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Conference Paper

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The Simulation Analysis of Optimal Policy Including Introduction of Biomass Plant Technology for Decreasing Water Pollutions in Jiaxing City, China

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Abstract:

In the study, we proposed the environmental policies to decrease water pollutants that generate from household, non-point and production in Jiaxing city of China. We especially introduced biomass plant technology for pig farming industry in order to improve the water environment. We constructed environmental model and social economic model by computer simulation that evaluated the efficiency of biomass plant technology from both water environmental preservation and social economic development. The research established the significance and feasibility of introducing biomass plant technology that allows simultaneous pursuit of environmental improvement and regional development. The comprehensive evaluation and optimal policies are expected to form the basis of decision-making in Jiaxing city.

Keyword: Biomass plant, Environmental policy, Simulation, Model

1. Introduction

With rapid economic growth, environmental problem resulted from an increase of waste that emitted by mass consumption activities is being actualized in China. The low efficiency of waste treatment system resulted in serious pollution, and the untreated wastewater directly flows into the river system. The Green House Gas (GHG) like the methane and the nitrous oxide are generated from such waste and global warming is promoted, and these GHGs with greenhouse effect equals to tens to hundreds times of carbon dioxide. Moreover the untreated wastes make the problem of water pollutants more serious. It is expected that the global warming issue or the water pollution problem resulted from the untreated waste will become important more and more in the future.

Based on the background, we reconstructed biomass recycle system to convert the current waste treatment system, minimize the negative environmental impact, and improve a series of process like production, consumption, abandonment and so on. It is necessary to evaluate the technology that can actually introduce it to solve the current state of environmental problems, and the resource and energy problems is understood, finally to materialize immediately as a policy that should be executed.

Recently, many studies have undertaken efforts to protect the water environment and improve economic development. In Japan, Hirose and Higano [1] constructed simulation analyses to evaluate water purification policies in the catchment area of Lake kasumigaura, Japan. Mizunoya et. al [3] analyzed and assessed synthetic environmental policies to reduce environmental burdens by biomass technology Studies about comprehensive environmental evaluation in China are mainly concerned with theories and theoretical model at national level. Researches on integrated practical assessment of environmental degradation and economic development are in initial stages. Wang and Tang [5] constructed a two-level theoretical model of environment and economic development to analyze the efficiency of environmental subsidies. The state environmental protection administration of China [4] estimated the pollutants from stockbreeding wastes and the benefits of methane fermentation. In most of these studies, conclusions are derived from simple data analysis and foreign experiences. There has been little research into the construction and analysis of a comprehensive simulation policy that is includes the introduction of current treatment technologies to control water pollutant emissions without deteriorating the socio-economic activities level, especially in the suburb around large cities.

However, there is little research that constructs and analyzes a comprehensive simulation model based on the economic characteristics and situations of China, especially for rural suburbs of big cities. Therefore, feasible simulation should be constructed to realize the simultaneous pursuit of environmental preservation and economic development on the basis of characteristics of china.

In the study, we selected Jiaxing city as an object region, and evaluated the effect of the advanced biomass technology is introduced with introduction of an existing environmental policy from the aspects of environmental impact, economy, and possibility of introduction of biomass technology.

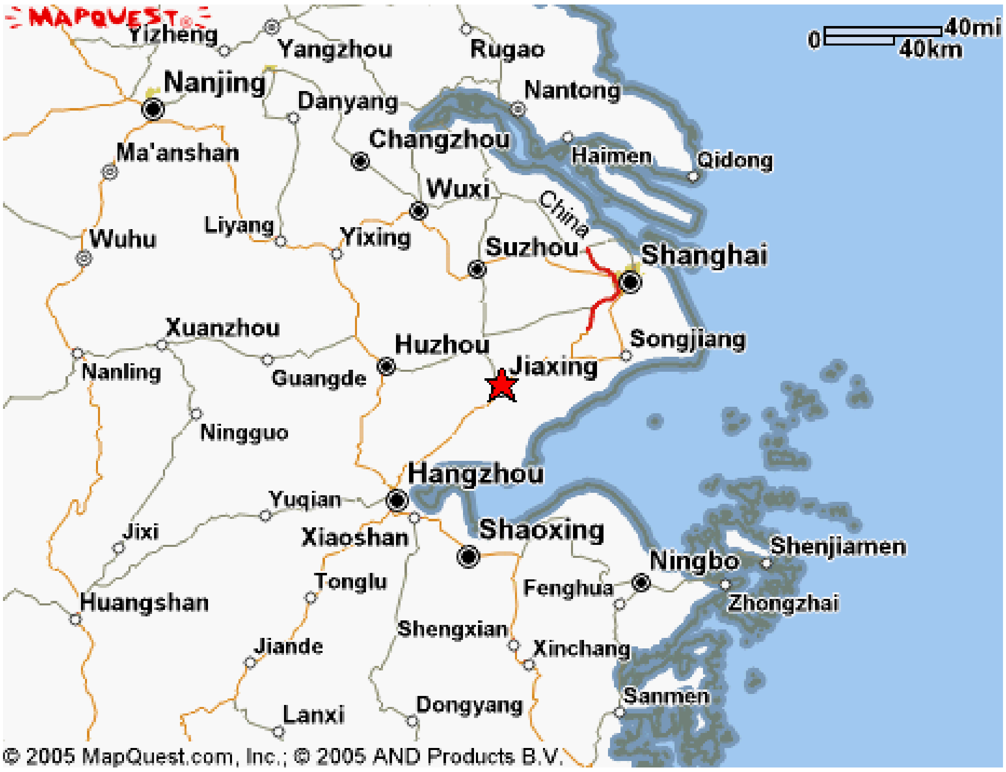

Fig. 1 Location of Jiaxing City

2. Simulation Model

2.1 Skeleton of Simulation Model

The dynamic simulation model consisted of a water pollutants flow balance model, socio-economic model and one object. The water pollutants flow balance model describes how the pollutants flow into the rivers. The socio-economic model represents the social and economic activities in the region and the relation between the activities and emission of pollutants (Fig. 2)

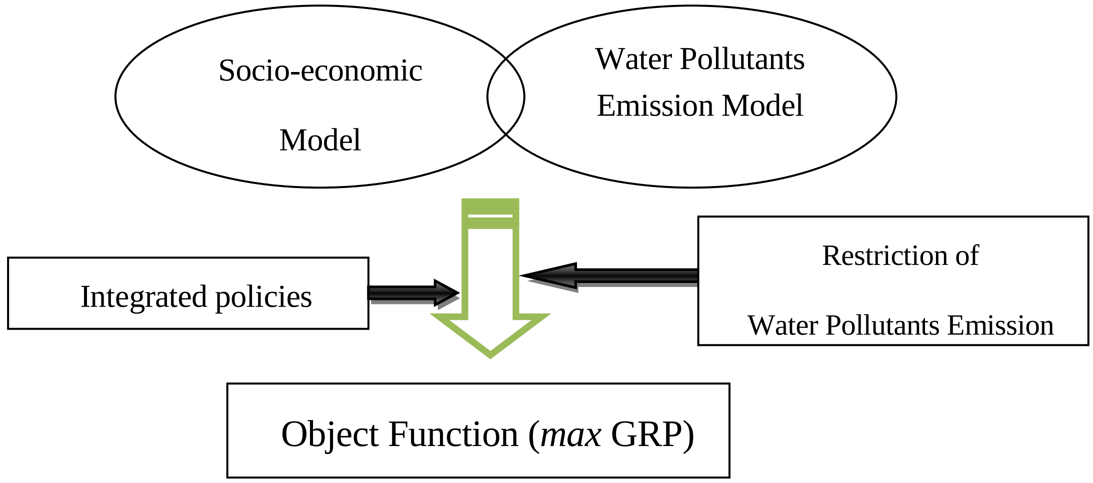

Fig. 2 Construction of Sub-model

2.2 Framework of Simulation Model

The pollutants measured in this study included T-N (total nitrogen), T-P (total phosphorus), COD (chemical oxygen demand) (Table 1). Table 4 represents the integrated policies used in the simulation model to reduce water pollutants and conserve water resource for the target area, and the government selected hybrid policies to realize efficient improvement of the water environment. Table 3 shows net load of water pollutants by different sources. Stockbreeding wastes in the catchment areas contribute heavily to water pollutants, especially pig farming has become the source of the most serious pollution in the catchment areas (Table 3).

Table 1 Classification of water pollutants

Index	Name
1	T-N
2	T-P
3	COD

Table 2 Integrated policies for the catchment area

Objectives		Name of policy
Household		Sewage system
Non-Point		Promotion of organic fertilizer and fallow field
Production	Pig Farming	Reduction of the capital employed and adoption of biomass plant technology
	Other Industry	Reduction of the capital employed

Table 3 Net load of water pollutants by different sources (2006)   (t/year)

Index		T-N	T-P	COD
Manufacturing Industry		7,802	897	17,925
Household		9,066	824	17,953
Pig Faming		10,514	2,628	26,286
Other Stockbreeding Industries		370	97	4,020
Non-point	Upland Cropping	532	158	265
	Rice Cropping	1,292	31	5,698
Fisheries		1,525	497	10,170
Other Industries		3,859	294	6,153
Total amount		34,960	5,426	88,480

Source: yearbook of Jiaxing County, 2007   [2]

3. Model structure

3.1 Objection function

The objective function was constructed to maximize the total Gross regional Product (GRP) over the target term (t=10) in order to determine an optimal policy.

$$MAX\sum_{t=1}^{T}\left(\frac{1}{1+\rho}\right)^{t-1}GRP(t) \qquad (1)$$

in which, en: endogenous, ex: exogenous, ρ: social discount rate (=0.05)

3.2 The material flow balance model

Total pollution of the net load of water pollutants is defined by socio-economic activities of each municipality. Moreover, the water pollutant emitted by socio-economic activities composed of pollutants from households, non-point sources and production activities.

(1) Water pollutant load of the catchment area

$$Q^{p}(t) = Q_j^{Hp}(t) + Q_j^{Lp}(t) + Q_j^{Ip}(t) \qquad (2)$$

$Q_j^{Hp}(t)$: water pollutant p emitted by households in municipality j at time t (en)

$Q_j^{Lp}(t)$: water pollutant p emitted by non-point sources in municipality j at time t (en)

$Q_j^{Ip}(t)$: water pollutant p emitted by production activities in municipality j at time t (en)

(2) Pollutants from household wastewater in each municipality

$$Q_j^{Hp}(t) = \sum_{k=1}^{2} E_j^{pk} Z_j^{k}(t) \qquad (3)$$

(k:1=sewage plant; k:2=untreated waste water)

E_j^{pk}: the pollution emission coefficient of sewage plant k in municipality j (ex)

$Z_j^{k}(t)$: the population that use sewage plant k in municipality j at time t (en)

(3) Load of water pollutants from non-point sources in each municipality

$$Q_j^L(t) = \sum_{l=1}^{5} Q_j^{Lpl}(t) = G^{pl} \cdot L_j^l(t) \qquad (4)$$

(l:1=paddy field; l:2=rice field; l:3=forest; l:4=city area; l:5=other land use)

$Q_j^{Lpl}(t)$: pollutants p emitted by land use l in municipality j at time t (en)

G^{pl}: coeffient of water pollutant p emitted through land use l (ex)

$L_j^l(t)$: area of land use l in municipality j at time t (en)

(4) Load of water pollutants from production activities in each municipality

$$Q_j^{Ip}(t) = \sum_{m=1}^{7} Q_j^{Ipm}(t) = p^{pm} \cdot X_j^m(t) \qquad (5)$$

(m:1=upland cropping; m:2=rice cropping; m:3=manufacturing industry; m:4=fisheries; m:5=pig faming; m:6=other stockbreeding industries; m:7=other industries)

$Q_j^{Ipm}(t)$: pollutants p emitted by production of industry m in municipality j at time t (en)

p^{pm}: coeffient of water pollutant p emitted by industry m (ex)

$X_j^m(t)$: amount of production of industry m in the area of municipality j (en)

$$Q^{Ip5}(t) = P^{p5} \cdot X_j^5(t) \qquad (6)$$

$$Q_j^{IP5}(t) = P^{P5BP} \cdot TS_j^{BP}(t) + P^{P5N} \cdot TSD_j^{5S}(t) \qquad (7)$$

$Q_j^{IP5}(t)$: water pollutant p emitted by pig farming industry in municipality j at time t (en)

P^{P5BP}: coefficient of water pollutant p emitted in pig feces and urine treated by biomass plant (ex)

$TS_j^{BP}(t)$: number of pig for which feces and urine were treated by biomass plant in municipality j at time t (en)

P^{P5N}: coefficient of water pollutant p emitted in pig feces and urine without any treatment (ex)

$TSD_j^{5S}(t)$: number of pig for which feces and urine were not treated in municipality j at time t (en)

3.3 policies for household wastewater generation

According to the characteristics and situations of the catchment area, the treatment of household wastewater mainly depends on the sewage systems. These measures are implemented by the municipality.

(1) Population increase in each municipality

$$Z_j(t+1) = Z_j(t) + \Delta Z_j(t) \qquad (8)$$

$$\Delta Z_j(t) = \eta_j \cdot Z_j(t) \qquad (9)$$

$Z_j(t)$: population in municipality j at time t (en)

η_j: coefficient of population growth in municipality j (ex)

$\Delta Z_j(t)$: population increase in municipality j at time t (en)

(2) Population that uses the sewage systems

The population that uses the sewage systems is equal to the total population of catchment area.

$$Z_j(t) = \sum_k Z_j^k(t) \qquad (10)$$

$Z_i^k(t)$: population that uses the sewage systems in municipality j at time t (en)

(3) Increase in the population that uses the sewage systems

$$\Delta Z_j^k(t) \le \Gamma_j^k \cdot i_j^k(t) \qquad (11)$$

$i_j^k(t)$: increase in the population that uses the sewage systems in municipality j at time t (en)

Γ_j^k: reciprocal of the necessary construction investment per person that uses the sewage plant

(ex)

3.4 Treatment policies for non-point sources

(1) Land use

$$\overline{L} = \sum_{j=1}^{6}\sum_{l=1}^{5} L_j^l(t) \qquad (12)$$

$\overline{L}$: Gross area (ex)

$L_j^l(t)$: area of land use in municipality j at time t (en)

(2) Conversion of paddy fields and rice fields to other land

$$L_j^l(t+1) = L_j^l(t) + \sum_{L \neq l} L_j^{lL}(t) - \sum_{l \neq L} L_j^{Ll}(t) \quad (13)$$

$L_j^{lL}(t)$: conversion of land from l to L in municipality j at time t (en)

$L_j^{Ll}(t)$: conversion of land from L to l in municipality j at time t (en)

3.5 Treatment measures for production activities

(1) Production function and curtailment

$$X_j^m(t) \leq \alpha^m \left\{K_j^m(t) - S_j^m(t)\right\} \qquad (14)$$

α^m : ratio of capital to output in industry m (ex)

$S_j^m(t)$: subvention to industry m from government in municipality at time t (en)

$$K_j^m(t+1) = K_j^m(t) + i_j^m(t) - d^m K_j^m(t) \quad (15)$$

$K_j^m(t)$: capital available for industry m in municipality j at time t (en)

$i_j^m(t)$: investment by industry m in municipality j at time t (en)

d^m : depreciation rate of industry m (ex)

3.6 Flow balance in the commodity market

$$\begin{aligned} X(t) \geq AX(t) + C(t) + I^m(t) + B^S \cdot i^1(t) \\ + B^{BP} \cdot K^{BP}(t) + e(t) \end{aligned} \qquad (16)$$

$X(t)=\sum_j X_j(t)$: column vector of the m-th element that is the total product of industry m in the basin (en)

$I^m(t)=\sum_j I_j^m(t)$: total investment at time t (en)

$i^1(t)=\sum_j i_j^1(t)$: total investment for construction of sewage system (en)

$K^{BP}(t)=\sum_j K_j^{BP}(t)$: capital available for biomass plant at time t (en)

A: input-output coefficient matrix (ex)

$C(t)$: total consumption at time t (en)

B^S: column vector of m-th coefficient that induced production in industry m by construction of sewage system (ex)

B^{BP}: column vector of m-th coefficient that induced production in industry m by construction of biomass plant (ex)

$e(t)$: column vector of net export (en)

3.7 Gross regional product

We adopt the index of GRP to reflect the development of the local socio economy.

$$GRP(t)=\nu X(t) \qquad (17)$$

ν: row vector of m-th element that is rate of added value in m-th industry (ex)

4. Simulation results

4.1 simulation cases

In this study, we define the simulation cases that water pollutants amount reduces 15% per year during the future 10 years than 2006, and we set case 1 that 15%-N and case 2 are 15%-BP (Table 4).

Table 4 Simulation cases

Case	Note
Case 1 (15%-N)	Water pollutants amount reduces 15% Not biomass Plant technology
Case 2 (15%-BP)	Water pollutants amount reduces 15% Take biomass plant technology

4.2 Results

In this study, we introduced biomass plant technology and adopted integrated policies to construct environment-social economy simulation model, and the optimal simulation was carried out to analyze the efficiency of biomass plant technology. In this simulation, we set the purpose that the emission amount of water pollutants COD, T-N, T-P realize the reduction of 15% during the period of 2007 to 2016 as compared to 2006. Therefore, we set the cases that with and without adoption of biomass plant technology to compare the possibility and feasibility of introduction of biomass plant technology for the objective area. According to the simulation results, when we did not adopt the biomass plant technology, the development of GRP was restricted in order to realize the purpose of water pollutants decease 15%; however, when the biomass plant technology was adopted in the simulation, the introduction of biomass plant technology allows simultaneous pursuit of environmental preservation and economic development.

Moreover, with the same constraints functions and purpose that realize water pollutants decrease 15%, the amount of objective function (accumulated amount of GRP over 10 years) has a difference of about 172 billion Yen, when we adopt the biomass plant technology. The treatment scale of biomass plant technology is 1,000 pigs and construction cost of the facility is 8 million Yen when the technology is made in Japan. Based on the results of simulation, when the technology facility is made in Japan, about 5,705 of biomass plant technology facilities should be construction in the study area, the total construction cost and the maintenance cost are 40.6 billion Yen and 18 billion Yen, respectively. The total cost is about 58.6 billion Yen over 10 years; on the other hand, the amount of objective function increase 172 billion Yen as compared with not adopt biomass plant technology. We should make a point that the cost of technology facility would be down when the facility is made in China. According to the technical expert, the China made cost of biomass plant technology facility is about 20% as compared when it is made in Japan. Therefore, the amount of subsidization for biomass plant technology is about 12.6 billion Yen over 10 years. Therefore, it is absolutely of necessity and possibility to introduction biomass plant technology into the study area. Moreover, untreated stockbreeding wastes are the most serious resource of water pollution and green house gases (CH_4, NO_2). The biomass plant technology contributes to the reduction of GHG. In this simulation, when we adopt biomass plant technology facility, the GHG emission (calculated by GWP) would decrease about 9,253,368 tons over 10 years.

According to this research, the following conclusions can be obtained. When we did not adopt biomass plant technology, the purpose of water pollutants emission decrease 15% can be realized at the cost of significant reduction of the production of each industry in the study area. When we adopt biomass plant technology, it allows simultaneous pursuit of environmental preservation and economic development. The cost-benefit analysis result shows there is a great feasibility and possibility to introduce biomass plant technology in the study area.

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