The land use pattern and its changes in the upper reaches of the Yangtze River from 1980 to 2015

Yuting Liu1,2, Jijun Xu1,2, Liqiang Yao1,2, Pengzhe Guo3 and Zhe Yuan1,2

1Department for the Integrated Use of Water Resources, Yangtze River Scientific Research Institute, Yangtze Water Resources Committee, Wuhan, Hubei, China
2Hubei Key Laboratory of Water Resources & Eco-Environmental Sciences(Changjiang River Scientific Research Institute), Wuhan, Hubei, China
3Geological Resources and Geological Engineering, College of Geosciences and Engineering, North China University of Water Resources and Electric Power, Zhengzhou, Henan, China

Corresponding author’s e-mail: 1990688789@qq.com

Abstract: Using the land use data in 1980, 1990, 1995, 2000, 2005, 2010 and 2015 in the upper reaches of the Yangtze River(UYRB), the area and changes of various types of land use in the study area were analyzed, and the transformation characteristics of various land use types were expounded. Suitable landscape indices such as Patch Number(NP), Patch Density(PD), Connectivity Index (COHESION) and Shannon Diversity Index (SHDI)were used to explore and analyze the land use pattern of the study area. The results showed that from 1980 to 2015, farmland, forest and grassland were the main land use types in the UYRB. The area of construction land and grassland increased, the area of farmland, forest, wetland and desert decreased, and the area of lake/river did not change much. The main direction of land use type transfer in the study area was the conversion of farmland to forest, grassland and construction land, grassland to forest, wetland to lake/river, and desert to grassland. Through the analysis of landscape level indicators, it is concluded that the degree of landscape fragmentation in the UYRB in the past 20 years has gradually increased, the heterogeneity of the landscape has gradually increased, and the types of land use have developed towards diversification. Through the analysis of the patch type level indicators in the study area, results showed that farmland, forest and grassland occupied an absolute dominant position in the study area, resulting in a large separation of the rest of the landscape types. The separation of farmland and construction land under the strong interference of human activities, Fragmentation showed a trend of first decreasing and then increasing.

1. Introduction

Land use change (LUCC) affects the energy exchange, water cycle, soil erosion and accumulation, and biogeochemical cycle of the ecosystem, which has become a research hotspot of global environmental change in the past 20 years [1]. The core research project of LUCC launched in 1995 and the Global Land Program (GLP) launched in 2005 have further deepened the research on the human-terrestrial environmental system under the background of global climate change [2-3]. In recent years, the rapid development of social economy has aggravated the change of landscape pattern. Ecological problems such as biodiversity reduction and land desertification have emerged one after another, posing challenges to the sustainable development of landscape patterns. Under this background, it is
particularly important to study the changes of landscape pattern [4]. At present, many scholars have conducted comprehensive research on the relationship between land use change and landscape ecological process, and this has formed a mature theoretical system [5]. These studies are of great significance to reveal the macroscopic change characteristics of regional landscape pattern and the effect of ecological environment on the whole [6].

The upper reaches of the Yangtze River (UYRB) is a key ecological area and an important barrier to the ecological security of the entire Yangtze River Basin. Its complex and diverse ecosystems, rich biodiversity and special natural environment determine its strategic ecological position which cannot be ignored [7]. Due to the large-scale development of the river basin, rapid economic development, global climate change and the intensification of human activities, the ecological environment load on the UYRB has become heavier, and the ecological security of the river basin has received scholars’ increasing attention [8].

2. Data sources and methods

2.1. Study area

The UYRB (90 ~ 105°E, 25 ~ 36°N) is from Geladandong, Qinghai-Tibet Plateau to Yichang, Hubei. The UYRB has a total length of 4529 km, accounting for 72% of the total length of the Yangtze River, and an area of about one million km². From east to west, the altitude rises from 265m to 6492m, among which the area with an altitude of 3000 m to 4000 m and below 1000 m accounts for 31%, 12% and 25% respectively. The UYRB spans three climatic regions: the plateau (arid region), the North subtropical (sub-humid region) and the Central Subtropical (humid region) [9]. And the UYRB crosses the first and second steps, and the area of mountains and hills accounts for more than 90%. Surface fragmentation, steep slopes and deep valleys are the basic geomorphologic features of this region [10]. The vegetation types are different in the UYRB due to terrain diversity and climate change [11]. The western region is the Qinghai-Tibet Plateau and the Hengshan Mountains, in which the landform is mainly the alpine plateau with a large vertical difference in bioclimatic climate, low annual average temperature and abundant water resources. The vegetation types include shrub meadow, grassland, evergreen broad-leaved forest and evergreen deciduous broad-leaved mixed forest and so on [12]. The central region includes the Yunnan-Guizhou Plateau, the Sichuan Basin, the Qinba Mountains and the Sichuan-Eshan Mountains, in which the terrain are mountains, hills, basins and inter-mountain basins, with a mild climate and ample rainfall. And the forest vegetation is dominated by dark coniferous forest and evergreen broad-leaved forest [13].
2.2. Data sources
With Landsat TM/ETM remote sensing images provided by the Data Center for Resources and Environmental Sciences (http://www.resdc.cn/) as the main data source, by a total of the national land use type 1 km resolution data in 1980, 1990, 1995, 2000, 2005, 2010 and 2015, this study comprehensively analyzed the spatial distribution pattern area change and landscape pattern index of different types of land use in the study area from 1980 to 2018, revealed LUCC in the area over the past 40 years, and provided a scientific basis for environmental investigation and ecological assessment.

2.3. Methods
Based on the classification of terrestrial ecosystems in our country in 2015 by Xie Gaodi [14] and the characteristics of land use in the study area, the land use types in the UYRB are divided into 7 categories: farmland, forest, grassland, lake/river, construction land, wetland and desert. Using the overlay analysis module in ArcGIS, the seven periods of land use data were overlaid and analyzed to obtain the land use transition matrix.

The landscape index is a simple quantitative index that reflects the composition of landscape and the characteristics of spatial configuration, and can satisfy the requirement of quantifying the origin of landscape heterogeneity and its ecological significance [15]. In this study, the change characteristics of the landscape pattern of the region are studied from two levels: one is the category index level, which reflects the change characteristics of each landscape type; the other is the landscape index level, which reflects the overall change of the landscape [16]. At the level of category measurement, Number of Patches (NP), Landscape Shape Index (LSI), Connectivity Index (COHESION) are selected; at the level of landscape indicators, Number of Patches (NP), Patch Density (PD), Landscape Shape Index (LSI), Separation Index (SPLIT), Contagion Index (CONTAG) and Shannon Diversity Index (SHDI) are selected [17]. ArcGIS was used to convert land use data into raster data, which was imported into Fragstats software to calculate landscape index.
3. Results and discussion

3.1. Land use statistics and changes
From Figure 2 and Table 1, it can be seen that from 1980 to 2015, the land use types in the UYRB were mainly grassland, forest and farmland. Among them, about 35% of the grassland area was mainly distributed in the northwest, 33% of the forest area was mainly distributed in the southeast, and 22% of the farmland area was mainly spread over the Sichuan Basin. The grassland area showed an increasing trend from 1980 to 1990, and the change was not obvious after that; the forest area changed most actively with little change from 1980 to 1990, and then showed a trend of increase-decrease-increase-decrease; the farmland area continued to decrease over the 35 years, while the area of construction land and lake/river continued to increase; the wetland area changed little from 1980 to 1990, and then gradually decreased; the area of deserts decreased significantly from 1980 to 1990, and there has been little change since then.

Specifically, compared with 1980, the grassland area in 1990 increased by 2.01 thousand km$^2$ sharply, the area of lake/river and construction increased by 0.17 thousand km$^2$ and 0.32 thousand km$^2$, and the area of farmland and desert decreased by 0.65 thousand km$^2$ and 1.82 thousand km$^2$, the area of forest and wetland didn’t change much. Compared with 1990, the area of farmland and grassland in 1995 decreased by 0.47 thousand km$^2$ and 0.43 thousand km$^2$, the area of forest and construction area increased by 0.69 thousand km$^2$ and 0.39 thousand km$^2$, and the area of lake/river, wetland and desert decreased slightly. Compared with 1995, the area of forest in 2000 decreased by 1.43 thousand km$^2$, and the area of grassland, lake/river, construction land and desert increased by 0.72 thousand km$^2$, 0.16 thousand km$^2$, 0.44 thousand km$^2$ and 0.19 thousand km$^2$ respectively. The area of farmland and wetland didn’t change much. Compared with 2000, the area of farmland decreased by 1.33 thousand km$^2$ in 2005, and the area of forest, grassland, lake/river and construction land increased by 0.41 thousand km$^2$, 0.15 thousand km$^2$, 0.14 thousand km$^2$ and 0.73 thousand km$^2$. The area of wetland, and desert didn’t change much. Compared with 2005, the area of farmland decreased by 0.99 thousand km$^2$ in 2010, and the area of forest, lake/river and construction land increased by 0.37 thousand km$^2$, 0.17 thousand km$^2$, and 0.61 thousand km$^2$. The area of grassland, wetland and desert changed little. Compared with 2010, the area of farmland, forest, grassland decreased by 2.17 km$^2$, 0.47 thousand km$^2$ and 0.39 thousand km$^2$ in 2015. The construction land area increased by 2.56 thousand km$^2$ by a large margin and the lake/river area increased by 0.49 thousand km$^2$. 
3.2. Land use conversion

From Table 2, it can be seen that from 1980 to 2015, the land use types in the UYRB have undergone different degrees of transformation. The specific conditions of the LUCC at each stage was: farmland mainly converted to forest, grassland and construction land, and the conversion area was respectively 2.38 thousand km², 1.22 thousand km² and 4.09 thousand km², accounting for 1.10%, 0.56% and 1.88% of the farmland area in 1980; forest mainly transformed into farmland and grassland, and the conversion area was 1.62 thousand km² and 3.27 thousand km², accounting for 0.48% and 0.96% of the forest area in 1980 respectively; wetland mainly transformed into grassland and lake/river, with a conversion area of 0.20 thousand km², accounting for 1.79% of the wetland area in 1980; desert...
mainly transformed into grassland with a conversion area of 2.06 thousand km², accounting for 3.88% of the grassland area in 1980. Construction land was the type of land with the largest increase in the entire study period and the area increased by 5.04 thousand km², converted by farmland mainly, accounting for 50.28% of the construction land area in 2015.

During the period 1980-2015, the LUCC was mainly manifested in the expansion of construction land and greening land, accompanied by severe farmland loss. The UYRB is located in the transition region from the first and second steps of the continental topography to the third step of the Qinghai-Tibet Plateau with broken surface, steep slope and deep valley. The strong torrential rain and the intense surface erosion in this area are easy to cause soil erosion [18]. Since the 1980s, the social and economic level of the UYRB have been remarkably improved. The vigorous development activities of human beings have caused the reduction and degradation of a large number of high-quality farmland, leading to a serious deterioration of the ecological environment. At the same time, there has been a fundamental shift in the type of land use, and construction land has replaced large amounts of farmland. In response to the deteriorating ecological environment caused by blind development, the government has implemented a series of ecological projects since the 1980s, such as the the Yangtze river shelter-forest system and the “returning farmland to forest and grassland” on some steep slopes. The conversion of farmland to forest land and grassland indicates that various land use structural adjustment policies have achieved certain results [19]. In addition, 1.8% of farmland transferred into construction land, and this transformation also reflected a significant urbanization process [20]. The proportion of continuous conversion from forest to grassland was also high. This may be due to the relatively single tree species used in the ecological construction, the poor restoration of ecological functions, and the degeneration of forests that were prone to pests and diseases in the study area. In addition, in some mountainous areas, because of the prominent human-land conflicts and insufficient policy supervision, it may generate some rebound phenomena of deforestation and land reclamation and conversion of farmland [21].

Table 2. Area transfer matrix of various land use types in the UYRB from 1980 to 2015.

|                 | Farmland 208647 | Forest 2377 | Grass 1222 | Lake/River 637 | Construction land 4091 | Wetland 41 | Desert 24 |
|-----------------|------------------|-------------|------------|---------------|-------------------------|----------|--------|
| Farmland        | 208647           | 1622        | 976        | 68            | 96                      | 21       | 3      |
| Forest          | 2377             | 333609      | 2740       | 14            | 12                      | 6        | 96     |
| Grass           | 1222             | 3271        | 350152     | 41            | 11                      | 179      | 2059   |
| Lake/River      | 637              | 223         | 262        | 5027          | 23                      | 183      | 41     |
| Construction land| 4091             | 505         | 366        | 37            | 3126                    | 8        | 3      |
| Wetland         | 41               | 4           | 119        | 60            | -                       | 9506     | 33     |
| Desert          | 24               | 99          | 324        | 31            | -                       | 73       | 50863  |
| 1980 (km²)      | 217039           | 339333      | 354939     | 5278          | 3268                    | 9976     | 53098  |

3.3. Landscape pattern changes

3.3.1. Characteristics of landscape pattern changes at the landscape level. Based on Fragstats 4.2 and the classified data of each land use type, the landscape pattern index was calculated under seven land use scenarios. It can be seen from Table 3 that NP in the UYRB decreased slowly from 1980 to 2000, and rose sharply from 2000 to 2015. PD refers to the density of land use types, reflecting the degree of dispersion of each land use type. A higher value of PD means more patches per unit area, a higher value of the fragmentation index and higher heterogeneity. The change trend of PD and NP were consistent, both decreased slightly first and then increased substantially, indicating that the degree of landscape fragmentation first decreased and then increased. This was related to the implementation of returning farmland to forest and grassland in 2000 and a series of ecological protection projects. LSI showed a trend of first decreasing and then increasing. Before 2000, there were large area of farmland, forest and lake/river in the UYRB. After 2000, the continuous expansion of urbanization caused a considerable increase in construction land and replaced the original forest and farmland. The original pattern of farmland as the main land use type has changed. Therefore, the degree of fragmentation of
the landscape has become more and more serious, and the shape of the patches has become more and more complex. The CONTAG of the study area was less than 65 and kept decreasing, showing that there were dominant patch types with better connectivity and more small patches in the landscape. SHDI explained a slight increase because of the ecological protection and management projects in the UYRB, and the ecological environment was gradually restored. In 2015, grassland became the main land use type.

### Table 3. Landscape indices of class metrics level.

| Year | NP   | PD   | LSI   | CONTAG  | SPLIT  | SHDI  |
|------|------|------|-------|---------|--------|-------|
| 1990 | 67645| 0.0219 | 118.8042 | 62.4012 | 2.5154 | 1.1759 |
| 1995 | 67592| 0.0219 | 118.6291 | 62.4245 | 2.5157 | 1.1754 |
| 2000 | 67373| 0.0218 | 118.3426 | 62.4237 | 2.5131 | 1.1757 |
| 2005 | 67274| 0.0218 | 118.6282 | 62.3825 | 2.5159 | 1.1766 |
| 2010 | 67503| 0.0219 | 118.8054 | 62.344  | 2.516  | 1.1776 |
| 2015 | 67819| 0.022  | 118.9388 | 62.3007 | 2.5162 | 1.1786 |

### 3.3.2. Characteristics of landscape pattern changes at the type level.

Table 4 shows the changing trend of the landscape pattern index in each period at the patch type level. The NP of farmland, forest and grassland were the most. The main reason was that the economy of the UYRB was relatively backward, and the production method was mainly agriculture and animal husbandry. Landscape types such as farmland and grassland occupied an absolute dominant position in the entire study area, so the connectivity of them was best, resulting in a large separation of other landscape types. The NP of farmland increased from 19248 in 1980 to 19344 in 2015, indicating that the dispersion of farmland was increasing, and it was susceptible to being disrupted by human activities and other factors. The NP of construction land increased from 2829 in 1980 to 4070 in 2015, mainly due to the rapid economic development caused by population increase, which led to growth in housing demand and a large number of construction sites.

LSI relates the area to the perimeter of the patch and reflects the complexity of the types of landscape elements. A higher LSI represents a more complex landscape type. It can be seen from Table 4 that the LSI of forest was the highest and reached 214, which showed that the LSI of forest was the most complicated, followed by grassland and farmland. From 1980 to 2015, the LSI of farmland, lake/river and construction land increased gradually, especially the largest increase of the LSI of construction land, meaning that the natural state of these landscape types was changed due to the strong interference of human activities, leading to the continuous dispersion and fragmentation of patch space.

COHESION reflects the aggregation degree of the landscape type. A higher COHESION represents higher the aggregation degree of the landscape type. the COHESION of farmland, forest, grassland and desert were the largest, and the trend was stable with little change; the COHESION of lake/river, construction land and wetland were relatively low, representing the discrete spatial distribution, high degree of fragmentation and worst aggregation. From 1980 to 2015, the COHESION of the lake/river and construction land continued to increase, indicating that the lake/river and construction land tended to be regular.

### Table 4. Landscape indices of class metrics level.

| Type     | 1980     | 1990     | 1995     | 2000     |
|----------|----------|----------|----------|----------|
|          | NP       | LSI      | COHESION | NP       | LSI      | COHESION | NP       | LSI      | COHESION |
| Farmland | 19148    | 189.37   | 99.19    | 19146    | 189.50   | 99.16    | 19068    | 190.07   | 99.09    |
| Forest   | 14884    | 214.26   | 99.60    | 14901    | 214.38   | 99.62    | 14900    | 214.50   | 99.59    |
| Grassland| 17063    | 202.59   | 99.69    | 16993    | 201.76   | 99.69    | 16884    | 201.23   | 99.70    |
| Lake/River| 3384    | 57.66    | 57.55    | 3437     | 58.13    | 57.54    | 3416     | 58.02    | 57.91    |
| Construction land | 2829 | 57.30 | 41.35 | 2847 | 57.77 | 46.42 | 2854 | 57.91 | 55.65 | 2920 | 58.36 | 58.48 |
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4. Conclusions
(1) From 1980 to 2015, farmland, forest and grassland were the main land use types in the UYRB, accounting for 90% of the study area. The grassland area increased by 2.01 thousand km² from 1980 to 1990, and the change was not remarkable after that; the forest area changed most actively, showing an increase-decrease-increasing-decreasing trend from 1990 to 2015; the farmland area decreased by 5.67 thousand km²; the area of construction land and lake/river increased by 5.04 thousand km² and 1.11 thousand km² respectively; the wetland area changed little from 1980 to 1990, and then slowly decreased; the desert area decreased significantly from 1980 to 1990, and then changed little, with a total decrease of 1.69 thousand km².

(2) In the seven periods, the land use types in the UYRB have undergone various degrees of transformation. Farmland mainly transferred into forest, grassland and construction land; desert mainly transferred into grassland; grassland mainly transferred into forest; wetland mainly transferred into grassland and lake/river; construction land was the land type with the largest increase in the whole study period, mainly by farmland, and the increased area accounted for 50.28% of the area of construction land in 2015.

(3) NP, PD and LSI in the UYRB decreased slowly from 1980 to 1990, and then gradually increased, indicating that the degree of landscape fragmentation first decreased and then increased. The NP of farmland, forest, and grassland were the largest, which occupied an absolute dominant position in the study area, so the connectivity of them was best, resulting in a large separation of other landscape types. From 1980 to 2015, changes in LSI and COHESION of farmland, grassland, lake/river and construction land reflected that these landscape types were more strongly disturbed by human activities, and patch spatial types continued to be scattered and fragmented.

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