

Research Article

Game Analysis and Strategy Research of Farmers Involving in the Agricultural Non-Point Source Pollution Prevention and Control

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Abstract: This thesis applies game theory to make a quantitative analysis of the outward problem of the agricultural non-point source pollution and discusses the basic starting point to study the agricultural non-point source pollution prevention and control and furthermore researches the measures and recommendations of agricultural non-point source pollution prevention and control.

Keywords: Agricultural non-point source pollution, environmental economic, game theory

INTRODUCTION

The Environmental Management of Non-Point Source Pollution (NSP) is a public utilities with global and extensive influence (Zhu and Sun, 2008). The strength of using of chemical fertilizer in China has reached more than 1.6 times of the world average. He *et al.* (2006) Because of the cognitive, economic and technical limitations, rural non-point source pollution control work has not been given due attention (Zhang, 2006). In China Non-point source pollution load has surpassed the industrial pollution, which directly damages the agricultural ecosystems. By the method of game, the present study analyzes the behavior of government, village community and framers on agricultural non-point source in china by theory (Lu and Xue, 2007), Government should participate in modern circular agriculture to internalize the externality of this field (Chen *et al.*, 2012), Based on gave theory, the effective management of local governments at all levels must unit and make out the range of treatment (Chen and Han, 2009), a reasonable environment subsidy and punishment mechanism and government's attaching importance to the self reputation and public image will play a positive role in promoting Non-point source pollution control (Zhang *et al.*, 2011). But studies in the government agriculture Non-point source pollution from the peasant household angle the achievement not to be many, it is necessary to analyze its control countermeasure.

GAME ANALYSIS OF AGRICULTURAL NON-POINT SOURCE POLLUTION

The aggregation of non-point source pollution will no doubt raise the cost of production, which will

inevitably damage the farmers' own benefits. As rational individuals, farmers may commit themselves voluntarily to environmental protection and afford the protection cost. However, without the economic and policy constraints, the participants' voluntary are extremely important. The extent of his voluntary will lead to the success of treatment of non-point source pollution. This can be analyzed through a simple game model.

To suppose that an agricultural non-point source pollution affected n farmers and these n farmers are regarded as rational individuals. In order to facilitate the understanding, they are marked as participants. M_i is marked as the total expenditure of the participant i ; x_i is marked as the participant's voluntary cost of treatment of the non-point source pollution; y_i for the participant's designed amount in other fields. P_x is marked as the cost of management of pollution of the same intensity; w_i is marked as the participant's intensity of the management of pollution and $w_i > 0$, $i = 1, 2, \dots, n$. So, $w_i p_x x_i$ reflects the total cost provided by the participant in the process of the control of the non-point source pollution. p_y is marked as the participant's other designed projects Unit costs (To simplify the model, assuming that all the participants' p_y are same).

Order $X = \sum_{i=1}^n x_i$, suppose $u_i(X, y_i)$ is the effectiveness of the participant's input of x_i and y_i and according to the actual significance, suppose:

$$\frac{\partial u_i}{\partial X} > 0, \frac{\partial u_i}{\partial y_i} > 0$$

Obviously, marginal rate of substitution of pollution control expenses and expenses of the other project designs is diminishing, that is:

$$P(X) = \frac{\partial u_i / \partial X}{\partial u_i / \partial y_i}$$

a decreasing function of X. If each participant i start considering their own interests and wants to be able to maximize their effectiveness. In such a case, each participant is faced with the problem that is to choose their own optimal Strategy (xi, yi) under the condition of other participants' choice are given and aims to maximizing the following issues:
 max $u_i(X, y_i)$ s.t.

$$\omega p_x x_i + p_y y_i \leq M_i, X = \sum_{i=1}^n x_i$$

By the use of Lagrange multipliers method, the optimization issue is equivalent to max:

$$L_i = u_i(X, y_i) + \lambda(M_i - \omega_i p_x x_i - p_y y_i)$$

λ is a Lagrange constant, the first-order condition of the optimization is as follows:

$$\frac{\partial u_i}{\partial X} - \lambda p_x \omega_i = 0, \frac{\partial u_i}{\partial y_i} - \lambda p_y = 0$$

result of elimination of λ is:

$$\frac{\partial u_i / \partial X}{\partial u_i / \partial y_i} = \frac{\omega_i p_x}{p_y}, i = 1, 2, \dots, n \quad (1)$$

n balanced conditions determine the voluntary pollution control costs of n participants, that is, the Nash equilibrium:

$$x^* = (x_1^*, x_2^*, \dots, x_n^*) \quad X^* = \sum_{i=1}^n x_i^*$$

However, taking the overall interests into account, the more participants supply voluntary costs, the better the result is. The overall interest is expected, which is Pareto optimal, so that the model has become: max

$$U = \sum_{i=1}^n \gamma_i u_i(X, y_i)$$

s.t.

$$\sum_{i=1}^n \omega_i p_x x_i + \sum_{i=1}^n p_y y_i \leq \sum_{i=1}^n M_i$$

the factor γ_i represents different status and the importance of different participants. By using Lagrange multiplier method, the optimization issue is equivalent to:

$$L_p = \sum \gamma_i u_i(X, y_i) + \lambda \left[\sum_{i=1}^n M_i - \sum_{i=1}^n \omega_i p_x x_i + \sum_{i=1}^n p_y y_i \right]$$

λ is a Lagrange constant, the first-order condition of the optimization is as follows:

$$\sum_{i=1}^n \gamma_i \frac{\partial u_i}{\partial X} - \lambda p_x \omega_i = 0, \frac{\partial u_i}{\partial y_i} - \lambda p_y = 0$$

result of elimination of λ and is:

$$\sum_{i=1}^n \frac{\partial u_i / \partial X}{\partial u_i / \partial y_i} = \frac{\omega_i p_x}{p_y}, I = 1, 2, \dots, n \quad (2)$$

This determines the Pareto optimal solution of the cost of non-point source pollution control is X^{**} .

By analyzing (1), (2) result is as following:

$$P(X^*) = \frac{\partial u_i / \partial X}{\partial u_i / \partial y_i} = \frac{\omega_i p_x}{p_y} > \frac{\omega_j p_x}{p_y} - \sum_{j \neq i} \frac{\partial u_j / \partial X}{\partial u_j / \partial y_j} = P(X^{**})$$

According to the fact that marginal rate of substitution of pollution control expenses and expenses of the other project designs is diminishing, result as following could be got: $X^* < X^{**}$

This shows that from the individual interests, all participants supply a voluntary expense less than the they do when they consider from the collective interests. That means of the supply of the Nash equilibrium of providing rural public goods is less than the Pareto optimal supply. The different considering points lead to a different supply of public expenses and the gap between the two expands as the number of participants increase.

Facts could be seen through this model: If the effectiveness generated by the treatment of unit non-point source pollution is higher than that generated by other units project design, that is, if the growth rate of effectiveness of control of the non-point source pollution is higher than that of other design projects, then individuals will tend to increase the cost of the treatment of pollution (which will prompt the Nash equilibrium go close to the Pareto optimal). As a result, the effectiveness of the individual's expense will increase rapidly and then the non-point source pollution control will be promoted further. This is why serious environmental pollution (such as a threat to the safety of life or development of society) (David, 2006) will make the participants take active measures to increase investment in pollution control and pay no attention to even delay the treatment when the problem is not serious.

THE BASIC STARTING POINT OF AGRICULTURAL NON-POINT SOURCE POLLUTION PREVENTION AND CONTROL

Since reform and opening up, under the development guideline of "high-yield, high-quality, high-performance", our agriculture department promotes production vigorously with the central

objectives of increasing agricultural production. The intensity of the development of agriculture is increased, resulting into the case that chemical fertilizer, pesticides, plastic sheeting and other elements are brought into wide use and the size of livestock and poultry breeding industry is also increasing. While the goal of increasing production is achieved, agricultural non-point source pollution is getting worse. The cause of this phenomenon is mainly due to our long-term lack of attention to the rural environment. There is no security policy, nor economic constraints. From the view of environmental policy, China's "People's Republic of China Environmental Protection Law", "Water Pollution Prevention Law" and "solid waste pollution prevention law" and other laws and their implementation details have not involve any content of non-point source pollution prevention and control. Therefore, when there is no legal prohibition, it is reasonable for the farmers to use a large number of pesticides and fertilizers in order to enhance economic efficiency and saving labor and time and just pay attention to the improvement of agricultural production while without considering the impact on the environment. This leads to the agricultural non-point source pollution. From the view of economic policy, the developed countries to make greater use of taxes and fees, subsidies, deposit-a refund, such as emissions trading across the economic means to carry out non-point source pollution control (Zhang, 2006). However, on the situation of undeveloped agriculture, large population and pressure on food, during the treatment of non-point source pollution, China has to maintain the grain production enthusiasm of broad masses of farmers. Because if China takes after the policy of adopting economic strategy as the developed countries and regions do, it is likely to turn into a constraint on output instead. As a result, inadequate information of monitoring will easily leads to reduction of the welfare of individual farmers, thus affecting the livelihood of farmers and agricultural production, which is contrary to goal of building a harmonious society. However, the aggregation of rural non-point source pollution and the agro-ecological and environmental damage has become one of the major factors that the constraint the healthy development of rural economy. The lack of concern about this problem is bound to the collapse of agriculture as the foundation, which is not in line with new socialist countryside development goals "the development of production, Health and well-off, then, the wind rural civilization and allow the village clean, democratic management ". So, agricultural non-point source pollution prevention and control should be listed as an important element of building new countryside. In the process of building new countryside, all levels of government should see the effectiveness of the results of the rural ecological environment with the vision of the strategy and get involved into the building of new countryside and the study of agricultural non-point

source pollution prevention and control issues and promote effective rural production and living environment.

The quality of the environment in rural areas affects quality of the living environment of the farmers within and the sustainability of production. Thus, agricultural non-point source pollution prevention and treatment should abide by the basic principles of the policy of the integration of agriculture and environmental. The policy of the integration of agriculture and environmental formed in Europe in the 1980s and was accepted and adopted by various governments. Environmental policy is the integration of environmental objectives into the policy of agriculture, industry and other sectors. For agriculture, agricultural - environmental policy integration is the basic principles of implementation of agricultural non-point source pollution control. The principle means that all the agricultural policy must be evaluated on the basis of environmental impact. "China Agenda 21" and "Environmental Protection and the State Council on a number of decisions," stressed the principles. Such as the departments of the State Council stressed the principles in the formulation of major policy decisions and we "must consider economic, social and environmental benefits" and "establish and improve the environment and the development of an integrated system of decision-making". In accordance with the requirements of integration, it is necessary to consider the environmental impact of agriculture, such as reducing agricultural non-point source pollution in the formulation and implementation of agricultural development policy; similarly, formulation and implementation of environmental policy cannot be divorced from The basic objective of agricultural development, it is necessary to take full account of their impact on agricultural production, the income of the farmers and agricultural prices. From the food security policy, the appropriate production goals should be determined on the carrying capacity of the environment and resources, for example, under certain conditions, the lower of China's grain self-sufficiency rate to 90% will be able to reduce the environmental pollution caused by fertilizer input. At the same time, efforts should be made to increase food production capacity, the ability to purchase, exchange and capacity of inter-regional allocation, to strengthen national food security and food security.

Experience has shown that the developed countries, agricultural non-point source pollution is complex issue that is related to the technical level, management level and system-level. The technical level, includes well-established agricultural technology and engineering technology; management level, studies how to organize and arrange for the production effectively in accordance with the established systems, as well as how to improve the efficiency of the allocation of resources; the system level, studies how to design a system, a reasonable

construction of the related subjects of interest. These three levels help each other for non-point source pollution prevention and control. System design keeps pace with the development level technology, management, thus, improving the system can effectively improve operational efficiency of the technical and managerial factors in the practice. Sound institutional environment creates the conditions for new technology in the successful use of non-point source pollution prevention and control and even plays the role of producing new technology and management measures. In contrast, the defected system will inhibit efficient environmental technology and management innovation to happen. And these three levels and coordinated operation among these three are weak links are in rural non-point source pollution prevention and control in our country.

POLICY RECOMMENDATIONS OF AGRICULTURAL NON-POINT SOURCE POLLUTION PREVENTION AND CONTROL

Technology:

Promote the mature technology of using chemical fertilizers pesticides and establish of environment-friendly agricultural technology system: Reducing nitrogen input, improving the efficiency of fertilizers and pesticides, increasing the organic manure input, improving the soil organic matter content, improving soil fertility basis, are all important tools to reduce non-point source pollution and improve environmental quality in rural areas. First of all, government should establish technical specifications system of cleaner production in line with local conditions and take advantage of standardized production and quality entire process control measure to encourage the production of high-performance, long-lasting, low-residue chemical fertilizer, pesticide products. Also, the government should implement identification systems, foster agricultural products brand and improve the inspection system. Furthermore, the government should expand the scope of regulatory control of the quality and safety of agricultural products, improve the rate of excellent products and safety standards of agricultural products and improve the advantages of the level of quality and safety of agricultural products comprehensively. Secondly, the government should promote the mature technology of using chemical fertilizers, on the one hand, government should take a reasonable method of fertilization and fertilizer, that is scientific use of chemical fertilizers and pesticides, such as the use of facilities supplies, methods, varieties and fertilizer application, on the other hand, government should adjust the structure of the fertilizer using, promote the use of high-quality organic and inorganic compound fertilizer for crop-specific, to take the place of chemical fertilizers or improper ratio of the high concentration of

chemical fertilizers. Thirdly, government should guide farmers to adopt environmentally friendly agricultural techniques, such as the implementation of the rotation, no-tillage, restoring of green manure planting and returning of the entire amount of straw and other measures. Through the use of fertilizer and soil eutrophication, combined with earth up, it will lead the broad masses of farmers from the land using to land eutrophication. Then the quality of arable land will be restored and improved and which will fundamentally solve the problem of pollution caused by excessive fertilizer inputs.

Implement eco-agricultural engineering technology:

Though agriculture posse's rich natural resources, the per capita natural resources is little. So that agricultural development should sufficiently take advantage of the strategy of raising the utilization rate of resources, recycling of resources, implementing the economic cycle and the combination of agriculture, forestry, animal husbandry, fisheries, which extends the ecological chain and make the traditional "resources-products-waste" turn into a model of "resources - products - renewable resources" model. The reason is that making full use of resources, will not only protect the ecological environment, but also reduce production costs and increase economic efficiency. Therefore, the government should promote the implementation of eco-agricultural engineering technology. In line with local conditions, the government could promote the "rice culture" and "rice-duck" and "duck-ponds" and "pig de fruit (rice, vegetables and fish)" eco-agricultural engineering model. Such as the government of Taihe in Jiangxi province combines afforestation, soil solidation and comprehensive management of soil and takes methane as a link to establish ten thousand mu "pig - de - fruit" ecological orchard. The application and the promotion of agro-ecological engineering technology will help to improve the modernization of agricultural production and control the agricultural non-point source pollution and therefore, it will be widely applied.

To build ecological engineering in line with local conditions in order to control agriculture non-point source pollution:

Eco-engineering measures can effectively reduce agriculture non-point source pollution. Ecological engineering includes the physics interception, filtration and plants purification and so on, that is, the remoulding of the riverdome and the green land around the lake and the increase of the artificial inceptor incept the rainfall runoff in the first place and then reduce the runoff through the way of natural infiltration and so as to reduce the pollution load. For example, through the use of eco-ditch, the wetland ecology, ecological zone of separation, the artificial filter and purification of plants will further remove suspended solids and reduce nitrogen, phosphorus,

organic matter and other pollution load in order to achieve non-point source pollution control. In rural areas, government may also establish a centralized and decentralized rural sewage treatment system, at the same time it may carry out research and demonstration of non-point source pollution control measures systems, especially develop the ecological technology which is fit for rural agricultural pollution control (Zhu and Sun, 2008). There are various ecological engineering technologies, but the choice of the specific one or what kind of composite of several ones should be in line with local conditions in order to achieve maxim ecological benefits and the environment economic benefits.

Management:

To perfect laws and regulations: Laws and regulations are extremely important ways to ensure the realization of the agricultural non-point source pollution control and are the premise and basis of other means of environmental protection. Only in the protection of the laws and regulations, the other means possesses legitimate authority and can be implemented with force.

Therefore, the Government must play a management function in the formulation and practical implementation of laws and regulations, policies, so as to guide and restraint, coordinate people's attitudes and behavior to ensure that the agricultural non-point source pollution control will be realized.

In terms of legislation, relevant state departments should amend the relevant provisions relating to agricultural non-point source pollution management in the following laws and regulations: "Environmental Protection Law" and "Water Pollution Prevention Law," "Water Law" and "Soil and Water Conservation Law," "Flood", "Fisheries Law" and "Nature Reserve Management Ordinance", reducing legal conflicts and increasing mutual relevance.

Based on the local characteristics, the local government should develop agricultural management system, strengthen the management of pesticide pollution, regulate the agriculture and organic waste discharge and the organic waste recycling system and improve the laws and regulations of rural environment management system.

- Referring to the laws and regulations of foreign fertilizer application, the government could develop agricultural management system, use legal and regulatory requirements to regulate and manage the behaviors in the process of agricultural production, stressed the importance of agricultural non-point source pollution control. The government could develop good security measures in the agricultural system, develop water conservation policy and make different technical standards for regional water resources protection. The government could regulate the type of crop

cultivation (rotation system), the amount, time, type and methods of fertilizer.

- The government should strengthen the control of pesticide pollution at the source, improve the pesticide pollution monitoring system and further improve laws and regulations, technical norms and standards of the management of China's pesticide. The government should strengthen the position and role of the environmental protection departments in the safety management of pesticides, make effective monitoring in the whole process of pesticides production, use, storage and transport, strict registration and use of pesticides species and adopt positive measures in a planned way in order to eliminate a group of highly toxic pesticides and persistent pesticides and research and develop new environment-friendly pesticides (high-performance, low toxicity and low-residue). In all, the government should improve the technology stander of the pesticides manufactures and further improve the quality of pesticides.

In the use of pesticides, government should develop national standards and norms of the pesticides use: following the guideline of prevention first and prevention and treatment combination, the government should establish information systems of forecasting plant diseases and insect pests, promote integrated diseases, pest and grass control techniques and biological technology, promote bio-pesticides and reduce the use of chemical pesticides amount. At the same time, the government should strengthen the basic research of the use of pesticide spraying equipment and methods use a new type of pesticide application equipment and improve pesticide application technology. Further, the government should encourage green food and organic food consumption, expand its market and promote the sustainable development of agriculture.

- The government should regulate organic waste recycling, promote China's industrial development of organic fertilizer commercialization and produce national standards of the production processes and the quality of related fertilizers. Policies could be made to encourage the research and the development of production technologies and methods of organic fertilizer. To reduce the loss of nutrients in the production and storage, efforts should be made to improve the utilization ratio of organic fertilizers resources and to improve the mechanism of "cycle of wide-area" (place recycling) and the "cycle of intravenous" (local recycling).

In the development of the laws and regulations of organic fertilizer application, the regional climate, soil,

crop conditions should be considered in the development of the amount, time and methods of use of organic manure, (including the development of a balanced application ratio between organic manure and inorganic fertilizer) in order to reduce non-point source pollution caused in the process of application. In development planning of the rural environment, a comprehensive utilization of straw is encouraged, reducing the burning of straw and the environmental damage caused by the accumulation of organic fertilizers. At the same time, government should carry out the construction of life garbage disposal facilities in towns and villages and speed up solid waste processing in the rural areas. From the economic, natural and technical studies and research, government should present a workable design for the recycling of the organic waste.

To establish rural environmental management system which includes agricultural non-point source pollution control: Combining the spirit of constructing a new socialist countryside, government departments prepare and revise agricultural non-point source pollution-related planning and environmental regulation, such as planning, agriculture and ecological planning, eco-industrial planning, rural living environment planning. Further, combining with the new rural building needs, departments establish rural environmental management system which includes agricultural non-point source pollution control, strengthen the government's macro-management guidance and develop effective laws and regulations, systems and standards. For the city, town, village households at different levels, related departments should strengthen responsibility of environmental management in rural areas, take the city (county) as unit for the establishment of rural environmental management system and give the township agricultural non-point source pollution control targets and indicators. Then, according to their own characteristics, each county makes the specific implementation methods of the agricultural non-point source pollution control and formulation of appropriate reward and punishment measures and monitoring mechanisms. The village should establish their own rules and regulations, add the clauses of the agricultural non-point source pollution control into their original regulations, strengthen the administrative measures, education and training measures and measures of economic levers. In addition, the village could introduce the rural non-point source pollution control model assessment index system and choose the ecological model village in the activity of "model village of a thousand, million village improvement" and then choose the model family and model individual from the model village and give them a certain degree of publicity and incentives. The above assessment will expand its influence and scope of the

radiation so that the rural non-point source pollution will be effectively controlled.

To strengthen the building of professional organizations of farmers: International experience has shown that farmer's technical association or professional organization for economic co-operation can effectively organize farmers and peasants to carry out marketing, get technical training, as well as to guide farmers to enhance public awareness of environmental protection. In the development of sustainable agriculture, Japanese government set up the honorary title of the eco-farmers (Eco-farmer) in order to encourage the farmers' incentive to protect the environment. In the construction of organic farms, British government required that farmer have to register every 1-2 years. So, environment-friendly farming can be encouraged from the aspect of increasing public credibility. From the general promotion of technology, environmental protection or market activities, our country is in an urgent need to establish this type of professional and technical organization of farmers. Although the government has promoted the establishment of such organizations from several aspects, a recent study showed that: only 2% of farmers took part in such professional and technical organization of farmers. On the other hand, due to the lack of legal status and the perfect management system, effect of such professional and technical organizations of farmers has been limited. In order to ensure the organizations' sound development, the following policy measures are recommended:

- To transform the government's functions: The Government needs to support professional and technical organizations of farmers from the areas such as: credit, training, information exchange
- To establish the relevant laws and regulations of the management of those professional and technical organizations of farmers and clear their legal status
- To create environmental conditions in order to encourage the building and the effective run of the professional and technical organizations of farmers
- To carry out the scale management of land in a timely manner, develop farming professionals and take advantage of professionals to do the job of dissemination and promotion of science and technology, to stress reasonable application of new technologies and the application of fertilizer so as to reduce fertilizer costs and improve efficiency of farming

To improve the means of treatment and to build a portfolio of policy-based control mechanism: The United States and the European Union's experience has shown that non-point source pollution is difficult to

regulate and control, because it comes from a large number of different geographic sources, each of which emits a small amount of pollutants. Effective policy must have impact on many of the actors in order to reduce the relatively small pollutants that cannot be observed. This leads to building a cost-effective system of policies. The policy system is formed by a wide range of policy tools, such as subsidies, education and standards of conduct and it encourages the farmers to improve the surrounding environment by use of a "chain reaction" mechanism. After years of research and exploration, China has formed the policy of diversification tool system which includes an order-control, economic incentives and voluntary policies. But, most of these policies have not yet been applied to the agricultural sector. This has seriously affected the agricultural non-point source pollution prevention and treatment. As a result, while theoretical research of the non-point source pollution and its external aspects is being strengthened, it is necessary to actively explore the application of the existing management tools into the agricultural non-point source management. Because it is hard to expand the area of China's current policy, agricultural non-point source pollution prevention and control has to take full advantage of some of their own existing resources, experience and human resources and so on to reduce costs and avoid waste. For example, it is one of the very urgent tasks to take the agricultural non-point source pollution reduction goals into the existing environmental policies of returning farmland to forests, preventing soil erosion and treatment of small river valleys the policy and to reestablish policy goals and establish mechanism of coordination between sectors.

Economic incentives: Agricultural non-point source pollution prevention and control policy aims at guiding the polluter to consider directly social costs that their production imposes on, that is, the internalization of external costs. An ideal policy objective is to maximize the net benefits (that is, the deduction of the social benefits and the costs caused by the pollution) through the pollution control, or control the pollution at the optimal level of pollution that maximizes the social welfare function. From the present situation, application of economic instruments in the agricultural non-point source pollution control is not very common and some policy even did not succeed. But economic incentives are still worthwhile to explore and try and are essential

parts of the policies of pollution control. At present, fertilizer tax and pollution fee policy, the cost-sharing policies, subsidies and ecological point source - non-point source of emissions trading and other external and internal policies of the pilot activities can be applied in the river levels and the mechanisms and channels of internalization of the agricultural non-point source can be explored. The form of green box policies can also be used to promote environmentally friendly modes of production and application of related technology standards. To the farmers who take the voluntary application of soil testing fertilizer or organic fertilizer formula or other environment-friendly technology, the Government should give them certain agricultural subsidies according to the actual situation.

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