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Analysis of urban landscape change driving forces based on principal component analysis: a case study of City S in North China

Yining Zhang[1], Zhigang Wang[1]*

[1]Hebei Agricultural University, Baoding, China

*Corresponding Author. Email: wzhg1956@163.com

Abstract. This study takes City S, a mega-city in North China, as the research object. Based on a thorough review of relevant literature and theoretical foundations, it employs the Principal Component Analysis (PCA) method to construct a multidimensional indicator system encompassing population, economy, society, and ecology. Using statistical data from 2013 to 2020, the study quantitatively analyzes the degree of influence exerted by various driving factors on urban landscape changes. The results show that natural factors, population factors, economic development factors, and social policy factors are the primary drivers of landscape change. Social development and ecological constraints also play a role in the adjustment of urban spatial structure to a certain extent. The study further reveals the comprehensive driving mechanism underlying urban landscape evolution and provides a theoretical basis and methodological support for urban land use optimization and landscape planning. PCA demonstrates strong applicability in identifying multifactor coupling mechanisms and can serve as a scientific reference for the formulation of urban sustainable development strategies.

Keywords: landscape driving force, principal component analysis, urban landscape

1. Introduction

Landscape driving forces can be defined as various factors and processes that influence and shape landscape change [1]. These forces may be natural, such as climate, landform, and hydrological processes, or anthropogenic, such as urbanization, agricultural expansion, road construction, and mining activities [2]. To explore the mechanisms driving landscape change, it is first necessary to identify the main driving factors and then examine their complex relationships with landscape pattern evolution. The complexity and uncertainty inherent in urban development are major contributors to changes in urban landscape patterns, permeating the entire process of urban ecosystem evolution and influencing both landscape patterns and processes. Therefore, it is essential to comprehensively consider the interactions among driving factors [3].

Since the 1960s, researchers in the field of landscape ecology have begun to explore the influence of natural factors on landscape change, including fire, floods, and wind erosion. In the 1980s, research expanded to include human activities, with a focus on agriculture and urbanization. Turner et al. proposed the "Pressure-State-Response (PSR)" model [4]. In the 21st century, American ecologist Jianguo Wu introduced the "landscape transformation framework," which systematically analyzes landscape changes across different scales, speeds, and intensities, as well as their impacts on human well-being [5]. Koomen analyzed land use and temporal driving forces in European rural areas [6]; Hersperger et al. studied the driving forces of landscape change during urbanization [7]; Aimes applied weighted regression to analyze forest landscape evolution in the State of Mexico [8]. At present, research on landscape driving forces has evolved into a series of quantitative analyses of driving factors. Gong Yingbi analyzed the driving mechanisms behind the spatial-temporal evolution of urban wetland landscape patterns in Changsha [9]; Fu Hongyan conducted a study on the evolution and driving forces of landscape patterns in Nanchang [10]; Hu Juan et al. analyzed the evolution and driving forces of wetland landscape patterns in the Ziya River Basin from 2000 to 2014 [11]; Luo Yunjian quantitatively studied the spatial-temporal evolution characteristics and driving mechanisms of urban construction land expansion in Yangzhou [12]; Che Tong et al. examined the characteristics and driving forces of landscape pattern changes in construction land during urban expansion [13]; Dong Yuhong et al., based on GIS technology, analyzed the changes in landscape patterns and their driving forces in Taocheng District of Hengshui City [14].

Landscape driving forces represent the comprehensive forces behind changes in landscape types. At small spatial and temporal scales, relatively stable natural factors play a constraining role in landscape pattern changes, while frequently changing socioeconomic drivers are the direct forces driving such changes. Research on landscape driving forces is problem-oriented and lacks a fixed methodology. Considering the short temporal scale of this study and the substantial influence of socioeconomic factors on landscape pattern change, a combined quantitative and qualitative approach is adopted for analysis. This study selects natural, demographic, economic development, and social policy factors affecting the landscape pattern of the study area. Through dimensionality reduction using PCA, key factors are extracted to reveal the causes of landscape pattern changes in the study area.

City S is located in the south-central part of Hebei Province, China, between 37°27'–38°47' N and 113°30'–115°20' E [15], and is one of the core cities in the Beijing-Tianjin-Hebei urban agglomeration, with a total administrative area of 14,530 km².

2. Research content

Based on statistical yearbook data for City S from 2013 to 2020 [16], this study selected 28 driving force indicators across four major categories—natural factors, demographic factors, economic development factors, and social policy factors—for analysis. These indicators include: annual average temperature, annual precipitation, resident population, non-agricultural population, agricultural population, gross regional product, gross output value of agriculture, forestry, animal husbandry, and fishery, the composition of the primary, secondary, and tertiary industries, total industrial output value above designated size (in 100 million RMB), profits of industries above designated size, actual utilization of foreign capital, total import and export value, general public budget revenue, fixed asset investment, total retail sales of consumer goods, disposable income of urban residents, disposable income of rural residents, consumption level of urban residents, consumption level of rural residents, grain output, cultivated land area, highway mileage, afforested land area, number of domestic tourists, number of people covered by the minimum living standard guarantee system, and number of health institutions.

The interactions among demographic, economic development, and social policy factors are particularly prominent, making their impact on landscape patterns more complex. The total resident population reflects, to some extent, the scale of the city, while the numbers of agricultural and non-agricultural populations indicate the level of urbanization and the scale of agricultural development. Gross Regional Product (GDP) represents the overall economic performance of the area; the gross output value of agriculture, forestry, animal husbandry, and fishery reflects the scale and results of agricultural production over a given period. The composition of the primary, secondary, and tertiary industries reveals the structure of the economy, where sectors like real estate and design in the tertiary industry rapidly reshape urban landscapes through efficient construction activities. The transformation of the secondary industry and the rapid development of the real estate sector have promoted changes in regional landscape patterns. The total industrial output value and profits of industries above designated size reflect the scale and outcomes of industrial production during a certain period. The actual utilization of foreign capital indicates the extent of economic development supported by external investment, while total import and export value represents the overall volume of foreign trade. General public budget revenue and fixed asset investment reflect the state's financial participation in social product distribution and serve as a financial guarantee for fulfilling government functions. Indicators such as total retail sales of consumer goods, disposable income of urban and rural residents, and their consumption levels reflect the income and consumption scales of urban dwellers. Grain output and cultivated land area indicate the state of agricultural development, which is influenced by temperature and precipitation and, in turn, affects rural residents' disposable income. Indicators such as highway mileage, afforested land area, the number of people receiving minimum living standard subsidies, and the number of health institutions reflect the living conditions of urban residents. Improvements in urban infrastructure and services have accelerated the urbanization process. The enhancement of road and transport infrastructure promotes urbanization along traffic corridors and acts as a major driver of the urbanization process. Increases in the mileage of urban roads, highways, and rail transit systems, along with the development of large-scale urban transportation networks, often lead to a grid-like urban landscape and contribute to greater landscape fragmentation. The number of domestic tourists reflects tourism development, which affects scenic area planning and landscape construction.

Among the 28 selected indicators, varying degrees of correlation were observed. Some are positively correlated—for instance, resident population and gross regional product show a correlation coefficient of 0.463—while others are negatively correlated, such as gross regional product and total industrial output value above designated size. These 28 indicators influence one another and jointly shape the landscape pattern.

The contribution rates of the first three principal components are 64.359%, 17.669%, and 8.300%, respectively, with a cumulative contribution rate of 90.328%, meeting the required threshold. Therefore, the first three principal components can be used to replace the original 28 indicators, effectively reflecting the vast majority of information in the dataset. The rotated component matrix of the principal component analysis displays the correlations of indicators within each principal component. Subsequently, the principal component score coefficient matrix was calculated, which was then used to compute the annual scores and composite scores for each year (see Tables 1–5).

Table 1. Statistical data of selected factors 2013- 2020 in Shijiazhuang metropolitan area

Index		Code	2013	2014	2015	2016	2017	2018	2019	2020
Natural Factors	Annual Average Temperature (℃)	Z1	10.96	11.5	11.22	11.23	11.56	11.22	11.58	11.25
	Annual Precipitation (mm)	Z2	508.3	294.8	534.5	712.6	558.6	351.7	470.6	551.4
Demographic Factors	Permanent Population (10,000 persons)	X1	1049.98	1061.6	1070.16	1078	1088	1095	1039.42	1124.15
	Non-agricultural Population (10,000 persons)	X2	643.18	651.8	659.96	666.6	673	675.2	617.42	788.88
	Agricultural Population (10,000 persons)	X3	406.8	409.8	410.2	411.9	415	420	422	335.27
Economic Development Factors	Gross Regional Product (100 million yuan)	Y1	3872	4063	4263.7	4643	5025	5375	5809.9	5933.2
	Gross Output Value of Agriculture, Forestry, Animal Husbandry and Fishery (100 million yuan)	Y2	677	683	670	631	635	673	726	810
	Primary Industry Share (%)	Y3	9.6	9.4	9.1	8.1	7.4	7.8	7.7	8.4
	Secondary Industry Share (%)	Y4	47.5	46.8	45.1	45.5	45.1	32.2	31	30.6
	Tertiary Industry Share (%)	Y5	42.9	43.8	45.8	46.4	47.5	59.9	61.3	61
	Total Output Value of Above-scale Industries (100 million yuan)	Y6	8443	9022	9410	9645	8816	4786	5096	5429
	Profit of Above-scale Industries (100 million yuan)	Y7	675	746	802.8	808.2	867.6	373	418	292.6
	Actual Use of Foreign Capital (100 million USD)	Y8	9.8	10.2	11.4	12.2	13.9	14.9	16.2	18.3
	Total Import and Export Value (100 million USD)	Y9	140	143	124.4	116.1	130.4	138	178	202
	General Public Budget Revenue (100 million yuan)	Y11	315.1	343.5	375.1	410.7	460.9	520	569	632
	Fixed Asset Investment (100 million yuan	Y12	4369.2	5076.4	5690	5916	6310	6716	7126	5786
	Total Retail Sales of Consumer Goods (100 million yuan)	Y13	1433	1586	1715	1861	2031	2181	2359	2280
	Per Capita Disposable Income of Urban Residents (yuan/person)	Y14	24074	26071	28168	30459	32929	35563	38550	40247
	Per Capita Disposable Income of Rural Residents (yuan/person)	Y15	9546	10542	11442	12345	13345	14518	15853	16947

Table 1. (continued)

	Per Capita Consumption Level of Urban Residents (yuan/person)	Y16	15292	16796	18165	19182	20339	21620	23349	24867
	Per Capita Consumption Level of Rural Residents (yuan/person)	Y17	6605	7258	7476	7894	8417	9082	9908	11186
Social Policy Factors	Grain Output (10,000 tons)	S1	525.6	503	504.8	495.9	500.9	487.3	484.4	430.8
	Cultivated Land Area (10,000 hectares)	S2	92	91.96	91.9	89.9	89.2	84.7	82.9	72.9
	Highway Mileage (km)	S3	17482	17974.3	18862	19178	19543	19386	19592	19327
	Artificial Afforestation Area (10,000 hectares)	S4	2.45	3.6	4	5	2.9	3.2	3.51	1.7
	Number of Domestic Tourists (10,000 person-times)	S5	4874.3	5778.6	6763.4	7628	9216	11038	12275.4	6229.34
	Minimum Living Security Beneficiaries in Urban and Rural Areas (10,000 persons)	S6	18.15	18.35	18.21	16.9	12.96	10.3	14.7	15
	Number of Health Institutions (units)	S7	6475	6571	6656	6892	7334	7563	7545	8369

Table 2. Driver indicator correlation

	Z1	Z2	X1	X2	X3	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y11	Y12	Y13	Y14	Y15	Y16	Y17	S1	S2	S3	S4	S5	S6	S7
Z1	1.000	-.232	-.119	-.184	.219	.383	.001	-.526	-.186	.230	-.108	.066	.308	.183	.322	.581	.458	.377	.365	.374	.315	-.166	-.099	.496	.146	.534	-.253	.240
Z2	-.232	1.000	.183	.207	-.198	.069	-.145	-.243	.181	-.144	.350	.299	.102	-.164	.058	.016	.060	.085	.084	.106	.058	-.097	-.054	.288	.243	-.121	.171	.072
X1	-.119	.183	1.000	.917	-.695	.463	.358	-.307	-.359	.369	-.254	-.328	.559	.263	.530	.139	.411	.495	.515	.528	.558	-.720	-.615	.431	-.391	-.099	-.452	.674
X2	-.184	.207	.917	1.000	-.924	.457	.638	-.089	-.392	.380	-.284	-.437	.585	.526	.553	-.045	.355	.491	.524	.535	.620	-.826	-.742	.263	-.559	-.297	-.202	.698
X3	.219	-.198	-.695	-.924	1.000	-.381	-.807	-.134	.364	-.331	.268	.474	-.519	-.696	-.490	.214	-.247	-.411	-.451	-.458	-.583	.800	.748	-.061	.634	.440	-.069	-.612
Y1	.383	.069	.463	.457	-.381	1.000	.594	-.756	-.917	.943	-.818	-.748	.986	.697	.991	.787	.986	.998	.994	.989	.969	-.815	-.881	.829	-.330	.661	-.700	.950
Y2	.001	-.145	.358	.638	-.807	.594	1.000	.065	-.701	.656	-.652	-.795	.676	.959	.678	.064	.479	.607	.638	.632	.750	-.814	-.860	.134	-.664	-.071	-.044	.697
Y3	-.526	-.243	-.307	-.089	-.134	-.756	.065	1.000	.524	-.596	.436	.231	-.681	-.110	-.679	-.890	-.825	-.742	-.713	-.713	-.599	.363	.403	-.915	-.073	-.831	.811	-.628
Y4	-.186	.181	-.359	-.392	.364	-.917	-.701	.524	1.000	-.996	.958	.930	-.904	-.753	-.927	-.681	-.890	-.913	-.914	-.901	-.908	.769	.872	-.630	.382	-.609	.642	-.870
Y5	.230	-.144	.369	.380	-.331	.943	.656	-.596	-.996	1.000	-.947	-.900	.923	.723	.944	.733	.924	.938	.935	.923	.918	-.763	-.865	.688	-.353	.658	-.686	.885
Y6	-.108	.350	-.254	-.284	.268	-.818	-.652	.436	.958	-.947	1.000	.954	-.796	-.726	-.823	-.578	-.782	-.799	-.795	-.770	-.792	.622	.784	-.461	.493	-.590	.677	-.779
Y7	.066	.299	-.328	-.437	.474	-.748	-.795	.231	.930	-.900	.954	1.000	-.760	-.807	-.786	-.383	-.677	-.739	-.748	-.726	-.787	.715	.848	-.316	.536	-.355	.489	-.765
Y8	.308	.102	.559	.585	-.519	.986	.676	-.681	-.904	.923	-.796	-.760	1.000	.748	.997	.696	.953	.990	.993	.991	.990	-.881	-.934	.788	-.427	.538	-.649	.983
Y9	.183	-.164	.263	.526	-.696	.697	.959	-.110	-.753	.723	-.726	-.807	.748	1.000	.752	.201	.592	.694	.716	.703	.805	-.786	-.873	.227	-.680	.108	-.166	.752
Y11	.322	.058	.530	.553	-.490	.991	.678	-.679	-.927	.944	-.823	-.786	.997	.752	1.000	.716	.962	.994	.997	.993	.991	-.876	-.932	.784	-.399	.568	-.656	.975

Table 2. (continued)

Y12	.581	.016	.139	-.045	.214	.787	.064	-.890	-.681	.733	-.578	-.383	.696	.201	.716	1.000	.877	.783	.757	.760	.642	-.387	-.420	.919	.184	.944	-.737	.595
Y13	.458	.060	.411	.355	-.247	.986	.479	-.825	-.890	.924	-.782	-.677	.953	.592	.962	.877	1.000	.984	.976	.973	.926	-.744	-.798	.894	-.205	.758	-.739	.900
Y14	.377	.085	.495	.491	-.411	.998	.607	-.742	-.913	.938	-.799	-.739	.990	.694	.994	.783	.984	1.000	.999	.997	.976	-.840	-.890	.840	-.316	.637	-.680	.955
Y15	.365	.084	.515	.524	-.451	.994	.638	-.713	-.914	.935	-.795	-.748	.993	.716	.997	.757	.976	.999	1.000	.999	.985	-.865	-.907	.825	-.332	.601	-.654	.962
Y16	.374	.106	.528	.535	-.458	.989	.632	-.713	-.901	.923	-.770	-.726	.991	.703	.993	.760	.973	.997	.999	1.000	.984	-.872	-.902	.839	-.309	.591	-.638	.958
Y17	.315	.058	.558	.620	-.583	.969	.750	-.599	-.908	.918	-.792	-.787	.990	.805	.991	.642	.926	.976	.985	.984	1.000	-.927	-.961	.733	-.429	.469	-.568	.977
S1	-.166	-.097	-.720	-.826	.800	-.815	-.814	.363	.769	-.763	.622	.715	-.881	-.786	-.876	-.387	-.744	-.840	-.865	-.872	-.927	1.000	.953	-.565	.433	-.146	.356	-.912
S2	-.099	-.054	-.615	-.742	.748	-.881	-.860	.403	.872	-.865	.784	.848	-.934	-.873	-.932	-.420	-.798	-.890	-.907	-.902	-.961	.953	1.000	-.542	.575	-.251	.457	-.956
S3	.496	.288	.431	.263	-.061	.829	.134	-.915	-.630	.688	-.461	-.316	.788	.227	.784	.919	.894	.840	.825	.839	.733	-.565	-.542	1.000	.098	.759	-.698	.720
S4	.146	.243	-.391	-.559	.634	-.330	-.664	-.073	.382	-.353	.493	.536	-.427	-.680	-.399	.184	-.205	-.316	-.332	-.309	-.429	.433	.575	.098	1.000	.187	.250	-.522
S5	.534	-.121	-.099	-.297	.440	.661	-.071	-.831	-.609	.658	-.590	-.355	.538	.108	.568	.944	.758	.637	.601	.591	.469	-.146	-.251	.759	.187	1.000	-.747	.428
S6	-.253	.171	-.452	-.202	-.069	-.700	-.044	.811	.642	-.686	.677	.489	-.649	-.166	-.656	-.737	-.739	-.680	-.654	-.638	-.568	.356	.457	-.698	.250	-.747	1.000	-.661
S7	.240	.072	.674	.698	-.612	.950	.697	-.628	-.870	.885	-.779	-.765	.983	.752	.975	.595	.900	.955	.962	.958	.977	-.912	-.956	.720	-.522	.428	-.661	1.000

Table 3. The driver indicator eigenvalues and contribution rate of driving force factors

Component	Initial eigenvalue			Sum of squared load			Sum of rotational squared load		
	Total	Variance rate/%	Total rate/%	Total/%	Variance rate/%	Total rate/%	Total	Variance rate/%	Total/%
1	18.021	64.359	64.359	18.021	64.359	64.359	11.295	40.339	40.339
2	4.947	17.669	82.028	4.947	17.669	82.028	10.729	38.319	78.657
3	2.324	8.300	90.328	2.324	8.300	90.328	2.227	7.954	86.612
4	1.183	4.226	94.554						
5	.923	3.297	97.852						
6	.522	1.863	99.715						
7	.080	.285	100.000						
8	1.305E-15	4.661E-15	100.000						
9	8.154E-16	2.912E-15	100.000						
10	5.579E-16	1.992E-15	100.000						
11	5.152E-16	1.840E-15	100.000						
12	4.268E-16	1.524E-15	100.000						
13	3.574E-16	1.276E-15	100.000						
14	2.148E-16	7.671E-16	100.000						
15	1.776E-16	6.343E-16	100.000						
16	1.123E-16	4.011E-16	100.000						
17	2.414E-17	8.622E-17	100.000						
18	-2.100E-17	-7.499E-17	100.000						
19	-1.149E-16	-4.104E-16	100.000						
20	-1.831E-16	-6.538E-16	100.000						
21	-2.565E-16	-9.161E-16	100.000						
22	-2.766E-16	-9.880E-16	100.000						
23	-4.333E-16	-1.548E-15	100.000						
24	-4.513E-16	-1.612E-15	100.000						

Table 3. (continued)

25	-5.472E-16	-1.954E-15	100.000
26	-6.590E-16	-2.354E-15	100.000
27	-1.230E-15	-4.391E-15	100.000
28	-4.796E-15	-1.713E-14	100.000

Table 4. The rotation matrix of principal components

Index	Component		
	1	2	3
Annual Average Temperature	.499	.060	.133
Annual Precipitation	.097	-.018	.804
Permanent Resident Population	.271	.406	.267
Non-agricultural Population	.042	.692	.277
Agricultural Population	.183	-.858	-.243
Gross Regional Product	.789	.607	-.044
Total Output Value of Agriculture, Forestry, Animal Husbandry, and Fishery	-.010	.982	-.167
Primary Industry Share (%)	-.962	.017	-.151
Secondary Industry Share (%)	-.643	-.649	.355
Tertiary Industry Share (%)	.704	.613	-.317
Total Output Value of Industrial Enterprises above Designated Size	-.557	-.567	.586
Profit of Industrial Enterprises above Designated Size	-.355	-.718	.523
Actual Use of Foreign Capital (USD 100 million)	.705	.693	.002
Total Import and Export Value (USD 100 million)	.135	.951	-.210
General Public Budget Revenue	.716	.689	-.039
Fixed Asset Investment	.969	.061	-.033
Total Retail Sales of Consumer Goods	.871	.490	-.030
Per Capita Disposable Income of Urban Residents (CNY/person)	.780	.622	-.007
Per Capita Disposable Income of Rural Residents (CNY/person)	.752	.656	.005
Per Capita Disposable Income of Rural Residents (CNY/person)	.752	.654	.044
Per Capita Consumption of Rural Residents (CNY/person)	.632	.770	.005
Grain Output (10,000 tons)	-.385	-.857	-.153
Cultivated Land Area (10,000 hectares)	-.427	-.872	.044
Highway Mileage (km)	.934	.181	.272
Afforested Area (10,000 hectares)	.121	-.620	.365
Number of Domestic Tourists (10,000 person-times)	.916	-.107	-.263
Number of People Covered by Minimum Living Security in Urban and Rural Areas (10,000 persons)	-.844	-.003	.330
Number of Medical Institutions	.634	.717	-.008

Table 5. Component score coefficient matrix

Index	Component		
	1	2	3
Annual Average Temperature	.025	.093	.159
Annual Precipitation	.028	.020	.383
Permanent Resident Population	.052	-.080	.057
Non-agricultural Population	-.021	.033	.105
Agricultural Population	.088	-.137	-.135
Gross Regional Product	.054	.033	.023
Total Output Value of Agriculture, Forestry, Animal Husbandry, and Fishery	-.104	.194	-.004
Primary Industry Share (%)	-.146	.101	-.071
Secondary Industry Share (%)	-.028	-.032	.131
Tertiary Industry Share (%)	.041	.021	-.115
Total Output Value of Industrial Enterprises above Designated Size	-.027	.003	.260
Profit of Industrial Enterprises above Designated Size	.014	-.042	.226
Actual Use of Foreign Capital (USD 100 million)	.039	.046	.041
Total Import and Export Value (USD 100 million)	-.088	.193	-.012
General Public Budget Revenue	.039	.047	.024
Fixed Asset Investment	.121	-.051	.018
Total Retail Sales of Consumer Goods	.075	.013	.029
Per Capita Disposable Income of Urban Residents (CNY/person)	.052	.038	.042
Per Capita Disposable Income of Rural Residents (CNY/person)	.045	.048	.049
Per Capita Disposable Income of Rural Residents (CNY/person)	.045	.051	.069
Per Capita Consumption of Rural Residents (CNY/person)	.017	.079	.055
Grain Output (10,000 tons)	.018	-.107	-.116
Cultivated Land Area (10,000 hectares)	.014	-.091	-.019
Highway Mileage (km)	.120	-.042	.150
Afforested Area (10,000 hectares)	.056	-.033	.191
Number of Domestic Tourists (10,000 person-times)	.125	-.085	-.101
Number of People Covered by Minimum Living Security in Urban and Rural Areas (10,000 persons)	-.149	.194	.221
Number of Medical Institutions	.036	.028	.017

3. Research results

A comprehensive principal component model was calculated using the proportion of each principal component's eigenvalue to the total eigenvalue of all extracted principal components as weights. The F values were then calculated, as shown in Table 6.

Table 6. Principal component analysis and comprehensive evaluation results by each year

Year	F1	F2	F3	F
2013	-1.55936	-.33600	-.83283	-.85277
2014	-1.10935	-.07604	-.37415	-.43776
2015	-.49986	-.41605	.55734	-.30381
2016	.21266	-.70933	1.52387	-.07638
2017	.79902	-.74254	.76752	.06869
2018	1.13642	-.55285	-1.55008	.03462
2019	1.05433	.59921	-.56427	.76414
2020	-.03386	2.23361	.47260	.80327

The trend of the F value is illustrated in Figure 1. From 2013 to 2020, except for a slight decline in a few individual years, the comprehensive value F of the driving force analysis model showed an overall upward trend. This indicates that the influence of the three principal components on the landscape pattern has generally increased year by year.

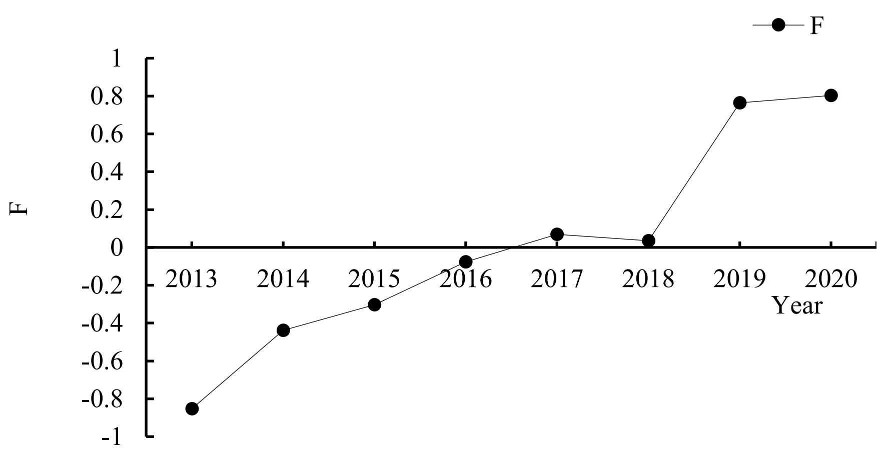

Figure 1. Changes of F value

An analysis of the three principal components reveals the following: The first principal component is mainly negatively correlated with the share of primary industry and the minimum living security coverage for urban and rural residents, and positively correlated with fixed asset investment, total retail sales of consumer goods, highway mileage, and the number of domestic tourists. The second principal component is primarily negatively correlated with the total output value of agriculture, forestry, animal husbandry, and fishery, as well as the total import and export value. It is positively correlated with the agricultural population, grain output, and cultivated land area. The third principal component is only negatively correlated with annual precipitation. In summary, four types of factors—natural factors, population factors, economic development factors, and social policy factors—serve as driving forces behind changes in landscape patterns.

Natural, population, economic development, and social policy factors collectively influence urban landscape patterns, interacting with and affecting one another. As cities are regions of intensive human activity, the influence of natural factors on urban landscape patterns is lower than their impact on natural habitat patterns. Over a ten-year timeframe, geological changes and wind direction have limited influence on the landscape pattern of the main urban area of S City, which is located in a plain region. The main driving factors are precipitation and temperature, which affect vegetation and the urban thermal environment.

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