АНАЛИЗ ПРОСТРАНСТВЕННО-ВРЕМЕННЫХ ИЗМЕНЕНИЙ ЗЕМЛЕПОЛЬЗОВАНИЯ В ЛАОСЕ НА ОСНОВЕ ГЕОИНФОРМАЦИОННОЙ ТЕХНОЛОГИИ «ТУПУ»

ANALYSIS OF TEMPORAL AND SPATIAL CHANGE OF LAND USE IN LAOS BASED ON GEO-INFORMATION TUPU

Ма Ц., Хромых В.В.

Ma Jun, Khromykh V.V.

e-mail: majun6982@gmail.com

Национальный исследовательский Томский государственный университет, Томск,

National Research Tomsk State University, Tomsk,

Аннотация. На основе растровых данных о землепользовании Лаоса в 2000, 2010 и 2020 годах с использованием таких технологий, как геолого-геофизический информационный атлас и пространственный анализ ГИС, для изучения изменения в Лаосе с 2000 по 2020 гг. Пространственные и временные изменения в землепользовании и процессах развития. Результаты показывают, что на карте изменений основных типов землепользования в Лаосе с 2000 по 2020 год преобладает преобразование лесов в обрабатываемые земли, и она охватывает весь период исследования, но есть некоторые различия в изменениях типов землепользования между странами. провинции Лаоса; на карте паттернов изменений паттерн «Без изменений» занимает основное положение, за ним следуют режим изменения профазы, режим изменения анафазы, а в наименьшей степени приходится «Повторяющееся изменение» и «Непрерывное изменение».

Abstract. Based on the land use raster data of Laos in 2000, 2010, and 2020, using technologies such as geoscience information atlas and GIS spatial analysis, two-time series maps of land use change and land use change patterns were constructed to explore the land use changes in Laos from 2000 to 2020. Spatial and temporal changes in land use and development processes. The results show that the change map of main land use types in Laos from 2000 to 2020 is dominated by the conversion of Forest to Cultivated land and runs through the entire study period, but there are some differences in the changes of land use types among the provinces of Laos; in the map of change patterns, the No change pattern occupies the Main position, followed by Prophase change mode, Anaphase change mode, and Repeated change, and Continuous change accounted for the least.

Ключевые слова: Изменение землепользования/покрова; геоинформация Тупу; блок геоспектра; временные и пространственные изменения; Лаос

Keywords: Land use/cover change; geo-information Tupu; geo-spectrum unit; temporal and spatial change; Laos

Introduction

Land use is among the more popular research fields in the international academic circle. When people change the land cover through land use, it will also cause changes in many natural elements and ecological processes. Therefore, research on land use has attracted the attention of scientists from all over the world [1]. The research methods of international scholars on land use can be divided into land use dynamics and land use transfer matrix based on time series [2, 3], as well as optimal allocation based on spatial pattern, CLUE-S model, and landscape pattern index [4–6]. A geological information atlas is an image representation and analysis method that can simultaneously reflect and reveal ground objects' spatial structure characteristics and time-varying laws [7]. Geo-information atlas provides theoretical and technical guidance for the coordinated, green, and innovative development advocated by the current world. Based on the raster data of land use in Laos in 2000, 2010, and 2020, this study uses technologies such as geoscience information map and GIS spatial analysis to construct two maps of land use change and change patterns in time series and explore the land use in Laos from 2000 to 2020. The spatiotemporal change and development process of land use in order to provide a reference for the rational use of local land.

Data and methods. Laos's raster land use data in 2000, 2010, and 2020 used in this research comes from GlobeLand30 (http://www.globallandcover.com/), with a resolution of 30m×30m. The data is based on the TM5, ETM+, and OLI multispectral images of the US Landsat (Landsat) and the multispectral images of the Chinese Environmental Disaster Reduction Satellite (HJ-1). The 2020 version of the data also uses the 16-meter resolution Gaofen-1 (GF-1). Using multispectral imagery as the primary information source, land use types are divided into eight types: Cultivated land, Forest, Grassland, Shrubland, Wetland, Water bodies, Artificial Surfaces, and Bare Land. First, import the original data into the ArcGIS platform (ESRI Inc.), use the reclassification function to reclassify it, and code it with 1-8 to obtain the primary data of the land use map.

1. Synthesis of Land Use Change Atlas and Land Use Change Pattern Atlas

First, import the reclassified land use data of Laos Phase 3 into the ArcGIS platform (ESRI Inc.), use the map algebra in the spatial analysis tool under the Arctoolbox tool of the ArcGIS (ESRI Inc.), and input the algebraic calculation formula of the land use change map into the raster calculator to obtain the 2000 -2010 and 2010-2020 time series land use change information map, and 2000-2020 land use change pattern map.

2. Characteristic Analysis of Land Change Pattern Atlas

Secondly, the obtained land change pattern map is divided into five categories (Table1), namely No change (Land use types no change), Prophase change (Land use types only transfer in the early period), Anaphase change (Land use types only shift in later stages), Repeated change (Land use types changed back to the original type after the transfer) and Continuous change (Land use types have undergone transfer and cannot be restored).

Table 1. Tupu Classification of Land Change Patterns

Type of Tupu	Meaning of Tupu	Code	Example of geo- spectrum		
			n-1 period	*n period*	*n+1 period*
No change	*Land use types no change*	*333*	*Forest*	*Forest*	*Forest*
Prophase change	*Land use types only transfer in the early period*	*311*	*Forest*	*Wetland*	*Wetland*
Anaphase change	*Land use types only shift in later stages*	*331*	*Forest*	*Forest*	*Wetland*
Repeated change	*Land use types changed back to the original type after the transfer*	*313*	*Forest*	*Wetland*	*Forest*
Conntinuous change	*Land use types have undergone transfer and cannot be restored*	*312*	*Forest*	*Wetland*	*Grassland*

Results and Analysis

From 2000 to 2010, there were 58 types of land use change maps in Laos, with a total area of 203,059.28 km². Among them, 47 types changed, with a total area of 13,775.14 km², accounting for 6.78% of the total map unit area. The map units that will change are Arranged in descending order according to the size of the area, and the results are shown in Table 2. It can be seen from Table 2 that the largest category of maps of land use change in Laos from 2000 to 2010 is "code 23", with a converted area of 4430.01 km², accounting for 32.16% of the total change area; the second largest category of maps is Grassland transformed into Forest, The conversion area is 3740.28 km², accounting for 27.15% of the total change area; the third largest category is the conversion of forest to cultivated land, accounting for the cumulative change ratio of the top three change map units as high as 78.59%. During this period, Forest and Grassland were mainly transformed into other land types. The cumulative change ratio of Forest was 53.24%, and that of Grassland was 33% (Fig. 1a).
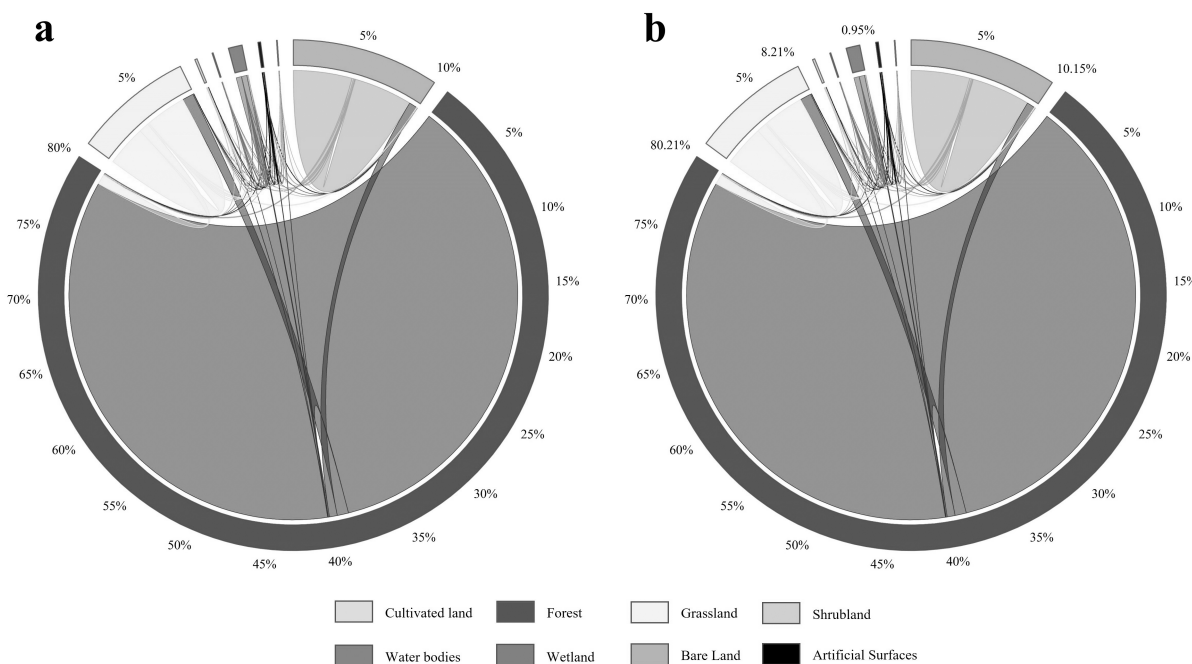

Figure 1. The chordal graph of the main map of land use change in Laos from 2000 to 2010 and from 2010 to 2020

From 2010 to 2020, there were 59 land use change maps in Laos, of which 49 types have changed. The total area of changes is 12015.01 km², accounting for 5.85% of the total map unit area. The changed map units are arranged in descending order according to the size of the area, and the arrangement results are shown in Table 2. It can be seen from Table 2 that the largest category of land use change maps in Laos from 2010 to 2020 is "code 23", and the converted area is 3622.6962 km², accounting for 30.15% of the total change area; Although the class map has not changed, it is still transformed from Forest to Grassland, but the converted area and proportion are less than those in 2000-2010. The second largest category is the conversion of Grassland to Forest, with a converted area of 3168.77 km², accounting for 26.37% of the total change area; the third largest category is the conversion of Forest to Cultivated land, with a converted area of 2526.44 km2. During this period, the transformation of Forest into other land types was the main factor, and the cumulative change ratio of Forest reached 51.18% (Fig. 1b).

Table 2. 2000-2010 and 2010-2020 main map units of landuse change in Laos in descending order

Year	2000-2010		2010-2020	
Land Use Change Code	Change area (km²)	Change ratio (%)	Change area (km²)	Change ratio (%)
23	4430.01	32.16%	3622.70	30.15%
32	3740.28	27.15%	3168.77	26.37%
21	2655.40	19.28%	2526.44	21.03%
12	1044.07	7.58%	546.06	4.54%
31	661.17	4.80%	385.98	3.21%

According to the land use data of Laos in 2000, 2010, and 2020, the land use change pattern map of 18 provinces in Laos was reconstructed (Fig. 2), and it was divided into five major change patterns according to the characteristics of the stage change and combined with the actual land use situation of Laos.
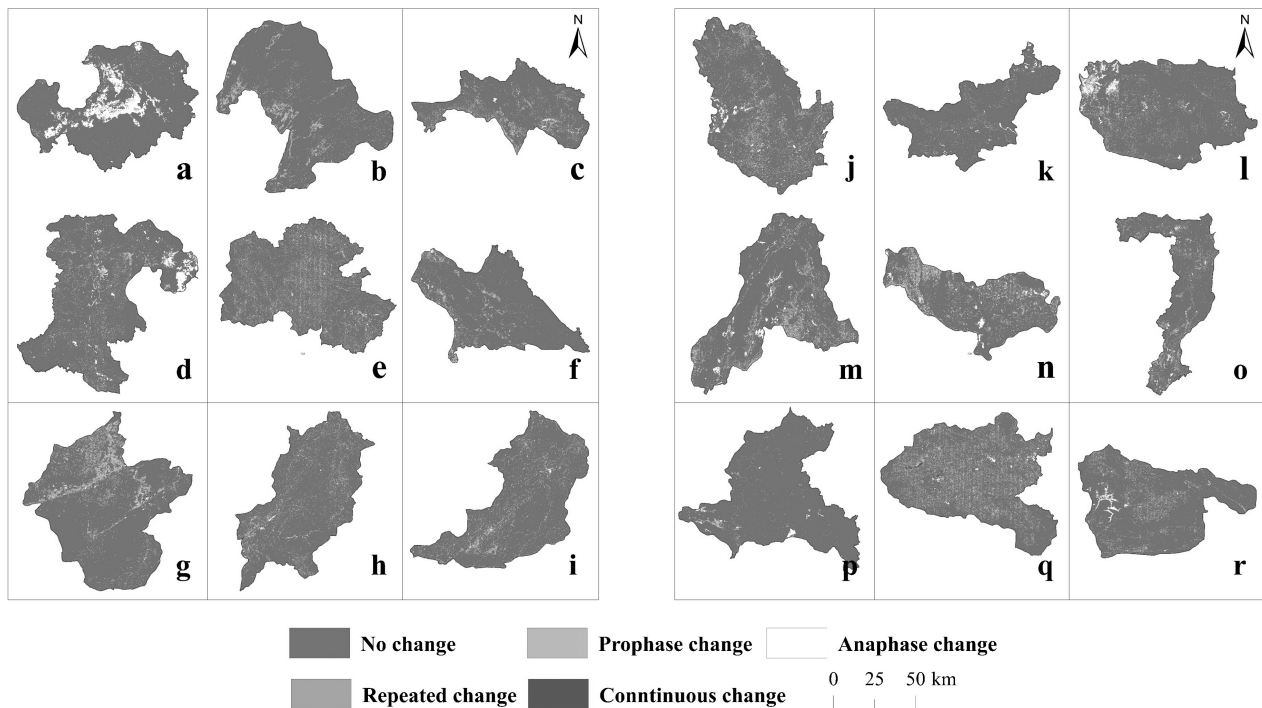

Fig. 2. The land use change pattern map of 18 provinces in Laos
(a: Attapu; b: Bokeo; c: Bolikhamxai; d: Champasak; e: Houaphan; f: Khammouan; g: Louang Namtha; h: Louangphrabang; i: Oudmxai; j: Phngsali; k: Saravan; l: Savannakhét; m: Vientiane; n: Vientiane [prefecture]; o: Xaignabouri; p: Xaismboun; q: Xékong; r: Xiangkhoang)

Conclusion

This study takes Laos as an example, based on multi-period land use data, constructs a land use spatio-temporal compound change map, quantitatively analyzes the characteristics of land use change, reveals the temporal and spatial change law of land use pattern in this region, and draws the following main conclusions: 2000-2020 Laos change map of main land use types is dominated by the conversion of Forest to Cultivated land and runs through the entire study period (Fig. 3). There are some differences in land use change patterns among the provinces of Laos; in the map of change patterns, the No change pattern occupies the leading position, followed by the Prophase change pattern. Among the Anaphase change mode and Repeated change, Continuous change accounts for the least amount.

This paper has made innovative research methods, perspectives, and map visualization explorations. However, the type of land use data adopted is relatively single, and new data such as socioeconomic data and night lights should be used more. With the future diversification of data sources and types, the integration and application of multi-source data should be strengthened. At the same time, due to the enormous scope of the study area, follow-up research should strengthen the critical analysis of the core area, deepen the coupling analysis of urban land expansion and economic and social development, and reveal the law of land use/cover evolution in a more in-depth manner.
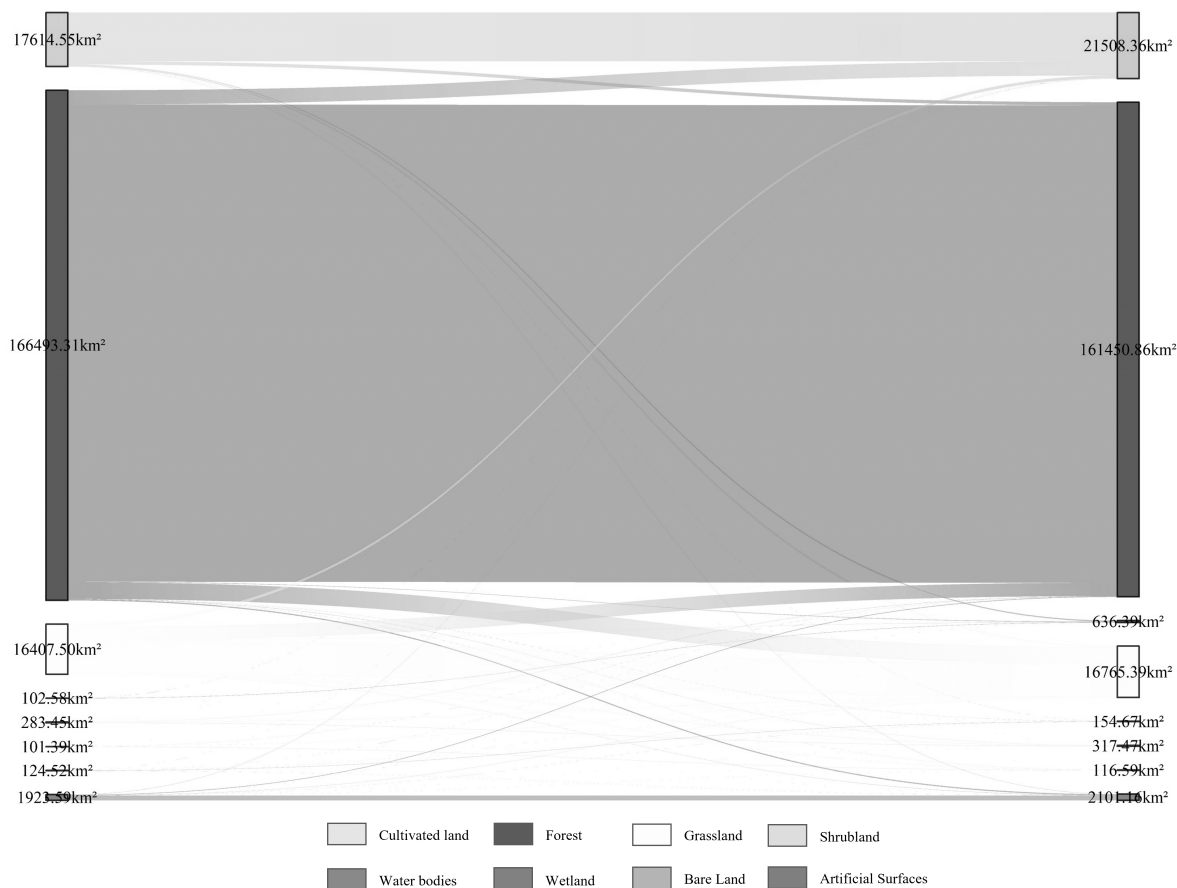
Cultivated land   Forest   Grassland   Shrubland

Water bodies   Wetland   Bare Land   Artificial Surfaces

Fig. 3. Sankey diagram of land use change in Laos from 2000 to 2020

References

1. Foley J.A. et al. Global Consequences of Land Use // Science. American Association for the Advancement of Science, 2005. Vol. 309, № 5734. P. 570–574.

2. Lambin E.F., Geist H.J., Lepers E. Dynamics of Land-Use and Land-Cover Change in Tropical Regions // Annual Review of Environment and Resources. 2003. Vol. 28, № 1. P. 205–241.

3. López E. et al. Predicting land-cover and land-use change in the urban fringe: A case in Morelia city, Mexico // Landscape and Urban Planning. 2001. Vol. 55, № 4. P. 271–285.

4. Yao Y. et al. Sensing spatial distribution of urban land use by integrating points-of-interest and Google Word2Vec model // International Journal of Geographical Information Science. Taylor & Francis, 2017. Vol. 31, № 4. P. 825–848.

5. Verburg P.H. et al. Modeling the Spatial Dynamics of Regional Land Use: The CLUE-S Model // Environmental Management. 2002. Vol. 30, № 3. P. 391–405.

6. O'Neill R.V. et al. Indices of landscape pattern // Landscape Ecol. 1988. Vol. 1, № 3. P. 153–162.

7. Du G.-M., Zhang R., Yu F.-R. [Analysis of cropping pattern in black soil region of Northeast China based on geo-information Tupu.] // Ying Yong Sheng Tai Xue Bao. 2022. Vol. 33, № 3. P. 694–702.