Comparison of Principal Component Analysis and Grey Correlation in Soil Fertility Evaluation Model

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Abstract

Soil fertility is the basic premise of crop yield guarantee, and the main indexes of soil fertility are organic matter, total nitrogen, hydrolyzed nitrogen, rapidly available potassium, slowly available potassium, available phosphorus, total phosphorus, etc. In the face of the severe challenge of soil degradation, it has become the primary task to accurately evaluate soil fertility to achieve the goal of sustainable agricultural development. Based on the main indexes of soil fertility, this paper firstly established a comprehensive evaluation model with principal component analysis method to evaluate the soil fertility at each point of outpost farm, constructed a comprehensive evaluation function F, and obtained the comprehensive evaluation results. Secondly, the comprehensive evaluation model of grey correlation analysis was used to evaluate soil fertility, and the evaluation results were generally consistent with the actual results. The grey correlation curve is used to analyze the close degree of each index, which further proves the rationality of the evaluation index selected in this paper.

Keywords

Soil fertility; Principal factor analysis; Grey relation analysis; SPSS.

1. Introduction

Soil fertility is related to crop yield, and soil fertility of different degrees is crucial to crop yield and quality. In order to ensure sustainable development of agriculture, it is essential to evaluate soil fertility scientifically and effectively. Meanwhile, the evaluation of soil fertility is conducive to land resource utilization, scientific fertilization, crop layout adjustment and land development and consolidation.

In 2004, J.L et al. comprehensively considered the factors affecting soil fertility, such as plant crop species, rainfall, and season, and comprehensively studied and analyzed soil fertility by comprehensively using rainfall sequences at different time periods and NDVI. Dhaeze studies the suitability of land for different USES under certain conditions based on the requirements of soil fertility and socio-economic factors in agricultural policy making. In 2007, Gonzalez used geographic information technology to analyze in detail the changes of farmland plot size in recent years, and finally concluded that the effects of soil fertility changes on soil productivity.

Cao Chengmian et al. had a sudden idea for the first time to obtain the weight in the mean sum through the correlation between the indexes of fertility index content, thus the evaluation of soil fertility by the numerical comprehensive evaluation model became a reality. Wu Wei et al. adopted the fuzzy mathematical model and assigned the corresponding membership degree to the selected indicators, so that the evaluation value could well reflect the correlation between the indicators and the evaluation level of the indicators themselves, and could accurately evaluate the fertility quality of the research area. Liu Changwen et al. selected 4 evaluation indexes in the research area and used multivariate statistical analysis method to evaluate soil fertility, and obtained a conclusion that was as high as 80% consistent with the reality. It reflected that soil physical characteristics were inextricably linked with crop yield and at the same time reduced the unreasonable influence brought by other factors. Zhong

Jihong et al. used numerical comprehensive evaluation method to analyze and study the soil fertility quality evaluation of forest lateritic soil. The BP neural network method proposed by Han Lei et al. established a comprehensive evaluation model of soil fertility in Ansai County, which not only compared the level of soil fertility but also visually identified the classification of soil fertility. In the soil fertility evaluation of Xi 'an Vegetable district, Wang Jing et al. firstly calculated their respective weights, supported by corresponding models, and then summarized them to obtain the comprehensive evaluation cloud model of soil fertility evaluation results.

2. Preliminary knowledge

Qianshao Farm, one of the world's three black soil belt, is a natural cradle for rice production and has been awarded the title of "The first Farm reclamation in the East". In this paper, 7 indexes related to outpost farm soil in 2017 were selected to study soil fertility.

Principal component analysis (PCA) : In the analysis of multi-indicator problems, considering that the information presented by multiple indicators may be overlapped and that multiple indicators may involve distribution rules in various aspects, we need to reduce the difficulty of operation and improve work efficiency in order to avoid the problem becoming complicated. In the case of little information loss, it is necessary to use the dimensionality reduction idea of principal component to reduce multiple indicators to several representative comprehensive indicators. It is for this reason that the principal component is more advantageous than the original data in some aspects.

Grey relational analysis: Grey relational analysis suggests that the similarity of the geometric shapes of sequence curves can be used to determine whether the objects are closely related to each other. The closer the curves are, the greater the correlation between the corresponding sequences is, and vice versa. Therefore, grey relational degree analysis provides a quantitative measure of development and change situation, which is very suitable for dynamic process analysis. First, the data sequence and the standard data sequence are determined, then the data is initialized, and finally the grey correlation coefficient between the evaluation factors is calculated.

Selection of indexes: The evaluation indexes of soil fertility must have scientific basis, and the evaluation indexes play a decisive role in the evaluation of soil fertility. According to the quality of agricultural land grading procedures "(GB/T28407-2012) and the second national soil survey classification standard of the nutrients in the pressure in the process of sand to the soil fertility evaluation, finally determined the soil organic matter, total nitrogen, total potassium and total phosphorus, available phosphorus and available potassium, hydrolysis nitrogen the seven indicators as a contestant factor of soil integrated fertility evaluation.

3. Establishment and Solution of soil fertility evaluation model

3.1 Principal component analysis evaluation model

The contents of organic matter, total nitrogen, total phosphorus, total potassium, hydrolyzed nitrogen, available phosphorus and available potassium in soil were determined by different methods.

Table 3-1 rice quality evaluation index system table

The evaluation index	Variable symbol
The organic matter	OM
Total nitrogen	TN
Hydrolysis nitrogen	WN
The effective phosphorus	AP
Available k	AK
Total phosphorus	TP
Total potassium	SK

Standardize the original data and conduct correlation test. The test results are shown in the table 3-2.

Table3-2 KMO and Bartlett's test table

KMO and Bartlett Inspection table		
Sample enough Kaiser-Meyer-OlkinTo measure the		0.663
Bartlett Test of sphericity	The approximate chi-square	338.463
	df	21
	Sig.	0.05

As shown in Table 3-2，Correlation is equal to 0.663>0.5，Therefore, principal component analysis is applicable.

Calculate the correlation coefficient matrix and the cumulative contribution rate:

Table 3-3 correlation coefficient matrix table

Correlation coefficient matrix								
		OM	TN	WN	AK	SK	AP	TP
related	OM	1						
	TN	0.152	1					
	WN	0.301	-0.086	1				
	AK	0.320	-0.024	0.209	1			
	SK	-0.192	-0.074	-0.044	-0.099	1		
	AP	-0.198	0.115	-0.310	-0.203	0.045	1	
	TP	0.244	-0.114	-0.097	0.458	0.069	0.364	1

Table 3-4 Cumulative contribution rate

The principal components	The eigenvalue	contribution	Cumulative contribution rate
1	1.933	42.646	42.646
2	1.586	34.547	77.193
3	1.181	10.061	87.254
4	1.018	9.032	95.286

According to Table 3-4, when there are 4 principal components, the cumulative contribution rate in the table is 95.286%, which meets the relevant requirements. Therefore, only 4 principal components are needed to accurately express the main conditions of soil fertility.

Calculate the corresponding eigenvectors of each principal component,

Table 3-5 The eigenvectors of the principal components

T1	T2	T3	T4
0.377	-0.380	0.361	0.623
-0.060	0.625	0.747	0.546
0.382	0.096	-0.202	-0.346
0.353	-0.048	0.267	-0.122
0.024	0.446	-0.158	0.099
0.348	0.733	0.387	-0.044
0.439	-0.072	0.710	0.012

According to Table 3-5, the following linear regression equation can be obtained:

$$Z_1 = 0.377 * OM - 0.060 * TN + 0.382 * WN + 0.353 * AK + 0.024 * SK + 0.348 * AP + 0.439 * TP$$

$$Z_2 = -0.380 * OM + 0.625 * TN + 0.096 * WN - 0.048 * AK + 0.446 * SK + 0.733 * AP - 0.072 * TP$$

$$Z_3 = 0.361 * OM + 0.747 * TN - 0.202 * WN + 0.267 * AK - 0.158 * SK + 0.387 * AP + 0.710 * TP$$

$$Z_4 = 0.623 * OM + 0.546 * TN - 0.346 * WN - 0.122 * AK + 0.099 * SK - 0.044 * AP + 0.012 * TP$$

By using the eigenvalues obtained from principal components, the weights of each component are obtained, and then the comprehensive evaluation function is written to show its relationship with each principal component $Z_i (i = 1, 2, 3, 4)$ linear function of:

$$F = 0.391 * Z_1 + 0.294 * Z_2 + 0.198 * Z_3 + 0.117 * Z_4$$

Table 3-6 The eigenvalue corresponding to the principal component

The principal components	The eigenvalue	Characteristic root weight
Z1	2.487	0.391
Z2	1.396	0.294
Z3	1.003	0.198
Z4	0.782	0.117

The principal component is known $Z_i (i = 1, 2, 3, 4)$, and each index factor OM、TN、WN the linear relationship between the comprehensive index function F and each evaluation index OM, TN, WN, etc., as well as the ranking of each index factor, see table 3-7.

Table 3-7 Index coefficient and ranking

Index factors	Index coefficient in comprehensive evaluation function	The ranking of influencing factors in the comprehensive evaluation index function
The organic matter（OM）	0.061	6
Total nitrogen（TN）	0.198	3
Total phosphorus（TP）	0.279	2
Total potassium（AK）	0.129	5
Hydrolysis nitrogen（WN）	0.118	4
The effective phosphorus（AP）	0.280	1
Available k（SK）	0.153	7

The comprehensive evaluation function model based on principal component analysis is:

$$F = 0.061 * OM + 0.198 * TN + 0.279 * TP + 0.129 * AK + 0.118 * WN + 0.280 * AP + 0.153 * SK$$

Table 3-8 Index coefficient and ranking

Sample area	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
score	-0.403	-0.736	-0.498	1.041	-0.387	-0.278	0.672	0.425	1.601	1.785
The sorting	22	27	24	3	21	19	5	9	2	1
Sample area	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20
score	0.386	-0.141	0.538	0.619	0.135	-0.128	0.712	-0.015	0.549	-0.427
The sorting	10	17	8	6	11	16	4	14	7	23
Sample area	Y21	Y22	Y23	Y24	Y25	Y26	Y27	Y28	Y29	Y30
score	-0.101	-0.853	-0.594	-0.601	-0.288	-0.816	-0.739	0.071	-0.246	0.102
The sorting	15	30	25	26	20	29	28	13	18	12

In the soil fertility score of the various test plots, the score of many test plots is negative, but it does not mean that the soil fertility score of the test plots is negative. The positive and negative values here only represent the location relationship between the sample plot and the average level, and the average level of soil fertility is counted as zero, which is the result of data standardization in the evaluation process.

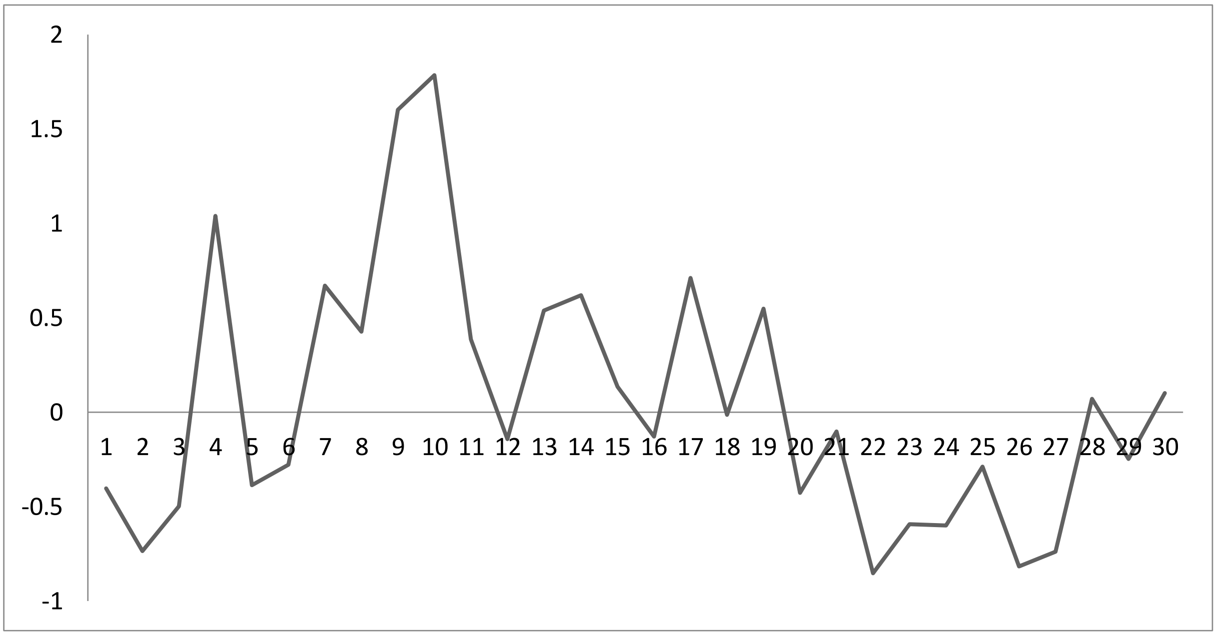

Figure3-1 Trend chart of soil fertility by principal component analysis

As can be seen from Figure 3-1, although the overall trend is that soil fertility first increases and then decreases, soil fertility in many test plots is inconsistent with the change trend. The evaluation model based on principal component analysis (PCA) is applied to the study of soil fertility in this paper, and the evaluation results obtained do not reach a high accuracy rate.

In the process of building a mathematical model based on principal component analysis, a quantifiable ranking of relative importance is obtained for the seven evaluation indexes selected. In this way, we can understand the main factors affecting soil fertility and provide practical guidance for improving soil fertility.

3.2 Grey relational analysis evaluation model

The decision matrix X is composed of 31 sample plots, real side values of 7 evaluation indexes and reference sequence.

Table 3-9 Decision matrix value

	OM	TN	WN	AK	SK	AP	TP
Y1	60.67	1.14	355	234	311	11.85	1.206
Y2	71.38	1.32	266.1	197	348	8.89	1.26
Y3	59.9	1.47	249.1	370	348	14.49	1.059
Y4	47.89	1.25	336.9	240	330	16.71	1.299
Y5	58.74	1.65	228.9	467	268	9.15	1.296
Y6	76.57	1.05	265.3	429	266	16.52	1.263
Y7	74.79	1.33	248.5	335	320	14.42	1.327
Y8	74.78	1.52	139.6	239	324	6.72	1.293
Y9	51.87	1.42	156.6	165	347	6.81	1.283
Y10	67.67	1.44	150.9	312	360	5.79	1.287
Y11	56.97	1.46	198.8	180	536	6.72	1.447
Y12	51.93	1.47	325.3	222	518	13.42	1.141
Y13	50.76	1.15	225.9	126	501	21.68	1.03
Y14	55.55	1.392	334.9	293	454	20.67	1.31
Y15	49.12	1.447	368.6	366	450	21.19	1.308
Y16	73.45	1.243	355.1	340	383	20.91	1.316
Y17	50.82	1.15	375.3	373	381	16.15	1.243
Y18	55.57	1.24	219.9	381	345	6.25	1.21
Y19	54.02	1.24	296.6	244	359	9.01	1.319
Y20	54.79	1.55	349.7	317	351	9.05	1.142
Y21	55.88	1.31	218.7	419	369	9.87	1.311
Y22	52.75	1.25	199.7	296	330	6.74	1.305
Y23	45.84	1.33	287.4	226	329	7.42	1.256
Y24	40.54	1.31	297.9	201	315	23.43	1.268
Y25	40.01	1.44	177.5	176	369	7.86	1.379
Y26	37.12	1.55	171.2	145	363	4.41	1.173
Y27	36.3	1.4	315.4	208	355	12.37	1.213
Y28	32.55	1.412	258.7	136	346	6.74	1.254
Y29	47.66	1.25	245.4	115	353	30.4	1.11

Standardize the data and apply transformations

$$f : Y \rightarrow Z$$

$$Z_i(k) = \frac{Y_i(k)}{Y_0(k)} (i = 0, 2, ..., n)(k = 1, 2, ..., m)$$

Get the matrix Y, and organize into a data table 3-10：

Table 3-10 The indicators are digitized

	Organic matter mass fraction	Total nitrogen mass fraction	Totalphosphorus mass fraction	Totalpotassium mass fraction	Hydrolyzed nitrogen mass fraction	Available p mass fraction	Mass fraction of available potassium
Y1	0.765	0.579	0.750	0.842	0.897	0.750	0.776
Y2	0.839	0.636	0.936	0.878	0.965	0.992	0.840
Y3	0.799	0.850	0.689	0.649	0.948	0.532	0.663
Y4	0.827	0.732	0.679	0.946	0.812	0.548	0.998
Y5	0.304	0.636	0.902	0.919	0.993	0.805	0.975
Y6	0.977	0.667	0.937	0.781	0.752	0.873	0.673
Y7	0.995	0.857	0.562	0.713	0.825	0.466	0.974
Y8	0.694	0.934	0.777	0.690	0.710	0.929	0.992
Y9	0.405	0.845	0.964	0.891	0.746	0.850	0.769
Y10	0.842	0.889	0.743	0.577	0.889	0.606	0.878
Y11	0.912	0.849	0.636	0.873	0.966	0.997	0.789
Y12	0.977	0.782	0.694	0.568	0.967	0.615	0.903
Y13	0.494	0.826	0.825	0.540	0.906	0.953	0.184
Y14	0.884	0.951	0.627	0.915	0.991	0.516	0.998
Y15	0.495	0.859	0.963	0.929	0.851	0.987	0.795
Y16	0.692	0.925	0.689	0.971	0.995	0.772	0.945
Y17	0.935	0.783	0.586	0.772	0.906	0.387	0.973
Y18	0.972	0.795	0.879	0.640	0.580	0.944	0.901
Y19	0.425	0.785	0.790	0.918	0.978	0.951	0.866
Y20	0.989	0.845	0.625	0.767	0.821	0.906	0.986
Y21	0.944	0.954	0.913	0.706	0.894	0.683	0.995
Y22	0.869	0.973	0.874	0.764	0.997	0.890	0.962
Y23	0.884	0.985	0.653	0.889	0.957	0.768	0.955
Y24	0.987	0.992	0.596	0.876	0.714	0.335	0.875
Y25	0.928	0.764	0.965	0.824	0.984	0.561	0.851
Y26	0.978	0.903	0.842	0.434	0.978	0.805	0.968
Y27	0.897	0.857	0.820	0.654	0.975	0.545	0.338
Y28	0.464	0.885	0.949	0.846	0.873	0.451	0.885
Y29	0.435	0.876	0.684	0.764	0.692	0.513	0.432
Y20	0.543	0.769	0.620	0.961	0.394	0.346	0.396

According to the formula

$$V_i(k) = \left|y_0(k) - y_i(k)\right| (i = 1, 2, ..., n)(k = 1, 2, ..., m)$$

The absolute difference sequence is calculated □(k)， see table 3-11.

Table 3-11 Sequence of absolute differences

Δ1	0.185	0.429	0.365	0.410	0.276	0.587	0.532
Δ2	0.278	0.599	0.418	0.242	0.184	0.548	0.577
Δ3	0.433	0.415	0.125	0.239	0.316	0.248	0.403
Δ4	0.124	0.578	0.325	0.346	0.485	0.654	0.465
Δ5	0.127	0.174	0.004	0.263	0.276	0.546	0.434
Δ6	0.145	0.616	0.178	0.064	0.264	0.545	0.038
Δ7	0.121	0.201	0.023	0.045	0.230	0.541	0.096
Δ8	0.295	0.268	0.369	0.155	0.002	0.015	0.293
Δ9	0.194	0.399	0.473	0.368	0.376	0.487	0.432
Δ10	0.179	0.549	0.335	0.348	0.284	0.448	0.319
Δ11	0.443	0.424	0.525	0.636	0.320	0.340	0.036
Δ12	0.123	0.538	0.385	0.326	0.425	0.754	0.467
Δ13	0.147	0.274	0.024	0.463	0.676	0.366	0.234
Δ14	0.267	0.526	0.238	0.191	0.464	0.547	0.438
Δ15	0.481	0.291	0.469	0.040	0.243	0.543	0.016
Δ16	0.395	0.318	0.378	0.025	0.495	0.019	0.299
Δ17	0.186	0.439	0.345	0.468	0.260	0.587	0.562
Δ18	0.478	0.419	0.635	0.247	0.384	0.580	0.540
Δ19	0.452	0.301	0.409	0.236	0.330	0.248	0.436
Δ20	0.324	0.442	0.386	0.336	0.685	0.654	0.435
Δ21	0.128	0.172	0.294	0.664	0.270	0.546	0.462
Δ22	0.165	0.613	0.358	0.564	0.460	0.496	0.498
Δ23	0.181	0.211	0.423	0.445	0.643	0.367	0.656
Δ24	0.245	0.349	0.471	0.381	0.042	0.095	0.203
Δ25	0.199	0.449	0.355	0.568	0.373	0.597	0.472
Δ26	0.288	0.559	0.461	0.398	0.249	0.447	0.648
Δ27	0.451	0.405	0.484	0.246	0.323	0.258	0.466
Δ28	0.129	0.479	0.331	0.306	0.499	0.634	0.565
Δ29	0.177	0.277	0.044	0.404	0.396	0.566	0.454
Δ30	0.475	0.626	0.408	0.164	0.364	0.483	0.058

Grey correlation coefficient $r\left(y_0\left(k\right), y_i\left(k\right)\right)$ can be calculated by the formula

$$r_{ij} = \frac{\min_m \min_n \left|V_i\left(k\right)\right| + \rho \max_m \max_m \left|V_i\left(k\right)\right|}{\left|V_i\left(k\right) + \rho \max_m \max_n \left|V_j\left(k\right)\right|\right|}$$

then form evaluation matrix R.

Table 3-11 The evaluation matrix

0.675	0.468	0.513	0.474	0.579	0.363	0.424
0.565	0.387	0.48	0.622	0.704	0.379	0.392
0.484	0.47	0.989	0.841	0.651	0.583	0.456
0.78	0.387	0.635	0.896	0.557	0.384	0.441
0.68	0.667	0.978	0.564	0.573	0.402	0.475
0.701	0.384	0.684	0.849	0.588	0.409	0.916
0.764	0.657	0.938	0.92	0.657	0.403	0.959
0.561	0.571	0.5	0.949	1	0.96	0.566
0.883	0.432	0.674	0.697	0.594	0.419	0.63
0.721	0.502	0.582	0.768	0.711	0.457	0.482
0.8	0.711	0.464	0.709	0.63	0.471	0.542
0.736	0.393	0.542	0.974	0.612	0.414	0.623
0.419	0.654	0.472	0.489	0.599	0.35	0.484
0.503	0.908	0.548	0.752	0.564	0.408	0.654
0.936	0.646	0.522	0.596	0.619	0.373	0.414
0.429	0.482	0.489	0.464	0.651	0.366	0.384
0.522	0.51	0.563	0.593	0.675	0.342	0.404
0.522	0.511	0.566	0.597	0.562	0.346	0.512
0.791	0.531	0.499	0.592	0.56	0.347	0.519
0.385	0.717	0.551	0.583	0.626	0.367	0.417
0.497	0.56	0.508	0.452	0.736	0.381	0.43
0.509	0.422	0.491	0.793	0.676	0.351	0.483
0.478	0.473	0.539	0.576	0.627	0.376	0.534
0.483	0.653	0.527	0.743	0.595	0.45	0.609
0.654	0.68	0.497	0.532	0.732	0.399	0.408
0.652	0.481	0.526	0.887	0.531	0.425	0.439
0.539	0.443	0.478	0.52	0.57	0.357	0.412
0.839	0.377	0.499	0.646	0.672	0.36	0.462
0.701	0.413	0.517	0.492	0.684	0.363	0.454
0.511	0.439	0.488	0.646	0.619	0.334	0.437

Because different indexes have different influences on soil quality, corresponding weight coefficients should be assigned to different indexes in the evaluation process, and the weight matrix should be obtained by AHP:

$$W^T = (0.076\ \ 0.053\ 0.037\ 0.071\ 0.540\ \ 0.089\ 0.078)$$

According to the formula

$$r(y_0, y_i) = \sum_{j=1}^{m} r_{ij} w_j (i = 1, 2, ..., n)$$

The grey relational degree of each index in the reference plot was calculated

Table 3-12 Index coefficient and ranking

Sample area	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
score	0.503	0.636	0.598	0.517	0.587	0.578	0.672	0.525	0.601	0.685
The sorting	22	27	24	3	21	19	5	9	2	1
Sample area	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20
Score	0.586	0.541	0.538	0.619	0.535	0.512	0.612	0.510	0.549	0.527
The sorting	10	17	8	6	11	16	4	14	7	23
Sample area	Y21	Y22	Y23	Y24	Y25	Y26	Y27	Y28	Y29	Y30
Score	0.511	0.698	0.594	0.601	0.528	0.506	0.689	0.571	0.546	0.502
The sorting	15	30	25	26	20	29	28	13	18	12

Figure 3-2 intuitively shows the change trend of soil fertility associated with gray.

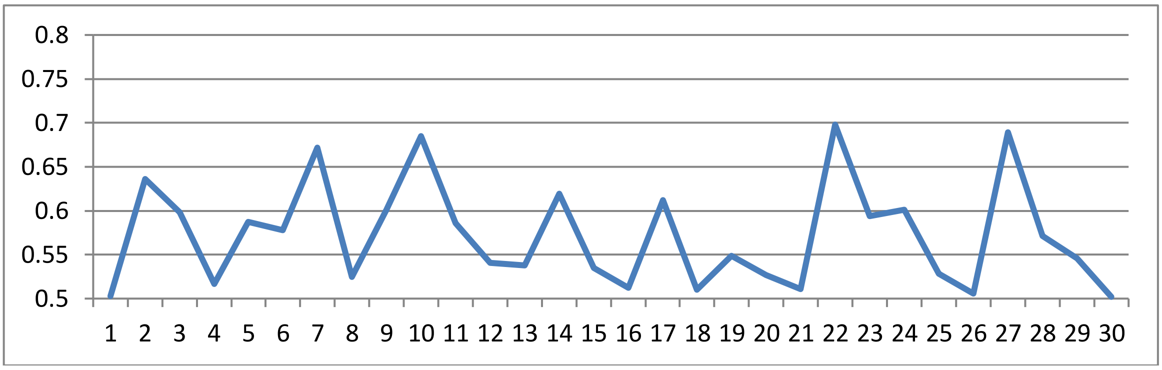

Figure3-2 A gray-related soil fertility trend chart

As can be seen from the figure above, the general trend is that soil fertility first increases and then decreases. The evaluation model based on grey correlation is applied to the study of soil fertility in this paper, and the obtained evaluation results can reach a high accuracy rate.

By comparing the principal component score with the gray correlation score, it can be found that the gray correlation has a better effect than the principal component analysis and is more suitable for the analysis and evaluation of soil fertility.

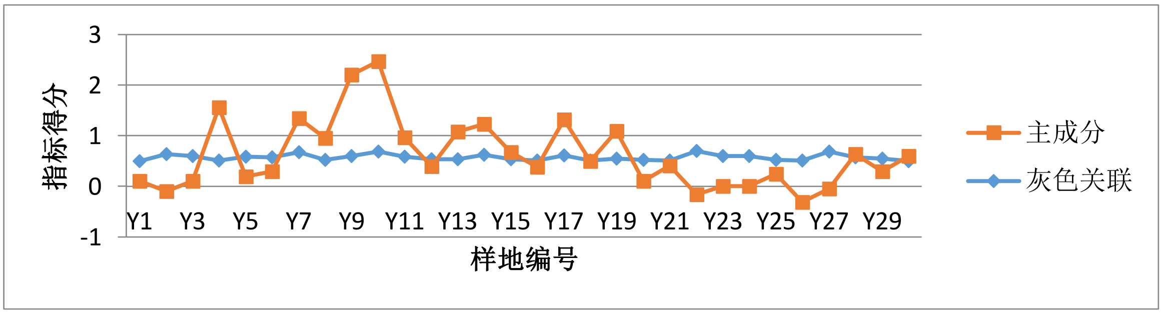

Figure 3-3 Effect comparison

4. Conclusion

In this paper, the evaluation model of grey correlation analysis and the comprehensive evaluation model of principal component analysis were established respectively, and the soil fertility of the outpost farm was comprehensively evaluated. It is found that the evaluation results of the two models are different. During the evaluation process, the standardization of the two evaluation methods is inconsistent, which leads to the slight difference of the evaluation results. Firstly, the comprehensive evaluation model of principal component analysis was used to evaluate soil fertility. In addition, the influence degree of each evaluation index on soil fertility was ranked from small to large as: available potassium, organic matter, hydrolyzed nitrogen, total potassium, total phosphorus, available phosphorus, and total nitrogen. Based on the principal component analysis (PCA) comprehensive evaluation model, the comprehensive soil fertility score of each outpost farm can be clearly seen. Secondly, the comprehensive evaluation model of gray correlation analysis is used to evaluate each outpost farm. The data showed that gray correlation was a better indicator of soil fertility than principal component analysis.

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References

[1] Zheng Li-chen, Yu Wan-tai, Ma Qiang, et al. Research progress on comprehensive evaluation of farmland soil fertility [J]. Acta Ecologica Sinica, 2004. 2(5): 156-161.

[2] Lindenmayer DB, Margules CR, Botkin DB. Indicators of Biodiversity for Ecologically Sustainable Forest Management [J]. Conservation Biology, 2000, 14(4): 941-950.

[3] Sun K G, Wang L G. Effect of different fertilization practices on yield of a wheat maizerotation and soil fertility[J]. Pedosphere. 2002, 12(3): 283-288.

[4] Xu Ming-xiang, Liu Guo-bin, ZhaoYun-Ge. Evaluation index of soil quality in loess Hilly region [J]. Journal of Applied Ecology, 2005, 16(10): 1843-1848.

[5] Wang Cai-de, Chang Qing-rui, Liu Jing, et al. Soil fertility evaluation in Shaanxi province supported by soil spatial database [J]. Journal of Northwest A&F University (Natural Science edition), 2008, 36(11): 105-110.

[6] Wang WN, Lu JW, Lu MX, etal. Status quo and variation of soil fertility in paddy field a case study of Hubei Province[J]. ActaPedologicaSinica, 2012, 49(2): 319–330.

[7] Chen Huan, Cao Chengfu, Zhang Cun-ling, et al. Evaluation of long-term fertilization on the fertility of black sand ginger soil based on principal component cluster analysis [J]. Acta Soilica Sinica, 2014, 51(03): 609-617.

[8] Du Dong, Pang Qinghua, Wu Yan et al. Modern comprehensive evaluation method and Case Selection [M]. Beijing: Tsinghua University Press, 2011: 11-21.

[9] Zhao Qing, Wang Zilong, Jiang Qiuxiang, et al. Application of attribute identification theory Model in comprehensive evaluation of soil fertility [J]. Agricultural System Science and Comprehensive Research,2007(03): 265-267.

[10] Lu Xiaonan, Lu Yunfu, Wang Renchao. Numerical Comprehensive Evaluation of red soil fertility in Zhejiang Low Hills [J]. Soil Bulletin,2000, 31(3): 107-110.

[11] Bi Xiaoli, Hong Wei. Progress in comprehensive evaluation of ecological environment. Agricultural system Science and Comprehensive Research [J]. 2001, 17(2): 122-124, 126.

[12] Pang Yuanming. Progress in soil fertility evaluation [J]. Shanxi Agriculture and Forestry Science, 2009, 37(2): 85-87.

[13] Liu Zhan-feng, Fu Bo-jie, Liu Guo-hua et al. Soil quality and soil quality indexes and their evaluation [J]. Acta Ecologica Sinica,2006(26): 901-913.

[14] Luo Dongqi, Bai Jie, Xie Deti, et al. Methods for evaluating soil fertility [J]. Soil and environment, 2002, 11(2): 202-205.