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Original Research

The Changes and Driving Factors of Coastal Areas Land Use in Time and Space: A Case Study in Fujian Province, Southeast China

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Abstract

In recent years, the development of coastal areas in China has accelerated rapidly, and the land used in coastal areas has undergone big changes. As an important area on the southeast coast of China, analyzing Fujian Province's process of land use changes and driving factors can lay a theoretical foundation for reasonable land planning in coastal areas. This paper utilizes transfer matrix, dynamic degree, information entropy, equilibrium degree, spatial autocorrelation and principal component to research the status and changes of land use in Fujian Province from 1980 to 2018. The results show that: (1) Over the past 39 years, the greatly decreased farmland and grass in Fujian Province has been mainly converted into construction land. The upward trend showed in forest, construction land, water area and unused land, and they are mainly occupied farmland and grass. (2) In Fujian Province, the change of land use structure is fluctuating, though the development of regional land structure tends to be stable. The food security land, ecological construction land and urban construction land have positive spatial agglomeration effect and spatial heterogeneity. (3) The main driving factors of land use change in Fujian Province are at an economic development level, industrial structure adjustments, population expansion and climate change.

Keywords: land use, dynamic degree, information entropy, spatial autocorrelation, coastal areas

Introduction

The coastal zone has an important function as the transition and interaction region between terrestrial ecosystem and marine ecosystem, and its ecological environment is fragile and easily affected by the natural environment and human activities [1-4]. Coastal zone land use change is an important part of the coastal ecological environment changes [5-7]. Since the 21st century, human activities have extended from land to sea, and the urbanization of coastal areas is continually improving. However, many major changes have taken place in coastal areas, especially in terms of land use, because of land requirements for industrial construction, in the process of urbanization requires land [8-9]. The over-exploitation and improper utilization of marine

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resources leads to ecological and environmental deterioration, which deeply influences human survival and the development of cities in the long term. Ecological protection and high-quality development in coastal areas needs the support of land use patterns with reasonable structure and orderly space. As such, coastal land use change has become a hot topic in the study of global environmental changes [10-13]. Alleviating the conflict between economic development and the ecological environment is of vital importance [14]. Therefore, it is essential to study the changing features and driving factors of land-use change in coastal areas of China, which can provide scientific guidance for land management planning and ecological protection in coastal areas.

At present, scholars have studied a variety of scenarios in coastal land use problems. For example, Atik et al. [15] studied the relationship between the changing land use and the development of Turkish Mediterranean coast tourism. They found that in planning coastal areas land, the ecological, social and economic systems of the tourism development planning and management area should be matched with each other. Olaniyi et al. [16] studied the driving factors of coastal land use change in Malaysia and found that urbanization is an important factor of the changing coastal land use. Bhagyanagar et al. [17] studied urban expansion and land use change in the coastal area of Dakshina Kannada in India from 1983 to 2008, and identified that activities brought by ports and the drivers of urbanization can increase the forces of urbanization and land changes. Schweizer et al. [18] studied land use changes and forest distribution in the coastal plain of Mississippi in the United States, and concluded that the changes in land use in coastal areas are due to the continuous expansion of neighboring cities rather than regional economic trends. Fan et al. [19] studied the quantitative and spatial dynamic changes of land use and ecosystem services from 1995 to 2015 in Nanping, China, they found that the population was one of the most important factors affecting land use change. However, the existing research has failed to study land use characteristics from the comprehensive level of land use structure and driving mechanism, and the research on the timeliness and completeness of land use evolution in coastal areas is not sufficient. Due to the uncertainty and complexity of the process of land use change in coastal areas, there is more scientific significance and application value in analyzing the spatiotemporal change and spatial characteristics of land use in large-scale and long-time series, and studying the driving forces of land use change by evaluating the contribution rates of different driving factors.

Fujian Province is located on the eastern coast of China, connecting the Pearl River Delta and the Yangtze River Delta, and is an important part of China's coastal economic belt [20]. There are many wetlands in Fujian, which are important areas for ecological environment protection. As the first pilot of strategic spatial planning in China, Fujian needs to actively coordinate land use, strengthen the overall control planning, and provide scientific guidance for the government and coastal ecological protection planning. Therefore, the main purpose of this paper is to study the spatial pattern of land use and its dynamic changes in Fujian Province from the perspective of spatial agglomeration by combining socio-economic and meteorological data to objectively explain the driving factors that cause changes, and promote the coordinated economic and ecological development of coastal areas. This study focuses on the following: 1) reveal the time and space characteristics of land use evolution in Fujian Province from 1980 to 2018; 2) analyze the spatial agglomeration characteristics of land-use in Fujian Province; 3) explore the driving factors of land-use change in Fujian Province.

Material and Methods

Study Area

Fujian Province (23°31′N to 28°18′N,115°50′E to 120°43′E) is located on the southeast coast of China and is one of the largest wetlands provinces in China (Fig. 1). The ranges from the subtropics to the south subtropics, with an annual average temperature of 19ºC around and an annual average rainfall of 1400-2000 millimeters. This region is blessed with as one of the richest rain falls in China. This is the optimum climate for humans to settle down and grow various types of crops. The nine prefecture-level cities under the charge of Fujian Province are Fuzhou, Quanzhou, Zhangzhou, Putian, Longyan, Sanming, Nanping, and Ningde. The province has numerous mountains and hills, dense rivers and water systems, vast ocean areas and its coastline, 3572 kilometers, is ranked second in China. As such, the Fujian Province is an important port of the Chinese mainland and an important window and foundation for China to communicate with the world.

The Origin of Data

The data consists of three parts: (1) landsat remote sensing images in 1980, 1990, 2000, 2010, TM and OLI remote sensing images in 2018; (2) meteorological data of Fujian Province; (3) socio-economic data of Fujian Province from 1980 to 2018. Among these data, the remote sensing images were downloaded from the United States Geological Survey (USGS, HTTP://www.usgs.gov); meteorological data of Fujian Province were derived from China Meteorological Data Sharing Network (HTTP:// cdc.cma.gov.cn/); social and economic data of Fujian Province were obtained from the Statistical Yearbook of Fujian Province.

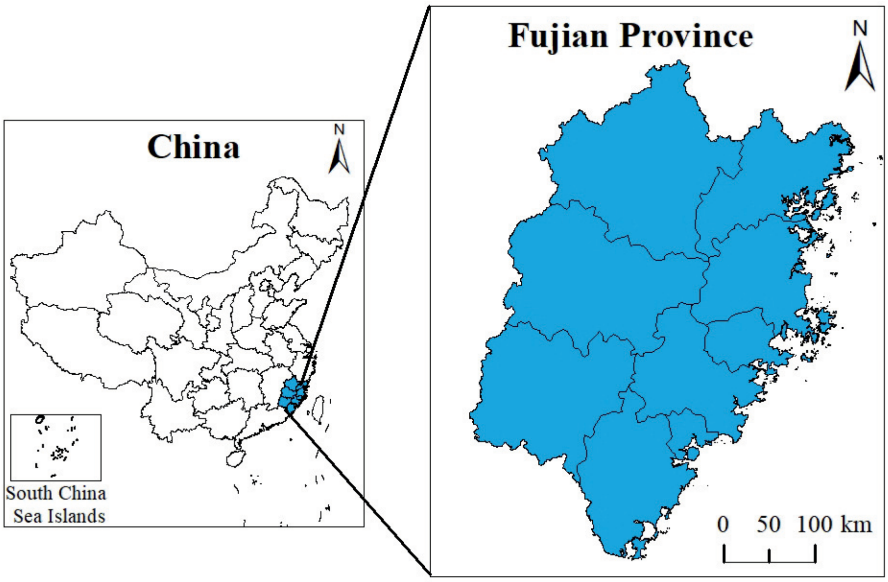

Fig. 1. Location of study area.

The Methodology

The land use transfer matrix [21-22] lists the changing area transferred by land type, which reflects the characteristics of land use change structure and the changing direction of various types of land. The mathematical form of the transfer matrix is as follows:

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

In this formula, S is the land area, n is the type number of land use, i and j represent the land use types at the beginning and end of the study period respectively.

The dynamic degree of a single land use type is usually represented by K [23-24], which reflects the annual average change rate of some land use types during the study period, and its expression is as follows:

$$K = \frac{U_a - U_b}{U_a \times T} \times 100\% \tag{2}$$

In this formula, K is a single dynamic degree of a certain land use type during the study phase; U_a and U_b are the area of the land use type at the beginning and the end of study and T is the study period.

The comprehensive land use dynamic degree [25-26] mainly reflects the changing rate of land use in the study area, and the expression is as follows:

$$L_c = \left(\frac{\sum_{i=1}^{n} \Delta LU_{i-j}}{2\sum_{i=1}^{n} LU_i} \right) \times \frac{1}{T} \times 100\% \tag{3}$$

In this formula, LU_i is the area of class i land used type at the beginning of monitoring time; ΔLU_{i-J} is the area of class i land use type converted to class j during the monitoring time and T denotes the study period.

The information entropy [27-28] of land use structure reflects the level of order in land use. The larger the information entropy value is, the higher the difference between the area of each type of land use is, so the more stable the land use structure is. And the expression is as follows:

$$G = -\sum_{i=1}^{n} p_i \ln p_i \tag{4}$$

In this formula, G is the information entropy of land use structure; p_i is the proportion of each type of land use area to the total land use.

The equilibrium degree [29-30] of land uses structure reflects the homogeneity of land use, the larger the value is, the stronger the homogeneity of land use structure is. And the expression is as follows:

$$J = \frac{G}{\ln \mathrm{N}} \tag{5}$$

In this formula, J is the equilibrium degree of land use structure; G is the information entropy of land use structure; N is the quantity of land use type.

Global spatial autocorrelation [31-32] reflects the spatial feature of a certain land use type in the study area. The most commonly used indicator is Moran's I (Moran index). And the expression is as follows:

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(x_i - \bar{x})}{S^2 S_0} \quad (6)$$

In this formula, x_i is the value of variate $\{x_i\}$ at position i; $\bar{x}$ is variable mean; S^2 is the variance of a variable; S_0 is the sum of space weights of all variables and W_{ij} is an element in the spatial weight matrix.

Local spatial autocorrelation [33-34] reflects the heterogeneity of spatial differences, and comprehensively shows the trend of spatial differences in the study area. At the same time, it further reveals the spatial differences of land use agglomeration. The Local Moran's I_i is expressed as follows:

$$I_i = z_i \sum_{j \neq 1}^{n} w_{ij} z_j \quad (7)$$

In this formula, z_i and z_j are the normalized attribute values and w_{ij} is the spatial weight between elements i and j.

Results and Discussion

Current Situation of Land Use Distribution

Ecognition 9.0 software was used to obtain the land cover information of phase 5 from 1980 to 2018 and the specific distribution was shown in Fig. 2. In order to verify the accuracy of classification, confusion matrix analysis was employed to analyze 986 field samples. The results show that the overall classification accuracy is 95.26%, and Kappa coefficient is 0.9146, which means a high classification accuracy.

Through the classification results, the classified area and proportion changes of land use types are obtained. As shown in Table 1: (1) the main land use types in Fujian Province from 1980 to 2018 were forest, farmland and grass, and the changing of their proportions in the study area are as follows: 61.49%~62.45%, 18.63%~17.01%, 17.12%~15.16%; (2) the total area of

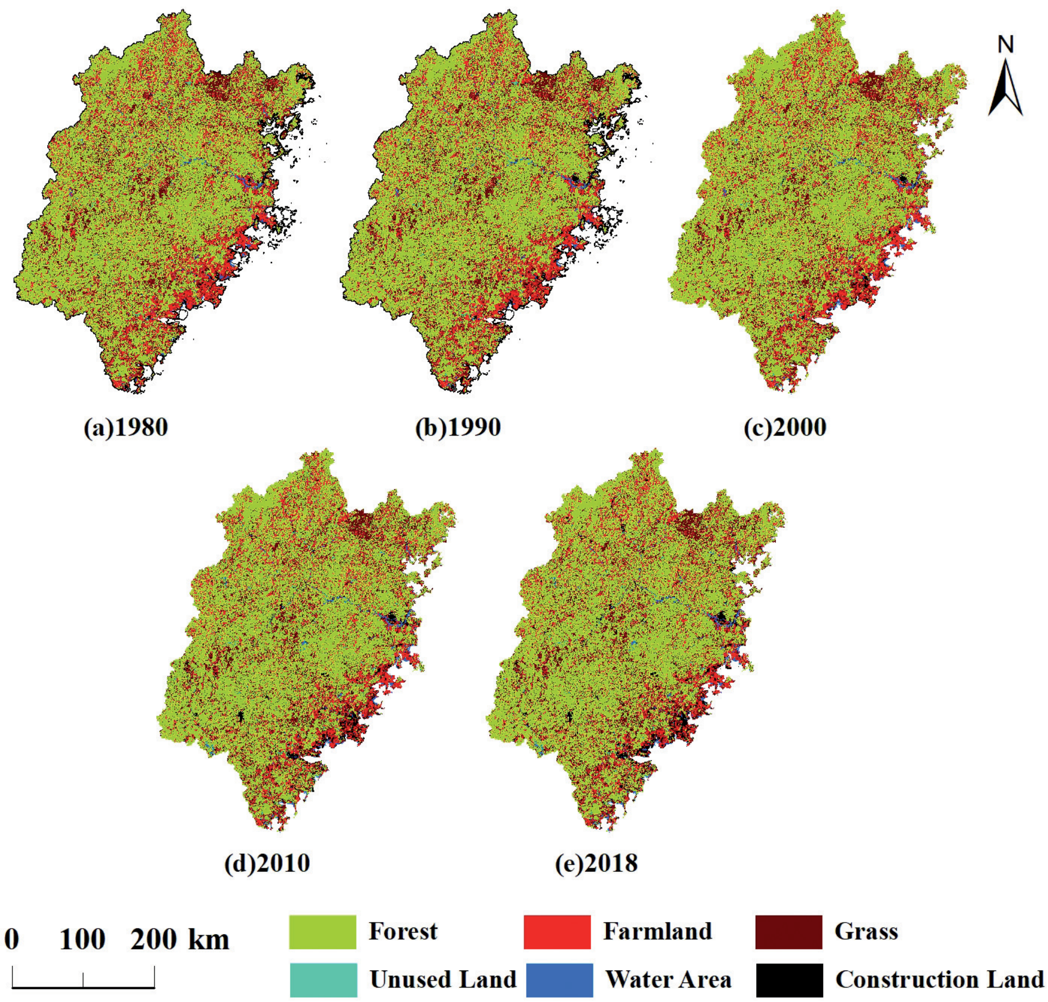

Fig. 2. Distribution of land use types in Fujian Province from 1980 to 2018.

farmland and grass showed a decreasing trend, while the forest showed an increasing trend; (3) the area of construction land in Fujian Province in 2018 increased by 2.53%, which is more than twice that of 1980; (4) the area of unused land and waters in Fujian Province fluctuated, but it showed a upward trend on the whole.

Land Use Transfer Matrix and Dynamic Degree Measurement

The transfer matrix and dynamic degree measurement of land use change in Fujian province in the past 39 years are shown in Table 2. The construction land type has increased at a rate of 19.67 from 1980 to 1990, mainly by conversion to farmland. The grass type has increased closely behind the construction land type with a rate of 0.17, which has mainly occupied forest type. Furthermore, unused land type increased closely behind the grass type, also mainly occupied forest type. The area of farmland suffered the biggest drop, followed by water area and forest, most of which were converted to construction land. K value in decreasing order was as follows: construction land, water area, unused land, farmland, grass and forest. During this period, the water area, construction land and unused land changed the most rapidly.

From 1990 to 2000, forest area rise was steepest, mainly occupied grass, and the rate of change was 2.51; the area of construction land and water area was mainly occupied farmland, and the rate change of construction land was 8.03. The grass area decreased the most, which was mainly converted to forest, with a rate of -8.97; farmland and unused land followed, and most of them were converted to forest, and significant changes appeared in the change rate of unused land it's valued -8.51. The K value in decreasing order was as follows: unused land, grass, construction land, forest, water area and farmland. During this period, the unused land, grass and construction land changed the most rapidly.

From 2000 to 2010, the area of construction land increased the most, mainly occupied farmland and forest, and the largest rate of change was at 84.40; water area and unused land come second, mainly occupied farmland and forest. The farmland was greatly decreased, which was mainly converted to the construction land, and it changed faster with a rate at -5.15. Then, the area of forest and grass has decreased. The K value in decreasing order was as follows: construction land, unused land, water area, grass, farmland and forest. During this period, the construction land, unused land and water area changed the most rapidly.

From 2010 to 2018, the area of construction land increased the most, mainly occupied farmland, and the rate of change was 13.72. The area of farmland decreased the most, followed by forest and grass, most of which were converted to construction land. The K value in decreasing order was as follows: construction

Table 1. Area and proportion of different land use types in Fujian Province from 1980 to 2018.

Land type	1980		1990		2000		2010		2018	
	Area/km^2	Proportion/%	Area/km^2	Proportion/%	Area/km^2	Proportion/%	Area/km^2	Proportion/%	Area/km^2	Proportion/%
Farmland	22508.94	18.63	22274.19	18.44	22097.93	18.29	20961.12	17.35	20555.16	17.01
Forest	74274.37	61.49	74242.49	61.46	76103.50	63.00	75612.78	62.60	75466.63	62.45
Grass	20675.49	17.12	20710.79	17.15	18854.51	15.61	18331.12	15.18	18317.17	15.16
Water Area	1462.19	1.21	1343.12	1.11	1352.39	1.12	1562.29	1.29	1572.39	1.30
Construction Land	1776.67	1.47	2124.26	1.76	2295.36	1.90	4226.13	3.50	4837.11	4.00
Unused Land	92.32	0.08	94.69	0.08	85.99	0.07	97.89	0.08	97.95	0.08

land, unused land, water area, farmland, grass, forest land. This shows that during this period, construction land, unused land and water area changed the most rapidly.

The comprehensive dynamic degree (L_C) increased from 0.03% to 0.18% during 1980-2010 and then decreased to 0.06% in 2018. It showed a strong change trend that the intensity of the mutual conversion of land use types in Fujian Province became weaker and change speed increased during 1980-2010. However, from 2010 to 2018, the change speed of Fujian Province gradually decreased, which indicated that the development of Fujian Province is gradually weakened, but it's still at the development stage.

In general, with the growth of urbanization, Fujian Province has shown rapid development over the past 39 years. Among them, the dynamic degree values of construction land, unused land and water area were relatively large, and the changed are the most active. Moreover, in order to strengthen urban construction, farmland and grass were decreasing, and construction land has increased significantly. Therefore, the land use structure of Fujian province has changed greatly and gradually stabilized in recent years.

Land Use Spatial Agglomeration Features

Land Use Structure Change Rules

Information entropy and equilibrium degrees reflect the quantity and homogeneity of land use function in a region. The information entropy and equilibrium degree of land use structure in Fujian Province is shown in Table 3. It shows that the change of land use structure in Fujian Province is fluctuating, showing a rising-declining-rising trend. In the 1980s, Fujian Province was in a low-speed development stage with low-level urbanization. There was a big difference in land area type and demonstrated by the low information entropy and equilibrium degree of land use structure. In the 1990s, land use information entropy and equilibrium degree increased, and urbanization intensified. However, in the 2000s, the land use structures information entropy and equilibrium degree were the smallest, indicating the largest difference in land type area exists in this period. Therefore, Fujian Province land structures lacked development order and its changes were fluctuating before 2000. From 2000 to 2018, the information entropy of land use continuously increased, and the equilibrium degree also gradually increased. It shows that the area gap of various land use types was diminishing, but regional development has matured. The one single dominant advantage of land use structure began to weaken. However, in the process of promoting urbanization, information entropy and equilibrium degree will continue to mount. While developing, it is necessary to strengthen the protection of farmland, forest and grass by preventing excessive construction occupation, and

Table 2. Land use transfer matrix and dynamic degree of Fujian Province from 1980 to 2018(km^2).

Land Type	1980-1990						1990-2000					
	Farmland	Forest	Grass	Water Area	Construction Land	Unused Land	Farmland	Forest	Grass	Water Area	Construction Land	Unused Land
Farmland	22184	74	11	45	198	-	21807	247	32	22	168	-
Forest	41	74163	54	7	28	4	204	72595	1420	4	26	16
Grass	4	25	20621	1	4	-	57	3238	17371	4	6	15
Water Area	47	3	3	1289	120	-	14	2		1321	6	-
Construction Land	2	-	-	-	1767	-	16	17	3	1	2081	-
Unused Land	-	1	1	-	-	90	1	28	9	-	1	55
Total	22278	74266	20690	1342	2117	94	22099	76127	18835	1352	2288	86
Rangeability	-234	-31	35	-120	348	2	-177	1862	-1856	9	170	-8
Rate of Change	-1.04	-0.04	0.17	-8.21	19.67	2.17	-0.79	2.51	-8.97	0.67	8.03	-8.51
K	0.002	0.000	0.000	0.015	0.020	0.007	0.003	0.007	0.023	0.004	0.012	0.074
L_C	0.03						0.17					

Table 2. Continued.

Land Type	2000-2010						2010-2018					
	Farmland	Forest	Grass	Water Area	Construction Land	Unused Land	Farmland	Forest	Grass	Water Area	Construction Land	Unused Land
Farmland	20538	282	63	129	1086	-	19915	437	107	25	474	1
Forest	299	74529	552	77	652	17	435	74570	412	21	189	3
Grass	90	773	17686	21	263	3	102	388	17747	6	67	1
Water Area	8	36	4	1260	43	-	21	17	7	1446	64	5
Construction Land	25	10	5	74	2174	-	80	67	21	52	3999	-
Unused Land	-	4	3	-	1	77	1	6	1	-	2	89
Total	20960	75634	18313	1561	4219	97	20554	75485	18295	1560	4798	99
Rangeability	-1138	-492	-523	210	1931	12	-405	-145	-16	0	579	0
Rate of Change	-5.15	-0.65	-2.78	15.54	84.40	14.12	-1.93	-0.19	-0.09	0.00	13.72	0.00
K	0.009	0.004	0.009	0.029	0.094	0.033	0.008	0.003	0.006	0.015	0.024	0.020
L_C	0.18						0.06					

Table 3. Land use information entropy and equilibrium degree of Fujian Province in 1980 to 2018.

Year	1980	1990	2000	2010	2018
Information entropy	1.035	1.040	1.022	1.063	1.072
Equilibrium degree	0.578	0.580	0.571	0.593	0.599

promoting the coordinated development of ecological conservation and urbanization construction in Fujian Province.

Spatial Autocorrelation Analysis of Land Use

In order to study land use spatial autocorrelation phenomenon in Fujian Province, this paper learns from the predecessors' research findings by using the production, ecology and living land tripartite method to cover the different land use types. Food production, eco-environment and urban construction can reflect the multiple dimensions of regional economic and social development. So, the land in Fujian Province is divided into three parts, which are used for food security (farmland), ecological construction (forest, grass, water area) and urban construction (construction land, unused land). Taking the counties as samples to do global spatial autocorrelation (Table 4) and local spatial autocorrelation analysis of food security land, ecological construction land, urban construction land per unit area (Fig. 3). According to the analysis, the P values of the three land use types were all less than 0.05, and the Z values were all more than 1.96. It showed that the data was credible and spatial aggregation phenomenon appeared in three land use types. Among them, the Moran index of ecological construction land was positive and both were greater than 0.7, which indicated that ecological land use had a strong positive spatial agglomeration effect and the agglomeration effect was on the rise. The Moran Index of food security land was positive and less than 0.5, but it was increasing year by year, which indicated that the spatial positive agglomeration effect of food security land was weak and showed an upward trend. The Moran index of urban construction land was positive but less than that of food security land, which indicated that the positive agglomeration effect of urban construction land is the weakest.

Based on the calculation results of Anselin Local Moran's I index, the spatial agglomeration characteristics were divided into HH region (high-high aggregation), LL region (low-low aggregation), HL region (high-low aggregation) and LH region (low-high aggregation). The local spatial autocorrelation results of the three land use types in 1980, 2000 and 2018 are shown in Fig. 3. It can be seen that the high-high aggregation area of food security land was mainly distributed in the northwest of Nanping City, while the low-low aggregation area was mainly distributed

Table 4. The global spatial autocorrelation index of land use in Fujian Province.

Type	Food Security Land			Ecological Conservation Land			Urban Construction Land		
	Moran Index	Z value	P value	Moran Index	Z value	P value	Moran Index	Z value	P value
1980	0.35	4.63	≤0.05	0.72	9.48	≤0.05	0.13	1.87	≤0.05
2000	0.36	4.82	≤0.05	0.73	9.50	≤0.05	0.19	2.78	≤0.05
2018	0.43	5.77	≤0.05	0.73	9.54	≤0.05	0.16	2.31	≤0.05

in the coastal areas of Xiamen City and Fuzhou City. The high-high aggregation area of ecological conservation land was mainly distributed in the northwest and southeast of Nanping City, the northeast of Sanming City and most parts of Longyan City, while the low-low aggregation area of ecological conservation land was mainly distributed in the coastal areas of several urban areas in the southeast of Fujian Province. The high-high aggregation area of urban construction land, contrary to the food security land and ecological construction land, was mainly distributed in the southeast coastal area of Fujian Province.

In general, three types of land use display certain spatial heterogeneity and spatial correlation. Land use types at the ends of the northwest, southeast of Fujian province shows high concentration, whereas middle land use type is relatively complicated with low concentration. Therefore, the location for the spatial

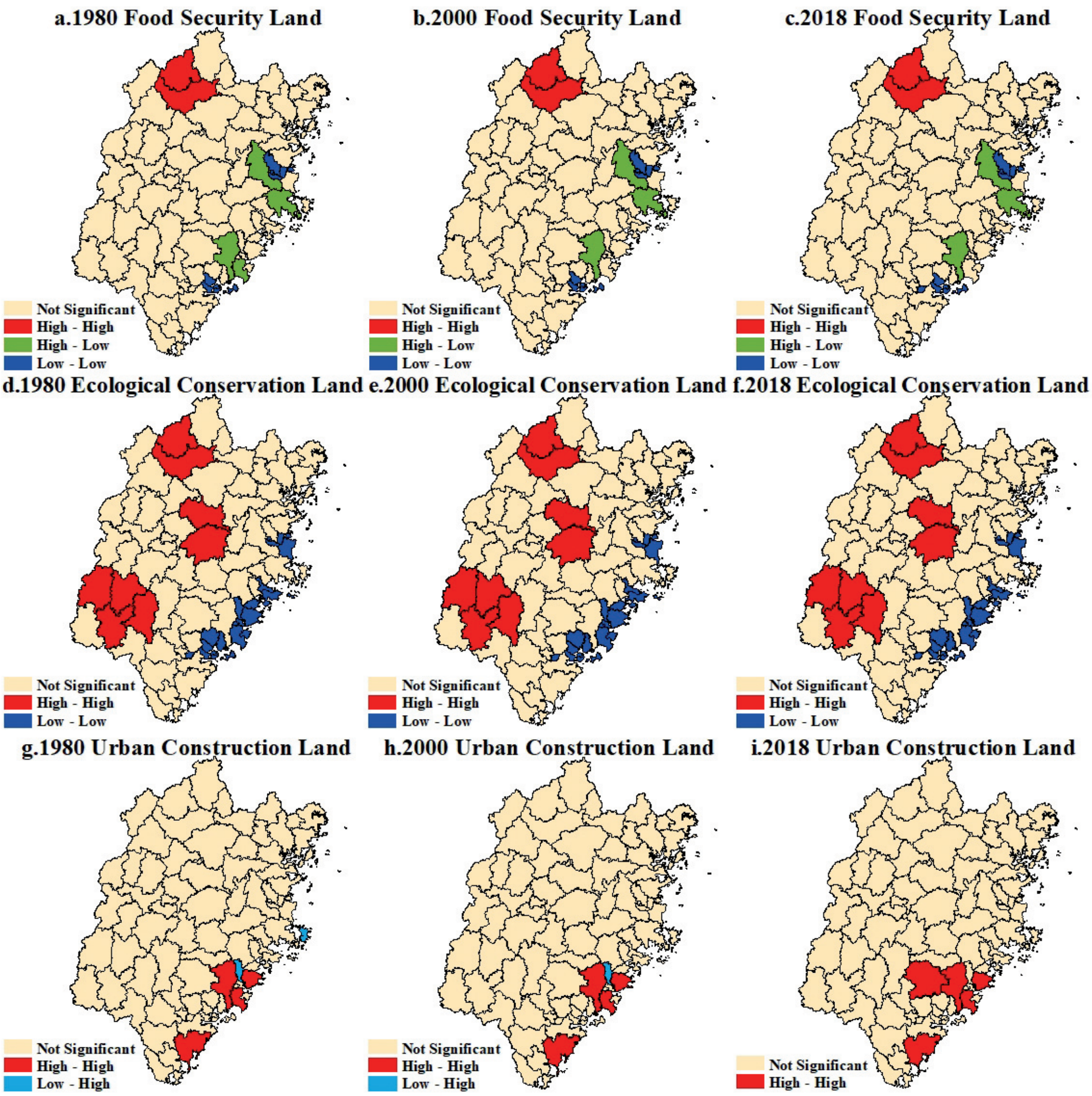

Fig. 3. Local spatial autocorrelation of land use in Fujian Province.

Table 5. Principal component eigenvalues and contribution rates of main land use types.

Principal Component	Farmland		Forest		Grass		Water Area		Construction Land		Unused Land	
	Eigenvalue	Contribution rate	Eigenvalue	Contribution rate	Eigenvalue	Contribution rate	Eigenvalue	Contribution rate	Eigenvalue	Contribution rate	Eigenvalue	Contribution rate
1	10.55	81.12	9.96	76.61	10.31	79.28	10.19	78.40	10.48	80.64	10.12	77.84
2	1.78	13.68	1.88	14.46	1.78	13.66	2.04	15.66	1.78	13.69	1.86	14.28
3	0.60	4.63	1.01	7.78	0.84	6.43	0.57	4.37	0.63	4.84	0.66	5.08
4	0.05	0.36	0.11	0.86	0.05	0.38	0.17	1.32	0.07	0.56	0.33	2.51
5	0.02	0.12	0.03	0.21	0.02	0.17	0.02	0.14	0.02	0.16	0.03	0.20
6	0.01	0.06	0.01	0.04	0.01	0.05	0.01	0.07	0.01	0.07	0.01	0.05
7	0.00	0.02	0.00	0.02	0.00	0.01	0.00	0.03	0.00	0.03	0.00	0.03
8	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01
9	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6. Principal component load matrix of main land use types.

Driving Factor		Principal Component 1					
		Farmland	Forest	Grass	Water Area	Construction Land	Unused Land
Population Structure	Total Population (10000 persons)	0.893	0.908	0.907	0.876	0.895	0.875
	Population of Per Sq.km (Person/Sq.km)	0.891	0.905	0.904	0.873	0.893	0.874
	Rural Population (10000 persons)	-	-	-	0.020	-	-
	Urban Population (10000 persons)	0.555	0.578	0.566	0.522	0.554	0.542
Industrial Structure	Primary Industry (100 million yuan)	0.993	0.994	0.995	0.992	0.993	0.990
	Secondary Industry (100 million yuan)	0.987	0.980	0.982	0.993	0.987	0.992
	Tertiary Industry (100 million yuan)	0.981	0.975	0.976	0.987	0.981	0.986
Economic Development	Gross Domestic Product (100 million yuan)	0.988	0.982	0.983	0.994	0.988	0.992
	Investment in Fixed Assets (100 million yuan)	0.954	0.945	0.945	0.962	0.953	0.962
	Households Consumption (100 million yuan)	0.994	0.993	0.993	0.996	0.994	0.993
	Revenue of Local Government (100 million yuan)	0.981	0.972	0.974	0.988	0.980	0.987
	Expenditure of Local Government (100 million yuan)	0.973	0.964	0.965	0.980	0.971	0.980

distribution and change of land use types have clear correlations: the closer to the coastal areas, the higher the concentration of land use types.

Analysis in Driving Factor

Socio-Economic Factors

Based on the driving factors of land use in Fujian Province, we selected 12 indicators that represented population structure, industrial structure, and economic development in combination with actual conditions and existing estimated data. SPSS25.0 software was used to the principal component analysis of the data, and main component feature values and their contribution rates of major land use types (Table 5) and principal component load matrix of major land use types (Table 6) were obtained. When the principal components of characteristic value were larger than 1, the contribution rates of the first principal components of farmland, forest, grass, water area, construction land and unused land were all higher than 75%, which respectively reached 81.12%, 76.61%, 79.28%, 78.40%, 80.64%, and 77.84%. This indicated that principal component 1 represented most of the information by the original factor. By calculating the load matrix of the corresponding index of each factor, we know that the larger the load coefficient is, the greater influence of this

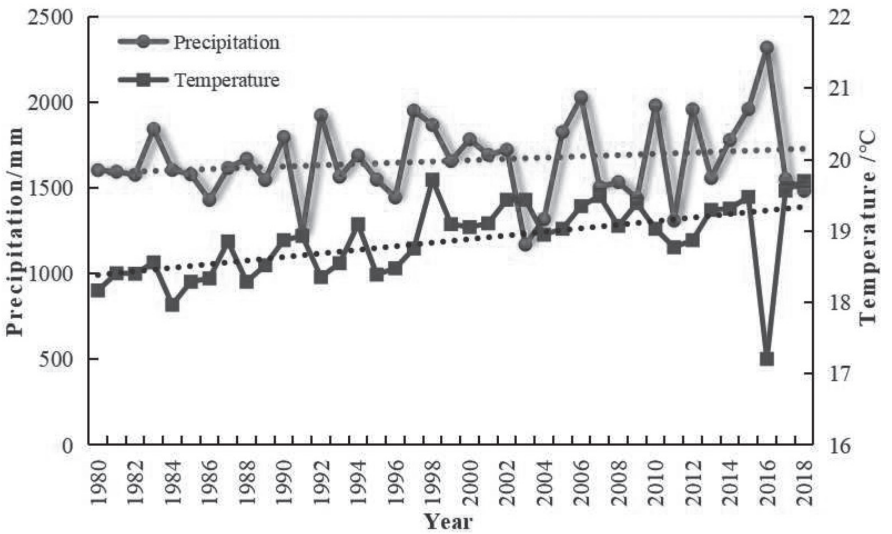

Fig. 4. Changes of precipitation and temperature in Fujian Province from 1980 to 2018.

index on the driving force of land use change factors. It can be seen from Table 6 that the eight indicators of industrial structure and economic development have significant influence on the change of six main land use types, all of which are larger than 0.9. The total population and population density in the population structure also affects the changes of the six main land use types, which are close to 0.9. Therefore, the main driving factors of land use change in Fujian Province from 1980 to 2018 are the rapid development of the economy and the adjustment of industrial structure. And the expansion of the total population also affected the changes in land use.

Natural Climatic Factor

Climate change in Fujian Province from 1980 to 2018 can be seen in Fig. 4. It can be seen that the annual average temperature fluctuation in Fujian Province increased, which has led to the increase of surface temperature, accelerated the transpiration of water in the soil of vegetation, and hindered the growth of vegetation. Additionally, the rising temperature has resulted in the upper sea water thermal expansion to rise to sea level, causing coastal vegetation was submerged, resulting in the area declining and the land degrading. The overall increase of precipitation in Fujian Province has led to the change of natural conditions and has further promoted the transformation and fluctuation among the land use types. Climate change is also affecting the ecological environment of Fujian Province. In order to deal with global warming, relevant government departments are responding to regional climate problems by strengthening ecological construction, which also affects the transformation of land use types. Therefore, the change of temperature and precipitation in Fujian Province is one of the natural and driving factors for changes in land use types.

Conclusions

This paper mainly uses land use transfer matrix, dynamic degree, information entropy, equilibrium degree, spatial autocorrelation and principal component analysis to analyze the characteristics and driving factors of land use change in Fujian Province from 1980 to 2018. The results show that: (1) From 1980 to 2018, land use changes tended to be unstable. Among them, construction land showed a substantial increase, while water area and forest exhibit a fluctuating change pattern. By calculating the comprehensive dynamic degree, it can be seen that the annual development speed of land use change in Fujian Province from 1980 to 2010 is relatively fast and the change trend is strong. The development speed of land use change in Fujian Province from 2010 to 2018 then weakens and tends to be stable. (2) Land use structure in Fujian Province is fluctuating and is rising on the whole, and regional development is becoming more and more mature. Therefore, we can carry out a new-type urbanization which takes ecological benefits into account step by step. (3) Food security land, ecological conservation land, urban construction land in Fujian Province all present spatial heterogeneity and positive agglomeration effect. The agglomeration effect in ecological construction land is the strongest, while that of urban construction land is the weakest. Land use types in the northwest and southeast of Fujian Province have high concentration, while the middle land use types are more complex and diverse, with low concentration, and the agglomeration effect in coastal areas is more significant. (4) The change and spatial difference of land use in Fujian Province are mainly affected by economic development level, industrial structure adjustments, population expansion and climate change.

In conclusion, ecological environmental protection in coastal areas is very important. Strictly protecting ecological conservation land and food security land from being occupied by urban construction land is the key to ecological protection and urban development in coastal areas. At present, the urban construction land in Fujian Province is increasing year by year, and the ecological environment is seriously damaged by its rapid growth. Due to this obvious heterogeneity in coastal areas, emphasis should be placed on strengthening ecological protection, coordinating economic development on the premise of ecological security and food security, and striving to promote the coordinated development of ecology and economy in coastal areas. In order to further optimize the allocation and utilization of land resources in China's coastal areas, we suggest that coastal areas must insist on ecological and environmental protection as an important support for the city's economic and social development in the process of urbanization. Relevant departments should coordinate the relationship between land use and ecological environment construction, and additionally promote the sustainable development of land resources by improving the quality of land ecological environment, actively responding to regional climate change issues, and controlling the scale of population growth.

However, it must be noted that this paper has not conducted in-depth discussions on land use quality, land use benefits, human-land relationship and other aspects. In the future, we intend on focusing on the analysis of these aspects, so that the study results have a more practical guide on the development of economic society and natural environment in coastal areas.

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Conflict of Interest

The authors declare no conflict of interest.

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