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Article

Investigation into the correlation between agricultural non-point source pollution and economic expansion in Xinjiang: A Kuznets Curve analysis

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Abstract: This study employs the output coefficient method to estimate the agricultural non-point source pollution load in Xinjiang and further analyzes its Environmental Kuznets Curve (EKC) characteristics. The objective is to conduct empirical research on the relationship between livestock, planting, rural living, and economic growth. The results indicate that: (1) The agricultural non-point source pollution load in Xinjiang, in terms of total nitrogen (TN) and total phosphorus (TP), is ranked from highest to lowest as follows: animal husbandry, planting industry, and rural life. The non-point source pollution from animal husbandry is predominantly attributed to cattle and sheep, while the planting industry's pollution mainly stems from wheat, corn, and cotton crops. The pollution associated with rural life is largely due to the increasing rural population; (2) The relationship between agricultural non-point source pollution and economic growth in Xinjiang is not only an inverted "U" type but also an inverted "N" type, "U" type, and linear type. This suggests that as the economy grows, the pollution load may initially increase, reach a peak, and then decline, or it may rise continuously or show a linear trend. The findings provide insights into the complex relationship between agricultural non-point source pollution and economic growth, which can inform policy-makers in developing strategies to balance economic development and environmental protection in the region.

Keywords: Xinjiang; agricultural non-point source pollution; load estimation; Kuznets Curve

Since the reform and opening up, with the deepening of resource intensive modern agriculture and the scale of animal husbandry, China's agricultural economy has developed rapidly, but a variety of agricultural environmental problems have become increasingly prominent. Among them, agricultural non-point source pollution has seriously hindered the sustainable development of rural ecological environment and social economy [1] (pp. 102–105). Agricultural non-point source pollution is mainly manifested in the excessive use of chemical fertilizers and pesticides, the discharge of livestock manure and rural domestic waste, etc. In recent years, China has successively issued the opinions of the Ministry of agriculture on combating agricultural non-point source pollution, the construction plan for the demonstration project of comprehensive treatment of agricultural non-point source pollution in key river basins (2016–2020), the action plan for the resource utilization of livestock and poultry manure (2017–2020), the strategic plan for Rural Revitalization (2018–2022), as well as the No. 1 central document in 2021 and other policy documents, which have proposed to continuously reduce the use of chemical fertilizers and pesticides, agricultural wastes have been utilized as resources, the rural ecological environment has been significantly improved, and the key requirements for agricultural non-point source pollution prevention and control, such as the relationship between pollution control and agricultural production and farmers' income increase, have been properly handled. The treatment of agricultural non-point source pollution is not only of great significance to the improvement of agricultural quality and efficiency and the basic improvement of agricultural ecological environment, but also helps to promote the national ecological protection work, the construction of beautiful villages and the strategy of Rural Revitalization. How to coordinate the relationship between agricultural production and agricultural non-point source pollution and improve the prevention and control ability of regional agricultural non-point source pollution is particularly important for the green and sustainable development of agriculture in China.

The oasis ecological environment in Xinjiang is fragile, unstable and irreversible. The continuous expansion of population size, the continuous advancement of industrialization, and the intensification of desertification and resource depletion have seriously hindered the sustainability of the ecological environment and the national economic and social development in Xinjiang. Xinjiang is an important production base of grain, cotton and livestock products in China. The production mode characterized by "high input and high energy consumption" has made great progress in agricultural and animal husbandry production, and seriously restricted the sustainable development of rural economy and agricultural ecological environment in Xinjiang [2] (pp. 1300–1307). This paper is different from the previous load estimation based on the division of land type or the amount of chemical fertilizer application. The main agricultural products in Xinjiang, such as cotton, grain and livestock, are classified as the standard, and the rural non-point source pollution is added to estimate the agricultural non-point source pollution load emission in Xinjiang, so as to conduct an empirical study on the Kuznets curve characteristics of the agricultural, animal husbandry and rural non-point source pollution emission in Xinjiang, this study aims to avoid the damage to the ecological environment caused by the pursuit of rapid economic growth, is conducive to finding the best balance point suitable for agricultural production and economic growth, has important practical significance for the scientific and reasonable control and prevention measures of agricultural environmental pollution, and can provide theoretical reference for improving the prevention and control capacity of agricultural non-point source pollution in Xinjiang, improving the regional agricultural ecological environment in Xinjiang, and promoting the coordinated development of agricultural resources, environment and economy.

1. Literature review

Economic growth is closely related to the ecological environment. As early as the early 1990s, American economists Grossman and Krueger put forward the hypothesis of Environmental Kuznets curve (EKC), which assumes that the environmental quality will gradually deteriorate with economic growth, but the environmental quality will gradually improve after the economic growth to a certain extent, that is, the change trend of environmental pollution and the change trend of economic development show an inverted "U" relationship. Since then, foreign scholars have done a lot of empirical research on the relationship between economic growth and environmental pollution among different countries based on the Kuznets curve. Through empirical analysis of the relationship between environmental pollution and economic development in many countries, some scholars have confirmed the inverted “U” shape theory of Environmental Kuznets curve [3] (pp. 1–13), while others have found that the Environmental Kuznets curve does not necessarily show an inverted “U” shape [4] (pp. 384–402). Early domestic research on the relationship between non-point source pollution and economic growth mostly focused on industrial non-point source pollution. Scholars carried out a large number of empirical studies in different countries and regions to verify whether there is an inverted “U” relationship between the two. In recent years, they began to devote themselves to the research on the relationship between agricultural non-point source pollution and economic growth. As for the measurement of agricultural non-point source pollution load, scholars mainly use fertilizer, pesticide, agricultural film application intensity or per capita total amount to express agricultural non-point source pollution [5] (pp. 132–139); [6] (pp. 12–19), or divide the factors causing agricultural non-point source pollution into three categories: agricultural land, livestock and poultry breeding, and rural life for estimation and analysis [7] (pp. 106–111). In terms of estimation methods, scholars often use mathematical models for estimation. The adopted estimation methods include output coefficient method [7] (pp. 106–111), investigation and monitoring method, model method, emission coefficient method [8] (pp. 1760–1769), etc. Among them, the output coefficient model method is easy to operate, with low parameter requirements, strong applicability and certain accuracy. The application of this method to estimate the pollution load of non-point source nitrogen (n) and phosphorus (P) is of great significance [9] (pp. 2278–2286). It has been widely used by domestic scholars and has obtained good application and research results in Niyang River Basin [7] (pp. 106–111), Hanfeng basin [8] (pp. 1760–1769), Beijing, Ningxia [10] (pp. 58–65) and other regions. With regard to the relationship between agricultural non-point source pollution and economic growth, some scholars used time series measurement method to explore the long-term relationship between agricultural non-point source pollution and economic growth in different regions, and concluded that EKC curve shape may present inverted “U”, “n” and “n” types [11] (pp. 157–160,181); some scholars also study the relationship between agricultural economic growth and agricultural environmental pollution based on China’s inter provincial panel data, and believe that China is still in the early stage of EKC curve [12] (pp. 216–217,221). It can be seen that the relationship between agricultural non-point source pollution and economic development in China will also show different shapes due to different development stages, regions, and the selection of pollution indicators.

The research on non-point source pollution in Xinjiang mainly focused on the control and treatment of agricultural non-point source pollution and the spatial differentiation of agricultural non-point source pollution in Xinjiang in the early stage, and later began to pay attention to farmers’ willingness to prevent and control agricultural non-point source pollution and its influencing factors [13] (pp. 150–156,181). However, there are few studies on agricultural non-point source pollution and economic growth in Xinjiang, which have only been involved in recent years.

Xiewenbao, Chen Tong, etc. Studied the decoupling relationship between agricultural non-point source pollution and agricultural economic growth in Xinjiang after estimating agricultural non-point source pollution emissions from the aspects of farmland chemical fertilizer, farmland solid waste, livestock and poultry breeding and rural life by using the pollution unit method [14] (pp. 68–75).

Domestic and foreign scholars have made some high-quality achievements in the research of agricultural non-point source pollution load estimation and its relationship with economic growth, which has laid a solid foundation for the research of this paper. Throughout the research at home and abroad, due to the high accuracy, reliability and scientificity of the output coefficient method, scholars at home and abroad mostly use the output coefficient model to estimate agricultural non-point source pollution, and divide it based on the type of agricultural land use, livestock and poultry breeding and rural domestic pollution, and rarely use the land for the production of agricultural products such as grain, cotton and livestock as the division standard. In terms of the relationship between non-point source pollution and economic growth, domestic research on agricultural non-point source pollution and economic growth is relatively few and started relatively late. There is a lack of empirical research on agricultural non-point source pollution emissions and economic growth in Xinjiang, and agricultural non-point source pollution and economic development will also present different situations due to different development stages, regions and pollution indicators. To sum up, this paper plans to use the output coefficient method to estimate the total nitrogen (TN) and total phosphorus (TP) load emissions of non-point source pollution from planting, animal husbandry and rural life in Xinjiang, and further empirically analyze the Kuznets curve relationship between non-point source pollution load emissions of agricultural structure and economic growth in Xinjiang. Under the background of agricultural supply side structural reform, it is of great significance to effectively improve the agricultural production environment in Xinjiang and promote the coordinated development of agricultural production environment and economy.

2. Estimation and characteristic analysis of agricultural non-point source load in Xinjiang

2.1. Estimation method

This paper will use the output coefficient method to estimate the agricultural non-point source pollution in Xinjiang. The output coefficient model was first proposed by American and Canadian scholars in the early 1970s. Since then, Johnes and other scholars established a more perfect output model in 1996. Different output coefficients are adopted for cultivated land planted with different crops, and livestock, population and other factors are added. The expression is:

$$L_j = \sum_{i=1}^{m} E_{ij} A_i + P \tag{1}$$

where, is L_j the total load of pollutants [kg/(hm^2E_{ij}·a)], is the output coefficient of pollutant J in the i-th pollution source [kg/(hm^2·a)]A_i or [kg/(CA·a)] or [kg/(ind·a)], and is the planting area (hm^2) or the number of livestock (head) or population (person) of the *i*-th pollution source in the study area. M is the number of pollution types, and P is the total amount of pollutants input by rainfall. This paper mainly discusses agricultural non-point source pollution without considering the influence of rainfall, so p is ignored in estimation.

2.2. Index selection and data source

The data used in this paper are from the website of the National Bureau of statistics and Xinjiang Statistical Yearbook (2007–2018). Since the control of agricultural non-point source pollution and reduction of large-scale use of chemical fertilizers were included in the Eleventh Five Year Plan for national economic and social development for the first time in 2006, the research period of this paper is from 2006 to 2017, aiming to observe the relationship between agricultural non-point source pollution and economic growth during the treatment period.

The selection of relevant indicators for agricultural non-point source pollution load estimation in this study is as follows:

1) In terms of agricultural non-point source pollution load estimation, according to Xinjiang Statistical Yearbook (2007–2018), the annual average output value of Xinjiang's planting industry accounts for 72% of Xinjiang's total agricultural output value, and that of animal husbandry accounts for 22%, which is the main source of agricultural non-point source pollution; however, forestry and fishery account for only 2% and 1% respectively, so they are ignored. In addition, the non-point source pollution brought by the life of rural residents is also one of the main sources of agricultural non-point source pollution [9] (pp. 2278–2286). Therefore, the agricultural non-point source pollution estimated in this paper is mainly composed of three load emissions of planting, animal husbandry and rural life, and the main estimation indicators are TN and TP output loads.

2) In terms of estimation of non-point source pollution in the planting industry, according to the data of crop planting structure in Xinjiang Statistical Yearbook (2007–2018), the planting structure in Xinjiang is dominated by food crops and cotton, and the sum of the two planting areas accounts for 73.7% of the total planting area of the planting industry in Xinjiang every year. Therefore, the non-point source pollution load emission of the planting industry is mainly calculated for food crops and cotton. Among the food crops, the proportion of the total planting area of wheat and corn in the total planting area of Xinjiang food crops in 2006–2017 reached 90% annually, so the load emission of food crops is mainly wheat and corn. TN and TP loss coefficients of grain crops and cotton respectively adopt the field crop parameters and cotton parameters in the "Northwest Arid and semi-arid area" in the "first national pollution source survey: manual on fertilizer loss coefficients of agricultural pollution sources", in which the TP loss coefficient of cotton is very small and can be ignored.

3) In terms of estimation of non-point source pollution in animal husbandry, livestock indicators are selected from cattle, pigs, sheep and poultry output and stock data. The TN and TP loss coefficients of animal husbandry are calculated in combination with the parameters of "Northwest China" in the "first national pollution source survey: manual on pollutant discharge coefficients of livestock and

poultry production", taking into account the breeding cycle of livestock and poultry, and referring to the existing research on livestock load discharge in Xinjiang [2], and the annual excretion coefficients of livestock and poultry feces in the study area are obtained. The total nitrogen and total phosphorus output coefficients of Xinjiang animal husbandry are taken as 15% of their respective excretion coefficients [15] (pp. 489–497).

4) In the estimation of non-point source pollution in rural life, the rural population is selected as the indicator of rural life. The population output coefficient recommended by the State Environmental Protection Administration will be used for the non-point source pollutant output coefficient of rural living. See **Table 1** for the output coefficient values of various agricultural industries.

Table 1. Value of output coefficient of planting, animal husbandry and rural life.

Pollutant category	**Planting output coefficient Kg/(hm²·a)**		**Output coefficient of animal husbandry kg/(CA·a)**			**Rural life output coefficient kg/(ind·a)**	
	Cotton	**Main food crops (wheat and corn)**	**Cattle**	**Sheep**	**Pig**	**Poultry**	**Rural life**
TN	8.41	10.12	52.87	2.28	11.56	0.54	1.58
TP	-	1.44	5.13	0.45	1.53	0.13	0.16

2.3. Estimation results and characteristic analysis

According to the output coefficient model of Equation (1), calculate the TN and TP load emissions of agricultural non-point source pollution in Xinjiang by using Excel, so as to obtain the total TN and TP load emissions of agricultural non-point source pollution in Xinjiang, and further analyze the results of the total emission characteristics of agricultural non-point source pollution in Xinjiang, the emission characteristics of planting non-point source pollution, the emission characteristics of animal husbandry pollution and the emission characteristics of rural non-point source pollution.

1) Analysis of total emission characteristics of agricultural non-point source pollution in Xinjiang

It can be seen from **Figure 1** that from 2006 to 2017, the total emissions of TN and TP from agricultural non-point sources in Xinjiang showed a trend of decreasing first and then increasing, and 2008 was the inflection point. From 2006 to 2008, TN and TP decreased, with an average annual decline rate of 8% and 9% respectively; from 2008 to 2017, TN and TP rose, with an average annual growth rate of 3.5% and 3.9% respectively. In addition, from 2006 to 2017, the average annual contribution rates of TN and TP of non-point source pollution from animal husbandry, planting and rural life in Xinjiang were 48.5%, 33.8% and 17.7% respectively, and 60.9%, 23.2% and 15.9% respectively, that is, the TN and TP emissions of agricultural non-point source pollution in Xinjiang were animal husbandry > planting > rural life. It can be seen that animal husbandry non-point source pollution has become the most important source of agricultural non-point source pollution in Xinjiang, while planting non-point source pollution and rural non-point source pollution can not be underestimated.

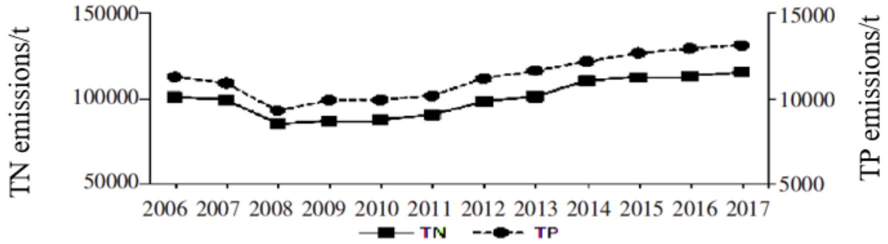

Figure 1. TN and TP load emissions of agricultural non-point source pollution in Xinjiang from 2006 to 2017.

2) Analysis of non-point source pollution emission characteristics of planting industry in Xinjiang

The application of chemical fertilizer in planting industry is one of the most important sources of agricultural non-point source pollution. Realizing the negative growth of chemical fertilizer is one of the most important measures to control agricultural non-point source pollution in China in recent years. From 2006 to 2015, the TN and TP load emissions of non-point source pollution from Xinjiang's planting industry showed a long-term growth trend, and only slightly slowed down from 2015 to 2017 (see **Figure 1**). Among them, the TN and TP load emissions of grain crops have been on the rise since 2007, reaching the maximum emissions in 2016, which were 22,346 t and 3180 t respectively, and showed a downward trend from 2016 to 2017. This is mainly because the planting area of wheat and corn continued to expand from 2007 to 2016 and began to be controlled in 2017. The TN load emission of cotton showed a fluctuating trend with the adjustment of planting structure, but showed an overall growth trend. In 2014, the maximum emission reached 20,375 t, which was due to the overall growth trend of cotton field area in Xinjiang. On the one hand, the planting industry in Xinjiang is mainly grain crops and cotton. Among the food crops, wheat and maize are the two single crops with the largest amount of chemical fertilizer in China [16] (pp. 140–147). From 2006 to 2017, the sum of wheat and maize planting areas in Xinjiang accounted for 90% of the total planting area of food crops, and the planting area of food crops accounted for 38.7% of the total planting area of crops. At the same time, the single agricultural planting structure and large amount of fertilizer for planting crops in Xinjiang are also important reasons for the heavy non-point source pollution load of planting industry. On the other hand, Xinjiang is the largest cotton producing area in China. From 2006 to 2017, the cotton planting area accounted for 35% of the total planting area of crops. The high-speed development of the cotton industry is inseparable from the high input of chemical fertilizer, and the application of chemical fertilizer per unit area of Xinjiang cotton fields has also increased rapidly over the years [17] (pp. 63–68). The utilization rate of chemical fertilizer for cotton planting is not optimistic. According to statistics, the utilization rate of nitrogen fertilizer is 30%~60%, and the utilization rate of phosphorus fertilizer is only 2%~25% [18] (pp. 99–103). The reality of high input and low utilization rate of chemical fertilizer in Xinjiang is also the main reason for the heavy load of non-point source pollution.

3) Analysis on emission characteristics of non-point source pollution from animal husbandry in Xinjiang

From 2006 to 2017, the TN and TP load emissions of Xinjiang cattle and sheep accounted for the first and second place respectively. The average annual contribution rate of TN load emissions was 58% and 28% respectively, and the average annual contribution rate of TP load was 39% and 36% respectively, far exceeding the contribution rate of pig and poultry load emissions (see **Figure 2**). The main reason is that Xinjiang's animal husbandry is mainly dominated by herbivores such as cattle and sheep, and cattle and sheep are the main livestock and poultry species of non-point source pollution emission of Xinjiang's animal husbandry. In addition, the TN and TP load emissions of pigs are relatively stable, but the TN and TP emissions of poultry have been increasing since 2008, which is closely related to the continuous expansion of poultry breeding scale in Xinjiang.

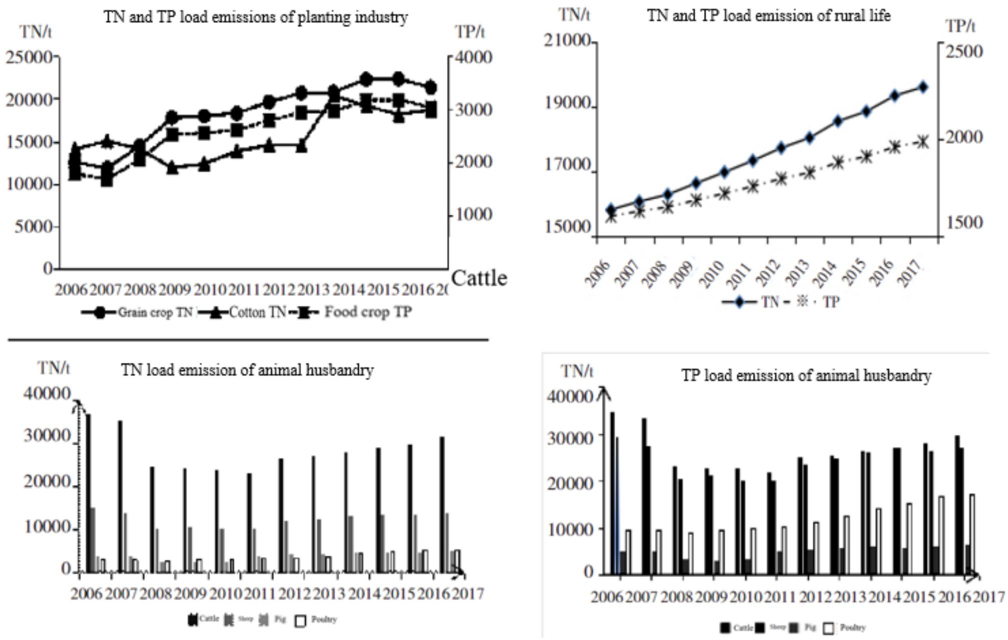

Figure 2. TN and TP load emissions of non-point source pollution from agricultural departments in Xinjiang from 2006 to 2017.

Xinjiang is the second largest pastoral area in China after Inner Mongolia. As a traditional industry in Xinjiang, animal husbandry has already become the pillar industry of agricultural development in Xinjiang. However, Xinjiang's animal husbandry is the most important agricultural non-point source pollution source in Xinjiang, and TN and TP load emissions account for the first place, which does not match the fact that the output value of animal husbandry accounts for only 22% of the total output value of agriculture, forestry, animal husbandry and fishery. It can be seen that from the perspective of sustainable development of ecological economy, the development structure of animal husbandry in Xinjiang needs to be adjusted.

4) Analysis on emission characteristics of rural non-point source pollution in Xinjiang

Rural non-point source pollution mainly refers to the discharge of rural domestic sewage and rural domestic garbage, which is one of the main sources of agricultural non-point source pollution. From 2006 to 2017, TN and TP load emissions of rural non-point source pollution in Xinjiang showed a continuous growth trend, which was due to the continuous growth of rural population in Xinjiang. For a long time, the population growth rate of Xinjiang has been higher than the national average, and the natural population growth rate ranks first in the country. Moreover, the rural population base of Xinjiang is relatively large. For example, in 2017, the rural population of Xinjiang accounted for 50.6% of the total population of Xinjiang, far higher than the national average of 41.5%.

3. Empirical analysis on the relationship between agricultural non-point source pollution and economic growth in Xinjiang

3.1. Model construction

The general model of economic growth and environmental pollution in EKC research is as follows:

$$Y = \alpha + \beta_1 X + \beta_2 X^2 + \beta_3 X^3 + \beta_k Z + \xi \quad (2)$$

where, y is the environmental pollution index, x is the economic growth index, α is a β_K constant, is a pending parameter, z is other control variables that affect environmental changes, ξ is the error term. In the actual model construction, other control variables Z affecting environmental changes are ignored. Model parameter β_1, β_2 and β_3 is of great significance. According to different values, it can reflect the relationship between environmental quality and economic development. The specific relationship types are:

1) $\beta_1 \neq 0, \beta_2 = 0, \beta_3 = 0$ at that time, there was a linear relationship between environmental conditions and economic growth;

2) $\beta_1 > 0, \beta_2 < 0, \beta_3 = 0$ at that time, the relationship between environmental conditions and economic growth was in line with the inverted “U” EKC;

3) $\beta_1 < 0, \beta_2 > 0, \beta_3 = 0$ at that time, there was a “U” curve relationship between environmental conditions and economic growth;

4) $\beta_1 > 0, \beta_2 < 0, \beta_3 > 0$ at that time, there was an “n” curve relationship between environmental conditions and economic growth;

5) $\beta_1 < 0, \beta_2 > 0, \beta_3 < 0$ at that time, the relationship between environmental conditions and economic growth was in line with the inverted “n” EKC;

6) $\beta_1, \beta_2, \beta_3$ when none is zero, the relationship between environmental conditions and economic growth is a cubic curve.

3.2. Index selection

The environmental indicators will select the above estimated TN and TP load emissions of planting, animal husbandry and rural life in Xinjiang from 2006 to 2017, and the economic indicators will select the per capita output value of planting, per capita output value of animal husbandry and per capita total agricultural output value (total output value of agriculture, forestry, animal husbandry and fishery). Take 2006 as the base period (2006 = 100) to deal with the per capita output value of planting industry, per capita output value of animal husbandry and per capita total agricultural output value (total output value of agriculture, forestry, animal husbandry and fishery) in Xinjiang, so as to avoid the interference of inflation on the results.

3.3. Fitting results of the model

In order to further analyze the relationship between TN and TP load emissions from planting, animal husbandry and rural life in Xinjiang and agricultural output value, this paper uses Stata software to fit the Kuznets curve respectively. The main estimation steps are as follows: (1) estimate the equation containing both cubic and square terms of per capita output value, and judge whether the model has an inverted "n" or "n" curve shape; (2) if the cubic term of per capita output value is not significant, remove the cubic term of per capita output value and re estimate the equation [15]. In this paper, the indicators of three types of pollution sources and per capita output value are estimated respectively. The results are shown in **Table 2**.

Table 2. Regression results.

Pollution type		**Planting**		**Animal Husbandry**		**Rural life**	
Variable	**Coefficient**	**TN**	**TP**	**TN**	**TP**	**TN**	**TP**
Constant term	β_0	335,000.3**	−6816.68***	3,347,506***	447,258***	9442.42***	951.85***
		(3.04)	(−3.87)	(4.11)	(4.58)	(5.51)	(5.58)
X	β_1	−188.71**	1.9023***	−4187.26***	−561.49***	0.6824***	0.0698***
		(3.13)	(4.54)	(−3.88)	(−4.34)	(2.26)	(2.33)
X^2	β_2	0.014***	−0.0009***	1.7527***	0.2358***		
		(−3.17)	(−3.73)	(3.70)	(4.15)		
X^3	β_3	-5.83×10^{-7}**		−0.000***	−0.000***		
		(3.04)		(−3.51)	(−3.94)		
R^2		0.9674	0.9466	0.8453	0.8870	0.9941	0.9943
DW value		2.14	2.15	2.22	2.32	1.98	1.99
F value		79.03	76.76	14.57	20.94	764.79	792.16
Curve shape		Inverted "n" type	Inverted "U" shape	"U" type	"U" type	Linetype	Linetype
Inflection point		6844, 10,250	10,568	2259	2230		

Note: () is the value of *t*, * means significant at the level of 10%, ** means significant at the level of 5%, *** means significant at the level of 1%.

3.4. Analysis of model fitting results

1) EKC curve analysis of non-point source pollution of planting industry and economic growth

The regression results showed that the fitting degree between the TN and TP load emissions of planting industry and the per capita output value of planting industry was very high, *r*2 were 0.9674 and 0.9466 respectively, and the equations passed the significance test ($p < 0.01$).

The curve between TN load emission of planting industry and actual per capita planting output value meets $\beta_1 < 0, \beta_2 > 0, \beta_3 < 0$. The inverse "n" curve shows two development trends: an upward inflection point and a downward inflection point. According to the estimation results, the inflection point of TN load emission of planting industry appeared in 2007 (the per capita output value of planting industry was 6844 yuan), and the first inflection point of TN load emission decreased in 2016 (the per capita output value of planting industry was 10,250 yuan).

The inverted "U" relationship between the TP load emission of planting industry and the $\beta_1 > 0, \beta_2 < 0, \beta_3 = 0$ output value of planting industry per capita conforms to the Environmental Kuznets hypothesis, that is, with the growth of the output value of planting industry per capita, the TP load emission of planting industry shows an inverted "U" trend of first rising and then declining. According to the estimation results, the inflection point of the inverted "U" decline is when the per capita planting output value is 10,568 yuan, which occurred in 2017 (Xinjiang's per capita planting output value was 10,250 yuan in 2016 and 10705 yuan in 2017).

To sum up, after a long period of continuous growth, the TN and TP load emissions from the planting industry in Xinjiang showed a turning point of decline in 2016 and 2017 respectively. How to do a good job in the prevention and control measures of TN and TP load emission in the planting industry and prevent the inverted "n" or inverted "U" curve from re-emerging the rising inflection point is an important task at present.

2) EKC curve analysis of non-point source pollution of animal husbandry and economic growth

The regression results showed that the fitting degree between the TN and TP load emissions of animal husbandry and the per capita output value of animal husbandry was good, *r*2 were 0.8453 and 0.8870 respectively, and the overall equation passed the significance test (p < 001). The "U" curve relationship between the TN and TP load emissions of animal husbandry and the per capita $\beta_1 < 0, \beta_2 > 0, \beta_3 = 0$ output value of animal husbandry is satisfied, that is, with economic growth, the TN and TP of animal husbandry show a downward trend first and then an upward trend. According to the estimation results, the inflection point of "U" shaped increase in TN load emission of animal husbandry is at 2259 yuan per capita output value of animal husbandry, and the inflection point of "U" shaped increase in TP load emission of animal husbandry is at 2230 yuan per capita output value of animal husbandry, both between 2011 (2112 yuan) and 2012 (2267 yuan), that is, TN and TP load emissions of animal husbandry reached the inflection point of increase in 2012, and have continued to increase with the increase of output value of animal husbandry in recent years. Animal husbandry non-point source pollution should become the top priority of the current agricultural non-point source pollution control in Xinjiang.

3) EKC curve analysis of rural non-point source pollution and economic growth

The regression results showed that the fitting degree of TN and TP emissions from rural non-point source pollution and the per capita gross output value of agriculture, forestry, animal husbandry and fishery in Xinjiang was very high, *r*2 were 0.9941 and 0.9943 respectively, and the equation passed the significance test as a whole ($p < 0.01$). The regression results of rural living TN, TP load emissions and per capita gross output value of agriculture, forestry, animal husbandry and fishery meet $\beta_1 \neq 0$, $\beta_2 = 0$, $\beta_3 = 0$ linear curve relationship, that is, with economic growth, TN and TP load emissions of rural life are also rising continuously. Therefore, attention should be paid to and efforts should be made to control non-point source pollution in rural areas. While building beautiful villages and optimizing the rural ecological environment, the level of urbanization should be increased and the growth of rural population should be moderately controlled.

4. Conclusions and suggestions

4.1. Conclusion

From the empirical analysis of EKC curve relationship between agricultural non-point source pollution load emission characteristics and economic growth in Xinjiang, this paper draws the following conclusions:

First, the TN and TP emissions of agricultural non-point source pollution in Xinjiang are on the rise, and the order of emission load from high to low is animal husbandry > planting > rural life. From 2006 to 2017, the average annual contribution rates of TN load emissions of animal husbandry, planting and rural non-point source pollution in Xinjiang were 48.5%, 33.8% and 17.7% respectively, and the average annual contribution rates of TP load emissions were 60.9%, 23.2% and 15.9% respectively. Moreover, the relationship between agricultural non-point source pollution and economic growth in Xinjiang showed different relationships such as inverted “U”, “inverted” “n”, “U” and linear.

Second, the TN and TP load emissions of non-point source pollution in Xinjiang’s planting industry continue to rise, which may be due to the single agricultural planting structure, the large fertilizer demand for planting crops, the low utilization rate of chemical fertilizer, the rapid growth of fertilizer application per unit area of cotton, etc.TN load emission from the planting industry has an inverted “n” relationship with economic growth, and TP load emission from the planting industry has an inverted “U” relationship with economic growth. In addition, TN and TP load emissions have declined inflection points in 2016 and 2017 respectively. Prevention and control measures for TN and TP emissions from the planting industry should be focused on to prevent the emergence of an inverted “n” or inverted “U” inflection point.

Third, animal husbandry has become the most important agricultural non-point source pollution source in Xinjiang, but the output value accounts for only 22% of the total output value of agriculture, forestry, animal husbandry and fishery. The contribution rate of TN and TP load of livestock and poultry in Xinjiang is: cattle > sheep > poultry > pigs from high to low. TN and TP load emissions of animal husbandry have a “U” shaped relationship with economic growth, and both have an upward inflection point after 2011. The current focus is to adjust the structure of animal husbandry, improve the level and efficiency of large-scale breeding, and prevent and control non-point source pollution in an all-round and multi angle way.

Fourth, non-point source pollution in rural areas has been growing continuously, mainly because the rural population base in Xinjiang is relatively large (the rural population accounts for 50.6% of the total population in Xinjiang), and has been growing continuously for a long time. The average annual growth rate from 2006 to 2017 was 1.98%, 0.45% higher than the national average. The TN and TP load emissions of rural life show a linear growth trend with economic growth. After that, the governance of rural non-point source pollution should be strengthened.

4.2. Policy recommendations

Since 2008, the total load emission of agricultural non-point source pollution in Xinjiang has been in a continuous growth trend. Under the control of all aspects, the current situation is still grim. It is imperative to improve the prevention and control capacity of regional agricultural non-point source pollution in Xinjiang.

1) In the treatment of non-point source pollution in the planting industry, the focus is to avoid the emergence of the rising inflection point, and the focus is on prevention and control. First, actively adjust the internal structure of the agricultural industry. In view of the problems of single agricultural planting structure and large fertilizer demand for planting crops, under the condition of stabilizing the planting area of grain crops, and in combination with the current situation of agricultural environment in different regions of Xinjiang, appropriately develop some high-quality and efficient characteristic crops with low fertilizer demand, low pollution, high economic benefits and suitable for local planting, such as peanuts, vegetables, lycium barbarum, etc.

The second is to improve the utilization rate of chemical fertilizer, advocate the application of more organic fertilizers and promote the use of scientific and reasonable fertilization methods and technologies. Thirdly, aiming at the problem of too large cotton planting area, we should strive to cultivate and promote high-yield, low-cost and low fertilizer and drug demand high-quality cotton varieties, and adjust the variety structure.

2) In view of the problem of non-point source pollution in Xinjiang's animal husbandry, in order to change the situation of large non-point source pollution load but low economic benefits in Xinjiang's animal husbandry, we can achieve a win-win situation in animal husbandry environmental pollution control and animal husbandry economic benefits by introducing advanced animal husbandry production technology, improving animal husbandry production mode, and promoting the upgrading and optimization of animal husbandry industrial structure. First, focus on improving the level of large-scale and intensive management of animal husbandry in Xinjiang. Xinjiang is an important beef cattle production base and fine wool sheep base in China. As the most important livestock and poultry varieties in Xinjiang, cattle and sheep are the main source of non-point source pollution load of animal husbandry in Xinjiang. While making full use of the inherent natural resource advantages of grassland animal husbandry in Xinjiang and vigorously promoting the development of animal husbandry, we should improve the level of large-scale breeding, change the current situation of decentralized grazing and small-scale operation, and reduce the number of abandoned grassland. Compared with the traditional free range breeding, it is more conducive to the treatment and utilization of livestock manure, feed residue and other wastes, and reduce the discharge of non-point source pollution load. Secondly, through the application of advanced technologies such as embryo transfer and improved breed breeding, livestock and poultry varieties with rapid growth, high meat yield and excellent meat quality can be cultivated, and the purpose of controlling non-point source pollution load emission can be achieved by improving the unit yield and production efficiency of animal husbandry.

3) In terms of prevention and control of non-point source pollution in rural life, we can effectively reduce the total load emission of rural life pollution by improving and adjusting the rural population structure in Xinjiang, promoting reasonable rural population flow and transfer, accelerating the urbanization process and expanding the scale of urbanization. In addition, we should actively promote the construction of rural ecological civilization in Xinjiang, and strive to basically achieve the goal of building beautiful villages in Xinjiang with a fundamentally improved rural ecological environment by 2035 by strengthening rural domestic sewage treatment, rural domestic waste recycling, village beautification and improving the rural living environment.

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