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Conference Paper

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Comprehensive watershed management policies for treatment of stockbreeding wastes and reduction of green house gas emission in the Dian Chi Lake, China

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Introduction

Using biomass to produce energy is often a way to dispose of waste materials that otherwise create environmental risks. In addition the use of biomass for energy slows down the risks of global climate change as well. In short, biomass energy is not only a new renewable and sustainable energy, but also an effective way to resolve environmental problems. Dian Chi Lake is the largest highland lake in Yun Nan Province and the sixth largest freshwater lake in China (Fig. 1). The water of Dian Chi Lake shows serious eutrophication that has also become a serious threat to the sustainable development of Kun Ming City. The treatment of Dian Chi Lake is listed in the Chinese national key management targets of “three rivers and three lakes”. In the next six years, the Kun Ming government will develop a policy to construct livestock industrial bases in some catchment areas. Therefore, we considered pig feces and urine as biomass resources by adopting a biomass recycle plant. The wastes from pigs can be rationally used and pollutants that flow into the lake can be decreased and the risks of the green house effect can be reduced by slowing down green house gas emissions. The results of this study may also provide useful information for municipal leaders.

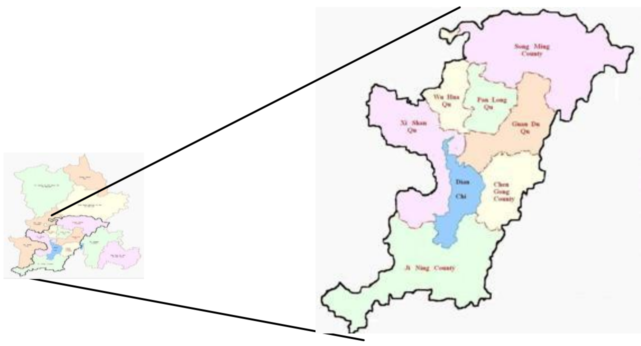

Fig. 1. Location of Dian Chi Lake

2. Method

The simulation models in this study are composed of four sub models (socio-economic model, material flow balance model, air pollutants flow balance model and energy balance model) and one objective function. The socio-economic model describes the social and economic activities and the relationships between the activities and the emissions of the pollutants. The material flow balance model describes changes in the generation and flow of pollutants in the lake. The air pollutants emitted into the catchment area can be determined by the air pollutants flow balance model. Three types of greenhouse effect gases (CO_2, CH_4 and N_2O) and two air pollutants (SOx and NOx) are controlled at minimum levels. How much electric energy can be generated by the biomass plant can be determined by the energy balance model. The driving force of the simulation model was obtained by maximizing the potential function of the GRP (Gross Regional Product), subject to the structural equations of the combined sub models. The framework of the simulation model is shown in Figure 2.

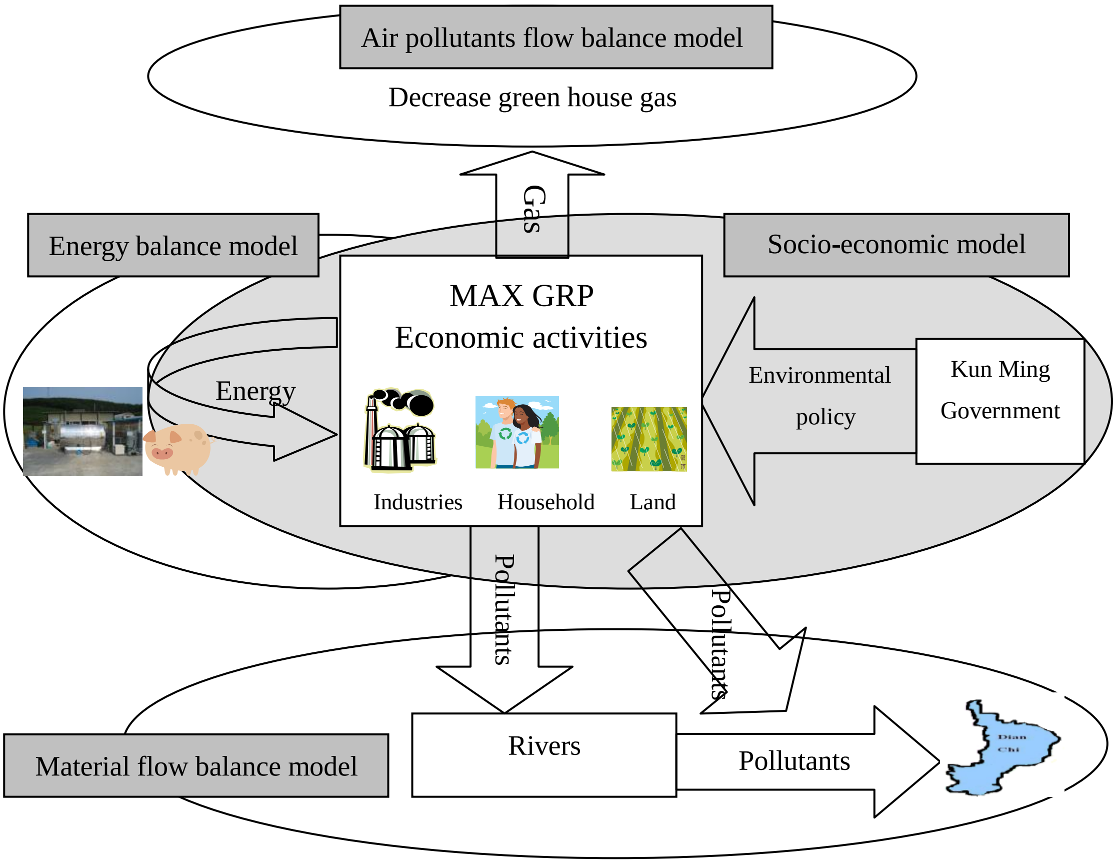

Fig. 2. Framework of the simulation model

3. Model structure

The target area was classified into seven zones (Table 1). We set the pollution sources as industry, household, land use and rainfall. The household wastewater disposal system was divided into 2 categories, land use into 5 categories and industry into 6 (Table 2). The simulation running period was from 2008-2017 (total 10 years) and the pollutants measured in this study were total nitrogen (T-N), total phosphorus (T-P) and COD which strongly affect the deterioration of water quality (Table 3). Measures for treatment of water pollutants included the current polices that have been adopted and the advanced technologies we adopted (Table 4).

The water pollutants flowing into Dian Chi Lake were set to reduce the pollutants year by year, leading to 37%, 40%, 45% and 48% decreases in the tenth year as compared with the actual data of 2007 with or without adopting a biomass plant, designated as not adopted Case 37, adopted Case 37, adopted Case 40, adopted Case 45 and adopted Case 48 (Table 5).

The biomass recycle plant was developed by Ibaraki Prefecture in the city area project for promotion of coordination between industry, academia and government and advancement of regional science and technology such as “The Lake Kasumigaura Biomass Recycling Development Project (2003-2005)”. The emissions of methane are zero and all methane generated is converted into carbon dioxide by generating electricity. This biomass recycle plant can generate 22.8 thousand kwh/year, and operation of the biomass recycle plant requires 4.2 thousand kwh/year. This is to say the biomass recycle biomass plant can generate a net of electric energy of 18.6 kwh/year.

Table 1. Classification of target area

No.	Towns and districts
1	Song Ming County
2	Guan Du District
3	Pan Long District
4	Guan Du District
5	Ji Ning County
6	Wu Hua District
7	Song Ming County

Table 2. Classification of land use, industry and household waste water disposal system

Index	Facility	Index	Land use	Index	Industry
1	Sewage Plant	1	Dry farmland	1	Agriculture
2	Untreated Waste Water	2	Rice field	2	Pig industries
		3	Wood land	3	Other stockbreeding industries
		4	City area	4	Fisheries
		5	Other land use	5	Manufactory industries
				6	Other industries

Table 3. Classification of pollutants

Index	Pollutants
1	Total nitrogen (T-N)
2	Total phosphorus (T-P)
3	Chemical oxygen demand (COD)

Table 4. Measures for treatment of water pollutants

Source of pollutants	Name of technology and policy	Measures
Production	Sewage system and sewage plant Reduce working capital	1. Subsidization for the municipality to install more sewage systems and sewage plants. 2. Subsidy for industries to reduce working capital to adjust to production.
Pig farming industry	Introduction of a biomass recycle plant and reduction of the capital employed	3. Subsidy to introduce a biomass recycle plant. 4. Subsidy to reduce working capital to adjust production.
Household	Sewage systems	5. Subsidization for the municipalities to install more sewage systems and sewage plants.
Land use	Changing land use policies Low-elution fertilizers	6. Subsidy to promote changing paddy field and dry farmland to land use of other purposes (categorized as “other land use”). 7. Subsidy to promote the use of low-elution fertilizer (Low-elution fertilizer is a coated fertilizer to control elution of nutrient into the soil).

Table 5. Simulation cases

Case name	Reduction rate in 2017 (compares to the real data in 2007 With or without biomass plant)	Constraints on the amount of T-N in 2017(ton)	Constraints on the amount of T-P in 2017(ton)	Constraints on the amount of COD in 2017(ton)
Not Adopted (Case37)	37%	14,382	1,318	49,670
Adopted (Case37)	37%	14,382	1,318	49,670
Adopted (Case40)	40%	13,697	1,255	47,305
Adopted (Case45)	45%	12,556	1,151	43,363
Adopted (Case48)	48%	11,871	1,088	40,997

4. Model structure

4-1 Objective Function

We considered the gross regional product of the basin as an index that reflects the level of socio-economic activities and the regional economic development. It is the objective function maximized over the target term in this study.

$$\max \sum_{t=1} \frac{1}{(1+\rho)^{(t-1)}} GRP(t) \tag{1}$$

$$GRP(t) = vx(t) \tag{2}$$

GRP(t): Gross Regional Products in term t (endogenous)

ρ : social interest rate=0.05

V: row vector of mth element that is the rate of added value in the mth industry (exogenous)

4-2 Water pollutants flow balance model

All rivers in the drainage river form a heart-shaped flow into Dian Chi Lake. Therefore we assume the net water pollutants in the Lake are defined as the sum discharged by socio-economic activities, the sewage plants, fisheries and rainfall in the drainage area of the lake.

Water pollutant load of Dian Chi Lake

$$Q^p(t) = \sum_i a_i^p(t) + Q^{FP}(t) + \sum Q^{Dp}(t) + Q^{rp} \tag{3}$$

$Q^{p}(t)$: total net load of water pollutant p in region i of the lake at time t (endogenous)
$a_{i}^{p}(t)$: load of water pollutant p by socio-economic activities in region i at time t (endogenous)
$Q^{FP}(t)$: load of water pollutant p by fisheries in region i at time t (endogenous)
$Q^{Dp}(t)$: load of water pollutant p by sewage plants in region i at time t (endogenous)
Q^{rp} : load of water pollutant p by rainfall in region i at time t (exogenous)

4-3 Air pollutants flow balance model

In this study, we controlled the total emission of greenhouse gas by considering the greenhouse effect potential of each gas.

$$TGG(t) = AZ_1 + AZ_2 \cdot GWP_2 \cdot PMCW_{12} + AZ_3 \cdot GWP_3 \cdot PMCW_{13} \tag{4}$$

$$\begin{aligned} AZ_g(t) &= AP_g^m \cdot \sum_i X_i^1(t) + X_i^2(t) + X_i^3(t) + X_i^5(t) + X_i^6(t)\} \\ &+ AP_g^{4BP} \cdot \sum_i TS_i^{BP} + AP_g^{4S} \cdot \sum_i TS_i^S(t) + AP_g^c \cdot C(t) \end{aligned} \tag{5}$$

$TGG(t)$: total emissions of greenhouse gases while considering the greenhouse effect potential of each gas (named TGG) at term t (endogenous)
$AZ_g(t)$: total emissions of greenhouse gases or air pollutant g at term t (endogenous) g=1 (CO_2), 2 (CH_4), 3 (N_2O)
GWP_g : potential index of greenhouse effect of each gas when greenhouse effect from discharge of one molecule of carbon dioxide is assumed to be one (exogenous)
$PMCW_{12}$: molecular weight ratio of CO_2 and CH_4 (=2.75) (exogenous)
$PMCW_{13}$: molecular weight ratio of CO_2 and N_2O (=1.00) (exogenous)
AP_g^m : coefficient of greenhouse gas and air pollutant g emitted by industry m ($\neq 4$) (exogenous)
AP_g^{4BP} : coefficient of greenhouse gas and air pollutant g emitted by pigs with feces and urine treated by a biomass recycle plant (exogenous)
AP_g^{4S} : coefficient of greenhouse gas and air pollutant g emitted by pigs without feces and urine treatments (exogenous)
AP_g^c : coefficient of greenhouse gases and air pollutant g emitted by final demand (exogenous)
C(t): column vector of consumption (endogenous)

5 Results of the simulation

In this study, feasible solutions were achieved for adopted Case0 to adopted Case48. No feasible solution could be obtained for Case 49 that both adopted and did not adopt a biomass recycle plant introduction policy. A feasible solution was achieved to Case 48, when we adopted introduction of biomass energy recycle plant policy.

5.1 Objective Function

The results show that it is very effective to adopt a biomass energy recycle plant when considering both the environment and the development of the local economy in all simulations.

In the simulation, no feasible solution was obtained for Case 38 if we did not adopt a biomass energy recycle plant. However, if we adopted a biomass energy recycle plant, a feasible solution was obtained until Case 48. Adopting a biomass energy recycle plant decreased the total amount of pollutant by 9.1%, 14% and 11.5% of T-N, T-P and COD respectively in adopted Case 37. This is a greater decrease in pollutants than without adopting a biomass recycle plant for the total ten years. Moreover, adopting a biomass energy recycle plant is more effective in promoting regional economic development. There is a difference in total ten years between adopting and not adopting a biomass energy recycle plant of 165 billion RMB (Figure 3). The increase in the GRP when not adopted Case 37 and adopted Case 48 is very similar, but the pollutants decrease at least 11% more while in adopted Case 48 than the not adopted Case 37 cases.

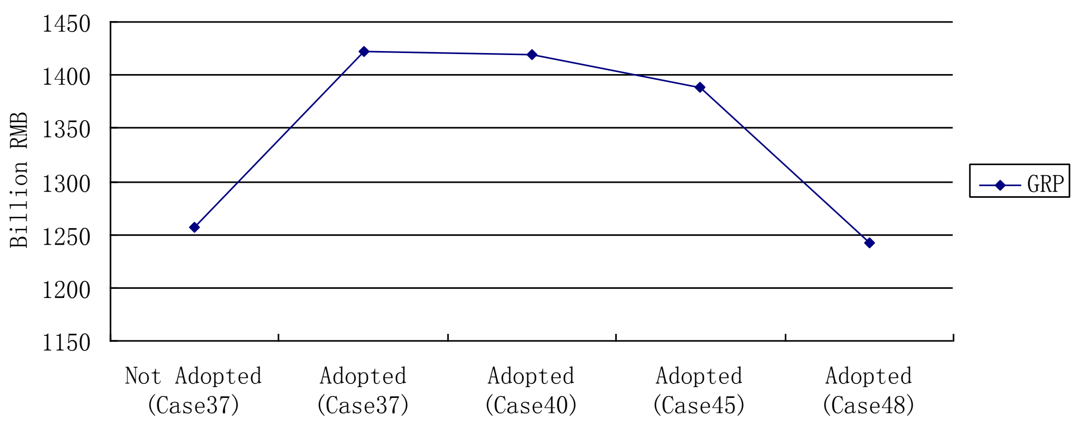

Figure 3 Objective value (GRP) in 2017

6 Conclusion

In this simulation, introduction of a biomass utilization plant was chosen as an effective tool to reduce environmental pollutants in all simulations. The introduction of a biomass recycle plant raised the rate of the reduction by 11% as compared to not adopting the introduction of the biomass recycle plant policy. In addition, when 37% was introduced with biomass recycle plants, the objective value showed a difference of more than 165 billion RMB as compared to not adopting a biomass recycle plant. Moreover, we also found that if biomass recycle plants introduction policy is adopted in the catchment area, production of the pig farming industry increases about 732 million RMB over the total ten year simulation period as compared with not adopting. Concerning environmental pollutants, we found that we can reduce total emission of greenhouse gas about 841 thousand tons, considered greenhouse effect potential of each gas (TGG), 309 tons of N_2O and 52,030 tons of CH_4 emitted by pig farming industry in the total ten year simulation (2008-2017) by introducing biomass energy recycle plants. In addition, we found that 33.9 thousand tons of T-N, 4.5 thousand tons of T-P and 170.8 thousand tons of COD emitted by pig farming industry in the total ten year simulation can be reduced by introducing biomass recycle plants. Also 1.87×10^5 Kwh electricity in ten years can be generated by introducing a biomass recycle plant when 40% was introduced. This result implies that promotion of biomass resource utilization can improve both the environment and economy of the Dian Chi Lake Basin.

References

[1] Chen, Q., Tan, K., Zhu, C and Li, R. (2009) Development and application of a two-dimensional water quality model for the Daqinghe River mouth of the Dianchi Lake. *Journal of Environmental Sciences*, 21(3), pp.313-318.

[2] Gunes, K. (2008) Point and nonpoint sources of nutrients to lakes-ecoechnological measures and mitigation methodologies-case study. *Ecological Engineering*, 34. pp.116-126.

[3] Higano,Y., Miaunoya, T., Kobayashi, S., Taguchi, K. and Sakurai, K. (2009) A study on synthetic regional environmental policies for utilizing biomass resources. *International Journal of Environmental Technology and Management*, 11(1-2), pp.102-117.

[4] Higano, Y., Sawada, T. (2003) The dynamic policy to improve the water quality of Lake Kasumigaura. *Association for Human and Environmental Symbiosis*, 8(7), pp.38-49.

[5] Higano, Y. and Yoneta, A. (1998) Economical policies to relieve contamination of Lake Kasumiaura. *Studies in Regional Science*, 29(3), pp.205-218.

[6] Hirose, F. and Higano, Y. (2000) A simulation Analysis to Reduce Pollutants from the Catchment Area of Lake Kasumigaura. *Studies in Regional Science*, 30(1), pp.47-63.

[7] Jlger, S and Higano, Y. (2002) An analysis of interrelation between current environment and socioeconomic status regarding water pollution in Turkish Black Sea Basin. *Studies in Regional Science*, 33(3), pp.67-84.

[8] Kun Ming Statistical Yearbook. (2008) *China Statistic Press*, Bei Jing.

[9] Li, Q.M., Zhang, W., Wang, X. X., Zhou, Y. Y., Yang, H and Ji, G.G. (2007) Phosphorus in interstitial water induced by redox potential in sediment of Dianchi Lake, China. *Pedosphere*, 19(6), pp739-746.

[10] Miaunoya, T., Sakurai, K., Kobayashi, S., Piao, S. and Higano, Y. (2007) A simulation analysis of synthetic environment policy: effective utilization of biomass resources and reduction of environmental burdens in Kasumigaura Basin. *Studies in Regional Science,* 36(2), pp.355-374.