Analysis of spatial-temporal evolution characteristics of abandoned cropland in Yunnan Province based on multi-temporal MODIS global land cover product

W J Xiao¹, J S Wang¹,²,³ and Y C Liu¹

¹School of Information Science and Technology, Yunnan Normal University, Kunming, 650500, China
²The Engineering Research Center of GIS Technology in Western China, Kunming, 650500, China

E-mail: wjerson@foxmail.com

Abstract. With the outflow of rural labour forces, the abandonment of cropland is widespread, which seriously affects food security. Obtaining the spatial and temporal evolution characteristics of abandoned cropland is particularly important for formulating cultivated land protection policies and the land transfer measures. However, Yunnan province lacks the data sets of space-time distribution of abandoned land. In order to enrich the data of abandoned cropland in Yunnan province and grasp its spatial-temporal evolution characteristics to manage abandoned cropland more conveniently. Based on MODIS global land cover products and by applying the method of change detection, we have already obtained the dataset of the abandoned land in Yunnan province. Also, analysed the evolution characteristics with gravitational center computation. The result shows that the average abandoned cropland is 1284 km² every year, among which 2003 witnessed the least abandoned cropland, which was 582.94 km² and 2011 witnessed the most abandoned land, which was 1961.21 km². It is found that the changes fluctuate obviously. The abandoned cropland is mainly distributed in the eastern plateau area of the study area. And the gravity of abandoned land shifted from Northwest Kunming to the border of Kunming city, Chuxiong and Yuxi city. But it located in Yuxi most years.

1. Introduction

Driven by the development of urbanization and industrialization, a large number of rural labor forces has moved to cities, resulting in the shortage of rural labor forces and the abandonment of cultivated land. The abandoned land directly leads to the decrease of actual cultivated land area and grain yield, which has an important impact on food security. Therefore, mastering the characteristics of spatial and temporal distribution of abandoned land can provide decision-making basis for cultivated land protection and food security. The abandonment of cultivated land is common all over the world, especially in developed countries. China began to experience the abandonment of land in the 1980s. Many domestic and international scholars carried on a great deal of research to this issue.

The phenomenon is the most common in developed countries [1]. The movement of a large number of rural labour force to the city has become the direct cause of the abandoned arable land [2]. Europe is the main research area of idle farmland [1,3]. Such as Lesiv et al [4] used the Soviet Union Countries as the study area, blended a variety of land use data based on Bayesian network. For example, the data of abandoned cultivated land in Europe [5], global cultivated land data with 30m resolution [6], MODIS...
Collection 5 global land cover with 500m resolution [7] and so on. For that, the 10 arc-second resolution cultivated land products and abandoned cultivated land products in 2010 were obtained. More often, MODIS time series data are used for the extraction and analysis of abandoned cultivated land [5,8]. However, it is limited to the extraction of wasteland information in a short time range, and it is impossible to obtain long-term characteristics of abandoned land.

Most studies have been carried out to analyze the driving force of cultivated land abandonment [9,10], but the few studied for the spatial and temporal distribution of abandoned farmland. And these are mainly limited to small areas (counties). For example, Shi et al [11], used the existing land use map, data on conversion of farmland to forests and land for forestry etc., obtained the abandoned farmland in result after overlaying the cultivated land layers and removing the map spots of returning farmland to forest and forest engineering in typical counties of Chongqing city based on ArcGIS software. In addition, Yang et al [12] used the methods of inter-annual change detection and intra-annual change detection to extract abandoned arable land in Linger County, Hohhot, and Inner Mongolia. By comparison, the change detection method is more reliable than the former layer superposition method and avoids the problem of layer superposition mismatch. Compared with visual interpretation [13-15] assisted interpretation [16,17] unassisted interpretation [15] and other methods based on remote sensing image classification, this method avoids the problem of ground class confusion in the classification process. And it’s the workload can be reduced greatly compared with the sampling survey method [5,18,19]. In general, the change detection method is more suitable for the information extraction of long time series of abandoned farmland, and the results are reliable without a lot of work.

Yunnan province is located in the southwest of China, mainly in plateau and mountainous areas, with fragmented cropland and single income source of rural households. It is a province with more migrant workers in China, and its abandonment phenomenon is more common. At present, there is no study on the spatial-temporal distribution of abandoned land in Yunnan province. Therefore, based on the multi-temporal MODIS (Moderate-resolution Imaging Spectroradiometer) land cover products from 2001 to 2016 to analyze the spatial and temporal evolution characteristics of abandoned land in Yunnan province by using change monitoring and gravity center analysis method.

2. Data sources
The data used in this study is the global land cover type data of MODIS with medium resolution (MODIS Collection 6 global land cover) in 2001-2016, which is the longest land cover product in the world at present. It includes 17 international geosphere-biosphere program (IGBP) land cover classes. The data details are shown (see table 1). This comes from the Google Earth Engine platform (https://earthengine.google.com).

| Table 1. Basic information of remote sensing data of MODIS global land cover types. |
|---------------------------------------------------------------|
| MODIS global land cover types                                 |
| spatial resolution   | 500 m            |
| time range          | 2001-2016        |
| temporal resolution | 1 year           |
| 17 land cover classes| Needle leaf Forests(2 classes), Broadleaf Forests(2 classes), Mixed Forests(1 class), shrub lands(2 classes), Savannas(2 classes), Grasslands(1 class), Wetlands(1 class), Cropland(2 classes), The Impervious(Urban and Built-up Lands: 1 class), Snow and Ice(1 class), Bare Land(1 class), Water Bodies(1 class) |

3. Methods
In this paper, the abandoned land refers to the cultivated land which has not been planted for one year. The transfer direction of cultivated land is mainly woodland, grassland and bare land, hereinafter referred to as transferred land. Therefore, the basic idea of this paper is to extract the cultivated land each year first, and then judge the cultivated land abandoned situation of the next year by using the transferred land type in adjacent years. In MODIS Collection 6 global land cover, the transferred land corresponds to shrub lands, savannas, grasslands and bare land.

The technique route for the study is shown as below (figure 1).

Figure 1. Technique route.

3.1. Extraction of the range of cultivated land and transferred land
MODIS Collection 6 image dataset is composed of 17 refined land cover classes. It can be seen from step 2 that the cultivated land type includes 2 classes. shrublands include 2 classes: closed shrublands and open shrublands. Similarly, depending on density, grasslands also include two classes. In this study, the 17 refined land types were remapped into 3 categories, the 2 classes cultivated land were classified into the first category, the 6 classes that shrublands, savannas, grasslands and bare land were classified into the second category, and the remaining 9 classes land types were classified into the third category. After the remapping and classification of MODIS dataset, the first and second categories were masked respectively, and the cultivated land mask (figure 2) and transferred land (the shrublands, savannas, grasslands and bare) mask (figure 3) were obtained. It can be seen from figure 2 that the cultivated land in the study area is mainly distributed in Qujing city, Zhaotong city, Hani-Yi Autonomous Prefecture of Honghe and Wenshan city in East Yunnan. A small part of the distribution in Dali Bai Autonomous Prefecture, Dehong Autonomous Prefecture and the city of Baoshan and Lincang in West Yunnan. During the study period, the cultivated land in the study area shows a decreasing trend on the whole. But between 2001 and 2004, the cultivated land increased slightly. As can be seen from figure 3, the
study area is covered by shrublands, savannas, grasslands and bare land in a large scale and distributed around cultivated land. During the study period from 2001 to 2016, the total area of shrublands, savannas, grasslands and bare land in the study area decreased year by year, which was roughly the same as the trend of cultivated land.

**Figure 2.** Distribution of cultivated land in Yunnan province from 2001 to 2016.

**Figure 3.** Distribution of transferred land in Yunnan province from 2001 to 2016.

3.2. Extraction of abandoned land based on change detection

Changes in one type of land cover are accompanied by changes in other types. For example, when the first type of land (cultivated land) is transformed into the second type of land (transferred land), the area of the first type of land will decrease, while that of the second type of land will increase in the same region. Therefore, the abandoned land can be obtained by detecting the changes of these two types of land types within the same time interval.

This method is change detection. By the way, the part of cultivated land that flowing to shrublands, savannas, grasslands and bare land as abandoned land. Making use of the two mask images obtained in step 2 (cultivated land and transferred land), the steps for utilizing this method are as shown below:

**Step 1:** First of all, the interannual change result between the previous and the after were obtained by subtracting calculation. The calculation formula is as in equation (1):

\[
\text{Change}_{(\text{class}, T+1)} = \text{Class}_{T+1} - \text{Class}_T
\]

For the formula, \(\text{Change}_{(\text{class}, T+1)}\) is the interannual change result of the masked image in \(T+1\) (time range from \(T\) to \(T+1\) year). \(\text{Class}_T\) and \(\text{Class}_{T+1}\) are the masked images in \(T\) and \(T+1\) respectively. Taking the change in 2016 as an example, the results of interannual variation of two types of masked images of are as follows. The change of cultivated land is shown (see figure 4), while transferred land is shown (figure 5). By comparing the lost cultivated land (dark green part) in figure 4(c) with the newly increase shrublands, savannas, grasslands and bare land (black part) in figure 5(c), it can be concluded that almost all the decreasing cultivated land in Yunnan province in 2016 was converted into shrublands, savannas, grasslands and bare land.

**Step 2:** Interannual variation results of the two types of masked images obtained in step 1 are calculated to obtain the overlapping part of the images as the abandoned land as in equation (2).
\[ AL_{T+1} = \text{Change}_{(\text{class1,T+1})} \cap \text{Change}_{(\text{class2,T+1})} \]  

In the formula, \( AL_{T+1} \) represents abandoned land in \( T+1 \). \( \text{Change}_{(\text{class1,T+1})} \) is the loss of the first category of land in \( T+1 \). \( \text{Change}_{(\text{class2,T+1})} \) is the second category of new parts in \( T+1 \). An example of this step acquiring abandoned cultivated land is shown below (figure 6).

**Figure 4.** Sample results of change detection step 1: (a) Cultivated land distribution in 2015; (b) Cultivated land distribution in 2016; (c) Interannual change of cultivated land in 2016.

**Figure 5.** Sample results of change detection step 1: (a) Distribution of transferred land in 2015; (b) Distribution of transferred land in 2016; (c) Interannual change of transferred land in 2016.

**Figure 6.** Sample results of change detection step 2: (a) Distribution of lost cultivated land in 2016; (b) Distribution of increased transferred land in 2016; (c) Distribution of abandoned land in 2016.
4. Results and analysis

4.1. Validation of the results
Based on the abandoned land data in 2016, the accuracy of the results was verified by visual interpretation with Google Earth. A total of 300 sample points of abandoned land and 100 sample points of non-abandoned were obtained. The confusion matrix obtained by comparing the sample points with the extracted results are shown (table 2). The overall accuracy is 78.5% with confusion matrix. It shows that the distribution of abandoned lands in Yunnan province can be basically reflected by the research results. The reason why the accuracy is not high is that the spatial resolution of the data used is 500 m, while many cultivated lands in Yunnan province are scattered with small plots and easy to be confused.

| Actual category | Abandoned land | Non-abandoned land | Total |
|-----------------|----------------|--------------------|-------|
| Abandoned land  | 124            | 2                  | 126   |
| Non-abandoned land | 46          | 51                | 97    |
| total           | 170            | 53                | 223   |

4.2. Extracted results of abandoned land
The distribution results of abandoned land in Yunnan province from 2002 to 2016 were obtained through change detection, as shown below (figure 7).

The abandoned land mainly located in the mountainous and hilly areas of East Yunnan. Such as the west of Qujing city, the northwest of Hani-Yi Autonomous Prefecture of Honghe, the east of Kunming city, the west of Wenshan Zhuang and Miao Autonomous Prefecture and the southwest of Zhaotong city.

![Figure 7. The distribution of abandoned land in Yunnan province from 2002 to 2016.](image-url)

4.3. Analysis of area changes of abandoned land

- Analysis of variation characteristics of abandoned land area in Yunnan province from 2002 to 2016 are show below (figure 8). As we can be seen from figure 8, the abandoned cultivated land changed a lot in the three years of 2003, 2011 and 2016, while the fluctuation was less in other
years. This is because since the implementation of "regulations on returning farmland to forests" in 2003, part of the project has occupied the abandoned land and the abandoned land decreased eventually. After 2004, the intensity of returning farmland to forests weakened, and the development of industrialization and urbanization increased the degree of abandonment. By 2011, that was at highest. After 2011, the implementation of the "land reclamation regulations", abandoned arable land has decreased. And after 2015, a series of measures, such as the use of idle land and the measures to supplement the quantity of cultivated land, improve the quality of cultivated land, and achieve the balance between the occupation and compensation of cultivated land, have reduced the degree of abandoned land.

![Figure 8. The variation of abandoned land area in Yunnan province from 2002 to 2016.](image)

- Analysis on the relationship between the area of reduced cultivated land and abandoned land (see table 3). As we can be seen from table 3, the area of lost cultivated land is the same as that of abandoned land basically. It shows that during the change of cultivated land, almost all the lost parts are turned into shrublands, savannas, grasslands and bare land. The part of the reasons for the change is that cultivated land spread over flat areas. That is easy to cultivate and irrigate, and is used commonly, with little chance of fallow. The more likely change is to be for construction land, which is not the extent of fallow land. Compared with the cultivated land at higher elevations, it is less likely to be occupied by construction and more likely to become shrublands, savannas, grasslands and bare land.

| Year | Reduced cultivated land | Increased abandoned land |
|------|-------------------------|--------------------------|
| 2002 | 957.38                  | 956.25                   |
| 2003 | 584.99                  | 582.94                   |
| 2004 | 1057.90                 | 1056.54                 |
| 2005 | 1382.29                 | 1380.97                 |
| 2006 | 1305.12                 | 1300.59                 |
| 2007 | 1532.53                 | 1527.12                 |
| 2008 | 1316.80                 | 1312.49                 |
| 2009 | 1467.24                 | 1460.44                 |
| 2010 | 1516.08                 | 1506.79                 |
| 2011 | 1967.56                 | 1961.21                 |
| 2012 | 1530.43                 | 1524.16                 |
| 2013 | 1507.77                 | 1503.90                 |
| 2014 | 1588.95                 | 1587.72                 |
| 2015 | 1676.23                 | 1673.50                 |
| 2016 | 1128.93                 | 1127.80                 |

- Statistics of the change of abandoned area in the cities and states of Yunnan province. In order
to find the areas with serious abandoned land in the study area, the variation of abandoned land in various cities and states in the study area was analyzed (figure 9). As we can be seen from figure 9, the abandoned areas in Kunming, Qujing and Hani-Yi Autonomous Prefecture of Honghe are abandoned seriously. Among them, the change of the area of abandoned land in Qujing is highly consistent with that in the whole study area. Qujing is the second largest city in Yunnan province, and the development of urbanization and characteristic agriculture is in the forefront of the province. It is difficult to maintain the balance of between cultivated land occupation and compensation in some mountainous areas.

Figure 9. The change of abandoned land area in the cities and states of Yunnan Province.

4.4. Analysis of center of gravity changes
Analyzing the Center of gravity changes is a necessary work to further demonstrate spatial agglomeration characteristics [20,21] and migration characteristics [22] of abandoned land. The Mean Center in Spatial Statistics tools of ArcGIS software was used to calculate the Center of gravity of the changes of abandoned cultivated land from 2002 to 2016, that is, the changed curve of the Center of gravity of abandoned cultivated land was obtained (figure 10). As we can be seen from figure 10, the distribution of abandoned land is uneven, so the center of gravity of abandoned land does not overlap with the center of the study area. The center of abandoned land remained in the eastern part of the study area, changing back and forth among Kunming, Chuxiong and Yuxi. Among them, from 2004 to 2006, the center of gravity of abandoned land shifted to the southwest, from the border of Fumin County in Kunming city to Shuangbai County in Chuxiong. Then it moves east.

According to the analysis in figure 10 of step 4.3, it can be concluded that in the western or the western part of the study area, such as Baoshan, Dali Bai Autonomous Prefecture, Dehong Autonomous Prefecture and Lincang city, the abandoned cultivated land increased from 2004 to 2006. In Yuxi in Central Yunnan and Hani-Yi Autonomous Prefecture of Honghe in Southeast Yunnan, abandoned land is also growing. Therefore, the center of gravity of abandoned land shifted to the southwest, which is the result of the change of abandoned farmland in these two parts. After that, the growth in the east became apparent. As we can be seen from figure 10, till 2008, there is an obvious dividing line between the eastern and western parts of the abandoned land. In the west, the area of abandoned land is less than 86 km², while in the east, it is more than 168 km². The center of gravity shifted eastward.

5. Discussion
Based on the land cover products of MODIS from 2001 to 2016, this study uses the change detection method to study the spatial and temporal changes of abandoned lands in Yunnan province, and draws
the following conclusions:

- From 2002 to 2016, the abandoned land in Yunnan province fluctuated significantly, with an average uncultivated area of 1284.07 km² per year. In 2003, the least arable land was left uncultivated, and in 2011, the most.
- The abandoned lands in Yunnan province are mainly distributed in East Yunnan. Among them, Kunming, Qujing and Honghe have a high degree of abandoned land every year.
- The center of gravity of abandoned land changes back and forth among Kunming, Chuxiong, and Yuxi. From 2002 to 2006, the center of gravity was abandoned from east to west. From 2006 to 2008, the center of gravity was abandoned from west to east. However, due to the coarse spatial resolution of the data used in this paper, the accuracy of the extraction results is insufficient. In the future work, more accurate spatial and temporal analysis of abandoned land needs to be carried out based on high-resolution remote sensing data and products.

Acknowledgments
This work was supported by Scientific Research Foundation for Doctoral and Research and Innovation Fund for the Graduate of Yunnan Normal University (No. ysdyjs2019157).

References
[1] Li S F and Li X B 2016 Progress and prospect on farmland abandonment Acta Geogr. Sin. 71 370-89 (In Chinese)
[2] Shi T C and Li X B 2013 Farmland abandonment in Europe and its enlightenment to China Geogr. Geo-Inf. Sci. 29 101-3 (In Chinese)
[3] Ustaoglu E and Collier M 2018 Farmland abandonment in Europe: An overview of drivers, consequences, and assessment of the sustainability implications Environ. Rev. 26 1-21
[4] Lesiv M, Schepaschenko D, Moltchanova E et al 2018 Spatial distribution of arable and abandoned land across former Soviet Union Countries Sci. Data 5 180056
[5] Estel S, Kuemmerle T, Alcántara C et al 2015 Mapping farmland abandonment and recultivation across Europe using MODIS NDVI time series Remote Sens. 163 312-25
[6] Xiong J, Thenkabail P, Tilton J C et al 2017 Nominal 30-m cropland extent map of continental Africa by integrating pixel-based and object-based algorithms using sentinel-2 and landsat-8 data on google earth engine Remote Sens. 9 1065
[7] Friedl M A, Sulla-Menashe D, Tan B et al 2010 MODIS Collection 5 global land cover: Algorithm refinements and characterization of new datasets Remote Sens. Environ. 114 168-82
[8] Alcantara C, Kuemmerle T, Baumann M et al 2013 Mapping the extent of abandoned farmland in Central and Eastern Europe using MODIS time series satellite data Environ. Res. Lett. 8 35035
[9] Xiao T 2016 Study on the influence of rural labor force transfer on abandoned land in Jiangyang District (Sichuan: SAU) (In Chinese)
[10] Wu Y Y 2012 Reasons and solutions for abandoned land in Xiushan county South Chin. Agr. 6 54-7 (In Chinese)
[11] Shi T C and Xu X H 2016 Extraction and validation of abandoned farmland parcel in typical counties of Chongqing Trans. Chin. Soc. Agric. 32 261-7 (In Chinese)
[12] Yang T, Guo X D, Yue D P et al 2019 Information extraction and driving factor assessment of farmland abandonment based on joint change detection Trans. Chin. Soc. Agric. Mach. 2019 201-8 (In Chinese)
[13] Zhang B R, Hou Z H, Duan P et al 2018 Abandoned land extraction methods for different resolution images Geoma. Spati. Inf. Tech. 41 176-179 (In Chinese)
[14] Feng M Q, Pan H Y, Zhu F et al 2018 Spatial pattern of different abandoned farmland and its affecting Southwest China J. Agr. Sci. 31 1260-6 (In Chinese)
[15] Wang Y Q, Qin F Y, Yin S et al 2019 Land cover information extraction of dalinuoer wetland
nature reserve: Based on GF-1 satellite data and object-oriented classification Chin. Agr. Sci. Bull. 35 137-41 (In Chinese)

[16] Ma S J, Pei Z Y, Wang F et al 2019 Application on remote sensing survey of abandoned farmlands in winter along the Huaihe River based on GF-1 image Trans. Chin. Soc. Agric. 35 227-33 (In Chinese)

[17] Li J J, Chen G J, Li Z J et al 2018 Spatial distribution pattern of abandoned land based on GIS: A case study of Qinglong Township in Quxian County of Sichuan Province Guizhou Agr. Sci. 46 129-32 (In Chinese)

[18] Alcantara C, Kuemmerle T, Prishchepov A V et al 2012 Mapping abandoned agriculture with multi-temporal MODIS satellite data Remote Sens. Environ. 124 334-47

[19] Li S F, Li X B, Xin L J et al 2017 Extent and distribution of cropland abandonment in Chinese mountainous areas Resour. Sci. 39 1801-11 (In Chinese)

[20] Ge M L and Feng Z M 2009 Population distribution of China based on GIS: Classification of population densities and curve of population gravity centers Acta Geogr. Sin. 64 202-10 (In Chinese)

[21] Guan X L, Fang C L and Lu S S 2010 Analysis of satial distribution and gravity centers curve dynamic cultivated Lnd changes in China J. Nat. Resour. 25 1997-2006 (In Chinese)

[22] Liu B T, Song H P, Guo B et al 2012 Study on annual variation of rainfall erosivity in southwest China using gravity center model Trans. Chin. Soc. Agric. 28 113-20