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Research on the Governance of Rural Environmental Pollution in Heilongjiang Province Based on the Environmental Kuznets Curve

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ABSTRACT

At present, the effective management of the rural environment has drawn the attention of the entire global community. Heilongjiang Province majors in agriculture and animal husbandry resources. Compared with urban environmental pollution, the pollution caused by agriculture and animal husbandry has a strong impact on the use of agricultural elements and environmental constraints. At the same time, it has the characteristics of high governance cost, high governance difficulty, and difficulty in being monitored. In this study, the environmental Kuznets curve is used to verify the relationship between rural environmental pollution and economic growth in Heilongjiang Province, and a linear regression model is designed to verify time series data and indicators. The results show that the phenomenon of rural water pollution has become common in Heilongjiang Province, the discharge of rural environmental pollutants has exceeded the safe discharge limit value, and the pollution degree of the rural environment in Heilongjiang Province has exceeded the safety warning value at least, and it is very necessary for its treatment. This study enriches the research methods and content of the performance evaluation of rural environmental governance in my country helps to objectively evaluate the governance issues of the rural environment in Heilongjiang Province, and can be a functional area of grain production that is highly dependent on resources and environmental constraints of the same kind in my country. Rural environmental governance provides a universal reference.

INTRODUCTION

Heilongjiang Province is a large agricultural and animal husbandry province in China. Its arable land area and grain output are ranked first in the country. The development level of planting and animal husbandry is relatively high. However, in rural areas, the extensive growth mode has increased environmental pollution and severely imbalanced rural ecosystems. and restricted the development of the rural economy in Heilongjiang. While rural environmental pollution damages the rural ecological environment, it also has an impact on the health of rural residents, and contaminated agricultural products will further reduce the quality of life of urban residents. Therefore, only by fully understanding the characteristics and hazards of rural environmental pollution and exploring its causes can we propose targeted measures for the treatment of rural environmental pollution. Agricultural environmental pollution in Heilongjiang mainly includes agricultural chemical fertilizers, pesticide use, livestock and poultry breeding, plastic film pollution, soil erosion, forest vegetation loss, etc. Among them, chemical fertilizers and pesticides are important factors that cause soil compaction, reduced regeneration effects, and toxic pollution of agricultural products. It is also the main source of the deteriorating water quality of rivers and lakes.

The current health problems caused by environmental pollution are becoming more and more obvious, such as asthma (Choi et al. 2017), lung cancer (Wang et al. 2016), and mental illness (Roberts et al. 2019). At present, there is more and more research on the problems caused by environmental pollution in academia. For example, studies on the deterioration of water quality have predicted the trade-off between urban models and the production of ecosystem services: scenario analysis of alternatives to rapid urbanization area sprawl (Shoemaker et al. 2019), the impact of different media on constructed wetlands for rural domestic sewage treatment (Lu et al. 2016), the long-term impact of human factors on non-point source pollution in the upper reaches of the Yangtze River (Ding et al. 2019), rural watershed management (Ding et al. 2019), sustainable agricultural intensification practices and rural food security (Yahaya et al. 2018) and other studies. Research on pollution trends includes the changes in gas-phase air pollutants in New York State (Civerolo et al.

2017) and the temporal and spatial trends of ground-level ozone concentration and indicators in France from 1999 to 2012 (Sicard et al. 2016). Research on health risk assessment includes urban acoustic environment Quality evaluation (Di et al. 2018), the use of targeted ecological pharmacovigilance interventions to control antibiotic pollution in rural aquatic environments (Wang et al. 2019), the feasibility study of candidate reference materials for PM2.5 ions (Emma et al. 2018), Chinese residents Assessment of total environmental exposure of heavy metals (Zhao et al. 2019), Chinese motor vehicle emissions in 2006 and 2010 (Tang et al. 2016), etc. The research on the problems caused by environmental pollution has gradually matured, but there is a lack of research on the problems of environmental pollution control in Chinese rural areas.

Therefore, this study analyzes in detail the current situation of rural environmental pollution in Heilongjiang in the past ten years, based on the environmental Kuznets curve, to study the problems of rural environmental pollution control in Heilongjiang, and points out the current problems in the rural environmental pollution control in Heilongjiang. This study has certain reference values for future rural environmental governance.

MATERIALS AND METHODS

Rural environmental pollution in Heilongjiang is mainly divided into the pollution of agricultural production, pollution of rural life, pollution of sewage, and pollution from urban to rural areas. Rural environmental pollution in Heilongjiang has an "inverted U-shaped" relationship with the level of regional economic development, that is, when the level of economic development is relatively low, the rural environmental pollution is relatively low. With the continuous development of the economy, environmental pollution continues to deteriorate. The peak, that is, after the per capita GDP reaches a certain level, the rural environmental pollution will gradually improve with the improvement of the level of economic development. Therefore, based on the environmental Kuznets curve, this paper studies the rural environmental pollution control in Heilongjiang Province.

Environmental Kuznets Curve

The Environmental Kuznets Curve (EKC) describes Heilongjiang as follows: rural environmental pollution in Heilongjiang has an "inverted U-shaped" with the level of regional economic development, that is, when the economic development level is relatively low, the rural environmental pollution is relatively low. As the economy continues to develop, environmental pollution continues to deteriorate. When it reaches a certain peak, that is, when the per capita GDP reaches a certain level, rural environmental pollution will gradually improve with the improvement of economic development.

The theoretical reference of this study is to use this hypothesis to verify the relationship between rural environmental pollution and economic growth in Heilongjiang. The verification model is designed as follows:

$$N=\beta_0+\beta_1 Pergdp+\beta_2 Pergdp^2+\varepsilon \quad \ldots(1)$$

$$P=\beta_0+\beta_1 Pergdp+\beta_2 Pergdp^2+\eta \quad \ldots(2)$$

In this model, *N,* and *P* respectively represent the total nitrogen emissions and total phosphorus emissions of rural environmental pollution in Heilongjiang in y year and represent the per capita GDP of Heilongjiang in a certain year. Compared with total GDP, per capita GDP can more clearly reflect the real effect of environmental pollution on the level of economic development. b_0, $b_{1,}$ and b_2 are the coefficient values in the model, $\varepsilon$and η are denoted as random error terms respectively. The verification results of the model can be divided into the following situations:

(a) When $\beta_1 \neq 0$, $\beta_2 = 0$, there is a linear relationship between economic growth and environmental pollution;

(b) When $\beta_1 < 0$, $\beta_2 > 0$ there is an "inverted U-shaped" relationship between economic growth and environmental pollution; the inflection point of per capita GDP at this time is $Pergdp^* = -\beta_1/(2*\beta_2)$;

(c) When $\beta_1 > 0$, $\beta_2 < 0$, there is a "U-shaped" relationship between economic growth and environmental pollution.

Eco-environmental Factors of Governance Under the Framework of Environmental Kuznets Curve Analysis

Heilongjiang is a large ecological environment province with abundant natural resources. For rural environmental pollution control, the introduction of the ecological environment is quite important. Therefore, add the concept of ecological environment to the EKC curve, including environmental tolerance thresholds and safety warning lines. The pollutant discharge corresponding to the environmental tolerance threshold refers to the maximum amount of pollution that the ecological environment can withstand. Once the pollution exceeds this upper limit of pollution, the pollution is irreversible. No matter how the economy repairs the environment, the environment cannot be restored. The discharge of pollutants corresponding to the safety cordon refers to the discharge of a pollutant that has had a certain impact on the environment and must be treated in time. It is the limit value of the safe discharge of pollution at this point. If there is a timely "response" to environmental pollution, the damaged environment can still be repaired.

As shown in Fig. 1, within a certain period of time, points A, B, and C are the inflection points of three different "inverted U-shaped" curves and the pollutant emissions at the inflection points (that is the maximum pollutant emissions of the EKC curve). They are P_A, P_B, and P_C. The point where the environmental tolerance threshold line intersects the vertical axis is P_1, and the point where the safety pollution warning line intersects the vertical axis is P_2. Pollutant emissions $P_A<P_2<P_B<P_1<P_C$.

Definition of pollution level: assuming that other conditions remain unchanged, the EKC curve with the inflection point A is called the level-A pollution level curve, indicating that the pollution is at a relatively low level and has not reached the safety pollution warning line, which is an ideal state. The curve with the inflection point B is called the EKC curve of level B. The pollution at the inflection point is between the warning line and the threshold line. Economic growth has caused a bad impact on the environment, but the damaged environment can be repaired. The EKC curve with the inflection point C is called the level-C curve. It exceeds the environmental tolerance threshold. The pollution generated around inflection point C is irreparable to the environment. If the pollution level is on the curve of B or C, active control measures should be taken.

Rural water pollution has become more common in Heilongjiang, and the discharge of rural environmental pollutants has exceeded the safe discharge limit. This study roughly judges that the curve of the relationship between rural environmental pollution and economic growth in Heilongjiang must not be the curve of level-A in Fig. 6, but level B or level C. The level of pollution at the turning point has at least exceeded the safety warning value.

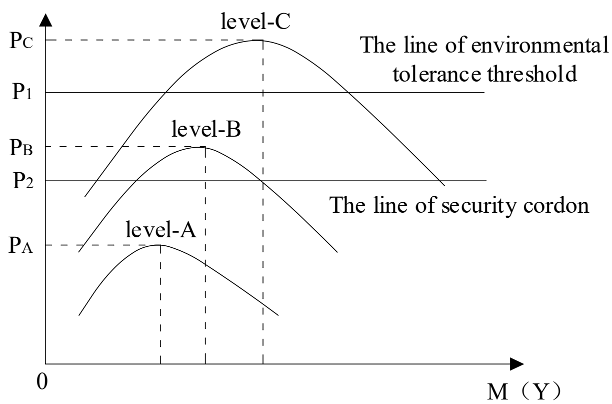

Fig. 1: The inflection point behind the threshold line and the safety guard line.

Theoretical Analysis of Governance Function Under the Framework of Environmental Kuznets Curve Analysis

Assuming that there is only one family in the economy and there are no externalities, the Pareto optimal of the individual family is the Pareto optimal of the whole society. The family utility function expression is as follows:

$$U=U(C, P) \tag{3}$$

In the above formula, household consumption is C, and consumption C will produce pollution as P. $U_C>0$ and $U_P<0$, respectively, indicate that the utility of the household increases with the increase in consumption, and decreases with the increase in pollution. There are two ways to reduce pollution, one is to directly reduce consumption and thus reduce the amount of pollution, and the other is to control the amount of pollution. When pollution is treated, the number of resources required to be input is E, assuming that the amount of pollution P is positively correlated with the amount of consumption C and the amount of governance resource input E, respectively, the pollution is a function of C and E, and the expression is as follows:

$$P=P(C, E) \tag{4}$$

In the above formula, $PC<0$ and $PE<0$, respectively, mean that pollution increases with the increase in consumption and decreases with the increase of the input of treatment resources. Assuming that the household income is constant, the income can be consumed and governed, and the relative cost of consumption and governance is standardized to 1, then there is the following formula:

$$M=C+E \tag{5}$$

In the above formula, M is the total household income. Assuming that the utility function:

$$U=C\text{-}zP \tag{6}$$

In the above formula, z is a constant greater than zero, representing the marginal utility loss of pollution. Suppose that the pollution function is formula (7), and it is assumed that unit 1 of consumption will produce unit 1 of pollution, C is the total pollution amount before treatment, and the pollution treatment function adopts the form of the C-D function.

$$P=C\text{-}C^{\alpha}E^{\beta} \tag{7}$$

The family's behavioral choice equation is the maximum utility of M under certain conditions, namely:

$$MaxU=C\text{-}zP \tag{8}$$

$$P=C\text{-}C^{\alpha}E^{\beta} \tag{9}$$

$$M=C+E \tag{10}$$

When z=1, $C^*=\frac{\alpha}{\alpha+\beta}M,\ E^*=\frac{\beta}{\alpha+\beta}M$

$$P^*(M)=\frac{\alpha}{\alpha+\beta}M-(\frac{\alpha}{\alpha+\beta})^{\alpha}(\frac{\alpha}{\alpha+\beta})^{\beta}M^{\alpha+\beta} \quad (11)$$

$$\frac{\partial P^*(M)}{\partial M}=\frac{\alpha}{\alpha+\beta}-(\alpha+\beta)(\frac{\alpha}{\alpha+\beta})^{\alpha}(\frac{\alpha}{\alpha+\beta})^{\beta}M^{\alpha+\beta-1} \quad (12)$$

When $\alpha+\beta=1$, , formula (12) is a constant, and P and M are linear relations.

When $\alpha+\beta\neq 1$, , the derivative of formula (12):

$$\frac{\partial^2 P^*(M)}{\partial M^2}=-(\alpha+\beta-1)(\alpha+\beta)(\frac{\alpha}{\alpha+\beta})^{\alpha}(\frac{\alpha}{\alpha+\beta})^{\beta}M^{\alpha+\beta-2} \quad (13)$$

When $\alpha+\beta<1$, , the scale benefit of pollution treatment is diminishing, and the second derivative value is greater than 0, so P and M have a U-shaped relationship.

When $\alpha+\beta>1$, the scale benefit of pollution treatment increases, and the second derivative value is less than 0, so P and M are in an inverted U-shaped relationship. That is, the shape described by the EKC curve.

The same can be proved, when $z\neq 1$, still only when the scale benefit of pollution control increases, P and M show an inverted U-shaped relationship.

RESULTS

In the research on the relationship between rural environmental pollution and economic growth in Heilongjiang Province, the time series data of rural environmental pollution in Heilongjiang Province from 2011 to 2020 in the "China Statistical Yearbook" was used. GDP per capita is calculated at the constant price of the initial calculation year to remove the price factor.

Model Estimation Result Analysis

According to the linear regression method and test, the relationship between the total nitrogen emission index and total phosphorus emission index of rural environmental pollution in Heilongjiang and the per capita GDP were used for the regression test. The results are shown in Table 3.

It can be seen from Table 3 that when the dependent variable is the total nitrogen emission of rural environmental pollution, the value of Adj-R2 is 0.8847, indicating that the explanatory power of total nitrogen in this model is 88.47%. It shows that in this model, the explanatory power of total nitrogen is 88.47%. The F value is large, and the model generally passes the 1% level of a significance test, which shows that the combined effect of the primary and square terms of the per capita GDP factor on total nitrogen emissions is significant. The first coefficient of per capita income is greater than zero, and the quadratic coefficient is less than zero, indicating that the relationship between total nitrogen emissions and per capita GDP presents an "inverted U-shaped" within a certain period of time, and an inflection point has appeared.

At the same time, when the dependent variable is the total phosphorus emission of rural environmental pollution, the value of Adj-R2 is 0.8567, indicating that the explanatory power of total phosphorus in this model is 85.67%. The F value is large, and the model generally passes the 1% level of a significance test, which shows that the combined effect of the primary and square terms of the per capita GDP factor on total phosphorus emissions is significant. The primary coefficient of per capita income is greater than zero, and the secondary coefficient is less than zero, indicating that the relationship between total phosphorus emissions and per capita GDP presents an "inverted U-shaped" within a certain period of time, and an inflection point has appeared.

Table 1: Gross national product and population in Heilongjiang (2011-2020).

Years	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
GDP (RMB 100 million)	6201.45	7065.00	8314.37	8587.00	10368.60	12582.00	13691.58	14382.93	15039.38	15083.67
Population (10,000)	3823.12	3824.37	3825.76	3826.43	3833.17	3834.75	3834.89	3835.09	3835.76	3812.17

Table 2: Variable name unit and descriptive statistical analysis.

Variable	Symbol	Unit	Average value	Standard deviation	Minimum	Maximum
Total nitrogen	N	10,000 tons	26.8381	4.2977	21.3452	28.4657
Total phosphorus	P	10,000 tons	2.7160	0.4431	2.3742	2.9372
GDP per capita	Pergdp	Yuan/person	2.9071	0.8653	1.6221	3.9567

The Factual Inference of Governance Under the Framework of Environmental Kuznets Curve Analysis

In view of the fact that there are many factors affecting rural environmental pollution, the corresponding treatment measures are also complicated. This section takes farmland fertilizers as an example to analyze the impact of treatment measures on the environmental Kuznets curve reflecting the relationship between farmland fertilizers and rural environmental pollution and economic growth. First, verify whether there is an environmental Kuznets curve between farmland chemical fertilizers and rural environmental pollution and economic growth.

(1) Verification of the curve of rural environmental pollution and economic growth caused by farmland chemical fertilizers

Using the theoretical analysis framework to verify the relationship between the environmental Kuznets curve and the economic growth of the rural environmental pollution caused by farmland fertilizers in Heilongjiang. The model to be verified is:

$$FN=\beta_0+\beta_1 Pergdp+\beta_2 Pergdp^2+\varepsilon \quad (14)$$

$$FP=\beta_0+\beta_1 Pergdp+\beta_2 Pergdp^2+\eta \quad (15)$$

Among them, *FN* and *FP* respectively represent the total nitrogen emissions and total phosphorus emissions of rural environmental pollution caused by farmland fertilizers in Heilongjiang. Pergdp represents the per capita GDP value of Heilongjiang. After calculation, the meaning of each variable and descriptive statistical analysis are shown in Table 4. The estimated results of the model are shown in Table 5.

It can be seen from table 5 that when the dependent variable is the total nitrogen emission of rural environmental pollution caused by farmland chemical fertilizers, the value of Adj-R2 is 0.8241, which means that in this model, the explanatory power of nitrogen emissions is 82.41%. The F value is relatively low. The model generally passes the 1% level of a significance test, which shows that the combined effect of the primary and square terms of the per capita GDP factor on fertilizer nitrogen emissions from farmland is significant. The first coefficient of per capita income is greater than zero, and the quadratic coefficient is less than zero, indicating that the relationship between total nitrogen emissions and per capita GDP presents an "inverted U-shaped" within a certain period of time, and an inflection point has appeared.

At the same time, when the dependent variable is the total phosphorus emission of rural environmental pollution caused by farmland chemical fertilizers, the value of Adj-R2 is 0.7465, indicating that the explanatory power of nitrogen emissions in this model is 74.65%. The F value is larger, the model is Overall, it has passed the 1% level of a significance test, which shows that the combined effect of the primary and square terms of per capita GDP factor on farmland fertilizer nitrogen emissions is significant. The first coefficient

Table 3: Model estimation results.

Variable	N	P
Pergdp	23.47***	2.14***
	(10.47)	(12.35)
$Pergdp^2$	-0.00047***	-0.000051***
	(-9.51)	(-8.79)
Constant	276639.9***	37063.72***
	(27.64)	(39.41)
Adj-R^2	0.8847	0.8567
F	93.17***	82.34***
Prob(F)	0.0000	0.0000

Note: *** means passing the 1% level of significance test; parentheses are T values.

Table 4: Variable name unit and descriptive statistical analysis.

Variable	Symbol	Unit	Average value	Standard deviation	Minimum	Maximum
Nitrogen emissions from farmland fertilizers	FN	10,000 tons	57.8435	3.2076	35.3351	78.4879
Phosphorus emissions from farmland fertilizers	FP	10,000 tons	37.7261	1.2561	28.3632	54.9271
GDP per capita	Pergdp	Yuan/person	2.9071	0.8653	1.6221	3.9567

Table 5: Model estimation results.

Variable	FN	FP
Pergdp	19.23^{***}	0.84^{***}
	(9.49)	(9.35)
$Pergdp^2$	-0.00034^{***}	-0.000018^{***}
	(-8.47)	(-6.71)
Constant	18675.9^{***}	7869.75^{***}
	(25.73)	(35.40)
Adj-R^2	0.8241	0.7465
F	73.77^{***}	51.34^{***}
Prob(F)	0.0000	0.0000

Note: *** means passing the 1% level of significance test; parentheses are T values.

of per capita income is greater than zero, and the quadratic coefficient is less than zero, indicating that the relationship between total nitrogen emissions and per capita GDP presents an "inverted U-shaped" within a certain period of time, and an inflection point has appeared.

DISCUSSION

Through the above analysis, we can know that some achievements have been made in the control of rural environmental pollution in Heilongjiang Province, but there are still five problems. They are the main body of environmental governance, residents' environmental awareness, grassroots environmental protection agencies, environmental supervision, and legal systems.

Problems in the Main Body of Rural Environmental Governance

Public economics believes that the non-competitive and non-exclusive characteristics of public products determine that a competitive market cannot provide sufficient public products. The supply of public goods by the private sector cannot be compensated through the market. Therefore, letting private individuals provide public products is bound to be a serious shortage of output, and it is impossible to meet the requirements for the effective allocation of resources.

The government is the main body of governance, and other public organizations are less involved, so the governance methods are relatively traditional. Although there are environmental protection departments at the provincial and county levels, they are subordinate to the government. As a quasi-public good, the environment is non-exclusive. Excessive consumption by some people will inevitably affect the use of others. However, the government attaches greater importance to economic development. Environmental pollution control is difficult to produce large economic benefits within a certain period of time.

It is difficult for law enforcement agencies to achieve good results in solving practical problems, and lack of voluntary and equal cooperation in all aspects. Corresponding to this is that the operation of traditional enterprises is relatively traditional. The disadvantage is that there is a fluke mentality when responding to government inspections. The equipment used is aging, and pollution cannot be monitored in real-time. The governance body lacks a long-term environmental governance and supervision mechanism. According to the author's investigation, after the establishment of environmental protection facilities and environmental protection projects in some areas, there is no special person to supervise and manage the normal operation of the project. The basic government has financial difficulties and lacks operating funds. Some facilities, In the end, became a decoration, which not only failed to achieve the effect of improving the rural environment, but wasted a lot of investment funds.

Problems in the Environmental Protection Awareness of Rural Residents

With the construction of new rural areas, the living standards in rural areas are getting higher and higher, but rural lifestyles have not undergone fundamental changes. Heilongjiang's rural areas are remote, scattered, and the villages and towns are not centralized. It is difficult to train and publicize environmental protection in rural areas. The literacy and comprehensive quality of the residents are not high, they are unclear about the importance of environmental hazards, excessively chasing economic benefits, and ignoring potential environmental pollution.

Some rural cadres do not have a good understanding of environmental protection. Some cadres believe that the vast rural area and loose residential living make it difficult to carry out proper environmental protection publicity and education, and it is difficult to build a new environmental protection system. Therefore, to pursue political achievements, blindly construct and introduce some polluting enterprises with serious pollution, and do not pay attention to the improvement of environmental protection infrastructure.

In many places, the construction and operation of sewage treatment plants and supporting pipeline networks have the phenomenon of focusing on cities and towns. At present, there is no township sewage treatment plant in some rural areas. The rural garbage collection, transfer, and harmless disposal systems are not sound, and almost 76% of rural domestic garbage has not been collected.

Problems in Rural Grassroots Environmental Protection Agencies

According to investigations, each township in the province is only equipped with part-time environmental protection personnel, and the counties and districts have not yet set up township environmental protection offices, so they cannot effectively deal with the increasingly heavy rural environmental problems. The existing rural environmental protection agencies do not have a fixed model. Each township environmental protection agency is set up in one sentence. The organization, personnel, funding, establishment, and responsibilities are not unified, and there is a lack of unified rules and regulations, and supervision procedures, which are also to a certain extent. Affected the work of grassroots environmental protection agencies.

If a township environmental protection station is established, the staff can live in the countryside for a long time, publicize policies, laws, and regulations to key polluters, and carry out various forms of publicity and education activities to cultivate farmers' environmental awareness.

At present, the main body of environmental governance in my country is the government. Due to geographical limitations, rural areas have the characteristics of vastness, dispersion, and complex pollution. The government cannot centrally manage the rural environment, which leads to insufficient administrative efforts.

Problems in Forces of Rural Environmental Supervision

The effects of environmental supervision, monitoring, and emergency response cannot meet the current increasing demands for environmental supervision. According to investigations, in most areas of the province, the three aspects of team building, equipment, and business premises of environmental supervision agencies have failed to meet the requirements of the national environmental supervision effect construction level one standard. Most of the construction of environmental monitoring effects in all districts did not meet the requirements of the national third-level standards.

Taking Shuangyashan City in Heilongjiang as an example, the staffing of the Environmental Monitoring Center Station, monitoring funding, and monitoring housing did not meet the second-level national environmental monitoring station construction standards in the central region. Baoqing County in Shuangyashan City has serious shortages of environmental protection personnel and funding guarantees. There are 33 people, 19 of whom are self-raised and self-financed. Self-raised funds reach 925,000 yuan, and there is an annual law enforcement funding gap of 300,000 yuan.

Problems in the Legal System of Rural Environmental Governance

There are not many administrative laws that regulate the administrative relationship between agriculture and the rural economy in Heilongjiang.

Some existing separate laws for the protection of the rural environment and resources can no longer meet the needs of rural environmental protection development. The rural cadres and the masses have strong policy awareness and weak legal awareness, resulting in many laws and regulations being policy-oriented in the process of rural implementation. The principle, practice, and flexibility of policies have replaced the compulsory and normative nature of laws and regulations. It has caused numerous obstacles to the construction of the rule of law in the rural market economy.

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