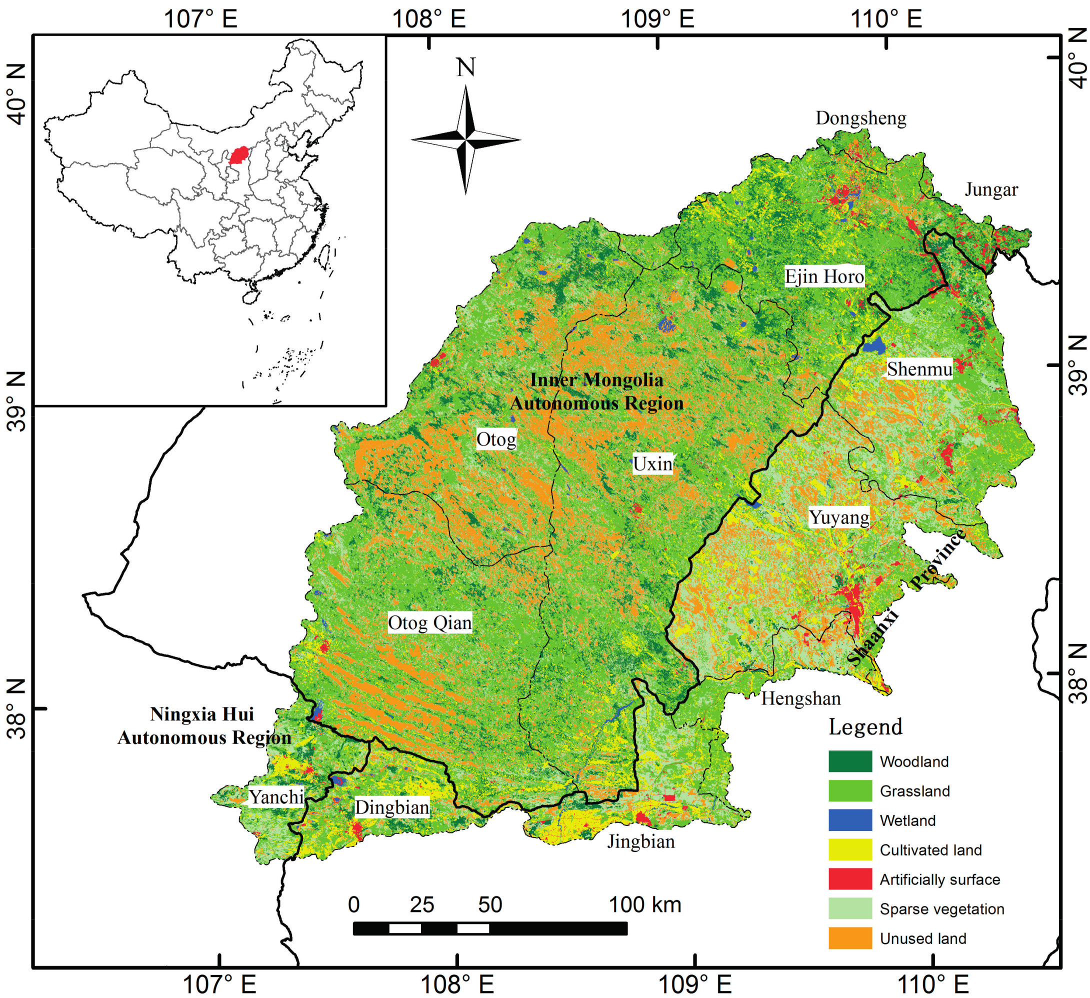

Figure 2. Location and land-use/cover (2015) in the study area.

2.2. Data Sources

Multisource images from eight time periods were obtained to monitor the spatiotemporal changes of the MUSL from 1965 to 2015. The images were Keyhole photographs (nominal resolution of 2.7 × 2.7 m) from 1965; Landsat MSS from 1975 (nominal resolution of 57 × 57 m), Landsat TM images from 1990, 1995, 2005, and 2010; ETM+ from 2000; and OLI from 2015 (nominal resolution of 30 × 30 m). All images were acquired in the region's growing season in the study years when the spectral features of each class are most obvious. However, it was almost impossible to obtain cloud-free images that covered the entire study area within a given year because of the revisit cycle of Landsat (16 days). Therefore, some images from adjacent years were chosen to replace the images that could not be gained in the target years [27]. The ancillary data included the 1:100,000 topographic map that came from the Chinese State Bureau of Surveying and Mapping [28].

Additionally, land-use/cover landscape photographs accurately positioned using a HOLUX GPS were obtained to classify the land-use/cover a priori and verify classification accuracy. According to the sampling strategy of reference [29,30], a minimum of about 40 random points are needed for each class to be used to verify the accuracy. Thus, there are 714 sampling points, including the field survey data (209 points) in mid-July 2012 and 2013 (Figure 3) and the random samples (705 points) obtained from Google Earth using visual interpretation.

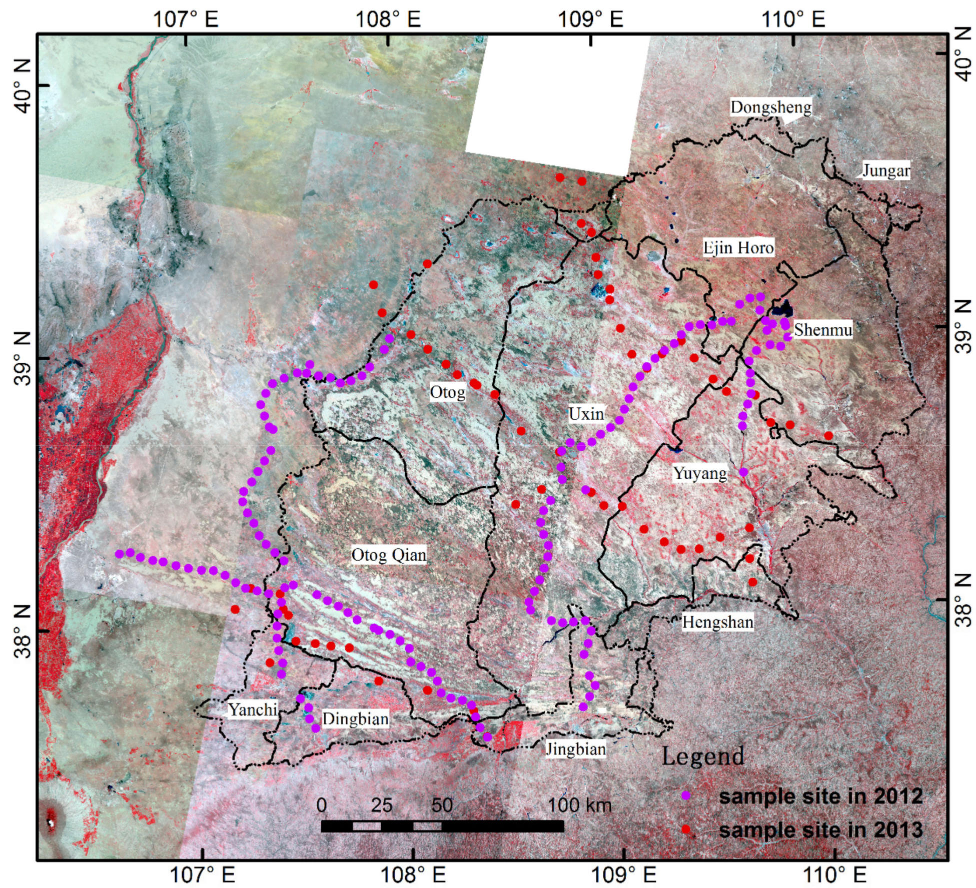

Figure 3. The sample site in the MUSL in July 2012 and July 2013 (the background is the false color image of Landset TM5 in 2010).

2.3. Image Processing

Using ENVI 4.7 software (Research System Inc., Boulder, CO, USA), the 2010 TM images were georeferenced and orthorectified by means of the evenly distributed 30–40 ground-control points (GCPs) from the topographic map. The mean location error after georectification was <0.5 pixel in plain areas and 1 pixel in hilly areas. The images from the other periods were matched with the 2010 TM images via an image-to-image matching method. The evenly distributed 40–50 GCPs in both the target images were extracted to cover the image during the image matching process. The root-mean-square error was also <0.5 pixel in plain areas and 1 pixel in hilly areas.

Radiometric calibration was used to transform digital number (DN) values of the images into radiance using gain and offset parameters [31]. Then, the FLAASH atmospheric correction model in the ENVI 4.7 software was used to convert the radiance to reflectance.

To make these images compatible [32], all of the Keyhole photographs and MSS images were reassembled to 30 × 30 m pixel size, which is the same as the cell size of Landsat TM, ETM+, and OLI, using the bi-linear interpolation (Keyhole) and nearest-neighbor (MSS) re-sampling techniques [33,34].

2.4. Classification System and Interpretation

The land-use/cover classification system was used in this study based on previous work [26,35] and the "status, speed, mechanism and potential of carbon storage in ecosystem" project [36]. Seven primary land-use/cover types, woodland, grassland, wetland, cultivated land, artificial surface, sparse vegetation, and unused land, were defined by detailed consideration of the object features, such as spectral characteristics, shape, area, and position. The classification system is shown on Table 1.

Table 1. The land-use/cover type classification system used in this study.

Type	Description
Woodland	Shrubs, trees, and other forested lands; $C_r > 20\%$; 3 m < H < 30 m; 0.3 m < height of shrub < 5 m
Grassland	Meadow, lawn and grass cluster; cover ratio (C_r) > 20%; 0.03 m < H < 3 m
Wetland	Reservoir or pond, river, beach, lake, bottomland, forest swamp, herbaceous swamp
Cultivated land	Irrigable land, paddy field, dryland
Artificial surface	Urban area, rural residential area, industrial land mining region, other built-up area
Sparse vegetation	The same secondary types with vegetation; 4% < C_r < 20%
Unused land	Saline land, sandy land, naked rock, bare soil, other unused land

Note: the parameters of vegetation cover ratio (C_r): the percentage or fraction of occupation of a vegetation canopy over a given ground area in a vertical projection; vegetation height (H): vegetation height (H).

An object-based approach, i.e., eCognition Developer 8.64 [37–39], was chosen due to its known advantages over pixel-based methods with respect to high spatial resolution land-cover classification [40–43], as for example the "salt-and-pepper" effect was avoided and object features were fully utilized. Land-use/cover information for the year 2010 was extracted via the following steps: After a "trial-and-error" method, the meaningful and homogeneous objects was segmented using multiresolution segmentation method, with the parameters of scale, shape, and compactness of 15, 0.1, and 0.5, respectively [44,45]. Then, the objects was exported from eCognition and 2000 random samples was selected by means of "the Creat Random Points" tool in Arcgis 10.0 and the land use attributes of selected samples was assigned by visual interpretation. The tool of "classified image to samples" was used to extend the sample of point to the sample of object. Segmented objects were assigned into specific land-use/cover types by the nearest neighbor classifier. Subsequently, the manual editing tool was used to correct the error objects of "classify by visual interpretation." Landsat images are classified into seven primary categories, as required: woodland, grassland, wetland, cultivated land, artificially surface, sparse vegetation, and unused land. Finally, the verification sample data obtained from the field survey and Google Earth was imported into eCognition. The classification results were assessed through the Google Earth image available sampling points and field survey data using "Error Matrix based on Samples." The overall classification accuracy were above 90% (Table 2).

Table 2. Classification accuracies of land-use/cover in 2010 (PA: producer accuracy; UA: user accuracy; OA: overall accuracy; and Kappa: inter-observer Kappa statistic).

	Woodland	Grassland	Wetland	Cultivated Land	Artificial Surface	Sparse Vegetation	Unused Land
Woodland	72	2	2	1	0	1	0
Grassland	3	369	5	2	1	4	2
Wetland	2	5	42	0	0	0	0
Cultivated land	1	1	0	118	0	0	0
Artificial surface	0	0	0	0	35	1	2
Sparse vegetation	2	5	-	1	1	93	3
Unused land	1	2	0	2	3	3	127
UA	92.31%	95.60%	85.71%	98.33%	92.11%	88.57%	92.03%
PA	88.89%	96.09%	85.71%	95.16%	87.50%	91.18%	94.78%
Kappa	91.75%						
OA	93.65%						

The land-cover map of the other periods was completed using the change detection method, which uses the segment similarity of a spectrum vector based on a knowledge base in the MUSL region. The implementation process was as follows. The spectrum feature vector of a segment in a Landsat image can be regarded as a vector in six-dimensional feature space. If the angle between two vectors is small and the vector mode close, the two vectors are similar. Therefore, the cosine of the angle between two vectors and the ratio of the vector mode was used to establish a vector similarity index for measuring vector similarity. Then, the 2010 land-cover data cited above were used a priori to classify regions of change. Change detection was simplified to divide all pixels into two types:

changed region and unchanged region. For the unchanged regions, the land-cover type remained the same in 2010. The object-based approach previously mentioned was applied to the changed regions. Finally, the land-cover map of the other periods was acquired by the superposition of changed data and unchanged data. Because KH image is a pan image, it cannot use segment similarity of a spectrum vector to change detection. Land-use/cover in 1965 was obtained using visual interpretation based on 2010 land-use/cover data. The accuracy of the land-use/cover in the other periods was tested by land-use/cover data in 2010, and the accuracy exceeded 85%.

3. Results

3.1. Land-Cover Change Processes

The results indicated that the land-use/cover pattern in the MUSL has changed significantly since 1965. Based on the aforementioned policy stages, the spatial distribution in different periods and their trends in the seven periods from 1965 to 2015 are provided in Figures 4 and 5, respectively. The statistical land-use/cover results are shown in Table 3. Grassland, which was a dominant type of land-use/cover, changed dramatically from 1965 to 2015, decreasing by 105.18 km^2 from 1965 to 1990. However, its total area decreased only slightly from 1975 to 1990. From 1990 to 2000, the grass land area increased by 421.71 km^2. Thereafter, the grassland area decreased at an accelerating rate. The woodland area increased by 83.49 km^2 from 1965 to 2010, except for a slight decrease during the period 1975–1990. Compared to the slow change in the other periods, the woodland area in the MUSL underwent a relatively pronounced decrease from 2010 to 2015. Sparse vegetation, the second type of land-use/cover in the MUSL, had fluctuating changes from 1965 to 2010. However, the extent of sparse vegetation changed slightly before 2000, and the changes increased after 2000. Unused land is a key type of land-use/cover that influences the ecological environment in the MUSL. Unused land decreased considerably from 1975 to 2015; and its area decreased from 9062.61 km^2 to 8438.90 km^2. Cultivated land in the study area first increased, then decreased and increased again over the study period. In 1965, there were 3702.51 km^2 of cultivated land, which accounted for 7.67% of the total land in the MUSL. Then, cultivated land expanded to 7.92% in 2000, but its area has decreased since 2000. In 2010, its percentage decreased to 7.80%, which was similar to the area in 1975. It has expanded again since 2010. In 2015, its percentage had risen to 8.71%. Wetland is not a leading type of land-use/cover in the MUSL. The area of wetlands decreased by 210.63 km^2 from 1965 to 2010, which accounted for 44.67% of the wetland area in 1965. However, there was a slight increase during the period 1975–1990. It has experienced a relatively steady increase since 2010; in 2015, it had increased to 282.71 km^2. Although construction land in the study area is also not a dominant type of land-use/cover, it has witnessed rapid growth during the past 50 years. In 1965, the percentage of construction land was only 0.34% of the study area. Subsequently, the figure increased to 0.39% in 1975, 0.45% in 1990, 0.64% in 1995, 0.67% in 2000, 0.93% in 2005, 1.25% in 2010, and 1.66% in 2015.

Table 3. Areas of changes in different land-use types in the MUSL, 1965–2015.

Year	Statistic Type	Land-Use/Cover							Total Area
		Woodland	Grassland	Wetland	Cultivated Land	Artificial Surface	Sparse Vegetation	Unused Land	
1965	Area (km^2)	4289.91	21,164.86	471.49	3702.51	164.70	9498.21	8996.41	48,288.09
	%	8.88%	43.83%	0.98%	7.67%	0.34%	19.67%	18.63%	100.00%
1975	Area (km^2)	4296.74	21,064.57	426.51	3769.27	189.42	9478.98	9062.61	48,288.09
	%	8.90%	43.62%	0.88%	7.81%	0.39%	19.63%	18.77%	100.00%
1990	Area (km^2)	4293.68	21,059.68	443.37	3780.20	217.02	9489.03	9005.11	48,288.09
	%	8.89%	43.61%	0.92%	7.83%	0.45%	19.65%	18.65%	100.00%
1995	Area (km^2)	4319.63	21,332.70	399.70	3780.97	310.74	9485.32	8659.03	48,288.09
	%	8.95%	44.18%	0.83%	7.83%	0.64%	19.64%	17.93%	100.00%

Table 3. *Cont.*

Year	Statistic Type	Land-Use/Cover							Total Area
		Woodland	Grassland	Wetland	Cultivated Land	Artificial Surface	Sparse Vegetation	Unused Land	
2000	Area (km^2)	4346.67	21,481.39	280.84	3822.68	321.29	9486.38	8548.84	48,288.09
	%	9.00%	44.49%	0.58%	7.92%	0.67%	19.65%	17.70%	100.00%
2005	Area (km^2)	4358.32	21,462.18	262.45	3789.76	448.46	9459.96	8506.95	48,288.09
	%	9.03%	44.45%	0.54%	7.85%	0.93%	19.59%	17.62%	100.00%
2010	Area (km^2)	4373.40	21,315.73	260.86	3767.23	604.73	9514.11	8452.04	48,288.09
	%	9.06%	44.14%	0.54%	7.80%	1.25%	19.70%	17.50%	100.00%
2015	Area (km^2)	4308.02	20,922.78	282.71	4204.92	802.91	9327.86	8438.90	48,288.09
	%	8.92%	43.33%	0.59%	8.71%	1.66%	19.32%	17.48%	100.00%

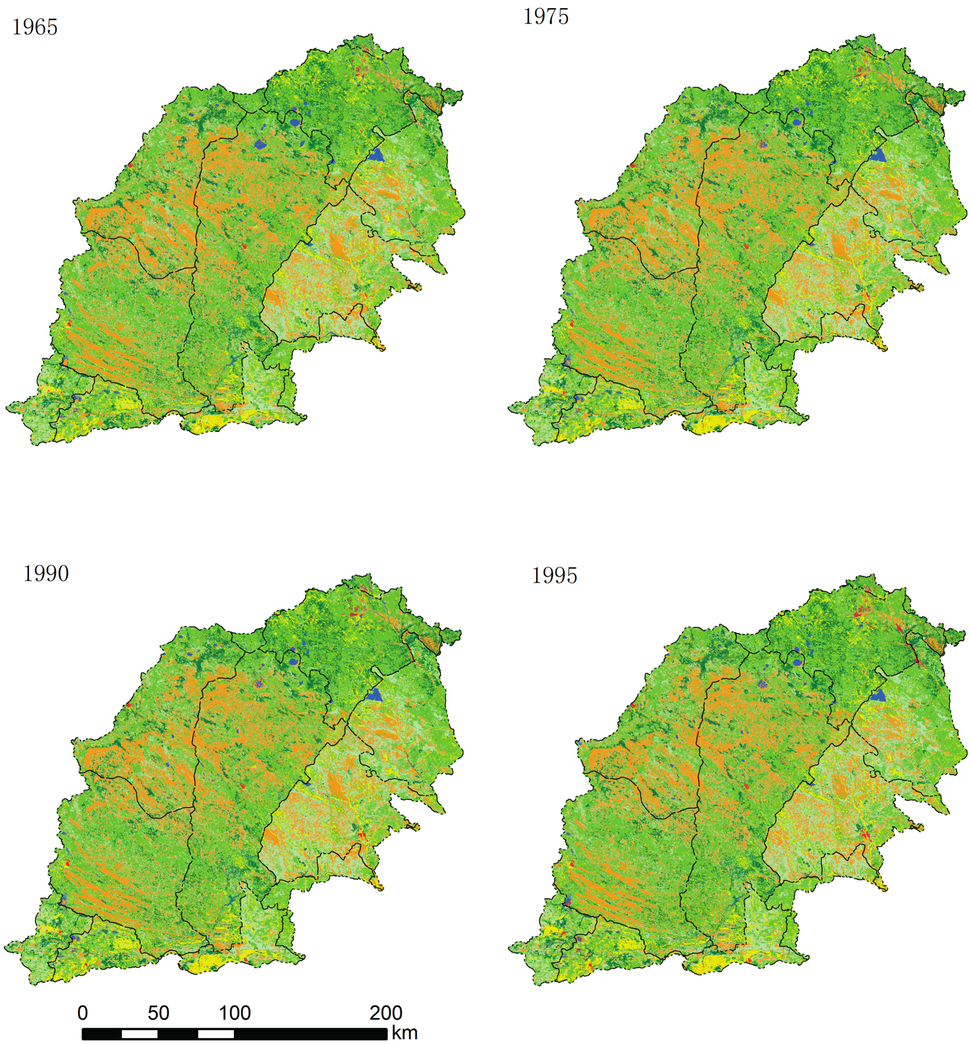

Figure 4. *Cont.*

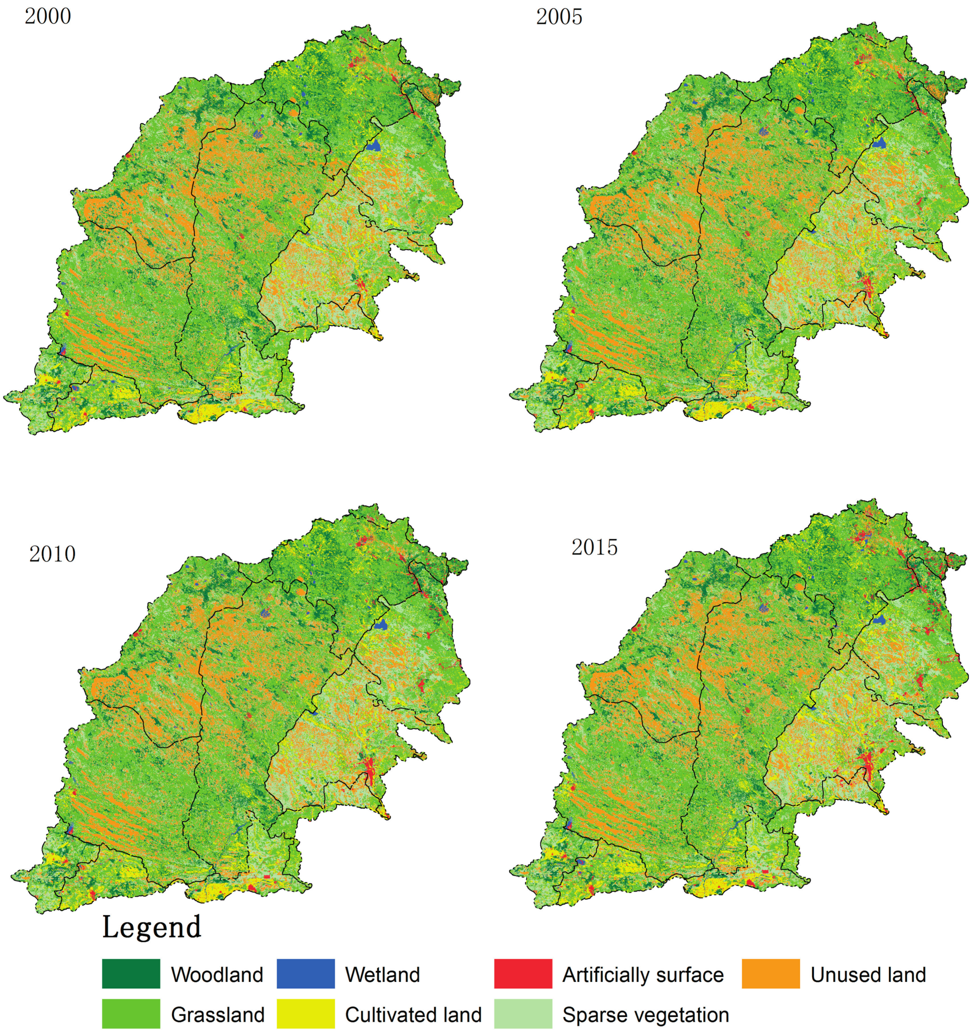

Figure 4. Spatial distribution of land-use/cover in the MUSL, 1965–2015.

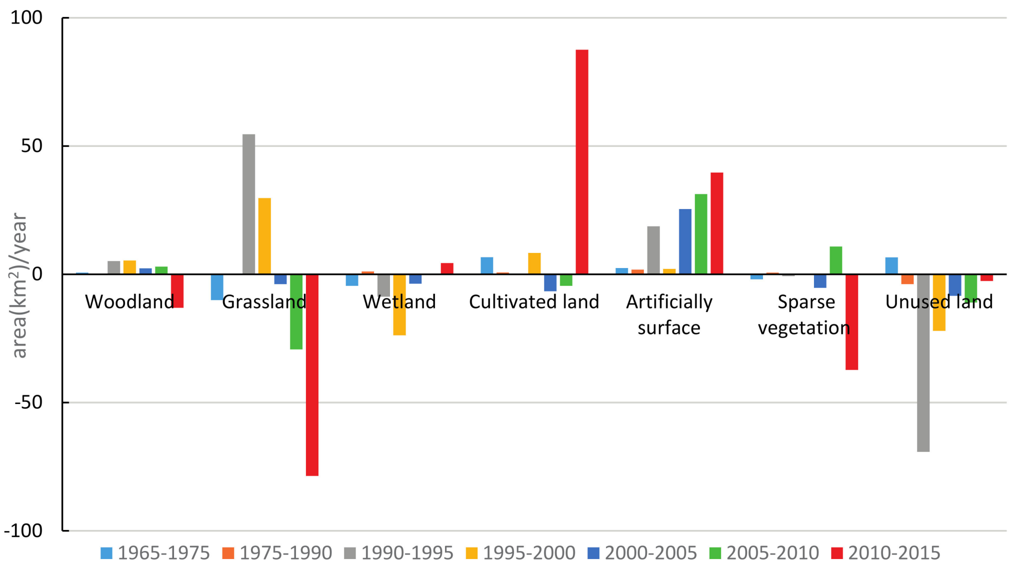

Figure 5. Land-cover trends in the seven periods from 1965 to 2015.

3.2. Land-Cover Transitions at Different Stages

3.2.1. The Stage of Great Cultural Revolution (1965–1978)

There were two land-use data layers (1965 and 1975) during this stage. The transition matrices for LUCC from 1965 to 1975 (Table 4) were calculated by overlaying the data layers for these two years. In Table 4, the rows represent the outward transfer of each land-use/cover type to other types during the study period, and the columns represent the inward transfer of each land-use/cover type and from where it was transferred. The loss of grassland is obvious from the differences in the grassland transferring-out area. The outward transfer area of grassland amounted to 137.28 km^2, of which 47.73 km^2 (34.77% of the area of the outward transfer of grassland) was converted to cultivated land, and 45.38 km^2 (33.06%), 18.18 km^2 (13.24%), 13.07 km^2 (9.52%), and 12.84 km^2 (9.35%) were converted to unused land, artificial surface, sparse vegetation, and wetland, respectively. Sparse vegetation, wetland, and unused land contributed to the inward transfer area of grassland. The gains in unused land and cultivated land are well-defined by comparing the differences in their inward transfer areas. The inward transfer area of unused land totaled 111.07 km^2, of which 49.82 km^2 (44.85%) of wetland was converted to unused land, and 45.38 km^2 (40.86%) of grassland was converted to unused land. The cultivated land that was newly opened between 1965 and 1975 totaled 91.32 km^2, of which 52.27% of grassland and 18.47% of sparse vegetation were converted to cultivated land.

Table 4. Land-use transfer matrix, 1965–1975.

Change in Area (km^2) by 1975								
1965	**Woodland**	**Grassland**	**Wetland**	**Cultivated Land**	**Artificial Surface**	**Sparse Vegetation**	**Unused Land**	**Sum (1965)**
Woodland	-	0.02	0.02	2.58	0.15	0.00	0.00	2.77
Grassland	0.08	-	12.84	47.73	18.18	13.07	45.38	137.28
Wetland	3.48	12.54	-	14.16	0.30	6.52	49.82	86.82
Cultivated land	0.98	3.39	4.45	-	3.17	9.67	2.91	24.57
Artificial surface	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00
Sparse vegetation	3.05	13.12	3.98	16.87	2.21	-	12.96	52.19
Unused land	2.01	7.91	20.55	9.98	0.71	3.71	-	44.87
Sum (1975)	9.60	36.98	41.84	91.32	24.72	32.97	111.07	348.50

3.2.2. The Stage of the Modernization of the Economy (1978–2000)

There were four land-use data layers (1975, 1990, 1995, and 2000) during this stage. The transition matrices for LUCCs in 1975–1990 (Table 5), 1990–1995 (Table 6), and 1995–2000 (Table 7) were calculated by overlaying the data layers for these four periods.

Table 5. Land-use transfer matrix from 1975 to 1990.

Change in Area (km^2) by 1990								
1975	**Wood Land**	**Grass Land**	**Wetland**	**Cultivated Land**	**Artificial Surface**	**Sparse Vegetation**	**Unused Land**	**Sum (1975)**
Wood land	-	0.04	0.70	0.80	0.07	2.82	2.01	6.44
Grass land	0.03	-	6.45	10.75	7.88	11.64	2.30	39.05
Wetland	0.46	4.46	-	5.83	1.29	2.28	10.18	24.50
Cultivated land	0.53	0.96	3.80	-	6.53	7.63	2.94	22.39
Artificial surface	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00
Sparse vegetation	0.01	8.59	1.60	11.64	4.66	-	4.73	31.23
Unused land	2.36	20.12	28.81	4.30	7.17	16.91	-	79.67
Sum (1990)	3.39	34.17	34.91	33.32	27.6	41.28	22.16	203.28

Table 6. Land-use transfer matrix from 1990 to 1995.

	Change in Area (km²) by 1995							
1990	**Wood Land**	**Grass Land**	**Wetland**	**Cultivated Land**	**Artificial Surface**	**Sparse Vegetation**	**Unused Land**	**Sum (1990)**
Wood land	-	35.56	5.14	15.75	1.87	4.98	1.12	64.42
Grass land	33.99	-	14.86	62.08	33.80	181.33	115.49	441.55
Wetland	11.65	21.30	-	16.23	6.60	17.77	52.57	126.12
Cultivated land	7.20	67.69	6.36	-	14.03	26.08	14.29	135.65
Artificial surface	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00
Sparse vegetation	25.31	263.9	8.43	30.31	14.99	-	111.05	453.99
Unused land	12.21	326.12	47.64	12.04	22.44	220.14	-	640.59
Sum (1995)	90.36	714.57	82.43	136.41	93.73	450.30	294.52	1862.32

Table 7. Land-use transfer matrix from 1995 to 2000.

	Change in Area (km²) by 2000							
1995	**Wood Land**	**Grass Land**	**Wetland**	**Cultivated Land**	**Artificial Surface**	**Sparse Vegetation**	**Unused Land**	**Sum (1995)**
Wood land	-	8.22	0.01	1.72	0.42	1.74	0.21	12.32
Grass land	24.66	-	0.61	29.74	2.08	23.43	4.99	85.51
Wetland	5.67	19.90	-	10.21	0.75	10.01	81.60	128.14
Cultivated land	3.08	19.55	0.33	-	2.67	4.63	1.71	31.97
Artificial surface	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00
Sparse vegetation	1.22	85.01	0.42	19.29	2.44	-	0.39	108.77
Unused land	4.74	101.53	7.90	12.72	2.19	70.02	-	199.1
Sum (2000)	39.37	234.21	9.27	73.68	10.55	109.83	88.90	565.81

During this stage, the outward transfer rate of unused land was larger in the three periods, and unused land was primarily transferred to grassland, sparse vegetation and wetland; the separate proportions of unused land that was transferred to grassland in the three periods were 25.25% (1975–1990), 50.91% (1990–1995), and 50.99% (1995–2000). The inward transfer rates of grassland and sparse vegetation were larger in this stage, and unused land was the primary source of the new area. The expansion of grassland was attributed to the reclamation of unused land. Unused land was mainly transferred to sparse vegetation and wetland. In the three periods, the separate contribution rates of unused land to sparse vegetation were 21.23, 34.37, and 35.17%, and the contribution rates of unused land to wetland were 36.16, 7.44, and 3.97%. The proportion of cultivated land and artificial surface increased, and grassland, sparse vegetation and unused land were the primary sources of the increase. However, cultivated land will decrease by a larger proportion in the future with the implementation of the Grain for Green Policy. Woodland was a relatively stable land-use type. The outward transfer areas of woodland were 6.44, 64.42, and 12.32 km^2 in the three periods, and woodland was mainly transferred to sparse vegetation and unused land during the period 1975–1990, grassland and cultivated land in 1990–1995, and grassland in 1995–2000.

Additionally, 1990–1995 was the most intense period of LUCCs, and the total area of LUCCs was 1862.32 km^2 in the three periods. Figure 5 shows that the trends in unused land, grassland, and artificial surface were significantly higher than those of the other land-use types during the period 1990–1995.

3.2.3. The Stage of the Great Ecological Project (Post-2000)

In this stage, the GGP and the "reform of the system of collective rights and land transfer" policy had the largest effects on LUCCs. Accordingly, LUCC was analyzed through two main phases (2000–2010 and 2010–2015). There were also four land-use data layers (2000, 2005, 2010, and 2015) during this stage. The transition matrices for LUCC in 2000–2010 (Table 8) and 2010–2015 (Table 9) were calculated by overlaying the data layers for these three years.

During this stage, the focus of the analysis was the conversion of cultivated land, vegetation (including woodland, grassland, and sparse vegetation), and unused land. In the two periods 2000–2010 and 2010–2015, the outward transfer areas of grassland were 314.00 km^2 and 414.50 km^2

and the inward transfer areas of grassland were 148.34 and 21.55 km^2, respectively. Grassland was mainly transferred to artificial surface, or unused land during the period 2000–2010 and to cultivated land, artificial surface or unused land during the period 2010–2015. During the period 2000–2010, the proportions of woodland and sparse vegetation increased due to the accomplishment of the GGP. Then, these two types significantly decreased with the end of the GGP. The trend in cultivated land was opposite that of woodland and sparse vegetation. However, cultivated land was not converted to grassland. Instead, it was mainly converted into artificial surfaces. This was also the reason for the decrease in grassland during the implementation of the GGP. Unused land decreased, although the rate of decrease was less than that of the last stage (1978–2000).

Table 8. Land-use transfer matrix from 2000 to 2010.

	Change in Area (km^2) by 2005							
2000	**Wood Land**	**Grass Land**	**Wetland**	**Cultivated Land**	**Artificial Surface**	**Sparse Vegetation**	**Unused Land**	**Sum (2000)**
Wood land	-	7.95	0.04	0.90	3.00	0.52	0.58	12.99
Grass land	24.08	-	5.84	9.38	138.07	19.98	116.66	314.00
Wetland	1.75	8.34	-	5.26	1.72	3.89	37.72	58.68
Cultivated land	2.99	27.19	4.21	-	42.33	6.99	0.82	84.54
Artificial surface	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00
Sparse vegetation	6.97	20.16	4.26	10.92	66.69	-	22.91	131.91
Unused land	3.91	84.70	24.35	2.63	31.64	128.26	-	275.50
Sum (2010)	39.71	148.34	38.70	29.09	283.44	159.64	178.70	877.61

Table 9. Land-use transfer matrix from 2010 to 2015.

	Change in Area (km^2) by 2015							
2010	**Wood Land**	**Grass Land**	**Wetland**	**Cultivated Land**	**Artificial Surface**	**Sparse Vegetation**	**Unused Land**	**Sum (2010)**
Wood land	-	0.94	1.96	28.7	30.82	0.08	6.11	68.61
Grass land	3.18	-	7.95	258.74	92.04	0.89	51.7	414.5
Wetland	0.00	7.12	-	0.04	0.03	0.01	1.65	8.85
Cultivated land	0.05	7.8	1.93	-	10.09	0.15	4.71	24.73
Artificial surface	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00
Sparse vegetation	0.00	3.01	1.64	121.42	36.9	-	24.44	187.41
Unused land	0.00	2.68	17.21	53.52	28.3	0.03	-	101.74
Sum (2015)	3.23	21.55	30.69	462.42	198.18	1.16	88.61	805.84

4. Discussion

In the stage of Great Cultural Revolution, the policies were mostly related to food production due to the influence of the Great Leap Forward Movement (1958–1960) and the Great Chinese Famine (1959–1961). The "grain first" policy and the People's Communes, which were proposed in 1958, had profound impacts on LUCCs. In 1965, the "Learning from Dazhai" movement originated in Dazhai village, Shanxi Province, emerged as a model for socialist development, and then the movement quickly spread over China [46]. To counterbalance the farming focus of the Dazhai model, Ulanhu, the chairman of the Inner Mongolia Autonomous Region, named Uxin Ju as the "pastoral Dazhai" for its effort to improve grasslands [47], located in the Uxin banner of the MUSL. The pastoral Dazhai advocated "planting grass and trees and improving sheep/goat varieties." However, the subsequent Cultural Revolution threw Inner Mongolia into disarray [48]; the policies existed in name only and had even been distorted by leftists. For example, the leftist regional leadership claimed that "pastoralists do not eat unethical grain [*mu min bu chi kui xin liang*]," meaning that grain was unethical if it was not self-produced [49]. Therefore, the newly opened cultivated land was mainly contributed by grassland and sparse vegetation. The unused land increased due to the influence of leftist policies. Additionally, the population policy was "larger population, greater labour force, and increased working morale [*ren duo, liliang da, reqi gao*]" in this stage, which led to the doubling of the Chinese population in 30 years [50]. This policy indirectly led to the expansion of cultivated land and construction land.

Because the aforementioned policies belonged to the central government's policy, the influence is not limited to the MUSL, but also to other ecologically fragile areas, as for example cultivated land in Yiliang County in the upper reaches of the Yangtze River, which increased by 71.27 km^2 from 1960 to 1980, with the main driving forces being policy failures and pressure of population growth [51].

In the stage of the modernization of the economy, China, facing near-bankruptcy, desperately needed to place development on the national agenda after the end of the Cultural Revolution. In 1978, economic reform was launched. Meanwhile, government control began to loosen and collective resource management gradually transformed into the household. A market economy, carried out in the late 1980s, completely caused the optimization of land resources. The economy of the MUSL continued to grow due to the exploitation of abundant mineral resources. This policy promoted increased construction land, especially mining regions. Because of the large amounts of capital that flowed into the property market and the country's real estate boom during the study period, construction land increased fastest during the period 1990–1995.

In Inner Mongolia, the policies of "chant the grass-tree mantra and develop pastoral economy" were reemphasized under a new system (i.e., a household-based economy), and were supported by entirely new ideologies: economic modernization and the application of ecological science [49]. From 1983 to 1985, the HRS was put into effect in Inner Mongolia, first distributing livestock (1983) and then usable grassland (1984–1985) to households; the commune system was dismantled at the same time (1984); and the preceding factors were largely responsible for the increase in grassland and cultivated land during this period. At the beginning of the HRS (1975–1990), overgrazing and deforestation had worsened because of the imperfection of grassland and woodland management and the enthusiasm of farmers and herdsmen for production. Meanwhile, cultivation land continued to encroach on grasslands, leading to what was considered a new wave of open grassland and woodland from 1975 to 1990. The areas of grassland and woodland were reduced simultaneously (see Table 5). From 1990 to 2000, the grassland area in the MUSL increased. Many pastoralists expanded their meadows by clearing sparse vegetation and unused land. The land-use transfer matrix analysis indicated that approximately 85.62% of newly created grassland was from sparse vegetation and unused land (see Tables 6 and 7). Cultivated land, which was not the primary land-use type in the MUSL, was mainly distributed in the southern part of the MUSL (see Figure 4); however, its area increased by 53.41 km^2 from 1975 to 2000 under the influence of the HRS.

Along with economic development, ecological science became the second principle of LUCC. Governmental ecological programs have been launched since 1978, starting with the TNSP that has promoted tree planting in northern China in order to combat land sandy desertification and reduce dust storms [52]. Subsequently, the government issued a series of environmental protection policies, such as the police and project of migration (1982–2008) and the poverty alleviation policy (1986), and environmental protection, and sustainable development were established as the basic national policy in 1986 and 1992, respectively. These policies/projects aimed at forest and ecoenvironmental protection and have resulted in macroscopic impacts on LUCC in the MUSL. The forest coverage area in the MUSL continuously increased since 1990. The change in unused land was also closely related to those policies in the study area since 1975.

Because precipitation cannot satisfy the demands of reforestation, crop production and the daily life of people, forestland, cropland, grassland, and the increasing population require the support of vast amounts of water resources in the MUSL. The previously mentioned policies indirectly affected wetland change. The wetland area firstly increased slowly, but then declined dramatically between 1975 and 2000. According to the land conversion matrix analysis, 52.92% of the wetland area deteriorated into unused land (saline land).

In the stage of the Great Ecological Project, China became the second largest economy in the world and lifted hundreds of millions of people out of poverty [53]; however, the environment was increasingly deteriorating. Massive deforestation and erosion contributed to severe flooding along the Yangtze River in 1998 [54] and approximately 12 sandstorms enveloped most of northwestern China during the spring of 2000 [55]. The Natural Forest Conservation Program (NFCP) [56] was extensively implemented following these events. The government promulgated the law on desert prevention and transformation in 2001. Table 8 has shown that the area of unused land decreased by 96.81 km^2 and the area of woodland and sparse vegetation increased by 26.72 and 27.73 km^2, respectively, between 2000 and 2010. Then, in succession, the GTGP [57] and the Grazing Forbidden Project (GFP) [58] were carried out. The area of cultivated land decreased by 55.45 km^2 from 2000 to 2010 (see Table 8) by the implementation of these two policies. Grassland area was originally expected to trend upward, although it actually decreased by 165.66 km^2. This change did not mean that the two policies failed to take effect. The transport matrix of Tables 6 and 7 have shown that a large amount of grassland were brought under cultivation between 1990 and 2000. However, only 9.50 km^2 of grassland was converted to cultivated land in the periods 2000–2010. This means that cultivated land occupation of grassland decreased significantly due to the two policies. However, why did the grassland area decrease? The nation implemented many economic policies and projects at the same time, such as the great western development strategy (2000), the property sector as a pillar industry of the national economy (2003), and the new rural development strategy (2004). These policies had a superposition effect on land-use/cover, converting large amounts of cultivated land and grassland into artificial surfaces. According to the land conversion matrix analysis, approximately 58.55 km^2 and 79.51 km^2 of grassland was converted to artificial surface during the periods 2000–2005 and 2005–2010, respectively.

The period 2010–2015 was the most intense period of LUCC. During this period, woodland, grassland, and sparse vegetation decreased sharply, and cultivated land and artificial surface area increased accordingly. The primary policy reason for LUCC in this period was that, with the end of the policy of GTGP, the agropastoralists started a new round of cultivation due to the loss of ecological subsidies. Additionally, canceling the agricultural tax (2006), reform of the system of collective rights and land transfer (2008), the construction of ecological civilization (2012), and the belt and road initiative (2015) had important impacts on LUCC in the MUSL. The majority of newly cultivated land was jointly led by the government and enterprises through this field investigation in 2017. The more serious consequence is that newly cultivated land is irrigated with groundwater, and uncovered in the spring. That may cause serious ecological disaster and the managers should continue to strictly implement the policy of ecological protection in ecologically fragile areas, such as the MUSL, in the future.

5. Conclusions

In this paper, the integrated techniques of RS, GIS, and field-based datasets were used to reveal LUCC from 1965 to 2015 in the MUSL, and to further explore the roles played by different policies at different periods. It was found that land-use/cover in the MUSL has undergone complex changes due to the rapid economic and social development that has occurred in the study area since 1965. Grassland, a dominant type of land-use/cover, decreased gradually before 1990, increased significantly during the period 1990–2000, and finally declined after 2000. Cultivated land in the study area first increased (1965–2000), then decreased (2000–2010), and increased again (2010–2015). The area of woodland continued to increase from 1965 to 2010, except for a slight decrease in the period 1975–1990. The extent of sparse vegetation changed slightly pre-2000 before increasing after 2000. The area of wetlands decreased from 1965 to 2010, except for a slight increase in the period 1975–1990; a relatively continuous increase has occurred since 2010. Artificial surfaces have continuously increased because of accelerating social and economic development stimulated by the Chinese Economic Reform and rapid population growth. Unused land decreased gradually before 1975 due to the influence of leftists, and then shrank considerably from 1975 to 2015.

Since 1965, three policy phases have been divided in the MUSL. In each period, the national policy differed because the national focus changed. The different national policies had differing impacts on land-use/cover. Although the ecological protection policy was sometimes disrupted by extremists, it continued through all of the periods, such as "pastoral Dazhai," the TNSP, NFCP, GTGP, and the Grazing Forbidden Project. The main effects of these policies were increased woodland and grassland areas, and decreased unused land and cultivated land. Many ecological problems, such as desertification and grassland degradation, have been effectively controlled. However, the land-use/cover data of 2015 show that large tracts of grassland were reclaimed. This may lead to exposed surfaces and, when combined with the excessive consumption of groundwater, may possibly initiate new desertification and grassland degradation in the future. Therefore, the government should be cautious about newly cultivated land, and continue to strictly implement the policy of ecological protection in ecologically fragile areas, such as the MUSL. In summary, policy has had an important influence on LUCC in the study area. The policies were formulated by the government and land-use/cover was changed by agropastoralists. Therefore, the key is to balance the interests of agro-pastoralists and governments in the policy-making process.

In this paper, we mainly focus on the impact of policy on LUCC in agropastoral ecotone of China. However, there are still other driving forces that should not be ignored, particularly climatic variation. Further efforts are needed to quantitatively evaluate the contribution of each factor to LUCC.

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