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How Does Ecological Migration Drive Land Use in Resettlement Areas?

--Taking the Shule River Resettlement Project as an Example

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ABSTRACT

Eco-migration is a special migration formed to improve the habitat environment and alleviate the ecological pressure, which is an important initiative to realize the United Nations sustainable development goals, and a livelihood project to promote the harmonious coexistence of human-land relationship. Due to the external migration of large-scale immigrants, it leads to abrupt and special land use changes in resettlement areas compared with general areas. [Model] This paper systematically studies the impact of the Shule River resettlement project on land use change by comprehensively applying the land use transfer matrix, information entropy, and the human activity intensity index model with the support of land use data from 1996 to 2010. [Results] The study found that: 1. The change process of land use reflects the change process from micro-change→dramatic change→smooth change in the early stage of migration→middle stage of migration→end stage of migration, and reflects the order of priority needs of life→production→ecology. 2. In the early and middle stages of migration, the grassland is mainly transformed into arable land and construction land, and in the end stage, when the migrants realize the basic "living and working in peace and contentment", they begin to pay attention to the optimization of the living environment, and the amount of forest land increases. 3.The entropy of land use structure information and the degree of balance are both on the rise, and are closely related to the resettlement mode and scale of immigrants, with large-scale immigrant resettlement bases tending to be more diversified and balanced. On the contrary, the degree of dominance shows a decreasing trend, indicating that with the migration process, land use has gradually moved from purely favoring production (construction land) and production (arable land) to taking ecology into account. 4. The migration process is projected on the human activity intensity index, which shows stage and spatial heterogeneity. There is a significant positive correlation between the rise and fall of the human activity intensity index in the project implementation period and the intensity of migration, and the larger the scale of migration, the greater the intensity of human activities and the stronger the shaping effect on land use. [Conclusion] Ecological migration is the dominant force driving land use change.

KEYWORDS

Ecological Migration; Land Use; Resettlement Area; Migration Stage; Shule River Basin.

1. INTRODUCTION

Eco-migration is a special migration to transfer the population and all kinds of economic activities living in areas with poor natural environment (or serious damage), important ecological function areas, and poor habitat environment to areas with relatively better survival and economic conditions and long-term stable development through relocation [1]. It is an important initiative to achieve the United Nations sustainable development goals and a livelihood project to promote the human-environment interaction [2].

Ecologist Myers N first warned in 1993 that hundreds of thousands of people would escape their home town in the 21st century for reasons directly or indirectly attributable to the environment [3]; Tolba, the executive director of the United Nations Environment Programme, emphasized that if the world didn't take positive action in support of sustainable development, "up to 50 million people could become environmental refugees"[4], which triggered alarm and reflection on ecological (environmental) migration [5]. Ecological migrants, initially known as environmental refugees/environmental migrants, were first proposed by L Brown, a scholar at the Worldwatch Institute, in 1976 [6], and first defined by E El-Hinnawi, a researcher at the United Nations Environment Programme, as: People who have been forced to temporarily or permanently leave their traditional habitat due to obvious environmental damage (natural and/or human-induced) that jeopardizes their survival and/or seriously affects their quality [7]. The International Organization for Migration defines environmental migration as "forced or active, temporary or permanent movement of people caused by sudden or gradual changes in the environment that negatively affect their living conditions". Similar concepts include Environment/Climate Change Migration, Environment induced or forced immigration, Ecological/Environmental refugees, etc. [3,5-8]. Despite the diversity of opinions [9-12], ecological migration is generally considered to be forced migration caused by environmental degradation [13]. Black R and other scholars questioned Myers' speculation, pointing out that so far there is no convincing evidence that environmental change will directly lead to large-scale environmental refugees. Environmental factors are only one of the causes of "environmental refugees", may not be the primary factor, environmental refugees is a strategy to deal with environmental problems rather than a passive initiative [9]. Moreover, from the perspective of international law, "environmental refugees" cannot obtain the qualification and treatment of "Convention refugees", so "environmental/ecological migrants" replaced "environmental refugees" [14].

Due to different national conditions and contexts, the meaning and use of eco-migrants differ at home and abroad. Eco-migrants in China are government-led migrants related to environmental change, and the relocation and resettlement process emphasizes two consequences of action: one is government-led; the other is that the migrant subject has a certain passivity or voluntariness [15]. According to the Institute of Territorial Development and Regional Economy of the National Development and Reform Commission, eco-migration refers to the special migration for the purpose of eliminating poverty, developing the economy and protecting the ecological environment. And special migrants who are located in ecologically fragile areas (or severely damaged areas), important ecological function areas, and areas with poor habitat environment, through relocation, transfer to areas with relatively better living and economic conditions and long-term stable development [16]. Thereby realizing harmonious development of the economy, society and population, resources and the environment. The Chinese government-led eco-migration, with the main purpose of restoring and protecting the ecological environment, while taking into account poverty alleviation and raising economic income, embodies both the causes and purposes of eco-migration [15]. A similar concept is that of relocation (poverty alleviation), which usually refers to the relocation of residents to places more suitable for survival and development in order to solve the poverty problem or environmental problem in a specific area, so as to promote their poverty alleviation and enrichment or to improve the ecological environment. Relocation and eco-migration overlap in their objectives, both aiming to improve the living conditions of residents and protect the ecological environment, and both realize their objectives through population relocation. However, the starting point and mode of implementation are slightly different, with relocation focusing more on poverty alleviation and economic development, while ecological migration focuses more on environmental protection and ecological restoration.

Beginning in 1982, our country first implemented a large-scale ecological migration project in the Hexi Corridor of Gansu, Dingxi, and the Xihaigu region of Ningxia (the “Three Wests” region), which is characterized by chronic drought, water shortages, overpopulation and extreme poverty. The Eleventh “Five-Year”Plan for Poverty Alleviation and Relocation, issued by the State in 2006, clearly states that: Relocation for poverty alleviation, also known as eco-migration, ..., achieves the dual goals of poverty eradication and ecological improvement through the relocation of poor people living in areas unsuitable for human survival. The No. 1 article of the Central Committee in 2024 pointed out that it is necessary to promote the sustainable development of resettlement areas for poverty alleviation and relocation. From 1980 to 2020, the Chinese Government solved the livelihood problems of more than 10 million people through a series of land-based poverty alleviation and relocation and ecological migration projects [1,17].

Ecological migration is not a simple spatial transfer of population living space, but also an external intrusion into the three living systems of the resettlement area, and the spatial and temporal transformation process of the population from the out-migration place to the in-migration place is the process of re-exploiting and utilizing the land resources of the resettlement area and the process of reshaping the landscape pattern[18,19], This has led to an intense interaction between physical geographic and anthropogenic processes in the resettlement area, resulting in a series of changes and reorganizations. In contrast to the smoothness of land use change in the general area, the change in the resettlement area due to the strong entry of eco-migrants is characterized by significant abrupt changes. The most direct manifestation of ecological migrants moving into the area is the change in the structure and type of land use [20], even causing systematic changes in the transfer of land management rights [21], land management practices and livelihood patterns [22].

The “Three Western Regions” and the “Three Rivers Source Region” are hotspots for ecological migration research [19,23]. Gansu Province is a key area for ecological migration, and has implemented the “Two West Agricultural Construction Migration Project” in 1982, the “Gansu Province Hexi Corridor (Shule River) Agricultural Irrigation Migrant Resettlement Comprehensive Development Project” in 1996 and the “Jiudianxia Reservoir Resettlement Project” in 2007. One such project, the Shule River Ecological Migration Project, is “by far the largest in the world in terms of the number of migrants” (World Bank comment) and has had a wide international impact. Since its implementation, the project has been widely followed by scholars, and feasibility, early warning, follow-up and reflective studies have been carried out at the pre-migration, migration and post-migration stages. Wang Junde found that forest land, grassland, and watershed in the middle and lower reaches of the Shule River underwent different degrees of change from 1970 to 2013 [24]; oases slowly shrank due to the reduction of grassland and watershed areas [25]; and changes in the intensity of land use in the three major irrigation districts were related to migration [26]. These studies have provided an in-depth understanding of the relationship between migration and changes in land use and landscape patterns, but there are shortcomings such as “scale confusion”, “time confusion” and “process ambiguity”: “Scale Confusion” - Many studies nominally examine the effects of ecological migration on LUCC changes in the Shule River, but do not visualize the real resettlement areas, but substitute basin-wide or mid- and lower reaches (replace the small with the large), and therefore cannot conclusively prove that Is the change in LUCC the result of ecological migration or is it the result of other causes? In fact, ecological resettlement is a process of population location that takes place under specific spatial and temporal conditions, and the Shule River Resettlement Project adopts a resettlement method that combines large-scale resettlement bases with small-scale resettlement bases and resettlement sites, with a very limited resettlement area. Therefore, it is practically impossible to accurately examine the relationship between LUCC changes in the resettlement area and migration by using the whole basin and the middle and lower reaches of the river. “Time confusion” - the Shule River resettlement project is a planned act under government leadership, with clear time points and landmark events: the Shule River resettlement project was launched in 1996 and ended in 2010, with a mid-term project in 2002 Adjustment. Most of the existing results use equally spaced years to divide the time period, which cannot fit the migration process. “Process ambiguity” - the migration process is a developmental process from nothing, from little to much, from unstable to stable, during which the changes in LUCC cannot be gradual, and there is mutability in some specific periods. Therefore, the main goal of this paper is to anchor the migrants to set the resettlement area - 3 major irrigation areas, large (small) migrant bases and resettlement sites, to clarify the temporal boundaries, to subdivided the eco-migration activities into the early, middle and late stages of migration, to construct the spatial and temporal unity of the eco-migration process - land use change process, so as to answer the question of how exactly does migration drive land use change? The results of the study provide policy implications for sustainable land use in ecological migration zones.

2. DATA SOURCES AND METHODS

2.1. Overview of ecological migration on the Shule River

Shule River Basin is located in the west end of Hexi Corridor of Gansu Province, which is the second largest inland river basin in Hexi region, with the geographical position of 92°54′E~99°14′E, 38°36′N~41°34′N. The upper reaches of Shule River are from the southeast of Changmaxi Gorge, and Changmaxi Gorge-Shuangtabao Reservoir is the middle reaches, and the lower reaches of Shule River are below the Reservoir. The middle and lower reaches are flat, with oases and deserts interspersed, and are the main irrigation areas in the basin.

The Shule River Ecological Immigration Project is a key national comprehensive development project centered on poverty alleviation and immigration, water conservancy project construction as the backbone, and water and land reform as the center. The targets of poverty alleviation and migration are hundreds of thousands of people in 11 counties in the arid zone in the central part of Gansu Province and the alpine and humid mountainous zone in the south. The Shule River Migration Project completed its feasibility study in 1994, and in October 1995 World Bank experts carried out a formal evaluation of the project; on July 2, 1996, the Chinese Government formally signed the “Project Agreement”, “the Development Credit Agreement ”and “the Loan Agreement” with the World Bank in Washington. This determine the use of the World Bank loan of 150 million U.S. dollars, the estimated total investment of 2.673 billion yuan, the new development of 54,600 hm2 of land, resettlement of 200,000 immigrants, the development of irrigated areas of 97,800 hm2, the construction of the total construction period of l0 years. In June 1996, the voluntary resettlement of immigrants for the Shule River project was formally launched, and in September 2010 the transfer of the last two immigrant villages to the Yumen Municipal Government was completed, marking the full completion of the resettlement of immigrants for the Shule River project. In 2002, the Gansu Provincial Government reached a consensus with the World Bank on the basis of the actual situation of water resources development and utilization, ecological and environmental protection, and the ability to raise supporting funds in the Shule River Basin, and made mid-term adjustments to the project, and the scale of migration was reduced from 200,000 to 75,000; the new immigrants' townships were reduced from 16 to 6, and the number of new villages was reduced from 160 to 57.

Migrants were mainly concentrated in the period 2002-2006, totaling 53,716 persons, accounting for 86.64% of the total number of migrants, who were mainly resettled in the Changma Irrigation District in Guazhou County, the Shuangta Irrigation District and the Huahai Irrigation District in Yumen City. Among them, Changma Irrigation District resettled 7,455 households, 37,908 people (accounting for 61.14% of the total immigrants), mainly resettled in the waist station sub-townships, and a new

Shuangta Township, Qidun Township, Shahe Township and other immigrant townships. Shuangta Irrigation District moved in a total of 9,419 people (15.19%), and a new immigration point Lianghu Township. The Huahai Irrigation District has resettled 14,673 immigrants (23.67%) and built new immigrant townships such as Dushanzi Township and Xiaoginwan Dongxiang Ethnic Township (Figure 1 and Table 1).

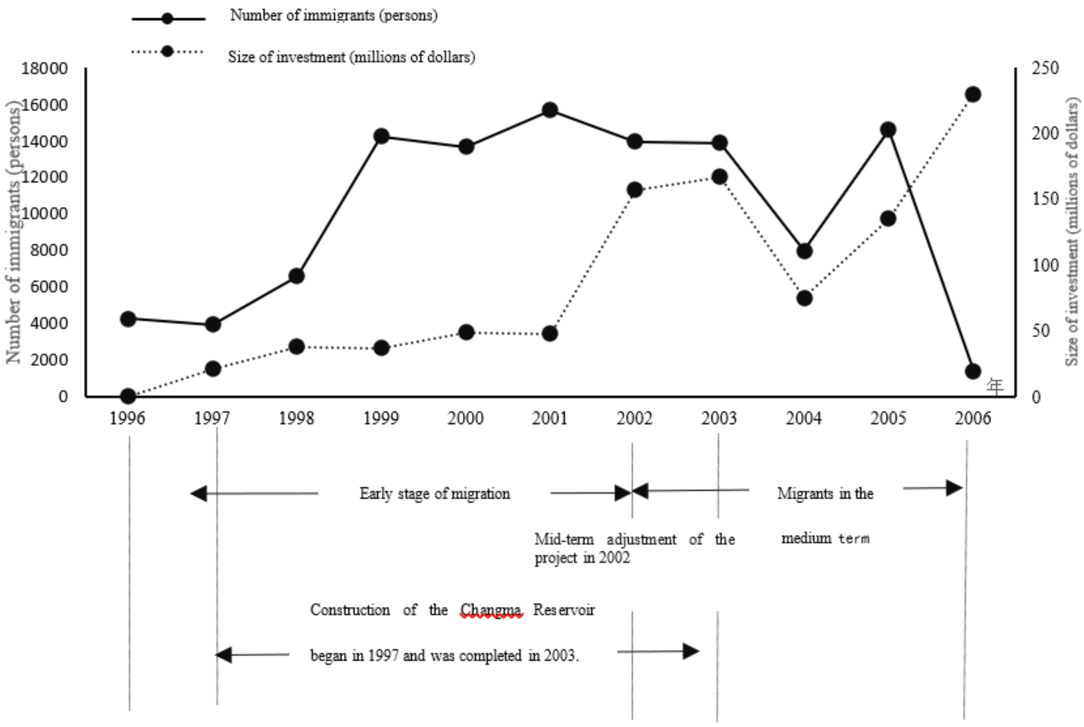


Figure 1. Changes in population and investment at different stages of the Shule River Ecological Migration Project

“The Shule River Resettlement Project ”adopts a combination of large-scale resettlement bases, small-scale resettlement bases and resettlement sites (i.e., centralized resettlement and decentralized resettlement). According to the “Highlights of Comprehensive Development Plan for Agricultural Irrigation and Resettlement in Shule River Basin of Gansu Province, China” (the “Highlights of the Plan”), one large-scale resettlement base is planned to be constructed: the base of Yaozhanzi; four small-scale resettlement bases: Qidougou Village of Hedong Township of Guazhou County, Blongji Village of Blongji Township, Guazhou Township Comprehensive Agricultural Development Zone and Chengnan Resettlement Development Zone, and six resettlement points: Guazhou County West Lake Township farm, Nancha Town nine south village, West Lake Town Xiangyang village, Guazhou town Sangong village, Sandaogou town North Beach village, the original steadfast township west canal village.The scope of the study area in this paper mainly involves three major irrigation districts (Shuangta Irrigation District and Changma Irrigation District in Guazhou County, and Huahai Irrigation District in Yumen City) and specific migrant resettlement areas. The irrigation districts follow the traditional division program, and the migrant bases and resettlement points are decided based on the administrative boundaries of the migrant townships (towns) and villages (Figure 2). In this paper, the period 1996-2002 is categorized as the early stage of migration, 2002-2006 as the middle stage of migration, and 2007-2010 as the late stage of migration.

Table 1. Migrant influx in the Shule River ecological resettlement area (1997-2006)

Area under irrigation	Townships and farms	Number of households moved in/household	Number of people moving in/person
Changma irrigation district	Shuangta Township	2762	12988
	Qidun Township	1467	7103
	Qidaogou Farm	1568	8755
	Huanghua Farm	770	3861
	Yinma Farm	429	2667
Shuangta irrigation district	Zhahua Village	459	2534
	Lianghu Farm	1575	7769
	Huancheng Township	342	1650
Huahai irrigation district	Bijiatan Township	1390	6301
	Dushanzi Farm	1823	8372
Sum		12585	62000

Source: Completion report of the WB loan project for the Hexi Corridor (Shule River), Gansu, China.

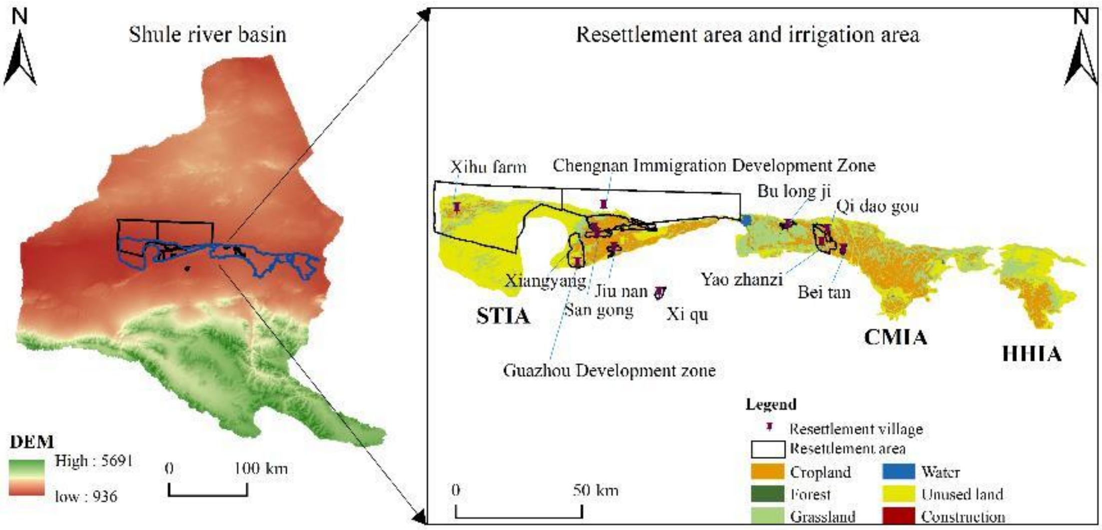


Figure 2. Schematic of the study area

2.2. Data sources

The primary data sources for this study are:

(1) Land use data from 1996 to 2010, from the China Land Cover Dataset (CLCD) of Wuhan University, all with a spatial resolution of 30m.

(2) Shule River ecological migration, investment and other data from "Completion Report of the World Bank Loan Project for the Western Corridor (Shule River) in Gansu, China".

(3) Vector maps of administrative boundaries from Gansu Provincial Bureau of Surveying and Mapping; DEM data from Geospatial Data Cloud (http://www.gscloud.cn/search).

(4) Socio-economic and other statistical data come mainly from "the Yumen City Statistical Yearbook" and "the Guazhou County Statistical Yearbook".

2.3. Research methodology

2.3.1. Land-use transfer matrix [27]

The land use transfer matrix is used to reflect the status of transfers out and in for each land category at the beginning and end of the study period, thus reflecting the process of land use change.

$$K_{ij}=\begin{bmatrix} K_{11} & K_{12} & \cdots & K_{1n} \\ K_{21} & K_{22} & \cdots & K_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ K_{n1} & K_{n2} & \cdots & K_{nn} \end{bmatrix}$$

Where: K is the area (km²); i is the land use type at the beginning of the study; j is the land use type at the end of the study; n is the number of land use types.

2.3.2. Comprehensive Land use dynamic degree

It reflects the overall rate of change for each land use category. The higher the value, the more drastic the degree of land-use change.

$$L = \left\{\frac{\sum_i^n |\Delta Z_{i-j}|}{2\sum_i^n Z_i}\right\} \times \frac{1}{T} \times 100\% \quad (1)$$

Where: L is the integrated land use dynamics (%), n is the number of land use types, ΔZ_{i-j} is the absolute value of the area (km2) of land of category i converted to category j; Z_i is the area of land of category i at the beginning of the period; and T is the time period of the study (years).

2.3.3. land use structure information entropy

This is used to reflect the complexity, concentration and equilibrium of land-use types, as well as the level of conversion of land classes. The higher the entropy value, the more land use types and small differences in area, the more balanced the distribution of land use; conversely, it tends to be unbalanced [28].

$$S_i = \frac{P_i}{P} \quad (2)$$

$$H = -\sum_i^n (S_i)\,(lnS_i) \quad (3)$$

Where: S_i is the proportion of land category i to the total area of the study area; P_i is the area of land category i and P is the total land area of the study area; H is the entropy value of land use structure information.

The equilibrium is calculated by the formula:

$$J = \frac{H}{H_{max}} = \frac{-\sum_i^n (S_i)(lnS_i)}{ln_n} \quad (4)$$

Where: J represents the degree of equilibrium, H and Hmax represent the actual value and theoretical maximum value of the entropy of the information structure of land use, i.e., when the land use area is equal, i.e., p1=p2=...=pn, the entropy of information is the largest, i.e., Hmax=lnn[27,28]; because H≤Hmax, so 0≤J≤1. The larger the value of J, the greater the homogeneity of land use. the greater the value of J, the stronger the land use homogeneity.

The dominance degree expression is:

$$K = 1 - H \tag{5}$$

Where: the degree of dominance K indicates the degree of dominance of one or more dominant land categories over the land in the region. the higher the value of K, the more dominant.

2.3.4. Comprehensive index of land use degree

$$L_j = 100 \times \sum_{i=1}^{n} A_i \times C_i \tag{6}$$

Where: Lj refers to the comprehensive land use index of a certain region, the larger the value indicates that the higher the degree of land use in the region; Ai is the grading index of the degree of land use at level i. Referring to the grading standards in the existing studies [28,29] and combining with the actual situation in the study area, the value of barren land is assigned as 1, the value of forest land, grassland and water is assigned as 2, the value of cultivated land is assigned as 3, and the value of construction land is assigned as 4; Ci is the percentage of area for the grading of land use at level i; n is the number of land use degrees, and this study takes the value of 4. Ci is the percentage of area of the ith level of land use degree grading; n is the number of land use degree grading, and the value of this study is 4.

2.3.5. Land use degree change model

This is used to reveal the level of integration and trends in land use, expressed as:

$$\Delta I_{b-a} = [(\sum_{i=1}^{n} A_i \times C_{ib}) - (\sum_{i=1}^{n} A_i \times C_{ia})] \times 100 \tag{7}$$

$$H = \frac{(\sum_{i=1}^{n} A_i \times C_{ib}) - (\sum_{i=1}^{n} A_i \times C_{ia})}{\sum_{i=1}^{n}(A_i \times C_{ia})} \tag{8}$$

Where: Ai is the graded index of land use degree of level i; Cia and Cib are the percentage of area of land use degree of level i in the study area in time periods a and b; when ΔIb-a>0 or Hi>0, the land in the study area is in the period of development, and vice versa in the period of decline.

2.3.6. Human activity intensity index model

Quantification of the intensity of human activities through the use of land-use equivalents of construction and land-use equivalents of construction conversion factors [29].

$$HAILS = \frac{S_{CLE-i}}{S} \times 100\% \tag{9}$$

$$S_{CLE} = \sum_{i=1}^{n}(SL_i \times CI_i) \tag{10}$$

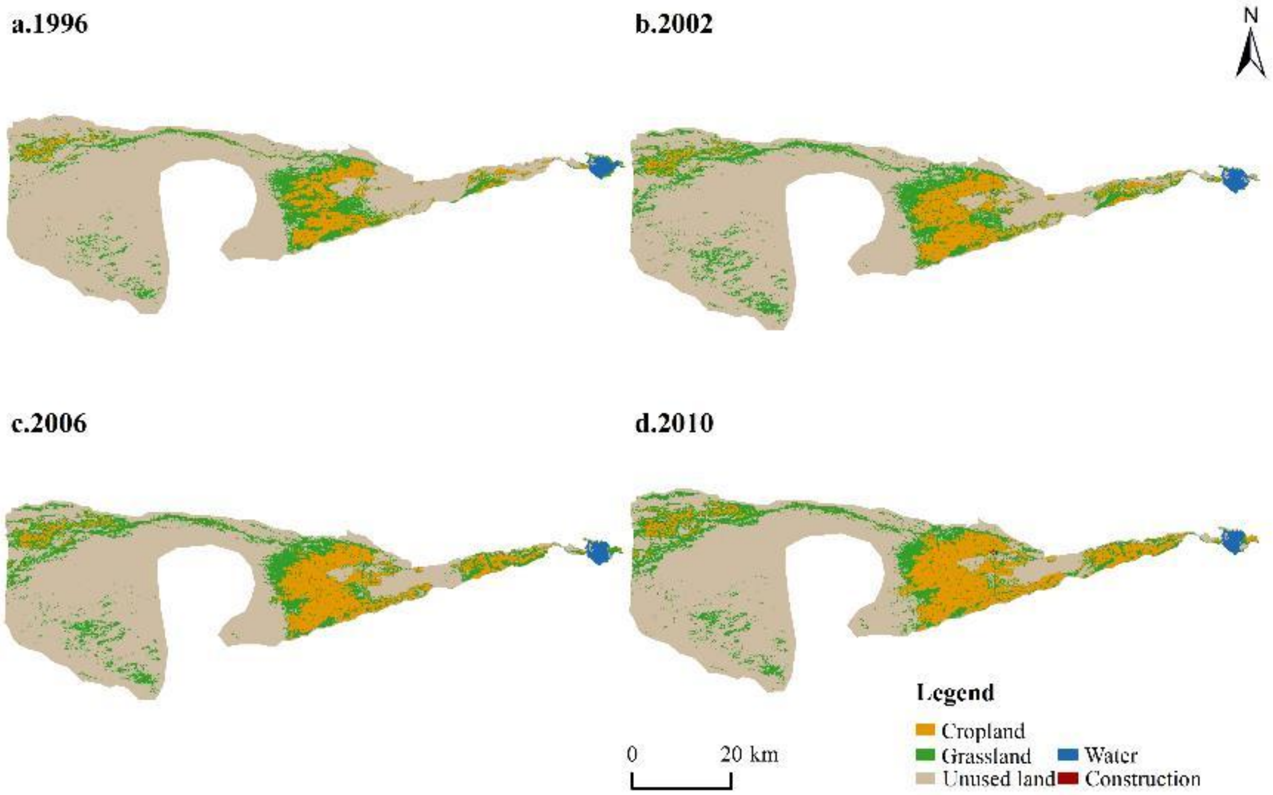
Where: HAILS is the intensity of human activities, SCLE is the equivalent area of construction land; S is the total area of the study area; SLi is the area of the ith land use type, and CIi is the conversion factor of the ith land use type.

3. RESULTS AND ANALYSIS

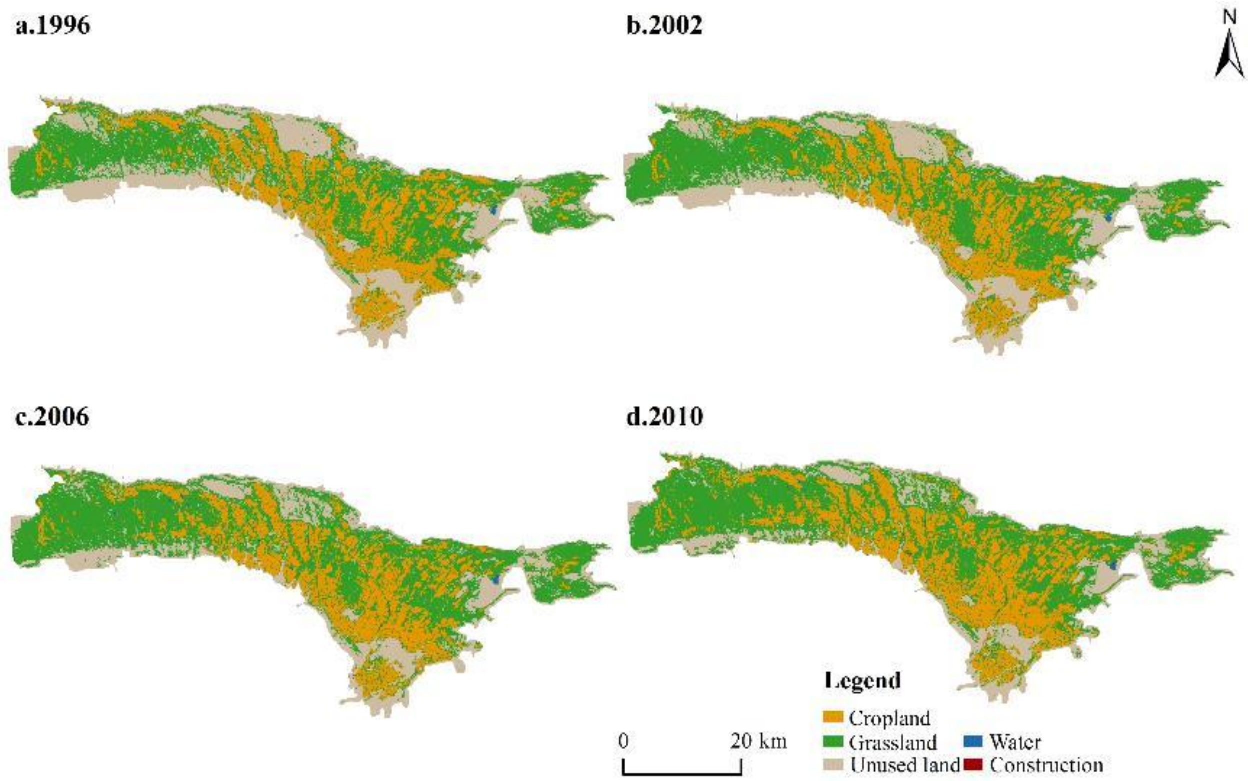
3.1. Land use change

The process of land use change reflects the process of change from micro-change → drastic change → smooth change in the early stage of migration → middle stage of migration → end stage of migration, thus reflecting the order of priority needs of life → production → ecology.

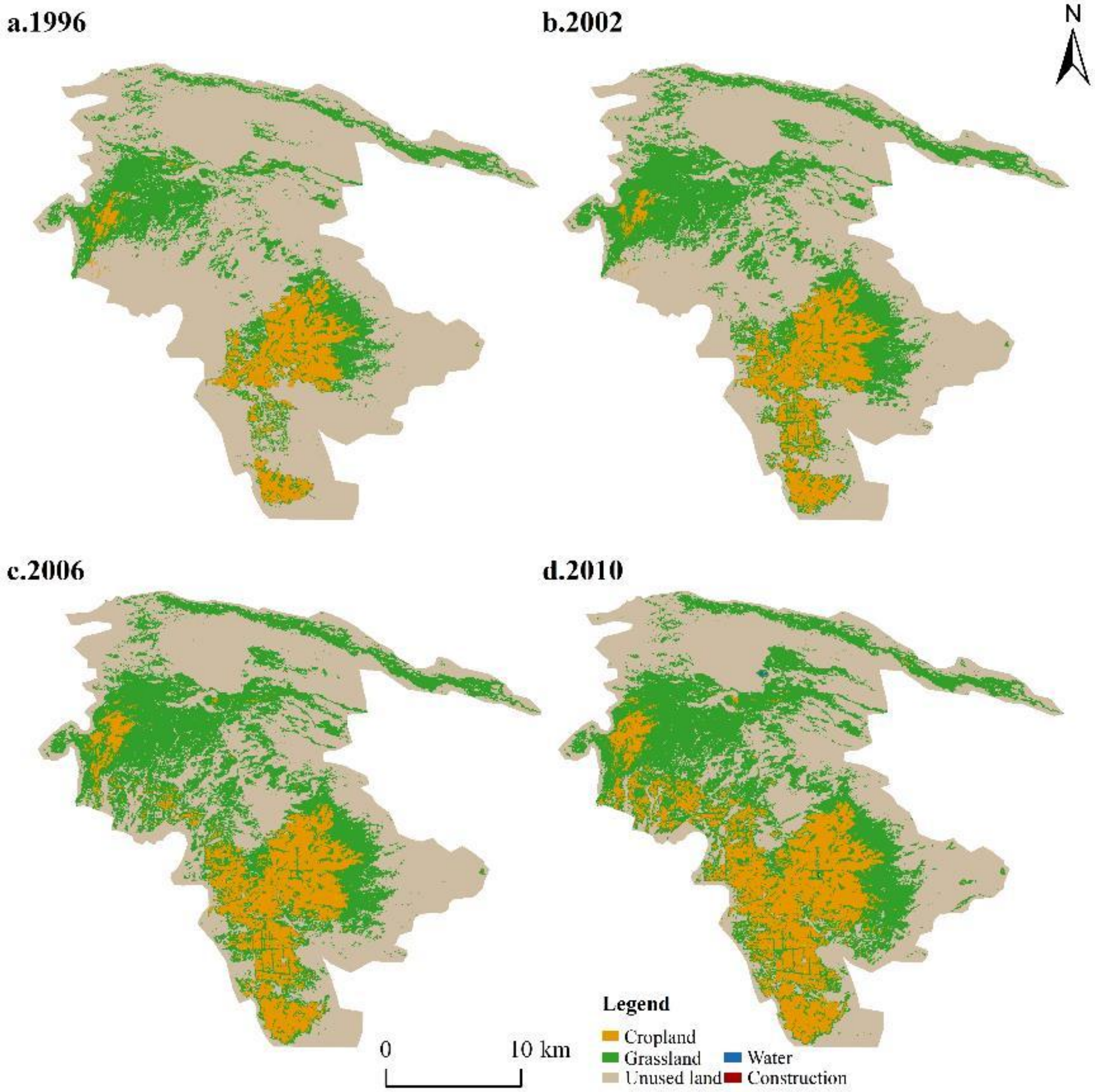
Between 1996 and 2002 (the beginning of the migration period), there was a significant increase in the area of both cultivated and built-up land (Figure 3). The net increase of arable land in Changma, Shuangta and Huahai irrigation districts is 21.24km2, 53.14km2 and 11.91km2 respectively; Changma Irrigation District and Shuangta Irrigation District have a net increase of 0.12km2 and 0.10km2 of construction land respectively. From 2002 to 2006 (the middle period of migration) was the period of large-scale migration into the area, Changma, Shuangta and Huahai Irrigation Districts respectively increased the cultivated land by a net of 31.79km2, 54.25km2, and 18.07km2; the construction land Changma Irrigation Districts increased the land by a net of 0.22km2, Shuangta Irrigation Districts both increased the land by a net of 0.18km2, and Huahai Irrigation Districts were not significant. From 2007 to 2010 (the end of the migration period), Changma, Shuangta and Huahai Irrigation Districts had a net increase of 44.48km2, 47.55km2, and 22.83km2 of arable land, respectively; and the net increase of construction land in the Changma Irrigation District was 0.14km2, and that in the Shuangta Irrigation District was 0.28km2. In contrast, the wasteland is decreasing on a large scale, with 169.68km2, 240.16km2, and 140.76km2 reduction in Changma, Shuangta, and Huahai Irrigation Districts, respectively, during the whole migration period, which, combined with the land-use transfer matrix, indicates that the wasteland is being reclaimed as arable land.



(a) Shuangta irrigation area



(b) Changma irrigation area



(c) Huahai irrigation area

Figure 3. Land use change in Shuangta, Changma and Huahai irrigation areas

Examined at the scale of the resettlement area. The strongest change in building land was seen in the resettlement base of Yaozhanzi Dongxiang nationality town, which is a completely new resettlement township (Yaozhanzi Dongxiang nationality town), and thus the building land experienced a sudden change from nothing to something (Figure 4). There was a total increase of 1.24hm2 between 1996 and 2010, with more growth especially during the peak migration period in 2006. There was a net increase of 13.80km2 of cropland, of which 4.71km2, 3.59km2, and 3.80km2 of cropland were added at the beginning, middle, and end of the migration period, respectively, and thus the single-movement attitude of cropland was also the largest (6.98% to 8.81%).Grassland and wasteland are decreasing, especially in the early stage of migration, the net decrease of grassland is 2.18km2; wasteland is even sharply reduced from 13.26km2 in 1996 to 2.28km2 in 2010, and its single-movement attitude in the early stage, middle stage, and the end of the migration amounted to -7.87%, -13.63%, and -8.04%, respectively. The four small-scale resettlement bases have a total net increase of 10.16km2 of arable land and 0.99km2 of construction land (Figure 5). Similarly, there is a significant reduction in heathland (a total net reduction of 31.69km2), with the only difference being a continued increase in grassland.

The Single Land use dynamic degree of cultivated and wasteland at the beginning, middle and end of migration were 1.77%, 6.52%, 6.48, -0.21%, -0.36%, -0.34%, respectively. A total net increase of 51.96km2 of cultivated land and 0.37km2 of construction land was realized in the six resettlement sites of migrants (Figure 6), and similarly a large reduction of wasteland (114.25km2), and the single-motivation attitude towards cultivated land and wasteland at the early, middle and end stages of migration was 3.36%, 4.42%, 3.85%, -1.27%, -1.00%, and -0.38%, respectively. It is clear that there is a very close correlation between land use change and the scale of migration. While land for production is increasing, land for ecological functions is decreasing.

Figure 4. Land use changes in the migrant base in Yaozhanzi

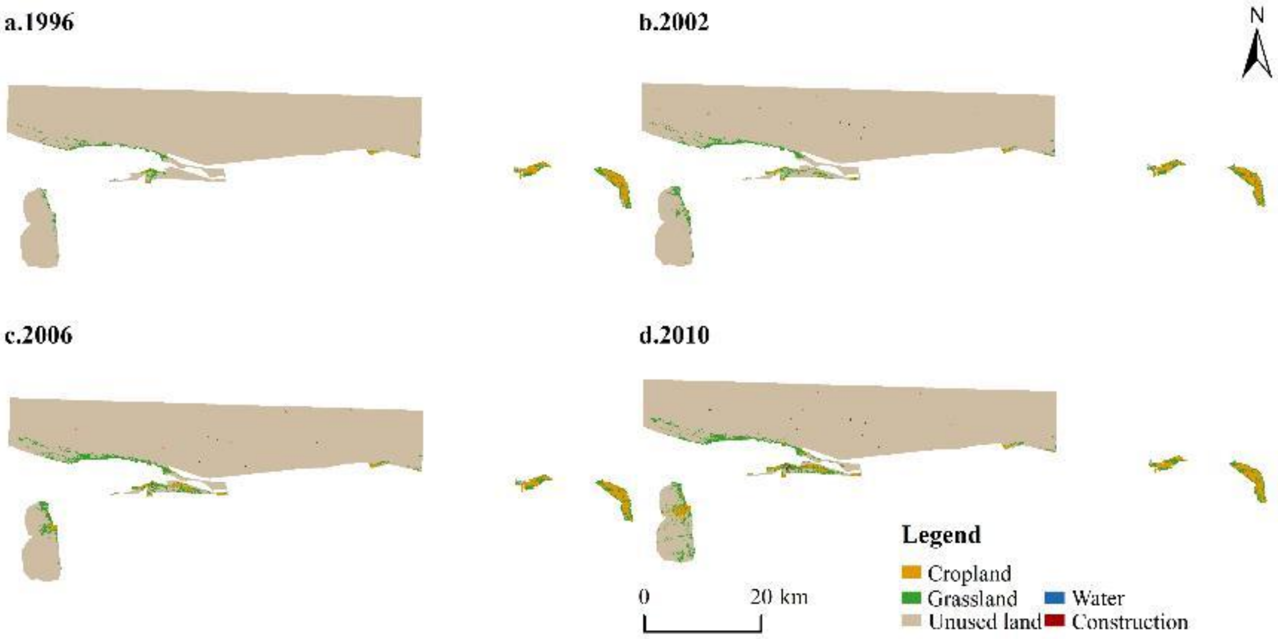


Figure 5. Land use changes in the four small migrant bases

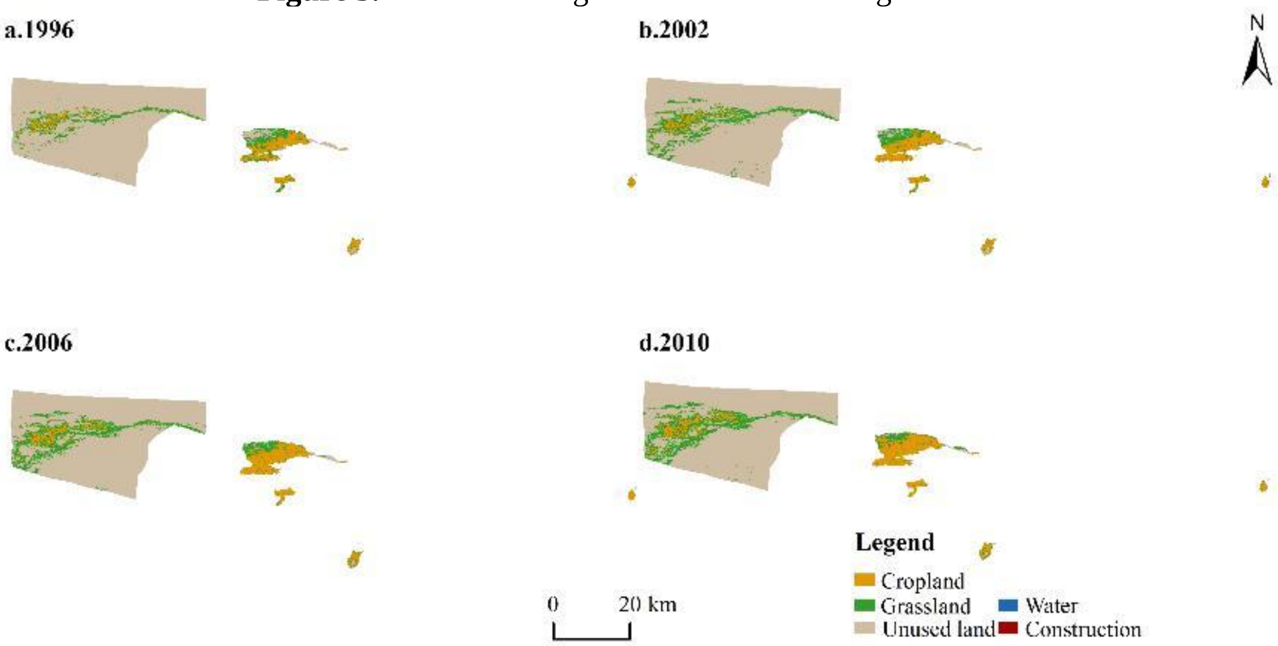
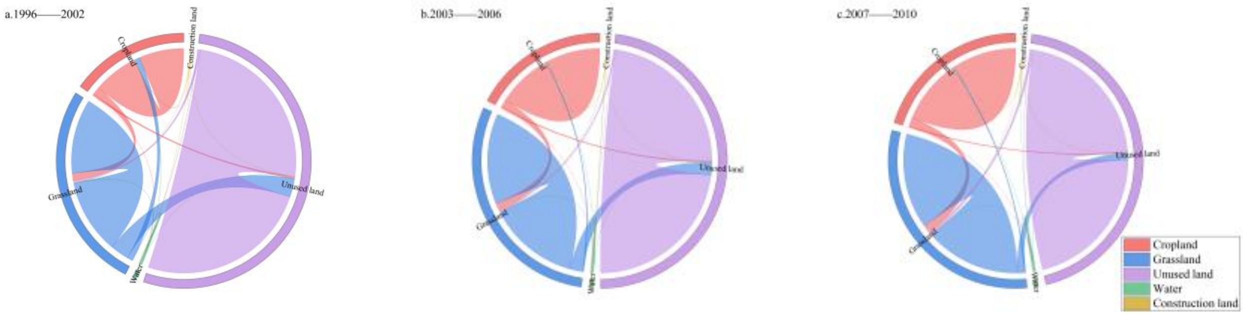


Figure 6. Land use changes in the six resettlement sites

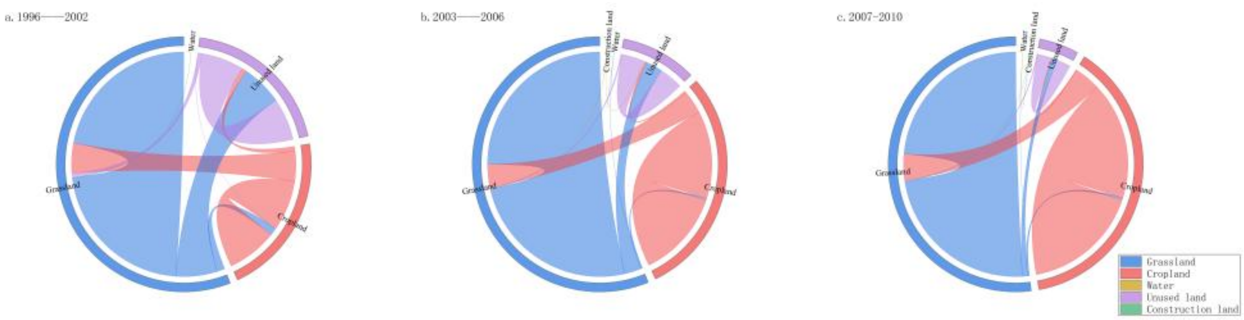
3.2. Land use transfer

The process of ecological migration is the process of continuous conversion of land use types.Throughout the migration period, the three major irrigation districts' land use diversion is ranked as follows: Barren land>Grass land>Crop land>Water>Construction land (Barren land >Grass land in the early and middle stages of migration; Grass land>Water in the late stage of migration);and the transfer in is ranked as follows:Grass land>Crop land>Barren land >Water>Construction land (Grass land>Crop land in the early and middle stages of migration, and construction land>water in the late stage of migration). And with the advancement of the migration process, the amount of transfer tends to diminish, such as the total amount of Water, Grass land, and Crop land transferred out in the early stage of migration amounted to 265.77km2, 128.03km2, and 72.06km2 respectively; in the middle stage, it amounted to 187.10km2, 122.16km2, and 14.10km2, respectively; and at the end of the stage, it amounted to 104.10km2, 154.31km2, respectively, 15.25km2 at the end of the period, indicating that the direction of land use is gradually stabilizing (Figure 7).The main reason is that at the early stage of migration, in order to solve the problem of food and clothing of the migrants, new requirements were put forward for arable land and Construction land, so that only Barren land and Grass land could be reclaimed, especially Barren land close to the migrant villages and Grass land with relatively good conditions of natural moisture were reclaimed as arable land in large quantities, but due to the fact that the deep impact on the ecological environment was not yet clear, the human-land-water relationship was not properly handled, resulting in part of the wasteland being abandoned due to the lack of water.However, due to the fact that the deep impact on the ecological environment was not clear at that time, the relationship between people, land and water was not properly handled, which led to the abandonment of some arable land due to the lack of water, and the inter-transfer of arable land and Barren land (Grass land) was very frequent.

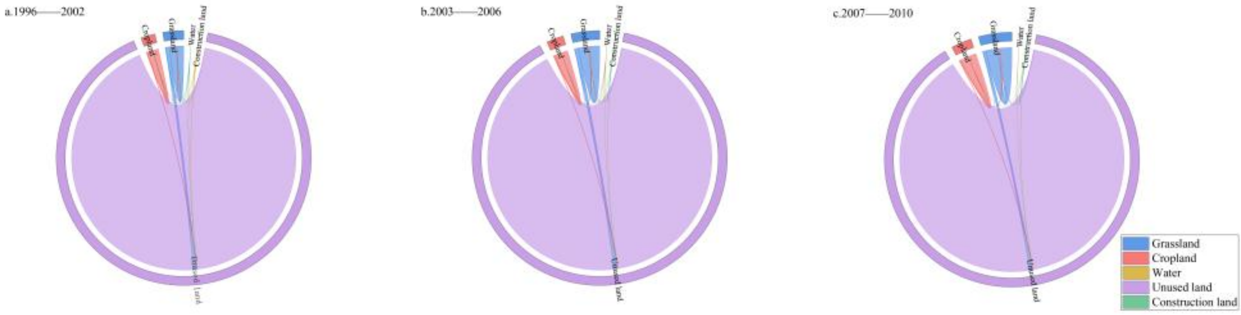
Resettlement areas show similar land use transfer characteristics. The total transfer of wasteland, grassland and cropland amounted to 1,643.62km2, 209.62km2, and 134.88km2 respectively at the beginning of the migration period, and 1,570.99km2, 229.49km2, and 186.85km2 respectively at the end. The amount of land transferred varies with the size of the migrants, and there are differences in the amount transferred at the beginning, middle and end of the migration period, with the middle of the migration period being the time period when the largest amount of all types of land is transferred, and grassland being the largest type of transfer.Grass land in the large-scale migration base (Yaozhanzi Dongxiang nationality town) was mainly converted to cropland, and the total amount of grassland transferred at the beginning, middle and end of the migration was 26.34 km2, 24.76 km2 and 28.89 km2, respectively. in comparison, the conversion of Cropland-Barren land and Barren land -Crop land was less, and the amount of the transfer contracted as the migration process progressed, which also indicates that the direction of the land use tends to be stabilized (Figure 7).



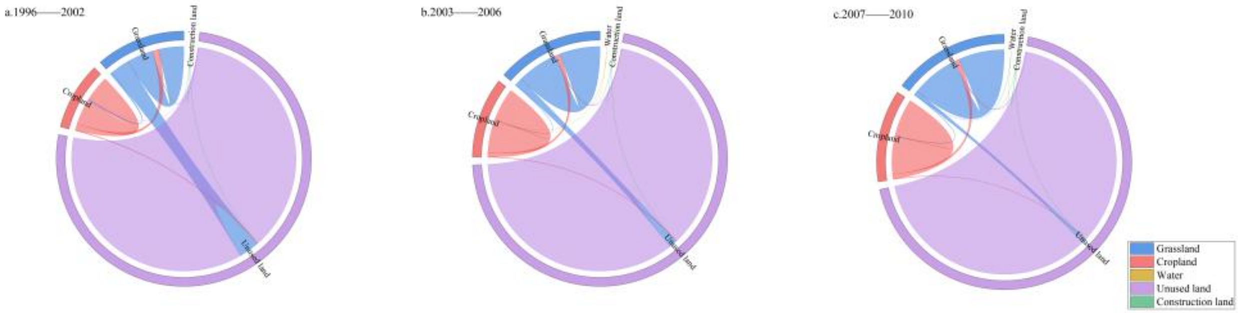
(a) Area under irrigation



(b) Large immigrant bases



(c) Four small migrant bases



(d) Six migrant settlements

Figure 7. Land use transfer map of irrigation area and resettlement area

3.3. Land use information entropy and equilibrium degree

The information entropy of land use structure is used to describe the orderliness and complexity of land use structure. Overall, it has abrupt changes in the early and adjustment periods of ecological migration, while the middle and end periods of migration show smooth changes. The information entropy and equilibrium of land use structure in Changma Irrigation District basically declined steadily from 1996 to 2010, whereas Huahai Irrigation District and Shuangta Irrigation District showed a steady increase, and the variation at the beginning of the migration was greater than that at the middle and end. Hanahai Irrigation District is the region with the greatest change, with information entropy increasing from 0.770 in 1996 to 1.031 in 2010, and equilibrium increasing from 0.479 to 0.640. The trend of change in dominance is the opposite (Table 2).

Table 2. Entropy, balance and dominance of land use information in irrigation areas (1996-2010)

Year	Information entropy (H)			Degree of equilibrium (J)			Degree of superiorit (K)		
	Changma	Shuangta	Huahai	Changma	Shuangta	Huahai	Changma	Shuangta	Huahai
1996	1.090	0.720	0.770	0.677	0.448	0.479	0.323	0.552	0.297
2002	1.077	0.845	0.883	0.669	0.525	0.549	0.331	0.475	0.341
2003	1.075	0.851	0.902	0.668	0.529	0.561	0.332	0.471	0.348
2007	1.062	0.897	0.972	0.660	0.557	0.604	0.340	0.443	0.375
2010	1.055	0.911	0.989	0.656	0.566	0.614	0.344	0.434	0.382

Table 3. Information entropy, balance and dominance of land use in resettlement areas (1996-2010)

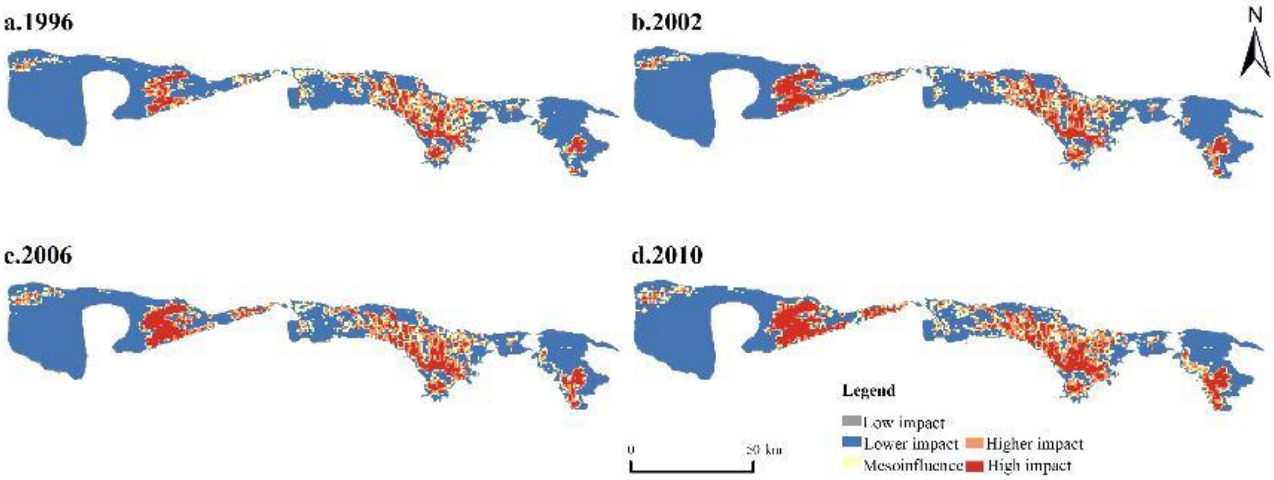
Year	Information entropy (H)			Degree of equilibrium (J)			Degree of superiorit (K)		
	Large immigrant bases	Four small resettlement bases	Six locations	Large immigrant bases	Four small resettlement bases	Six locations	Large immigrant bases	Four small resettlement bases	Six locations
1996	0.981	0.200	0.589	0.893	0.124	0.425	0.107	0.876	0.575
2002	0.654	0.247	0.713	0.472	0.154	0.515	0.528	0.846	0.485
2003	0.661	0.256	0.714	0.477	0.159	0.515	0.523	0.841	0.485
2007	0.879	0.292	0.756	0.546	0.181	0.470	0.454	0.819	0.530
2010	0.856	0.299	0.779	0.532	0.186	0.484	0.468	0.814	0.516

In the early stage of migration, the entropy of information on land use structure of large-scale migrant bases decreased dramatically from 0.981 in 1996 to 0.654 in 2002, and then tended to increase after the adjustment of the ecological migration project in 2003, and then declined steadily and slowly in the late stage of migration (Table 3).The degree of equilibrium and the degree of dominance show a smooth change in the middle and the end of the migration period, except for the drastic change in the beginning of the migration period. Generally speaking, in the middle and late stages of migration, the degree of equilibrium tends to increase, while the degree of dominance tends to decrease. This indicates that as the migration process advances, the direction and structure of land use are continuously adjusted, but the general trend is towards equalization and diversification. The information entropy, equilibrium and dominance of the land use structure of the four small-scale hair resettlement bases and the six migrant resettlement sites are characterized by smooth changes throughout the migration period.The information entropy of the four small immigrant bases increased slowly from 0.200 in 1996 to 0.299 in 2010, while the dominance decreased slowly from 0.876 to 0.814; the six immigrant settlements showed similar change characteristics. At the early stage of migration, the land use composite index of large migrant bases changed more strongly than that of small migrant bases and migrant settlements, which were 10.83%, 1.46%, and 6.30%, respectively, and with the process of migration, the large migrant bases in the middle and late stages showed a steady decline to 5.81% and 3.93%, which means that the larger the scale of the migration, the more obvious the perturbation of land use.

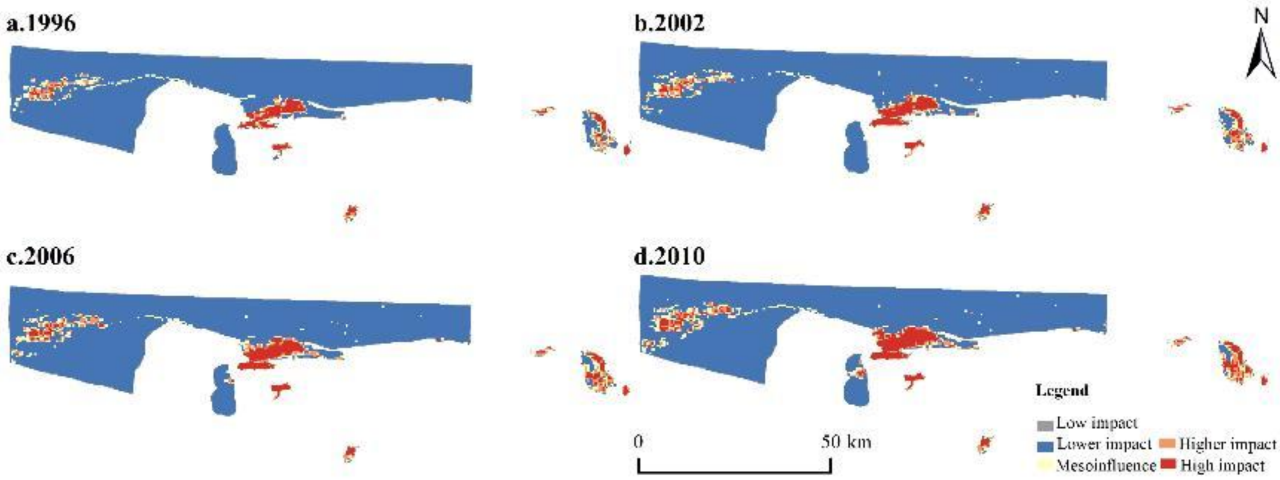
The fundamental reason is that the entry of immigrants has completely changed the native land use pattern dominated by natural processes. In June 1996, the Shule River Ecological Migration Project was officially launched, and voluntary migration and resettlement were initiated, leading to an accelerated transition of the LUCC from natural process dominance to artificial process dominance, and thus the greatest change from 1996 to 2002; fluctuating change from 2002 to 2006, after mid-term adjustments were made to the project in 2002. After 2007, with the orderly progress of migration activities, it entered a phase of smooth change. At the early stage of migration, due to the small scale of migration and less disturbance to the native environment of the resettlement area, a large amount of residential land and arable land is needed to solve the residence and livelihood problems of the migrants, which leads to a high degree of arbitrariness in land use (especially the act of reclamation); however, under the constraints of the special characteristics of the inland river basins in the arid zone (especially the constraints on the water resources and the fragile ecological environment), even if reclaimed as arable land, due to the lack of irrigation water, the scale of arable land is inevitably strongly limited. After the operation of Changma Reservoir in 2003, the bottleneck of irrigation water was fundamentally solved, which provided a basic and decisive guarantee for the diversified development of land use, coupled with the adjustment of the migration plan, which led to the rationalization and stabilization of the direction and structure of land use, and thus the entropy of the information on land use and so on showed a stabilizing trend of change. The trend of decreasing dominance indicates that with the migration process, land use has gradually moved from a pure preference for living (construction land) and production (arable land) to a balance between production, living and ecology. Compared with small migrant bases and resettlement sites, the larger the scale of migration, the more prominent the disturbance of land use, due to the differences in the intensity of migration, especially in the resettlement sites, which are also subject to the constraints of the original land use pattern.

4. ECOLOGICAL MIGRATION AS A FUNDAMENTAL DRIVER OF CHANGE

The process of ecological migration is the process of increasing human activity intensity, and the expansion of arable land and construction land is the intuitive appearance and reason for the change of human activity intensity. Examined from the irrigation district scale, the high value area of the human activity intensity index clearly points to the resettlement area, while at the resettlement area scale, around the resettlement villages (towns), the human activity intensity index decreases outward in a circle pattern, and the human activity intensity index of the wasteland area far away from the resettlement area is always a low-value area (Figure 8).



(a) Intensity of human activities in irrigation areas



(b) Intensity of human activity in resettlement areas

Figure 8. Distribution of human activity intensity in irrigation and resettlement areas, 1996-2010

From 1996 to 2002, the equivalent area of construction land within the resettlement area grew from 184.91km2 to 200.08km2, an increase of 8.20%; by the adjustment period of 2003, it grew to 202.50km2, an increase of 1.21%; and at the end of the project period of 2003-2007, it rose to 217.47km2, an increase of 7.39%.

The root cause of these changes is ecological migration. The Essentials of Planning require that agricultural development and resettlement be closely integrated, with development leading to resettlement and resettlement promoting development. Migration is aligned and synchronized with water projects, agricultural support and rural community building. The entire immigration project consists of three main projects: 1. Water conservancy project. It includes the construction of the Changma reservoir pivot project in the upper reaches of the Shule River and the reconstruction and expansion of the irrigation systems of the three irrigation districts of Changma, Shuangta and Huahai. After the completion of the project, the annual water supply will be increased from 636 million m3 to l0 million m3~8.6 billion m3, an increase of 71%; the irrigated area will be increased from 43.6 thousand hm2 to 98.2 thousand hm2, an increase of 125%.2.Within l0 years, 54,600 hm2 of wasteland will be reclaimed, and commercial grain bases, cotton bases and vegetable and melon fruit bases will be established.3. New afforestation of 9033.4hm2, closure of beaches for forestation of 3333.3hm2, closure of sand for forestation of 10.9hm2.The Shule River Basin is a typical inland river basin in the arid zone, with a very fragile ecological background, so the migration project is basically promoted in phases, batches and sections according to the construction sequence of water (irrigation water and domestic water), residence (migrant villages), field (arable land) and forests (protective forests).In the inland river basins of arid zones, there is a very close interdependence between the “mass point” (settlements) - “corridor” (drainage and road network) - “domain surface” (irrigation area) [30], and the healthy operation of production, life and ecology are all dependent on “water” as a fundamental and controlling factor.

The increase in built-up land is to address the “settlement” of migrants (subsistence land), while the increase in arable land and watersheds is to address livelihood issues (production issues). Life (housing) and production (arable land) are the most basic and urgent needs of migrant projects, and housing is an important material condition for “living in peace” and “working with joy”. For immigrants, having a warm and cozy little home is the starting point for saying goodbye to their homeland and rebuilding. According to The Essentials of Planning, the move-in site provides migrants with 0.8 acres as a homestead, along with 1 acre of yard forest and fruit land. After the immigrants entered the country, they first had to solve the problem of housing, and the initial housing (the first generation of houses) was figuratively called “ground nests” or “hidden head houses” (1997-2006). Generally, they were divided into family units, and they would find a depressing place with a backdrop, dig a pit one or two meters deep, put a few logs on the pit, lay a bundle of hay, and then lay a thick layer of wet meadow covered with soil. The pit is then covered with a thick layer of wet meadow and covered with soil.Hidden head house is also called temporary “resettlement house” “transitional house”, its main purpose is to solve the migrants “shelter” problem, so the impact of the initial period of migration on the land use pattern is mainly manifested in on the cultivated land.When immigrants first moved here, the per capita housing subsidy was only 600 yuan, each immigrant household spent only 2,000 to 3,000 yuan on building a house, so most of the houses were only 20 to 30 m2 in size, with a per capita housing area of less than 6m2. Thus, housing construction has a much greater impact on land use change than on landscape patterns. Around 2005, the Shule River Migration Project began to carry out large-scale reconstruction of the “Hidden Head Houses” in conjunction with the transformation of land and the construction of farmland facilities, and mixed brick and soil houses (commonly known as “second-generation houses”) and typical courtyard houses began to appear, with a corresponding increase in the amount of land available for construction. The amount of land available for construction increased accordingly. By around 2010, new brick houses were being built in succession in the migrant townships, and later concrete houses were constructed, with major improvements in living conditions and an increase in the size of the building sites. Housing is only a part of life, and at the beginning of the migration, there was no supporting solution to the problem of living fuel, so the migrants rely entirely on the red willow and white thorns on the Gobi Desert for cooking and heating, which has led to the disappearance of a large area of grassland, especially shrub forests, and the ecological problems caused by the fuel problem have become more prominent.

Crop land is fundamental to the livelihood of migrants. The environmental background of the Shule River Basin is not suitable for agricultural production, and it has been in a state of natural succession for a long time, so that grassland and wasteland are the main forms of land use. After the entry of ecological immigrants, in order to solve the “production” problems of the immigrants, they can only carry out large-scale development and utilization of native land, and carry out large-scale reclamation of desert grassland and scrub grassland that can be easily exploited and utilized, which leads to a sudden change in the type of land use. Theoretically speaking, inland river basins in arid zones (especially in the middle and lower reaches) do not lack “fine soil plains”, but in order to transform them into farmland suitable for cultivation, the first step is to solve the problem of “water” and soil “salinization” (i.e., “salt washing”) for farmland irrigation. The area of low-yield fields that need to be renovated in the migrant areas amounted to 228,500 acres (1.52×104hm2), accounting for 80% of the total cultivated land of the migrants, among which the area of saline-alkaline land amounted to 165,700 acres (1.10×104hm2) (with the heavy saline-alkaline land amounting to 79,200 acres), accounting for 58% of the total cultivated land of the migrants. The existing saline soil in Changma Irrigation District is 4.45×104hm2, accounting for 68.15% of the irrigation area, of which 1.76×104hm2, accounting for 26.95%, is salinized; 2.19×104hm2, accounting for 33.54%, is light and medium saline; and 0.5×104hm2, accounting for 7.66%, is heavy and extra heavy saline [31]. In order to solve the problem of water supply for production and daily life, it firstly constructed the upstream control project: Changma Reservoir (started in 1997) and renovated the original Shuangta Reservoir (started in 1958 and completed in 1960) and Chijinxia Reservoir (started in 1958 and completed in 1968); renovated and expanded the three irrigation districts of Changma, Shuangta and Huahai, and built 6 main canals (197.6 km), 21 branch canals (327.7 km), 120 branch canals (569.3 km), 298 bucket canals (627.3 km), 180 agricultural canals (158.6 Km). 6 main canals (197.6 km), 21 branch canals (327.7 km), 120 branch canals (569.3 km), 298 bucket canals (627.3 km), 180 agricultural canals (158.6 Km) were constructed, with a channel lining rate of 80.5%, 6,474 hydraulic buildings, and 2,083 electromechanical wells [32]. Although the construction of water conservancy facilities has solved the problem of water use for agricultural irrigation and migrants' daily lives, it has at the same time crowded out valuable ecological water, leading to a large-scale reduction and even the disappearance of natural grasslands and scrublands. On the other hand, after the construction of Changma Reservoir and Shuangta Reservoir, the runoff from the Shule River outflow was almost entirely controlled by human beings, and the artificial process almost completely replaced the natural process, so the change of land use pattern by human activities was more underlying and oriented.

5. CONCLUSION

Eco-migrants are special migrants formed in order to improve the habitat and relieve ecological pressure. Ecological migration is the process of continuously developing, utilizing, transforming and reshaping land use patterns and structures in resettlement areas. The large-scale intervention of immigrants has led to a typical abrupt change in the pattern and intensity of land use in resettlement areas compared to the general area. This paper systematically studies the spatio-temporal pattern of land use changes in the first, middle and last stages of the Shule River resettlement project from the perspective of temporal and spatial integration, supported by land use data from 1996 to 2010, and by comprehensively applying the land use transfer matrix, land use structure information entropy, and the Human activity intensity index model. The main conclusions are as follows:

(1)The process of land use change reflects the process of change from micro-change → drastic change → smooth change in the early stage of migration → middle stage of migration → end stage of migration, and reflects the order of priority needs of life → production → ecology.From 1996-2002 (the early stage of migration), arable land grew significantly; from 2002-2006 (the middle stage of migration), which was also a period of large-scale migration, both arable land and construction land exceeded the early stage of migration; and from 2007-2010 (the end stage of migration), arable land and construction land still maintained an increase, but the increase is slowing down. There is a strong correlation between the intensity of changes in cropland and built-up land and the intensity of migration. Large-scale resettlement bases for immigrants, with a total increase of 1.24hm2 of construction land from 1996 to 2010, especially more growth during the peak period of immigration in 2006. There was a net increase of 4.71km2, 3.59km2, and 3.80km2 of cropland at the beginning, middle, and end of the migration period, respectively. The four small-scale resettlement bases for migrants have a total net increase of 10.16km2 of arable land and 0.99km2 of construction land. The six resettlement sites for migrants have a total net increase of 51.96km2 of arable land and 0.37km2 of land for construction. leading to a phase change in the attitude of single and integrated land use dynamics.

(2) The process of ecological migration is the process of continuous conversion of land use types. Throughout the migration period, the order of transfer-out is: Barren land>Grass land>cropland>Water>Construction land (Barren land >Grass land in the early and middle stages of migration; Grass land> Barren land in the late stages of migration); The order of transfer-in is:Grass land>Crop land> Barren land >Water>Construction land (Grass land>Crop land in the early and middle stages of migration, and Construction land>Water in the later stages of migration).

And the amount of transfer tends to decrease as the migration process advances. Crop land – Grass land, Grass land - Barren land transfer is the main path.

(3) The information entropy value and equilibrium degree of land use structure have abrupt changes at the beginning and adjustment period of ecological migration, while the middle and end periods of migration show smooth changes.In the early stage of migration, the entropy of information on land use structure of large-scale migrant bases dropped sharply from 0.981 in 1996 to 0.654 in 2002, and then tended to rise after the adjustment of the ecological migration project in 2003, and then declined steadily at the end of the migration period. The information entropy, equilibrium and dominance of the land use structure of the four small-scale hair resettlement bases and the six migrant resettlement sites are characterized by smooth changes throughout the migration period. The information entropy of the land use structure continues to rise, while the degree of dominance slowly declines. Large-scale resettlement bases tend to be more diversified and balanced. On the contrary, the degree of dominance shows a continuous decline, indicating that with the migration process, land use is gradually moving from a preference for production (Construction land) and production (Crop land) to an ecological balance.

(4)The process of ecological migration is the process of incremental increase in the intensity of human activities, and the expansion of arable land and land for construction is the visual appearance and cause of the change in the intensity of human activities. Examined from the irrigation district scale, the high value area of human activity intensity index obviously points to the resettlement area, while in the resettlement area scale, around the resettlement village (town), the human activity intensity index shows a circling type of decreasing outward. The high impact area of human activity intensity is mainly concentrated in the resettlement area, and the rise and fall of human activity intensity index in the project implementation period has a significant positive correlation with the intensity of immigration, the larger the scale of immigration, the greater the intensity of human activity, and the stronger the shaping effect on land use. Ecological migration is the dominant force driving land use change.

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