

Research on the Performance Evaluation of Agricultural Non-point Source Pollution Prevention and Control in Anhui Province

-- Based on the Entropy Weight TOPSIS Method

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Abstract

Agricultural and rural pollution control is a key and difficult issue in the revitalization of rural ecology in China, and agricultural non-point source pollution, as the main source of pollution, is of the utmost importance. Building a performance audit system for agricultural non-point source pollution prevention and control is beneficial for measuring the degree of agricultural non-point source pollution prevention and control, identifying constraints, and is of great significance for agricultural non-point source pollution prevention and control. This article selects Anhui Province as the research object, and based on the PSR model of environmental resource management, constructs an agricultural non-point source pollution performance evaluation system. On the basis of this evaluation system, the entropy weight TOPSIS method is used to empirically investigate the agricultural non-point source pollution prevention and control data in Anhui Province from 2017 to 2021, and corresponding suggestions are proposed based on the specific analysis results.

Keywords

Agricultural Non-point Source Pollution; PSR Model; Performance Evaluation; Entropy Weight TOPSIS.

1. Introduction

Governing agricultural and rural pollution is an important task in comprehensively promoting rural revitalization. It is imperative to implement performance audits of resource and environmental pollution control and establish a sound performance audit evaluation system. Agricultural non-point source pollution refers to pollutants generated during agricultural production and rural life, which are caused by organic matter or nitrogen and phosphorus pollution through surface runoff or soil infiltration [1]. The causes of agricultural non-point source pollution mainly include four aspects: planting, livestock breeding, aquaculture, and rural life [2]. Domestic and foreign scholars have focused on the spatial and temporal evolution, influencing factors, and governance paths of agricultural non-point source pollution in their research perspectives [3-4]. The research objects mainly focus on provincial, municipal, specific river basins or lakes [5-7]. Regarding the research on agricultural non-point source pollution prevention and control auditing, Guo Pengfei (2020) [8] analyzed the audit objectives of agricultural non-point source pollution prevention and control in China, and proposed the key content and practical path of audit supervision. In terms of environmental pollution control performance auditing, Li Chunyu (2016) [9] constructed an atmospheric environmental governance performance system based on the PSR model; Yuan Hongchuan et al. (2021) [10] constructed a water environmental governance performance evaluation DPSIR model; Zhang

Mei et al. (2020) [11] initially established a rural environmental performance evaluation index system, providing ideas for rural environmental performance evaluation in China.

To sum up, scholars at home and abroad have conducted research on the performance audit of agricultural non-point source pollution prevention and control from a single perspective, such as water environment, atmospheric environment, and rural environment. However, the overall performance of agricultural non-point source pollution prevention and control has not been fully explored, and there is a lack of unified evaluation system and standard. Based on existing research and practice, this article attempts to construct an agricultural non-point source pollution prevention and control performance audit evaluation system based on the PSR model, in order to provide theoretical guidance for establishing a scientific and effective agricultural non-point source pollution performance evaluation system, and to provide support for the development of related audit work.

2. Theoretical Model and Indicator System

2.1. PSR Model

The full name of the PSR model is Pressure-State-Response, which is a commonly used evaluation model in the sub-discipline of ecosystem health evaluation in the discipline of environmental quality evaluation [12]. It is a conceptual model jointly established by the Organization for Economic Cooperation and Development and the United Nations Environment Programme. The application of the PSR model is mostly for the analysis and evaluation of environmental issues, while its application to agricultural non-point source pollution prevention and control performance audit is a new form of model application.

Based on the PSR model and the actual requirements of the country's "Three Rural Issues", and following the basic idea of "focusing on key points, treating by regions, and managing carefully", we construct three dimensions of agricultural non-point source pollution prevention and control: first, the pressure dimension of non-point source pollution, which refers to the dual pressure on the natural environment caused by agricultural and domestic sources, both of which are not optimistic; second, the status dimension of non-point source pollution, which refers to the severe environmental pollution in rural areas and the difficulty of rectification; third, the measure dimension of pollution prevention and control, which includes the government actively taking relevant measures to alleviate the problem of non-point source pollution and improve the ecological environment. The three dimensions interact with each other, thus establishing a complete PSR model system.

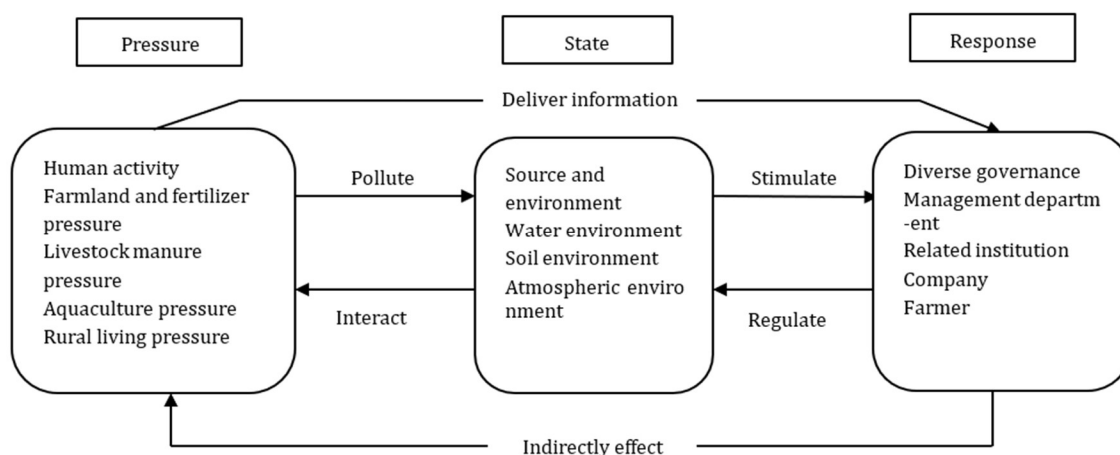


Figure 1. PSR model framework for agricultural non-point source pollution prevention and control performance

2.2. Indicator System based on PSR Model

Table 1. Performance evaluation system for agricultural non-point source pollution control under the PSR model

Target layer	Guideline layer	Indicator layer		Unit of measurement	Nature of indicator
Performance of agricultural non-point source pollution prevention and control	Pressure	P1	Emission of chemical oxygen demand per unit of gross output value of agriculture, forestry, animal husbandry and fishery	ton/100 million yuan	reverse indicator
		P2	Ammonia nitrogen emission per unit of gross output value of agriculture, forestry, animal husbandry and fishery	ton/100 million yuan	
		P3	Total nitrogen emission per unit of gross output value of agriculture, forestry, animal husbandry and fishery	ton/100 million yuan	
		P4	Total phosphorus emission per unit of gross output value of agriculture, forestry, animal husbandry and fishery	ton/100 million yuan	
	Status	S1	Proportion of excellent water quality in national assessment sections of surface water	%	Positive indicators
		S2	Percentage of days with good air quality on average	%	
		S3	Year-on-year reduction rate of fertilizer application amount (net amount)	%	
		S4	Decrease rate of pesticide application compared to the same period	%	
	Response	R1	Energy conservation and environmental protection fiscal expenditure	Ten thousand yuan	Positive indicators
		R2	Comprehensive utilization rate of livestock and poultry manure	%	
		R3	Comprehensive utilization rate of straw	%	
		R4	Harmless treatment rate of rural household waste	%	

The principles for selecting performance evaluation indicators for agricultural non-point source pollution are as follows. First, scientific and reliability. Construct an indicator system based on scientific research methods to determine scientific indicators, while ensuring the authenticity and reliability of the indicator data sources. Second, the principle of representativeness. On the basis of comprehensive consideration of various factors, select the most representative indicators related to agricultural non-point source pollution prevention and control. Third, the principle of independence. Each indicator cannot be repeated and will not be affected by any other factors [13]. Based on the conceptual framework of the PSR model

and the principle of indicator selection, the pressure indicators are measured by the ratio of agricultural non-point source pollutant emissions to the total output value of agriculture, forestry, animal husbandry and fishery. The smaller the indicator value, the less pressure human activities have imposed on the natural environment. The state indicators are measured by the improvement of environmental quality and the reduction of pollutant emissions. The larger the indicator value, the better the improvement of agricultural non-point source pollution. The reflection indicators are measured by the financial expenditure and action progress generated by the prevention and control of agricultural non-point source pollution. The larger the indicator value, the better the implementation of prevention and control actions. The indicator system constructed in this article is shown in Table 1.

3. Performance Evaluation

3.1. Data Source and Processing

The data in this article are from the China Environmental Statistics Yearbook, the China Animal Husbandry and Veterinary Yearbook, the China Rural Statistics Yearbook, the Anhui Statistical Yearbook, and the Anhui Provincial Environmental Status Bulletin. The empirical data on agricultural non-point source pollution in Anhui Province from 2017 to 2021 were selected and quantitatively analyzed using the performance evaluation system constructed. Among them, the emission data of chemical oxygen demand, ammonia nitrogen, total nitrogen, and total phosphorus in agricultural non-point source pollutants cannot be directly obtained. According to the "Manual of Emission Source Statistical Survey Production and Pollution Accounting Methods and Coefficients" issued by the Ministry of Ecology and Environment of China in 2021, the emission coefficients method was used to calculate the pollutant emissions from four aspects: planting industry, livestock and poultry breeding industry, aquaculture industry in agricultural sources, and rural domestic sewage in domestic sources.

In order to facilitate subsequent analysis, the maximum-minimum method is used to standardize the data to eliminate the impact of differences in dimensionality and value ranges between indicators. The specific formula is as follows:

Positive indicators:

$$X_{ij}^+ = \frac{x_{ij} - \min\{x_{ij}\}}{\max\{x_{ij}\} - \min\{x_{ij}\}} \quad (1)$$

Negative indicators:

$$X_{ij}^- = \frac{\max\{x_{ij}\} - x_{ij}}{\max\{x_{ij}\} - \min\{x_{ij}\}} \quad (2)$$

Among them, X_{ij} represents the standardized data of the j th evaluation index in the i -th year; x_{ij} It represents the data of the j th evaluation indicator in the i -th year before data processing. i represents the indicator year, and j represents the indicator category. After standardized processing, P1, P2, P3, P4, S1, S2, S3, S4, R1, R2, R3, R4 are represented by NP1, NP2, NP3, NP4, NS1, NS2, NS3, NS4, NR1, NR2, NR3, NR4.

3.2. Determination of Indicator Weight

The entropy weight method is used to calculate the weights of each evaluation index at the criteria and indicator levels. The specific calculation process and results are shown below.

(1) Calculate the proportion of the j th indicator in the i th year P_{ij} .

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^5 x_{ij}} \tag{3}$$

(2) Calculate the entropy value of the jth indicator e_j .

$$e_j = \frac{\sum_{i=1}^5 P_{ij} \ln(P_{ij})}{[-\ln(5)]} \tag{4}$$

(3) Calculate the weight of each indicator w_j .

$$w_j = \frac{1-e_j}{\sum_{j=1}^m (1-e_j)} \tag{5}$$

Table 2. The weight of each indicator in the performance evaluation system for agricultural non-point source pollution prevention and control

Guideline layer	Weighted	Indicator layer		entropy value	Weighted
Pressure	0.272	NP1	Emission of chemical oxygen demand per unit of gross output value of agriculture, forestry, animal husbandry and fishery	0.802	0.065
		NP2	Ammonia nitrogen emission per unit of gross output value of agriculture, forestry, animal husbandry and fishery	0.782	0.071
		NP3	Total nitrogen emission per unit of gross output value of agriculture, forestry, animal husbandry and fishery	0.778	0.073
		NP4	Total phosphorus emission per unit of gross output value of agriculture, forestry, animal husbandry and fishery	0.808	0.063
Status	0.400	NS1	Proportion of good water quality in national assessment sections of surface water	0.769	0.075
		NS2	Percentage of days with good air quality on average	0.754	0.081
		NS3	Year-on-year reduction rate of fertilizer application amount (net amount)	0.715	0.093
		NS4	Year-on-year reduction rate of pesticide application amount	0.54	0.150
Response	0.328	NR1	Financial expenditure on energy conservation and environmental protection	0.471	0.173
		NR2	Comprehensive utilization rate of livestock and poultry manure	0.859	0.046
		NR3	Comprehensive utilization rate of straw	0.829	0.056
		NR4	Innocuous treatment rate of rural household waste	0.837	0.053

3.3. TOPSIS Evaluation Analysis

The TOPSIS method was used to evaluate and rank the performance of agricultural non-point source pollution prevention and control in Anhui Province in each year. The specific steps and calculation results are as follows.

(1) Weighted decision matrix V.

$$V = X_{ij} \cdot w_j = \{v_{ij}\}_{m \cdot n} \tag{6}$$

Where, V is the weighted decision matrix, and m and n represent the row and column numbers of the matrix, respectively.

(2) Determine positive and negative ideal solutions V^+, V^- .

$$V^+ = \{\max v_{ij} | j = 1, 2, 3, \dots, m\} = \{v_1^+, v_2^+, v_3^+, \dots, v_m^+\} \tag{7}$$

$$V^- = \{\min v_{ij} | j = 1, 2, 3, \dots, m\} = \{v_1^-, v_2^-, v_3^-, \dots, v_m^-\} \tag{8}$$

(3) Calculate the gap between each evaluation index and the positive and negative ideal solutions D_i^+, D_i^- .

$$D_i^+ = \sqrt{\sum_{j=1}^m (v_{ij} - v_j^+)^2} \tag{9}$$

$$D_i^- = \sqrt{\sum_{j=1}^m (v_{ij} - v_j^-)^2} \tag{10}$$

D_i represents the distance between the evaluation object and the positive or negative ideal solution, with a larger value indicating a greater distance. D_i^+ The larger the value, the farther away from the positive ideal solution; D_i^- The larger the value, the farther away from the negative ideal solution.

(4) Measure the closeness of the evaluation object to the optimal state C_i :

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{11}$$

C_i is used to measure the degree of proximity between the performance of agricultural non-point source pollution prevention and control in each year from 2017 to 2021 and the optimal state, with a value ranging from 0 to 1. The larger the value is, the better the performance in that year.

According to the research of domestic and foreign scholars [14], the performance is divided into four grades: poor, intermediate, good and excellent according to the degree of closeness, as shown in Table 3. The final result of TOPSIS evaluation is shown in Table 4. The results show that the performance grade was poor in 2017, and the performance was transformed into a good grade in 2021. The overall agricultural non-point source pollution in Anhui Province showed an upward trend from 2017 to 2021.

Table 3. Performance rating standards for agricultural non-point source pollution

Value range of closeness	Performance grade
0-0.3	Poor
0.3-0.6	Intermediate level
0.6-0.8	Good
0.8-1.0	excellent grade

Table 4. Performance evaluation system for agricultural non-point source pollution prevention and control in Anhui Province

Years	Positive ideal solution distance (D_i^+)	Negative ideal solution distance (D_i^-)	Proximity (C_i)	Performance rating	Sorting
2017	0.946	0.106	0.101	relatively poor	5
2018	0.801	0.277	0.257	relatively poor	4
2019	0.447	0.730	0.620	Good.	2
2020	0.604	0.670	0.526	Intermediate level	3
2021	0.499	0.827	0.624	Good	1

4. Conclusion and Suggestion

4.1. Conclusion

Based on the PSR model, this article constructs an evaluation index system for agricultural non-point source pollution performance auditing, and uses the entropy weight TOPSIS method to evaluate the performance of non-point source pollution prevention and control in Anhui Province.

In terms of performance level, the closest degree in 2017 was the lowest, and the performance level of agricultural non-point source pollution prevention and control was poor. The closest degree in 2021 was the highest, and the prevention and control performance was significant. The performance of agricultural non-point source pollution prevention and control showed an overall upward trend with time. From the perspective of each system, the agricultural pollution non-point source pollution status system was the most important in evaluating the performance of agricultural non-point source pollution prevention and control, followed by the response system, and the pressure system was the last. In the pressure system, the total nitrogen emission per unit of agricultural, forestry, animal husbandry and fishery production had the highest weight and had the greatest impact on non-point source pollution. In the status system, the reduction rate of pesticide application volume had the highest weight and contributed the most. In the response system, the energy conservation and environmental protection fiscal expenditure had the highest weight and had the greatest impact. The above conclusions are in line with objective reality, and have certain scientific and reliability.

4.2. Suggestions

This study constructs a performance evaluation system based on the situation of agricultural non-point source pollution prevention and control in Anhui Province from 2016 to 2017, which enriches the audit evaluation ideas and methods of agricultural non-point source pollution prevention and control to a certain extent. However, due to data acquisition and conditions limitations, the indicator system still has some shortcomings, such as considering the impact of spatial differences and the subjective nature of indicator selection. Therefore, further research and improvement are needed. The following three suggestions are put forward for the improvement of agricultural non-point source pollution prevention and control performance audit work in the future:

First, from the perspective of pressure system, the nitrogen emissions of agricultural, forestry, animal husbandry and fishery production are excessive, and it is necessary to minimize the nitrogen emissions in animal husbandry and fishery, and regularly detect the emission of trace elements in the industry. At the same time, the total phosphorus emissions of agricultural, forestry, animal husbandry and fishery are relatively low, and it is necessary to continue to control the total phosphorus emissions within a certain range, gradually reduce the nitrogen and phosphorus emissions, and promote the improvement of water quality in the basin. Second,

from the perspective of state system, on the one hand, we should continue to reduce the use of pesticides and adhere to green development. On the other hand, data show that the current water quality of surface water is worrying, and it is necessary to control the emission of pollutants, increase the treatment of sewage and industrial wastewater, and focus on the treatment of sewage discharge. Third, from the perspective of response system, the government has invested a lot of funds to support energy conservation and environmental protection. On this basis, it is necessary to increase the budgetary expenditure on environmental governance, pay close attention to the stable implementation of environmental pollution prevention and control work, and promote infrastructure construction.

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