Analysis of Ecological Environment Changes and Driving Forces in Boao town of Hainan Province

J Y Yang$^{2,3}$, Q JWang$^{1,2,3,*}$, Z CLI$^3$, J J Xie$^{2,3}$ and D K Chang$^{2,3}$

1. Key Laboratory of Earth Observation of Hainan Province, Hainan Research Institute, Aerospace Information Research Institute, Chinese Academy of Sciences, Hainan, 572029, China
2. Key Laboratory of Digital Earth Science, Aerospace Information Research Institute, Chinese Academy of Sciences, Beijing, 100094, China
3. University of Chinese Academy of Sciences, Yanqi Lake Campus of Chinese Academy of Sciences University, Beijing, 101408, China

*Corresponding author: wangqj@radi.ac.cn

Abstract. Based on the three phases of remote sensing imageries in 2000, 2010 and 2020, taking Boao town as the study area, this paper analyzed the changes in the ecological environment and the driving forces of ecological environment. The results showed that: (1) The main land use type of Boao town was forest, followed by cultivated land. The main change of land use types in Boao town from 2000 to 2020 is from forest to other land types. (2) The average vegetation coverage of Boao town was 70.68% in 2000, 62.49% in 2010 and 71.65% in 2020, which indicated a trend of first decreasing and then increasing. (3) The changes of landscape pattern index of type level from 2000 to 2020 were as follows: the landscape shape index and landscape fragmentation of cultivated land decreased gradually, while the landscape shape index and landscape fragmentation of construction land and forest land increased. The trend of landscape pattern index of landscape level from 2000 to 2020 was as follows: landscape fragmentation continued to increase, landscape spread continued to decline, landscape separation continued to rise, and landscape diversity and evenness continued to increase. (4) In the driving force analysis of ecological environment changes in Boao Town, the results of principal component analysis showed that human factors were the leading factors of ecological environment changes in Boao Town, and economic factors such as GDP, output value of the third industry and per capita disposable income of farmers were the main driving forces of landscape pattern changes in Boao town.
1. Introduction
Ecological environment is the basis of human existence and development [1], and the long-term development of human society must be guaranteed by maintaining the stability and balance of the environment. Studying the changing trend of ecological environment is conducive to make more reasonable environmental protection policies and adopt more appropriate environmental protection measures, so as to protect environment to make healthy and sustainable development, and to lay a good foundation for the further development of human society.

With all kinds of gradual development and mature of the theory and technology, such as environmental science, computer science, remote sensing technology, in view of the ecological environment change research can be mainly divided into climate changes[2], carbon emissions[3], environmental pollutions, land use/cover changes (LUCC)[4-5], the landscape pattern changes[6-8], such as a driving forces of the environmental changes[9-12]. In recent years, the focus of research on ecological environment change tends to be the quantitative analysis and introduction model of all kinds of information extracted from remote sensing data [13], so as to provide scientific decision-making basis for ecological environment protection and regional sustainable development. Remote Sensing (RS) technology has become a common method to analyze and evaluate the level of ecological environment, and has been widely used in various ecological fields.

This paper aims to use multi-temporal remote sensing data to analyze the spatial-temporal changes of land use and landscape pattern in Boao Town, and to explore the driving forces of ecological environment changes, so as to provide reference for the ecological environment protection in this area.

2. Materials and methods

2.1. Materials

2.1.1. Study area
As shown in the Figure 1, the study area of this article is Boao Town, located in the eastern coastal zone of Hainan Province, where Wanquan River flows into the South China Sea. Its central latitude and longitude is 110° 35’34”E, 19° 9’55”N, with an area of 86 km². According to the information released by the Qionghai Municipal People's Government, the total number of households in the town in 2019 was 8,873, with a total population of 31,884. Boao Town is adjacent to the South China Sea to the east, Longgun Town of Wanning City to the south, Jiaji Town and Zhongyuan Town of Qionghai City to the west, and Tanmen Town of Qionghai City to the north. It is about 110 kilometers away from Haikou City, 160 kilometers away from Sanya City, and 19 kilometers away from Jiaji Town. The Hainan East Ring High-speed Railway passes through Boao Town, so it has strong traffic connectivity. At the same time, it is also the location of the "Boao Forum for Asia" and has relatively complete tourist reception facilities.
2.1.2. Data

Three remote sensing imageries from 2000 to 2020 are selected, two of which are Landsat5 TM imageries in 2000 and 2010, and the other one is Landsat8 OLI imageries in 2020. The acquired date of the imageries are all in June and July, with vigorous vegetation growth, less cloud cover and good quality. Their parameters are as follows:

| Year | ID           | Sensor | Time       | Number | Cloud(%) |
|------|--------------|--------|------------|--------|----------|
| 2000 | LT51230472000209BJC00 | TM     | 2000.07.27 | 123/47 | 3.55     |
| 2010 | LT51230472010188BKT00  | TM     | 2010.07.07 | 123/47 | 0.7      |
| 2020 | LC81230472020152LGN00  | OIL    | 2020.05.31 | 123/47 | 9.01     |
The elevation data used is SRTM elevation data with resolution of 30m, which can completely cover the study area. Using which, a DEM map of Boao town was built and shown in the Figure 2.

![DEM of Boao](image)

**Figure 2.** DEM map of Boao town.

2.2. **Methods**

2.2.1. **Image pre-processing**

Geographically register the administrative division maps of sub-townships in Hainan Province with remote sensing imageries, so that they can be displayed on top of each other, delimit the administrative boundary of Boao Town, and obtain the vector file of administrative scope of Boao Town.

The remote sensing image is pre-processed by the following steps: (1) geographic registration; (2) Radiation calibration; (3) Atmospheric correction; (4) Geometric correction; (5) Image clipping. Thus, the remote sensing imageries of Boao Town from 2000 to 2010 are obtained. Figure 3 shows the comparison between the original and the processed spectra.

![Comparison between original and processed spectra](image)

**Figure 3.** Comparison between the original and the processed spectra
2.2.2. Image classification

Because the regional space of each study area is different, and the selected remote sensing data sources are different, the classification system of land use types is also different. According to the classification system of the National Land and Resources Division, considering the actual situation of Boao Town, the landscape types in the study area are divided into four types: forest land, cropland, water and built-up land.

As shown in Table 2 and 3, red, green and blue are the three primary colors, and it is their combinations that constructs this colorful world. At the same time, different bands contain different information, and the combination of multiple bands can provide us with abundant information, which helps us to improve the accuracy of visual interpretation.

| Table 2. Landsat5 TM band combination          |
|-----------------------------------------------|
| Band combination                              | Significance                                                                 |
| 3, 2, 1 Red, Green, Blue                      | Natural true color                                                           |
| 4, 3, 2 NIR, Red, Green                       | Standard false color, the vegetation shows red, the higher the vegetation coverage, the darker the red, and the color difference between the water body and other ground objects is obvious, which is mostly used for vegetation classification and water identification. |
| 4, 5, 3 NIR, SWIR, Red                        | False color synthesis can be used to identify water                           |
| 5, 4, 3 SWIR, NIR, Red                        | False color synthesis can be used to identify built-up land                  |

| Table 3. Landsat 8 OIL band combination        |
|-----------------------------------------------|
| Band combination                              | Significance                                                                 |
| 4, 3, 2 Red, Green, Blue                      | Natural true color                                                           |
| 5, 4, 3 NIR, Red, Green                       | Standard false color, vegetation displayed in red, can be used to identify forest land |
| 7, 6, 4 SWIR2, SWIR1, Red                     | False color synthesis, used for urban monitoring, can be used to identify construction land |
| 6, 5, 2 SWIR1, NIR, Blue                      | False color synthesis, the cropland covered with crops shows green, and the bare land without cover shows pink |
| 5, 6, 4 NIR, SWIR1, Red                       | False color synthesis can effectively distinguish land from water            |

According to the previous experience, the effect of supervised classification is generally better than unsupervised classification. Therefore, we choose the SVM support vector machine classification method in supervised classification, then use high-scoring imageries and Google Earth historical imageries to assist judgment. Next, select purer pixels as training samples, and finally classify the preprocessed imageries for land use to obtain the land use classification results in 2000, 2010 and 2020 shown in the Figure 4. In order to evaluate the accuracy of classification results, the random scatter function of ArcGIS was used to create verification samples, and the confusion matrix between
land classification results and independent verification samples was constructed.

The results show that the overall accuracy of classification in 2000, 2010 and 2020 are 92%, 90% and 89%, respectively, and the Kappa statistical coefficients are 0.89, 0.85 and 0.86, respectively. Which indicates that the classification accuracy can meet the research needs.

![Land use type map of Boao](image)

**Figure 4.** Land use type map of Boao (2000-2020)

2.2.3. Landscape pattern index extraction

Landscape pattern index can quantitatively describe the characteristics of landscape pattern, which can be divided into patch level, landscape type level and landscape level index from different scales. Different levels of index can reflect different landscape pattern characteristics. Landscape pattern index is helpful to understand the comprehensive information of ecological environment in a certain region, while landscape pattern index of different phases in the same region is helpful to understand the change of landscape pattern and the change trend of ecological environment in this region.

At present, there are many kinds of landscape pattern indexes, but there are interrelated relationships among many indexes. Therefore, when doing landscape pattern analysis, it is necessary to reasonably select various landscape pattern indexes to avoid redundant data, and to choose more basic indexes as much as possible.

The land classification data of Boao Town in the three phases (2000, 2010, and 2020) were resampled to the same resolution (30m*30m) by ArcGIS10.2, and exported to Fragstats4.2 to obtain the landscape index.

In this paper, landscape index at landscape scale level is selected from four aspects: (1) Shape index, which represents the geometric shape of landscape pattern; (2) Fragmentation index, which represents the fragmentation degree of landscape pattern; (3) Convergence index, representing the spatial distribution of landscape pattern; (4) Diversity index, representing the richness of landscape pattern types. Finally, as shown in Table 4, five class indexes, such as landscape shape index-LSI, patch number-NP, patch density-PD, patch COHESION and landscape separation-DIVISION are
selected. Six landscape indicators, including patch number-NP, patch density-PD, CONTAG index, landscape separation-DIVISION, Shannon diversity index-SHDI, Shannon uniformity index-SHEI, are selected to analyze the dynamic change characteristics of landscape pattern in Boao town.

**Table 4. Selection of landscape pattern index.**

| Indicators             | Formula                                                                 | Value range |
|------------------------|------------------------------------------------------------------------|-------------|
| **Shape**              |                                                                        |             |
| Shape                  |                                                                        |             |
| Shape Index            | $LSI = \frac{e_i}{\min e_i}$                                          | $\geq 1$    |
| It is an index to describe the shape of landscape patches. The larger the LSI value, the more complex the shape, and the smaller the value, the more regular it is. |
| Number of Patches      | $NP_i = N_i$                                                           | $\geq 0$    |
| Indicates the total number of landscape patches. |
| Patch Density          | $PD = \frac{\sum N_i}{A}$                                            | $\geq 0$    |
| Is the number of patches per unit area of landscape. |
| Landscape Division     | $DIVISION = \left[1 - \sum_{i=1}^{m} \sum_{j=1}^{n} \left( \frac{a_{ij}}{A} \right)^2 \right]$ | $\left(0, \ 100\right]$ |
| Indicates the degree of separation between different patches in a certain landscape type. |
| **Convergence and divergence** |                                                                        |             |
| Patch Cohesion Index   | $COHESION = \left[1 - \frac{\sum_{j=1}^{n} P_{ij}}{\sum_{j=1}^{n} P_j \sqrt{a_{ij}}} \right] \left[1 - \frac{1}{\sqrt{A}} \right]$ | $\left(0, \ 100\right]$ |
| Indicates the degree of bonding between plaques. The greater the COHESION value, the higher the connectivity between plaques. |
| Contagion Index        | $CONTAG = 1 + \sum_{i=1}^{m} \sum_{j=1}^{n} P_{ij} \ln P_{ij} \frac{P_j \ln P_j}{2 \ln M}$ | $\left(0, \ 100\right]$ |
| It indicates the gathering or spreading trend of different patch types in the landscape. When the CONTAG value is small, it indicates that there are many small patches in the landscape. When it tends to 100, it indicates that there are dominant patch types with high connectivity in the landscape. |
| **Diversity**          |                                                                        |             |
| Shannon's Diversity Index | $SHDI = -\sum_{i=1}^{m} P_i \ln P_i$                                | $\geq 0$    |
| Indicates the richness of each patch type in the landscape. When SHDI value is 0, it indicates that only one plaque type exists. The larger the value, the more
patch types in the landscape or the balanced distribution of each patch type

\[
SHEI = \frac{- \sum_{i=1}^{m} P_i \ln P_i}{\ln m} [0, \ 1]
\]

When the SHEI value is 0, it indicates that the landscape is composed of only one patch type and there is no diversity. When the value is 1, it indicates that all plaque types are evenly distributed, and there is no dominant plaque type.

2.2.4. Calculation of NDVI and vegetation coverage

Normalized Vegetation Index NDVI is an important index that can be used to detect the growth state of vegetation and the coverage of regional vegetation, because it can eliminate most irradiance changes related to instrument calibration, sun angle, terrain, cloud, shadow and atmospheric conditions, and enhance the response ability to vegetation, so it has been widely used\(^{[15]}\).

The NDVI calculation formula is:

\[
NDVI = \frac{NIR - R}{NIR + R}
\]

In which. NIR represents the near infrared band and R represents the red band. The range of NDVI is \([-1,1]\), and the area with \(NDVI<0\) is covered by water (cloud, snow, water, etc.), which has a large reflectivity to visible light; The area with \(NDVI=0\) has no vegetation coverage at all, which may be bare rock or land, and the near infrared band value is equal to the red band value; The area with \(NDVI>0\) is covered by vegetation, and the greater the NDVI value, the more the corresponding vegetation coverage.

![NDVI map of Boao (2000-2020) (a) (b) (c)](image-url)
After NDVI calculation is completed in the Figure 5, the corresponding vegetation coverage can be calculated according to NDVI value. Vegetation coverage refers to the percentage of the vertical projection area of vegetation (including leaves, stems and branches) on the ground in the total area of the statistical area. For each imagery, it can be roughly divided into three categories: waters, vegetation and buildings, and then the vegetation coverage is calculated by using the mixed pixel decomposition method, whose formula is shown as follows.

\[ F_V = \frac{NDVI - NDVI_{soil}}{NDVI_{veg} - NDVI_{soil}} \]

In which, \( NDVI_{soil} \) is the NDVI value of bare soil pixel and \( NDVI_{veg} \) is the NDVI value of vegetation pixel. According to the previous researches, taking 0.70 and 0.05 as the thresholds. That is, when the \( NDVI_{veg} \) of a pixel is greater than 0.70, \( F_V = 1 \); When it is less than 0.05, \( F_V = 0 \). Vegetation coverage map in Boao is shown in Figure 6.

![Vegetation coverage in Boao (2000-2020)](image)

**Figure 6.** Vegetation coverage in Boao (2000-2020)

2.2.5. *Driving forces analysis method*

There are many natural factors affecting the landscape pattern changes in the study area, such as topographic factors, climatic factors and so on. Climate changes, such as precipitation, sunshine and temperature, will directly lead to the spatial heterogeneity of water, light and heat, thus affecting the changes of landscape pattern. Elevation, slope, aspect and other factors in terrain are often closely related to human production and construction activities, which have a profound impact on landscape pattern.

The function of principal component analysis is to divide the original multiple variables into a few comprehensive indicators through transformation on various variables. These indicators can not only
fully reflect the information of more variables, but also weaken the mutual interference among the variables [16].

Climate, population, economy and technology are selected as the driving forces indicators to make principal component analysis and the results are shown in Table 5.

Table 5. Selection of driving factors.

| Driving factors | Indicators |
|-----------------|------------|
| Climate         | X1: annual average temperature (°C) |
|                 | X2: annual total sunshine hours (h) |
|                 | X3: annual total precipitation (mm) |
|                 | X4: total number of households (households) |
| Population      | X5: total population (person) |
|                 | X6: agricultural population (person) |
|                 | X7: GDP (ten thousand yuan) |
|                 | X8: primary industry (10,000 yuan) |
| Economics       | X9: secondary industry (ten thousand yuan) |
|                 | X10: third industry (ten thousand yuan) |
|                 | X11: per capita disposable income of farmers (yuan) |
| Technology      | X12: total power of agricultural machinery (10,000 kilowatts) |
|                 | X13: Fertilizer application amount (10,000 tons) |

Table 6 shows the correlation coefficient matrix of each selected index. From which, it can be seen that X1 has a highly positive correlation with X2, but its correlation with other indexes is not high. Because sunshine hours (X2) will affect air temperature (X1) to a certain extent, generally speaking, the higher the sunshine hours, the higher the corresponding air temperature will be.

The correlation coefficients of X4 with X5, X7, X8, X9, X10, X11, X12 and X13 are all more than 0.8, among which, its correlations with X5, X9 and X12 are more than 0.9, and the correlation with X12 is even more than 0.98. It shows that the total number of households has a high correlation with GDP, primary industry, third industry, per capita disposable income of farmers, fertilizer application amount, and a strong correlation with the total population, secondary industry value and total power of agricultural machinery, especially with the total power of agricultural machinery.

The correlations between X5 and X7, X8, X9, X10, X11 and X12 are more than 0.94, and the correlation between X5 and X9 is 0.99. It shows that the total population has a strong correlation with GDP, primary industry value, secondary industry value, third industry value, per capita disposable income of farmers and total power of agricultural machinery, among which, there is a highly positive correlation with the secondary industry.

The correlations between X6, X12 and X13 are higher than 0.7, which indicates that there is a certain positive correlation between agricultural population and fertilizer application amount and total power of agricultural machinery.

The correlations between X7 and X8, X9, X10 and X11 are more than 0.98, among which its correlations with X8, X10 and X11 are more than 0.995, and its correlation with X10 is 0.999. It shows that GDP has a strong correlation with primary industry value, secondary industry value, third industry value and per capita disposable income of farmers, especially with third industry value.

X8’s correlations with X9, X10 and X11 are higher than 0.98, and its correlations with X10 and X11 are 0.99, which indicates that the primary industry value has a high correlation with secondary
industry value, third industry value and per capita disposable income of farmers, and has a significant positive correlation with third industry value and per capita disposable income of farmers.

Correlations between X9 and X10, X11 and X12 are more than 0.9, and correlations between X9 and X10, X11 are more than 0.98, which indicates that the value of secondary industry has a strong correlation with the value of third industry, farmers' per capita disposable income and fertilizer application amount, and there is a significant positive correlation with farmers' per capita disposable income and fertilizer application amount.

The correlation between X10 and X11 is 0.997, which indicates that there is a significant high positive correlation between the secondary industry value and the third industry value. The correlation between X12 and X13 is 0.879, which indicates that there is a strong correlation between fertilizer application amount and total power of agricultural machinery.

**Table 6.** Correlation coefficient matrix

|    | X1    | X2    | X3    | X4    | X5    | X6    | X7    | X8    | X9    | X10   | X11   | X12   | X13   |
|----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| X1 | 1     | 0.688 | -0.064| 0.248 | 0.268 | -0.194| 0.324 | 0.314 | 0.299 | 0.331 | 0.334 | 0.245 | 0.236 |
| X2 | 0.688 | 1     | -0.278| 0.634 | 0.603 | 0.203 | 0.573 | 0.561 | 0.586 | 0.572 | 0.581 | 0.613 | 0.456 |
| X3 | -0.064| -0.278| 1     | -0.003| -0.056| 0.206 | -0.139| -0.12 | -0.111| -0.152| -0.132| -0.106| -0.116|
| X4 | 0.248 | 0.634 | -0.003| 1     | 0.964 | 0.74  | 0.883 | 0.874 | 0.937 | 0.87  | 0.891 | 0.98  | 0.839 |
| X5 | 0.268 | 0.603 | -0.056| 0.964 | 1     | 0.674 | 0.973 | 0.968 | 0.99  | 0.966 | 0.974 | 0.943 | 0.789 |
| X6 | -0.194| 0.203 | 0.206 | 0.74  | 0.674 | 1     | 0.541 | 0.549 | 0.622 | 0.518 | 0.539 | 0.738 | 0.706 |
| X7 | 0.324 | 0.573 | -0.139| 0.883 | 0.973 | 0.541 | 1     | 0.995 | 0.988 | 0.999 | 0.997 | 0.868 | 0.719 |
| X8 | 0.314 | 0.561 | -0.12  | 0.874 | 0.968 | 0.549 | 0.995 | 1    | 0.983 | 0.99  | 0.99  | 0.857 | 0.73  |
| X9 | 0.299 | 0.586 | -0.111| 0.937 | 0.99  | 0.622 | 0.988 | 0.983 | 1    | 0.982 | 0.988 | 0.926 | 0.784 |
| X10| 0.331 | 0.572 | -0.152| 0.87  | 0.966 | 0.518 | 0.999 | 0.99  | 0.982 | 1    | 0.997 | 0.855 | 0.697 |
| X11| 0.334 | 0.581 | -0.132| 0.891 | 0.974 | 0.539 | 0.997 | 0.99  | 0.988 | 0.997 | 1    | 0.875 | 0.712 |
| X12| 0.245 | 0.613 | -0.106| 0.98  | 0.943 | 0.738 | 0.868 | 0.857 | 0.926 | 0.855 | 0.875 | 1    | 0.879 |
| X13| 0.236 | 0.456 | -0.116| 0.839 | 0.789 | 0.706 | 0.719 | 0.73  | 0.784 | 0.697 | 0.712 | 0.879 | 1    |

From the above analysis, it can be seen that some of the selected indexes have strong correlation with each other, so it is necessary to carry out principal component analysis.

### 3. Analysis of Ecological Environment Change

#### 3.1. Analysis of Land Use Change

##### 3.1.1. Characteristics of quantity change

The land use classification imageries of Boao Town in different years obtained by SVM are described and analyzed from qualitative and quantitative aspects.

Firstly, according to the land use classification imageries of Boao Town in 2000, 2010 and 2020, the area distribution of various land use types in Boao Town in each year is counted, and the basic information of land use in Boao Town in three different periods is obtained, as shown in Table 7.
Table 7. The area of land use types in Boao town (2000-2020)

| Land use type | 2000 Area /km$^2$ | Proportion/% | 2010 Area /km$^2$ | Proportion/% | 2020 Area /km$^2$ | Proportion/% |
|---------------|--------------------|--------------|--------------------|--------------|--------------------|--------------|
| Cropland      | 23.3               | 27.57        | 27.04              | 31.99        | 28.58              | 33.81        |
| Forestland    | 46.42              | 54.92        | 43.37              | 51.31        | 25.65              | 30.35        |
| Water         | 13.71              | 16.22        | 12.85              | 15.20        | 17.37              | 20.55        |
| Built-up land | 1.09               | 1.29         | 1.26               | 1.49         | 12.92              | 15.29        |

It can be seen that in the land use type information of Boao Town in each year, the area distribution of the four land use types is in the order of forestland > cropland > water > built-up land.

In 2000, forestland occupied the main position, with a total area of 46.42km$^2$, accounting for 54.92% of the total area of Boao Town, followed by cropland of 23.3km$^2$, and accounting for 27.57% of the total area of Boao Town. These two land use types accounted for 82.49% of the total area of Boao Town, while the area of built-up land was 1.09km$^2$, accounting for only 1.29% of the total area. Which indicates that in the early stage, there is little difference between the scale and structure of land use in 2010 and that in 2000. Cropland and built-up land increased slightly, while forest land and water body decreased slightly, which indicates that Boao Town developed slowly in the past 10 years. In 2020, forest land and cropland still occupy 64.26% of the total area, which is the main land. However, forest land is reduced to 25.65km$^2$, cropland is slightly increased, and built-up land is increased to 12.92km$^2$, accounting for 15.29% of the total area, which reflects the rapid development of Boao Town in the past 10 years.

From Table 8, we can see that from 2000 to 2020, the change rate of built-up land in Boao Town was the largest, and the scale continued to expand. From 2000 to 2020, the built-up land area increased by 11.66 km$^2$, and the change rate reached 1085.32%. Changes of forestland and water are also relatively high, and the scale of forestland decreased. From 2000 to 2020, the forestland area decreased by 20.77 km$^2$, with a change rate of -44.74%. The scale of water and cropland is expanding, with areas of 3.66 km$^2$ and 5.28 km$^2$ respectively, and the change rates of 26.7% and 22.66% respectively.

Table 8. Area change of land use types in Boao town.

| Year | 2000-2010 | 2010-2020 | 2000-2020 |
|------|-----------|-----------|-----------|
| Change Type | Variation /km$^2$ | Change rate/% | Variation /km$^2$ | Change rate/% | Variation /km$^2$ | Change rate/% |
| Cropland | 3.74 | 16.05 | 1.54 | 5.70 | 5.28 | 22.66 |
| Forestland | -3.05 | -6.57 | -17.72 | -40.86 | -20.77 | -44.74 |
| Water | -0.86 | -6.27 | 4.52 | 35.18 | 3.66 | 26.70 |
| Built-up land | 0.17 | 15.60 | 11.66 | 925.40 | 11.83 | 1085.32 |

From Table 8, we can see that from the data of each period, there are differences in the changes of each land use type during different periods, and the period with the largest change of cropland is from 2000 to 2020, during which, the growth rate of cropland area is 22.66%; The period of the smallest change of cropland is from 2010 to 2020, during which, the cropland area in Boao Town increased by 1.54 km$^2$, with a growth rate of only 5.7%. The maximum change of forest land is from 2000 to 2020, with the change rate of -44.47%; the minimum change range of forest land was from 2000 to 2010,
with a change rate of -6.57%. The maximum change in water is from 2010 to 2020, with a change rate of 35.18%; the minimum water change is from 2000 to 2010, with a decrease of 6.27%. The maximum built-up land change is from 2000 to 2020, with a rate of 1085.32%. The minimum change of built-up land is from 2000 to 2010, with a rate of 15.6%.

3.1.2. Dynamic attitude of land use changes

Single land use dynamic attitude is an index describing the change speed of a certain type of land use in the study area, and its formula is

\[ K_i = \frac{A_b - A_a}{A_a} \times \frac{1}{T} \times 100\% \]

In which, \( A_a \) is the area of land use type at the beginning and \( A_b \) is the area of the end, and \( T \) is the time.

The results can be shown in Table 9.

**Table 9.** Dynamic degree of single land use in Boao town.

| Type          | 2000-2010 | 2010-2020 | 2000-2020 |
|---------------|-----------|-----------|-----------|
| Cropland      | 1.61%     | 0.57%     | 1.13%     |
| Forestland    | -0.66%    | -4.09%    | -2.24%    |
| Water         | -0.63%    | 3.52%     | 1.33%     |
| Built-up land | 1.56%     | 92.54%    | 54.27%    |

During 2000-2020, the maximum change type was cropland, which was 54.27%, while the smallest change type was built-up land, which was only 1.13%, indicating that the change speed of cropland was the fastest and the change speed of built-up land was the smallest. At the same time, it can be noted that compared with 2000-2010, the change of cropland in 2010-2020 was great, and the change of forest land and waters were also great, which showed that the change speed of cropland, forest land and water in the last 10 years was obviously faster than that in the previous 10 years.

Comprehensive land use dynamic attitude is an index describing the change speed of the overall land use in the study area, and its formula is:

\[ S = \sum_{i=1}^{n} \frac{|\Delta A_i|}{nA} \times \frac{1}{T} \times 100\% \]

\( \Delta A_i \) is the total area of land use type I converted to other land use types, and \( A \) is the total land use area at the initial stage of research, and \( T \) is the time.

The results can be shown in table 10.

**Table 10.** Dynamic degree of comprehensive land use in Boao town.

| Time              | 2000-2010 | 2010-2020 | 2000-2020 |
|-------------------|-----------|-----------|-----------|
| Comprehensive     |           |           |           |
| dynamic attitude  | 1.20%     | 2.98%     | 1.15%     |
It can be seen from the table that the comprehensive dynamic attitude of land use in 2000-2020 is the smallest and the comprehensive dynamic attitude of land use in 2010-2020 is the largest, indicating that the land use in 2000-2020 was under tremendous changes in the last 10 years.

3.1.3. Transfer matrix analysis

Use the spatial statistical analysis function of ArcGIS to compare the land use data of Boao Town from 2000 to 2020, and generate the land use confusion matrix as shown in Table 11.

| Type       | Cropland | Forestland | Water | Built-up land | Roll in | Total for 2010 |
|------------|----------|------------|-------|---------------|---------|---------------|
| Cropland   | 22.56    | 4.03       | 0.31  | 0.04          | 4.38    | 26.95         |
| Forestland | 0.13     | 40.6       | 2.6   | 0.08          | 2.81    | 43.42         |
| Water      | 0.42     | 1.65       | 10.76 | 0             | 2.07    | 12.84         |
| Built-up land | 0.1      | 0.2        | 0     | 0.94          | 0.3     | 1.24          |
| Roll out   | 0.65     | 5.88       | 2.91  | 0.12          | 9.56    | 12.45         |
| Total out  | 23.21    | 46.49      | 13.68 | 1.07          | 9.64    | 84.45         |

From 2000 to 2010, the main transfer characteristics of land types are the transformation from forestland to cropland, and a small amount of water and forest land transform each other.

According to the characteristics of cropland transfer, the transferred area of cropland in Boao Town from 2000 to 2010 was about 7 times of the transferred area, and the increase of cropland area mainly came from forest land, with 22.56 km² of unchanged cropland, accounting for 97.2% of the total area of original cropland.

During 2000-2010, the area transferred out of forest land was twice that of transferred in, and the decrement of forestland area was mainly transferred to cropland, with an area of 4.03 km², accounting for 8.67% of the total area of original forest land.

During 2000-2010, the amount of water transferred in and out was similar, most of which came from forestland, and most of which also transferred out into forestland, so the overall area changed little.

As shown in Table 12, the main characteristics of land type transfer from 2010 to 2020 were the transformation from forestland to built-up land, cropland and water body, and the transformation from cropland to built-up land and forestland.
Table 12. Land use transfer matrix of Boao town (2010-2020)

| Type       | Cropland | Forestland | Water | Built-up land | Roll in | Total in 2020 |
|------------|----------|------------|-------|---------------|---------|---------------|
| Cropland   | 19.71    | 7.37       | 1.38  | 0.09          | 8.84    | 28.55         |
| Forestland | 2.47     | 22.09      | 0.93  | 0.16          | 3.56    | 25.65         |
| Water      | 1.7      | 5.68       | 9.95  | 0.01          | 7.39    | 17.34         |
| Built-up land | 3.06    | 8.25       | 0.56  | 0.99          | 11.87   | 12.86         |
| Roll out   | 7.23     | 21.3       | 2.87  | 0.26          | 31.66   |               |
| Total out 2010 | 26.94  | 43.39      | 12.82 | 1.25          |         | 84.4          |

According to the characteristics of forestland transfer, from 2010 to 2020, the transferred area of forestland in Boao Town was about 6 times of the transferred area. The unchanged forestland was 22.09 km$^2$, accounting for 50.91% of the total area of original forestland, and the changed forest land was 21.3 km$^2$, among which the transferred areas for built-up land, cropland and water were 8.25 km$^2$, 7.37 km$^2$ and 5.68 km$^2$ respectively.

From 2010 to 2020, there was little difference between the transferred-out amount and the transferred-in amount of cropland. The transferred-out amount of cropland was mainly transferred to built-up land and forest land, which were 3.06 km$^2$ and 2.47 km$^2$ respectively, and the transferred-in amount mainly came from forestland, accounting for 83.37% of the total transferred-in amount.

As shown in Table 12, from 2000 to 2020, the main characteristics of land type transfer were the transformation from forestland to built-up land, cropland and water body.

According to the transferred-out area of forest land, from 2000 to 2020, the transferred-out area of forest land in Boao Town was 14 times of the transferred-in area, and the unchanged forestland was 24.14km$^2$, accounting for 51.94% of the total area of original forestland, and the forestland area of 22.34km$^2$ changed, among which the transferred-out areas for built-up land and cropland were 9.06km$^2$ and 8.72km$^2$, respectively, which were the main land use types of forestland.

Table 13. Land use transfer matrix of Boao town from (2000-2020)

| Type       | Cropland | Forestland | Water | Built-up land | Roll in | Total in 2020 |
|------------|----------|------------|-------|---------------|---------|---------------|
| Cropland   | 18.59    | 8.72       | 1.21  | 0.04          | 9.97    | 28.56         |
| Forestland | 1.07     | 24.14      | 0.40  | 0.05          | 1.52    | 25.66         |
| Water      | 1.20     | 4.56       | 11.60 | 0.00          | 5.76    | 17.36         |
| Built-up land | 2.34    | 9.06       | 0.48  | 0.99          | 11.88   | 12.87         |
| Roll out   | 4.61     | 22.34      | 2.09  | 0.09          | 29.13   |               |
| Total out 2000 | 23.2    | 46.48      | 13.69 | 1.08          |         | 84.45         |

3.2. Landscape pattern changes

3.2.1. Class level
The landscape indexes of each year are shown in Table 14.
Table 14. Landscape pattern indexes of class level.

| Type      | Year | LSI  | NP (pieces) | PD (PCs/ha) | COHESION (%) | DIVISION (%) |
|-----------|------|------|-------------|-------------|--------------|--------------|
| Cropland  | 2000 | 16.61| 165         | 1.95        | 97.96        | 0.98         |
|           | 2010 | 15.05| 127         | 1.50        | 98.14        | 0.98         |
|           | 2020 | 13.90| 119         | 1.41        | 98.46        | 0.98         |
|           | 2000 | 15.29| 96          | 1.14        | 99.33        | 0.91         |
| Forestland| 2010 | 15.57| 139.00      | 1.64        | 99.27        | 0.93         |
|           | 2020 | 18.21| 155         | 1.83        | 98.21        | 0.99         |
|           | 2000 | 10.55| 33          | 0.39        | 99.04        | 0.98         |
| Water     | 2010 | 12.04| 53.00       | 0.63        | 99.11        | 0.98         |
|           | 2020 | 11.51| 67          | 0.76        | 98.76        | 0.98         |
|           | 2000 | 5.46 | 31          | 0.37        | 89.62        | 1.00         |
| Built-up  | 2010 | 5.57 | 30.00       | 0.35        | 89.74        | 1.00         |
| land      | 2020 | 10.16| 73          | 0.86        | 96.36        | 1.00         |

From 2000 to 2020, the LSI of forestland and built-up land in the study area showed a continuous growth trend. The landscape shape index of built-up land increased by 50%, and the change range of forestland was not as large as that of built-up land. This indicated that with the influence of the increment of human activity intensity in the study area, its fragmentation degree also increased. The LSI of cropland and water decreased with time, which indicated that the patches were influenced by human activities.

In total, cropland and forestland have higher NP and PD in each year, which indicates that the fragmentation of these two landscape types is higher, and the fragmentation of forestland landscape increases from 2000 to 2020 due to human interference. From 2000 to 2020, the PD of built-up land increased, which reflected that the degree of human interference on built-up land increased.

During 2000-2020, the DIVISION of each landscape type was small, which indicated that each landscape type was distributed in pieces. COHESION of built-up land increased obviously during 2010-2020, which indicated the trend of gradual agglomeration of built-up land.

3.2.2. landscape level

The landscape indexes of Boao Town in different years are shown in Table 15.

Table 15. Landscape pattern indexes of landscape level.

| Year | Index | NP (pieces) | PD (PCs/ha) | CONTAG (%) | DIVISION (%) | SHDI | SHEI |
|------|-------|-------------|-------------|-------------|--------------|------|------|
| 2000 | 325   | 3.85        | 51.43       | 0.87        | 1.04         | 0.75 |      |
| 2010 | 349   | 4.13        | 50.45       | 0.89        | 1.06         | 0.76 |      |
| 2020 | 414   | 4.90        | 45.45       | 0.94        | 1.38         | 0.86 |      |

From 2000 to 2020, the patch number (NP) and plate density (PD) showed a gradual upward trend, indicating that the fragmentation degree of landscape pattern continued to increase from 2000 to 2020, and was affected by human activities.

The decreasing trend of CONTAG indicates that the patches of various landscape types do not form a good connection, and the number of small patches in the landscape is gradually increasing, and the connectivity of the landscape becomes worse. The increment of DIVISION also shows that the landscape types tended to be obviously divided in the past 20 years.
Shannon diversity index (SHDI) and Shannon evenness index (SHEI) increased slightly by 0.02 and 0.01 from 2000 to 2010, and increased by 0.32 and 0.1 from 2010 to 2020. This indicates that the diversity of patch types in Boao Town has increased in recent 20 years, and the distribution of each patch type is more uniform, and the landscape pattern tends to be diversified, separated and broken.

### 3.3. Changes in vegetation coverage

The vegetation coverage data of Boao Town from 2000 to 2020 were extracted. In order to analyze the vegetation change characteristics of Boao Town, the vegetation coverage was divided into five grades: low vegetation coverage (F_v< 0.2), medium-low vegetation coverage (0.2<F_v<0.4), medium vegetation coverage (0.4<F_v<0.6) and medium-high vegetation coverage (F_v> 0.8). According to above standards, the vegetation coverage data of Boao Town in different years are reclassified in ArcGIS and the area is counted by region. The results are shown in Table 16.

**Table 16. Dynamic degree of comprehensive land use in Boao town (km²)**

| Grade        | 2000  | 2010  | 2020  |
|--------------|-------|-------|-------|
| Low          | 14.23 | 13.03 | 12.34 |
| Medium-low   | 4.88  | 8.35  | 6.45  |
| Medium       | 6.55  | 12.56 | 7.65  |
| Medium-high  | 10.05 | 21.38 | 10.38 |
| High         | 48.78 | 29.17 | 47.67 |

According to statistics, the average vegetation coverage in Boao Town was 70.68% in 2000, 62.49% in 2010 and 71.65% in 2020. From 2000 to 2010, the vegetation coverage decreased by 8.19%, which showed that there was a certain degree of vegetation degradation in Boao Town during this period. In 2010-2020, the vegetation coverage increased by 9.16%, and the vegetation was restored to some extent.

From 2000 to 2020, the area of high vegetation coverage in Boao Town decreased first and then increased, while the area of medium, high and low vegetation coverage increased first and then decreased and the area of low vegetation coverage showed a continuous downward trend. Among them, in the first 10 years, the area covered by high, medium, medium and low vegetation changed greatly, all of which were close to the change rate of 50%. In the last 10 years, the areas with high, medium and high vegetation coverage changed greatly, and the area with high vegetation coverage increased by 63.42%.

### 4. Driving forces analysis

Table 17 shows the eigenvalue and variance contribution rate of each principal component, in which the contribution rate of principal component 1 is 67.879%, the contribution rate of principal component 2 is 15.566%, and the cumulative contribution rate of both exceeds 83.4%, which can cover most information of original variables.
Table 17. Eigenvalue and variance contribution rate.

| Component | Initial eigenvalue | Extraction Sums of Squared Loadings | Rotation Sums of Squared Loadings |
|-----------|-------------------|------------------------------------|----------------------------------|
|           | Total | % of variance | Cumulative% | Total | % of variance | Cumulative% | Total | % of variance | Cumulative% |
| 1         | 9.216 | 70.89        | 70.89       | 9.21  | 70.89        | 70.89       | 8.824 | 67.879       | 67.879      |
| 2         | 1.632 | 12.555       | 83.445      | 1.63  | 12.555       | 83.445      | 2.024 | 15.566       | 83.445      |
| 3         | 0.963 | 7.41         | 90.855      |       |              |             |       |              |             |
| 4         | 0.684 | 5.265        | 96.12       |       |              |             |       |              |             |
| 5         | 0.305 | 2.344        | 98.464      |       |              |             |       |              |             |
| 6         | 0.12  | 0.922        | 99.386      |       |              |             |       |              |             |
| 7         | 0.058 | 0.449        | 99.949      |       |              |             |       |              |             |
| 8         | 0.009 | 0.069        | 99.904      |       |              |             |       |              |             |
| 9         | 0.006 | 0.045        | 99.98       |       |              |             |       |              |             |
| 10        | 0.004 | 0.03         | 99.98       |       |              |             |       |              |             |
| 11        | 0.003 | 0.02         | 100         |       |              |             |       |              |             |
| 12        | 4.36E-05 | 0            | 100         |       |              |             |       |              |             |
| 13        | 4.26E-17 | 3.28E-16   | 100         |       |              |             |       |              |             |

The factor load matrix can be obtained after principal component analysis. For more intuitive analysis, the maximum variance method is used to rotate the factor load matrix, and the rotated factor load matrix is obtained in Table 18.

Table 18. Factor and rotational factor load matrices.

| Factor load matrix | The rotated factor load matrix |
|-------------------|-------------------------------|
| one | 2 | one | 2 |
| X5  | 0.992 | 0.073 | X5  | 0.982 | 0.154 |
| X9  | 0.99 | 0.022 | X9  | 0.969 | 0.204 |
| X11 | 0.97 | -0.047 | X4  | 0.966 | 0.091 |
| X7  | 0.969 | -0.042 | X12 | 0.955 | 0.109 |
| X8  | 0.965 | -0.024 | X7  | 0.934 | 0.261 |
| X4  | 0.962 | 0.131 | X11 | 0.934 | 0.266 |
| X10 | 0.961 | -0.062 | X8  | 0.934 | 0.242 |
| X12 | 0.955 | 0.111 | X10 | 0.922 | 0.279 |
| X13 | 0.831 | 0.154 | X13 | 0.844 | 0.038 |
| X6  | 0.658 | 0.624 | X6  | 0.782 | -0.458 |
| X2  | 0.653 | -0.574 | X1  | 0.161 | 0.822 |
| X1  | 0.343 | -0.764 | X2  | 0.505 | 0.707 |
| X3  | -0.117 | 0.513 | X3  | 0.003 | -0.526 |

From Table 18, we can see that the first principal component is mainly X5, X9, X4, X12, X7, X11, X8, X10, X13 and X6, and the second principal components are mainly X1, X2 and X3. That is to say, first principal component mainly represents population factors, economic factors and technical factors such as total households, total population, agricultural population, GDP, primary industry, secondary industry, third industry, per capita disposable income of farmers, total power of agricultural machinery, and fertilizer application amount; The second principal component mainly represents climatic factors such as annual average temperature, annual total sunshine hours and annual total precipitation.
Therefore, the main driving forces for the change of ecological environment in Boao Town is human factors, followed by climate and natural factors such as temperature and sunshine. The next is economic factors such as GDP, primary industry, secondary industry, third industry and per capita disposable income of farmers.

5. Conclusions
This paper analyzes the dynamic changes of ecological environment in Boao town in recent 20 years (land use, vegetation coverage and landscape pattern), and discusses the driving forces of ecological environment changes in Boao town from human and natural factors. The main conclusions are as follows:

(1) The main types of land use in Boao Town are forestland and cropland. In 2000, the distribution of land use in Boao Town was as follows: forestland accounted for 54.92%, cropland accounted for 27.57%, water accounted for 16.22%, and built-up land accounted for 1.29%. In 2010, the distribution of land use in Boao Town was: forest land accounted for 51.31%, cropland accounted for 31.99%, water accounted for 15.2%, and built-up land accounted for 1.49%; In 2020, the distribution of land use in Boao Town was as follows: forest land accounted for 30.35%, cropland accounted for 33.81%, water accounted for 20.55%, and built-up land accounted for 15.29%. The results showed that the city development of Boao Town was obvious in the past 20 years, and the built-up land area was greatly increased.

(2) From 2000 to 2020, the biggest change of land use attitude in Boao Town was built-up land, while the smallest change was cropland, which showed that the built-up land expanded rapidly in Boao Town in recent 20 years, while the change speed of cropland was slow, and the change speed of forest land and water was consistent. The dynamic attitudes of comprehensive land use in 2000, 2010 and 2020 were 1.20%(2000-2010), 2.98%(2010-2020) and 1.15%(2000-2020), respectively. This shows that the land use change rate of Boao Town in the last 10 years was greater than that of Boao Town in the first 10 years, then greater than that of Boao Town in the last 20 years. The land use change rate of Boao Town is gradually increasing with the increase of years.

(3) In 2000, the distribution of vegetation coverage in Boao Town was as follows: high vegetation coverage (58.07%) > low vegetation coverage (16.94%) > medium high vegetation coverage (11.96%) > medium vegetation coverage (5.81%) > medium low vegetation coverage (5.81%). The distribution of vegetation coverage in Boao Town in 2010 was as follows: high vegetation coverage area (34.73%) > medium-high vegetation coverage area (25.45%) > low vegetation coverage area (15.51%) > medium vegetation coverage area (14.95%) > medium-low vegetation coverage area (9.94%). The distribution of vegetation coverage in Boao Town in 2020 was as follows: high vegetation coverage area (56.75%) > low vegetation coverage area (14.69%) > medium high vegetation coverage area (12.36%) > medium vegetation coverage area (9.11%) > medium low vegetation coverage area (7.68%). The average vegetation coverage was 70.68% in 2000, 62.49% in 2010 and 71.65% in 2020. This shows that the vegetation coverage in Boao Town has a trend of decreasing first and then increasing in the past 20 years.

(4) The change trend of landscape pattern index at the type level from 2000 to 2020 was: the landscape shape index and landscape fragmentation of cropland gradually decreased, the cohesion
sliightly increased and the change was not obvious, and the separation degree had no change; The landscape shape index of forest land continued to rise, and the upward trend in the last 10 years was more obvious than that in the previous 10 years. The landscape fragmentation continued to rise, the cohesion slightly decreased and the change was not obvious, but the separation gradually increased; The landscape shape index of water showed an overall upward trend of rising first and then falling: the landscape fragmentation continued to rise, the cohesion slightly increased and then decreased slightly, and the overall change was not significant, and the separation degree did not change. The landscape shape index and cohesion of built-up land showed an upward trend, which was obvious in the past 10 years. The landscape fragmentation first decreased a little and then increased a lot, but the separation degree remained unchanged. This shows that in the past 20 years, human activities had obviously affected the landscape pattern changes of various land types, cropland tends to be simplified in shape rules and spatial agglomeration. The shape of forest land and built-up land tended to be complicated, and the fragmentation and discreteness increased.

(5) The trend of landscape pattern change index at landscape level from 2000 to 2020 was as follows: landscape fragmentation continued to increase, separation level continued to rise, diversity and evenness continued to increase, and the changes of all kinds of indexes were stronger in the last 10 years. That is, the landscape pattern changed obviously from 2010 to 2020. The change of landscape pattern index in the past 20 years also fully reflects the interference of human activities on the local landscape pattern, which makes the landscape pattern be discrete, richer and more diverse in spatial structure.

(6) Based on natural and human factors, this paper analyzes the driving forces that lead to the change of ecological environment in Boao Town. Natural factors include precipitation, sunshine, temperature and other climatic factors, while human factors include population, economy, technology and policy. The results of principal component analysis showed that human factors were the leading factors making ecological environment change in Boao Town, and economic factors such as GDP, third output value and per capita disposable income of farmers were the main driving forces of landscape pattern changes in Boao Town.

6. References
[1] Zhao J 2009 Ecological environment evolution and driving force analysis of Sanjiangyuan based on RS and GIS technology(Jilin University )
[2] Avashia V, Garg A, Dholakia H 2021 Understanding temperature related health risk in context of urban land use changes Landscape and Urban Planning p 212
[3] Maheng D, Pathirana A, Zevenbergen C 2021 A Preliminary Study on the Impact of Landscape Pattern Changes Due to Urbanization: Case Study of Jakarta, Indonesia Land 10 p 218
[4] Lasode M K, Esobi I C, Anyanwu C I, Lasode D O 2020 2013 Assessing Urban Land Use Change in New Braunfels Journal of Geoscience and Environment Protection 08 p 232-243
[5] Lopes T R, Zolin C A, Mingoti R, Vendrusculo L G, Almeida F T, Souza A P, Oliveira R F, Paulino J, Uliana E M 2021 Hydrological regime, water availability and land use/land cover change impact on the water balance in a large agriculture basin in the Southern Brazilian Amazon Journal of South American Earth Sciences p 108
[6] Kowe P, Mutanga O, Odindi J, Dube T 2021 Effect of landscape pattern and spatial configuration of vegetation patches on urban warming and cooling in Harare metropolitan city, Zimbabwe GIScience & Remote Sensing58 p 261-280

[7] Marina P I, Josep M E, Javier G, Joan P 2020 Changes in forest landscape patterns resulting from recent afforestation in Europe (1990 – 2012): defragmentation of pre-existing forest versus new patch proliferation Annals of Forest Science: A journal of the French National Institute for Agriculture, Food and Environment (INRAE)77 p 971-980

[8] Sharareh M, Carlos S C 2020 Statistical index (SI) as spatial modeling to evaluate the potential for greenbelt development in medium-sized Iranian cities Spatial Information Research28 p 537-546

[9] Roger F A, Darrell E N, Steven K, Thomas R M J, Kristi L S 2012 The Driving Forces Of Land Change In The Northern Piedmont Of The United States Geographical Review 102 p 53-75

[10] Guilherme T N P L, Vivian C S H, Lidia S B, Rozely F S 2016 Identifying driving forces of landscape changes: Historical relationships and the availability of ecosystem services in the Atlantic forest Ecosystem Services22 p 11-17

[11] Jitendra T Quantifying 2018 The Importance of Driving Forces of Landscape Change Using Remote Sensing: A Case Study International Journal of Engineering and Future Technology15 p 15

[12] Zbelo T, Jan N, Tesfaalem G, Kelemework T, Amanuel Z, Jean P, Seppe D, Veerle V E 2019 Transhumance as a driving force of landscape change in the marginal grabens of northern Ethiopia Singapore Journal of Tropical Geography 40 p 20

[13] Difanty A, Supriatna S 2021 Spatial modeling for prediction agricultural land-use change in Jampang Kulon, Sukabumi Regency IOP Conference Series: Earth and Environmental Science 623 p 012-084

[14] Yang W 2014 Study on land use change in typical coastal zone: taking Sanya and Boao as examples( Nanjing University)

[15] Liu J 2008 Study on agricultural drought evaluation in three gorges reservoir area based on remote sensing technology(Southwest University)

[16] Lin H, Li N, Huang B D, Teng Y M 2020 Water quality evaluation of Nanliu river based on principal component analysis Guangdong chemical industry47 p 144-146+148.

Acknowledgement
This work was financially supported by Hainan Provincial Department of Science and Technology under Grant No. ZDKJ2019006 and Hundred person project of Hainan province under Grant No.[2018]31.