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환경지리정보시스템을 이용한 환경기초시설의 입지 결정요인 평가*

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The Evaluation of Location Decision Factors of Environmental Foundation Facilities using Environmental Geographic Information System*

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요 약

본 연구는 환경지리정보시스템을 활용한 활용하여 수질오염방지시설의 입지 결정요인을 분석하여 적정입지를 선정하는 방안을 제시하고자 한다. 이를 위해 수질오염총량제가 가장 먼저 실시된 낙동강 권역을 대상으로 환경지리정보시스템을 구축한 후 1) 수질오염방지시설의 처리용량에 영향을 미치는 오염원, 2) 수질오염방지시설의 입지와 오염원 배출량간의 관계를 분석하여 향후 어떤 오염방지시설을 어디에 입지시킬 것인가에 대한 정책대안을 제시하였다. 분석결과, 1) 수질오염방지시설의 처리용량 결정에 가장 큰 영향을 주는 오염원은 산업폐수발생량으로 판명되었으며, 2) 수질오염방지시설의 입지에 가장 큰 영향을 미치는 오염원은 산업체의 수로 나타났다. 이에 반해 인구수는 환경시설입지를 제한하는 효과가 있는 것으로 판명되었다. 또한, 경상북도 낙동강 중·상류 유역의 경우 주 오염원인 축산오염원에 대한 대처가 가장 미흡한 것으로 나타나 앞으로 축산오염원의 처리가 가장 시급한 것으로 판단된다. 본 연구는 장차 수질오염방지시설의 입지를 선정하는데 활용될 수 있을 것이며, 각 지역의 오염 특성에 따라 수질오염방지시설을 입지를 결정하는데 크게 기여할 수 있을 것으로 기대된다.

주요어 : 수질오염총량제, 수질오염원, 수질오염방지시설, 입지분석, 유역관리, 환경지리정보시스템

ABSTRACT

The purpose of this research is to select an appropriate location of water pollution prevention facilities(WPPF) through evaluating location decision factor using environmental geographic information system. To do that, this research reviewed the current location policies

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of WPPFs and its related researches. And this paper builds water pollutant statistical databases, integrated them with the geographic information system of the administrative areas where water pollutants are generated, and gears it with statistical programs such as correlation and regression analysis in order to figure out the pollution factors which influence on the location decision of WPPF on the real time base. The volume of discharge of industrial wastewater is one of the most important water pollutants on the location decision of WPPF. And the number of industrial facilities also was the most important location decision factor in constructing the WPPFs. In addition, this paper noted that the number of population in each area makes a role to restraint the construction of WPPF. It identified that the disposal facility in Nackdong river upper-middle watersheds was insufficient in treating the livestock pollutants. Therefore, Gyeongbuk should concentrate on the construction of disposal facilities of livestock pollutant in these areas. The results of this research will contribute to decide what kinds of WPPF should be constructed on which watershed in Nackdong River, and to forecast the future water quality of each watershed.

KEYWORDS : Limitation of Total Emission Volume of Water Pollutants, Water Pollutant, Water Pollution Prevention Facility, Location Analysis, Watershed Management, Environmental Geographic Information System

INTRODUCTION

The water pollutants(WP) of wastewater have been diversified and their emission volumes also have been increased since the process of industrialization of local areas. Therefore many local governments have made an effort to improve the water quality through establishing the water pollution prevention facilities(WPPF) such as wastewater, sewage, and livestock excretion treatment facilities. Eventually the central government has invested twenty four billion dollars on the construction of WPPFs and its technology development from 2001 to 2005, and many local governments also have constructed WPPFs in order to improve the river water quality. As a result the number of WPPF has gradually increased and water quality has gradually been improved in the aspect of some pollutants. However, there are no clear criteria and decision-making supporting system for deciding the location of WPPF. It often causes the dispute between the government and citizens or among governments or citizen groups in building the WPPFs.

The purpose of this paper is to suggest the policy alternatives for the location decision of WPPFs using environmental geographic information analysis system (EGIAS). To do that, it reviews the current location policies of WPPFs. Based upon these reviews, this study builds water pollutant statistical database(WPDB), integrated it with the geographic information system of administrative areas where the pollutants are generated, and links it with analysis programs such as correlation and regression analyses in order to figure out the real factors which influence on the location decision of WPPF on the real time base.

The analysis results note whether each WPPF can reduce what kinds of pollutants in each administrative or not. Moreover, the results of this research will contribute to decide what kinds of WPPF should be constructed on which watersheds in the Nackdong River upper-middle streams and to forecast the future water quality of each watershed.

REVIEW ON THE WATER POLLUTANT AND ITS PREVENTION POLICIES

1. The Concept of Water Pollutants and their Prevention Facility

Water pollution sources are divided into point and non point pollutant sources. The former is the pollution sources of the waste or sewage emission facilities, and livestock barns which have an exact emission location. Non point source pollution is also caused by wind, which, like rain, can pick up soil particles and deposit them in our lakes and streams. When it rains or the snow melts, water runs off the land into our streams, rivers, and inland lakes. As the water moves across various landscapes, such as plowed agricultural fields, city streets and residential backyards, it picks up soil particles, fertilizers, pesticides, animal wastes, road salt, motor oil and other land borne pollutants. The point pollutant is usually collected through the pipeline and purified by the treatment facilities. And then the emission location of these pollution sources can be easily identified. However, non-point pollution source can be emitted in several different areas where the emission location cannot be exactly specified. It can be subdivided into domestic, industrial, livestock, and underground water pollutants and so on. Therefore it is very difficult to note what kinds of pollutant sources are generated in which areas.

Water Quality Preservation Act Article 2 eventually guides the establishment of WPPF which reduces or eliminates the water pollutant sources(http://www.moe.go.kr, 2007). The Ministry of Environment defines its location standards which a WPPF cannot be established in the circumferential areas of public facilities, school zone, and high population density area because this facility is categorized into a disgusted one which is one of the NIMBY facilities. However, these standards can often cause the mismatch between the location and treatment volume of WPPF and the area or volume of pollutant emission, and also generate the dispute between the local government and the citizens or among the governments or the citizens.

2. Review of Literature on the Location Decision of the Water Pollution Prevention Facility

Jo et al. (1999) analyzed the spatial distribution of water pollutants in the upper stream of Gumho River using the geographic information system and satellite image. They figured out the pollution factors affecting water quality in these areas and compared its results with the actual measurement data. This study contributed to figure out a new research method for analyzing the water pollution factors. However, it only focused on the identification of existing water pollution status in their study area and did not suggest the policy alternatives to reduce or eliminate the water pollution sources. Bang et al. (2002) built a geographic information database which is composed of the natural environmental, socio-economic, and policy factors and it results applied into the location decision for small scale wastewater treatment facility which is based upon the land cover classification methods. Lee (2003) evaluated the suitability of sewage treatment facility using GIS in Daegu city. However, his research about the location decision of pollution prevention facilities concentrated on the selection of solid waste landfill site. He only used the land cover classification method for deciding the location of pollution prevention facility (Shin, 2001). Bae and Jang (1998) and Lee et al. (2000) also established the environmental attribute digital map which includes location factors and it was matched with land cover classification in order to figure out the optimal site of solid waste treatment facility. Braskerud (2002) identified factors affecting nitrogen retention in small constructed wetlands treating agricultural non-point source pollution.

However, there are few studies about the location decision of WPPFs in the large scale of water stream such as Nackdong River. Moreover, the characteristics of water pollutants and the volume of their emission are not reflected on the location decision of WPPFs but land cover classification is one of the most important factors in deciding the location of environment pollution prevention facilities such as landfill site and waste water treatment facility. And then these location decision standards often resulted in the mismatch between the WPPF and the actual water quality pollution status. The treatment capacity of WPPFs often does not cover the amount of waste water of each stream and also causes the conflict between the local government and citizens or environmental movement groups.

3. Integration the Geographic Information System with Water Pollutant Data

Goo (2000) proposed theoretically the integration the statistical data with the geographic information data for urban environmental analysis in the block level. He argued that the national statistical data should be stored into a block unit which is a subdivision of an administrative district unit, and the block unit should be a minimum unit for the integration of the national statistical data with geographic information system. However, he did not note how to integrate these databases with an administrative unit. Cho et al. (2001) also suggested the building of a national statistic geographical information system that integrates the statistical data of each administrative district with its geographic information system, but they did not define the specific level on the integration of database. Cho and Bae (2004) proposed the building of environmental geographic information system based upon the administrative zone and suggested the way of integration between a geographic data and an environmental statistic data using an administrative unit code. However they don't consider the link the geographic information system with analysis programs on these databases.

Recently, Ministry of Environment constructed a comprehensive GIS database on the natural environment but these databases have several limitations. A minimum unit of the database integration is a city level and this minimum unit is too big in deciding the location of WPPF in the local water stream level. Patra and Pradhan (2005) designed an environmental information system for monitoring water and air quality in urban areas. Sreenivasa et al. (2004) mapped the spatial distribution of water pollutants in Kolleru Lake, India using geographical information systems. Shattri et al. (2004) proposed various spatial technologies for natural risk management.

This research builds the water pollutant databases on the upper and middle streams of Nackdong River and these databases integrates with on the geographic information system based upon the administrative zone, and analysis programs such as variance and regression analysis tools will be linked in order to make possible an online and real time analysis. This study identifies water pollutants which are excluded in deciding the location of the current WPPFs and suggests the location and characteristics of WPPFs which should be built in this study area in order to improve the water quality.

THE BUILDING OF ENVIRONMENTAL GEOGRAPHIC INFORMATION AND ANALYSIS OF WATER POLLUTANTS

1. Characteristics of the Upper and Middle Streams of the Nackdong River

The Nackdong River watershed is one of the biggest basins in Korea and its upper and middle streams flow through various cities such as agricultural, industrial, and mountainous cities. And water qualities of these watersheds are very important for the citizens and local governments in the Gyeongbuk province because these water are used for the pipeline water resources, agricultural and industrial water sources. The Limitation of Total Emission Volume of Water Pollutants firstly was executed in the Nackdong River in the Gyeongbuk Province areas. Therefore several local governments have made efforts to build WPPFs and total 127 WPPFs such as Sewerage Plants, Wastewater Treatment Plants, and Livestock Wastewater Treatment Plants are located in these local governments such as Gumi city, Andong city, and so on (see Figure 1). The number of WPPFs will be continuously

Figure 1. The location of WPPFs in the research areas

increased and 30 million dollars has been invested in these areas to preserve the water quality after the implementation of Limitation of Total Emission of Water Pollutants. The Nackdong River watershed is composed of 98 sub-watersheds and had 48 water quality measurement facilities (http://water.nier.go.kr/weis/).

2. The Building of Water Pollutant Geographic Information System

This research uses environmental statistic data(Ministry of Environment, 2005), 2005 Statistics Yearbook of the Local Governments, the Nation-Wide Pollutants Investigation Data (National Institute of Environmental Research, 2004) in building the Water Pollutant GIS Database. To revise the mismatch between the administrative zone and watershed boundary, water pollutant data of each administrative zone are distributed into the each watershed. These water pollutant data are standardized by the area of watershed (㎡) to remove the bias occurred by the difference of the area of each watershed and to make an easy to compare the emission volume of water pollutants among each watershed. This study gathers the water pollutant data from 34 watersheds and these databases are integrated with the geographic information system of each administrative zone in order to figure out the exact locations of water pollutants. Water pollution data basically are composed by 7 major pollutants such as population, discharge of industrial wastewater, discharge living wastewater, the number of industrial facilities, the number of breeding cows, the number of breeding pigs, and the volume of water usage of household. These 7 categories are same that of Korea Pollutant Survey by Ministry of Environmental. More specifically, in order to establish the real time water quality analysis system on the WebGIS, at first, this research builds water pollutant database(WPDB), and joined it with geographic information system. Second, it produced water pollutants and WPPF location map. Third, water pollutants database imports to analysis programs using SAS Bridge for ESRI program, which include the geographic information system in the study areas(see Figure 2). Fourth, this study analyses the level of water quality, volume of pollutant emission, and the location of WPPFs like Chapter IV.

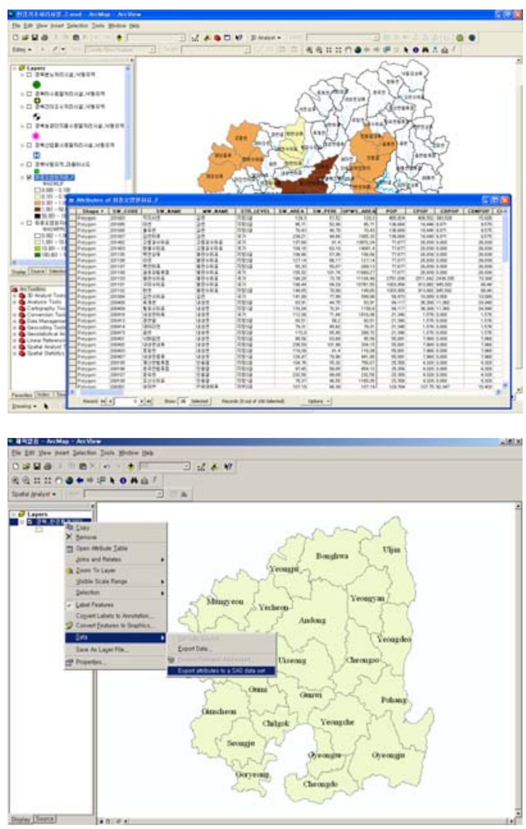

Figure 2. The building of WPDB, integration with geographic information system, and connection with statistical analysis program.

THE EMISSION OF WATER POLLUTANTS AND THE LOCATION OF WATER POLLUTION PREVENTION FACILITY

The WPPFs should be located in the area where the water pollutants are emitted in order to prevent effectively the spread of water pollution. And this paper figures out the match between the location of WPPFs and pollutant emission areas in the study areas. First of all, it notes the kind and amount of the emitted water pollutants and the location of WPPFs in the study areas. And water pollutant attribute maps are integrated with the location map of WPPFs in order to figure out visually the relationship of the pollutant emission and location of WPPFs like Figure 3~5. The living wastewater treatment facilities are classified into two types such as an industrial wastewater treatment facility which is relatively a large scale and a living wastewater treatment facility which is located in an agricultural or mountainous city. The level of living wastewater is relatively high at the cities of Gumi and Andong city because the number of population of these cities is more than that of any other local city in the study areas (Figure 3). Even though the discharge of living wastewater in the Andong and Youngju cities are large, the number and treatment capacity of living wastewater treatment facility are insufficient to clean up these wastewaters and it often results in the generation of the green tide in the Andong-Dam.

The discharge of industrial wastewater concentrated on the Gumi city. The location of WPPFs concentrated on the lower stream of Nackdong River in the Gumi city. Most industrial wastewater treatment facilities are located in the origin of pollutants in the Gyeongbuk province. The industrial wastewater treatment facility should be constructed in the Banbyun stream watershed because the volume of the discharge of industrial wastewater in this area is large (see Figure 4).

The number of livestock such as cow and pig are one of the important factors to cause the water pollution in the upper streams of the Nackdong River. The large number of cows and pigs are reared in these areas but only one or two livestock pollutant treatment facilities are located in each water stream. Therefore, these treatment facilities effectively cannot clean up the wastewater of livestock and it often results in the deterioration of water quality of the upper stream of Nackdong River. Eventually these streams are the main source of pipeline water for 7 million peoples in the Gyeongsang Province. Especially, considering the number of livestock, the more wastewater treatment facilities should be established in the Wuichen and Gamchen watersheds (see Figure 5). In summary, the emission of living and industrial wastewater and its treatment facilities are concentrated on some specific local cities such as the Gumi and Andong cities, but the emission of livestock wastewater is spread in the rural areas of the upper stream of Nackdong River and its treatment facilities are not sufficient, comparing them with the volume of livestock wastewater emission in these areas.

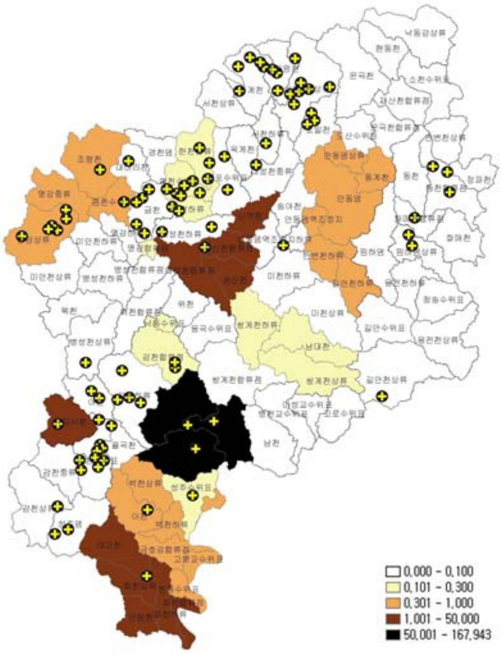

Figure 3. The discharge of living wastewater (㎥/㎡) and its treatment Facilities

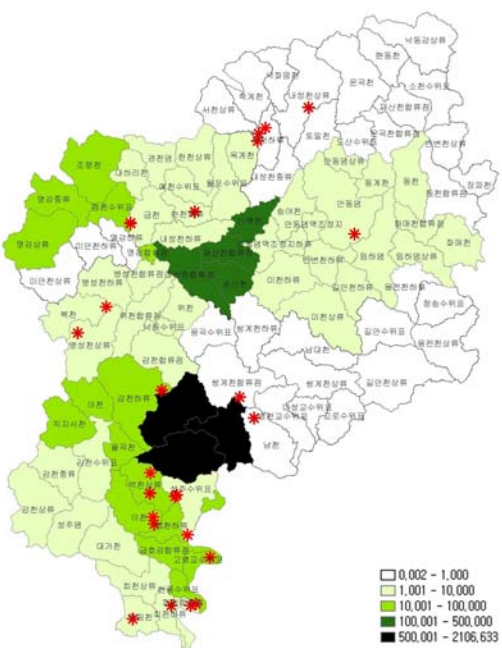

Figure 4. The discharge of industrial wastewater (㎥/㎡) and its treatment facilities

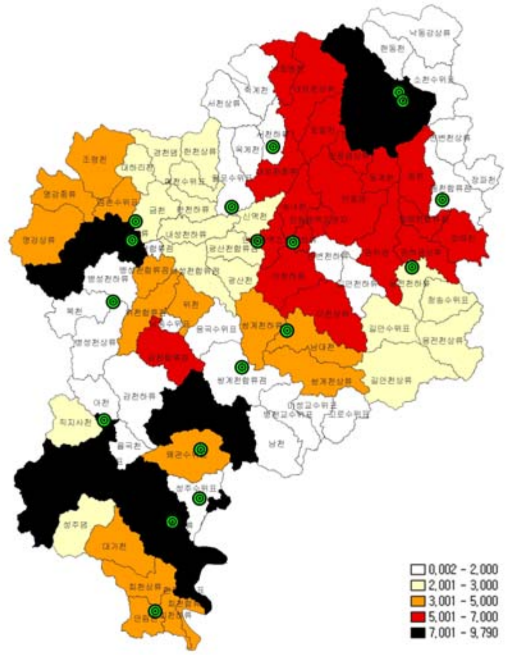

Figure 5. The level of wastewater of the livestock pollutants (number/㎡) and its treatment facilities

THE ANALYSIS OF THE RELATIONSHIPS BETWEEN WATER POLLUTANTS AND WATER POLLUTION PREVENTION FACILITIES

To establish the location policy of the WPPF which considered the characteristics and volume of WPs of each watershed, this paper measures the characteristics and volume of WPs of each watershed and identifies the relationships between WPs and WPPFs using the integrated database on the water pollution geographical information system.

1. The Analysis of the Determination Factors on the Treatment Capacity of Water Pollution Prevention Facilities

This research analyses that what kinds of water pollutants is the most important factors in the decision of capacity and location of WPPFs by implementing the multiple regression analysis. Before the execution of multiple regression analysis, it tests the regression model specifications errors. There are no problems such as the omission of necessary variable, including of unnecessary variable, additive, linearity, and so on (see Table 1.a and b). The value of R^2 in regression model was 0.927(Adj. R^2 =0.908). Three variables such as the discharges of industrial wastewater and living wastewater, and the usage of household water are statistically significant at five percent level. This result means that the discharge of industrial and living wastewaters and the usage of household water effect the decision of treatment capacity of WPPF. But the emissions of wastewater of livestock such as cows and pigs are not significant at five percent level.

The discharges of industrial wastewater

Table 1. Results of a multiple linear regression model

a: Model Summary

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
	.963(a)	.927	.908	226.779

b: Analysis of variance

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	18231360.979	7	2604480.140	50.642	.000(a)
Residual	1440008.572	28	51428.878		
Total	19671369.551	35			

c: Results of multiple linear regression analysis

	Unstandardized Coefficients	Std. Error	Standardized Coefficients	t-value	Sig.
Constant	49.307	61.600		.800	.430
Discharge of industrial wastewater	25.561	3.595	12.377	7.110	.000
Discharge living wastewater	252.032	41.840	9.726	6.024	.000
Population connected to sewerage area	-.087	.495	-.050	-.176	.861
Usage of household water	16.291	2.831	.418	5.755	.000
The number of breeding cows	-2.855	2.094	-.099	-1.363	.184
The number of breeding pigs	1.303	.718	.144	1.814	.080
The number of industrial facilities	2053.978	308.998	2.018	6.647	.000

and living wastewater and the usage of household water are the most important factors on the decision of the treatment capacity of WPPFs. Especially the discharge industrial wastewater turned out to be the most important variable relatively. The discharges of industrial and living wastewaters have been determined to have respectively 29.6 and 23.3 times more important than the volume of the water usage of household (Table 1.c).

2. The Analysis of Relationship between Water Pollutants and Water Pollution Prevention Facilities

This research identified 'what are the most important pollutants in location decision of WPPFs using logistic analysis. This model composed 7 independent variables and 1 dependent variable. A dependent variable is the presence or absence of WPPF(presence=1; absence=0). Logistic regression is used in order to figure out the presence or absence of WPPF based on the characteristics of water pollutants and their emission volumes.

1) The Model Test

Logistic regression is similar to a linear regression model but is suited to models where the dependent variable is dichotomous. Logistic regression coefficients can be used to estimate odds ratios for each of the independent variables in the model. The general logistic formulation is $Odd = e^{z(= B_0 + B_1X_1 + B_2X_2 + \dots + B_pX_p)}$. This formulation transformed Ln(odds)=Z=B0 + B1X1+ B2X2 + ⋯ + BpXp. A dependent variable is Ln (odds=absence/presence), and 7 WPs are independent variables.

This logistic model is tested by the goodness of fit tests. The value of −2 Log Likelihood is 25.836, and the value of Model Chi-square corresponding residual sum of squares is 19.994,6. So this logistic regression model is significant. In F-test, the value of Model Chi-square is significant at 0% level. Considering the results of model test, this model is acceptable (see Table 2).

2) The Identification of the Core Water Pollutants on the Construction of Water Pollution Prevention Facilities

3 water pollutants such as the number of industrial facilities, usage of household water, and population of sewerage area turned out statistically significant at five percent level. And the number of industrial facilities is the most important factor in deciding the construction of WPPFs among 7 WPs. This result means that the amounts of wastewater discharge and pollutants categories are not important in the construction of WPPFs. It often causes the mismatch between the amount of wastewater discharge and pollutant category and the WPPFs' treatment capacity.

The direction of casual relationship between the locations of WPPFs and 7 WPs can be figured out by the plus or minus sign of the parameter estimate value (Table 2). The number of population, discharge living wastewater, discharge of industrial wastewater, the number of breeding pigs presents the minus sign. However, the level of parameter estimate is very low. It means that these variables effects negatively on the construction of WPPFs but their effects are not high significantly. On the other hand, the usage of household water, the number of industrial facilities, and the number of cows have plus sign. However, the levels of parameter estimates of these variables are not high but that of the number of industrial facilities is extremely higher than that of any other variable. It means that the number of industrial facilities is only the most dominant variable in the location decision of construction of WPPFs even though there are several important variable in deciding its location and capacity. Especially, the discharge of livestock wastewater is the most important pollution factor in the upper stream of the Nackdong 3River but it is not significantly considered as the important factor in building the WPPF in this

CONCLUSION

This study notes that the discharge volume and the number of industrial wastewater are the most important WP on the decision of the treatment capacity and location of the WPPF. In addition, the construction possibility of the WPPF is low at the large population watershed. It means that the current WPPF cannot cover the several different pollutant sources such as the living and livestock wastewaters. Especially this research identifies that the disposal of livestock pollutants is insufficient in the upper stream of the Nackdong River watersheds. Therefore, the disposal facility of livestock pollutant should be constructed

Table 2. Results of logistic regression model

a: Statistics for model test

Criterion	Intercept Only	Intercept and Covariates	Chi-Square for Covariates
-2 LOG L	25.836	291.520	19.994 with 7 DF (p=0.006)

b: Results of logistic regression analysis Dep. Var. (0: absence 1: presence)

	Parameter Estimate	Standard Error	Wald Chi-Square	DF	Pr > Chi-Square	Standardized Estimate
Constant	-3.264	1.249	6.834	1	0.009	0038
The sewerage area of population	-0.035	0.018	3.707	1	0.050	0.965
The usage of household water	0.104	0.050	4.275	1	0.039	1.109
The discharge of living wastewater	-0.210	0.782	0.072	1	0.788	0.811
The number of industrial facilities	31.960	14.153	5.100	1	0.024	8E+013
The discharge of industrial wastewater	-0.016	0.050	0.100	1	0.752	0.984
The number of breeding cows,	0.028	0.023	1.488	1	0.222	1.029
The number of breeding pigs	-0.020	0.015	1.713	1	0.191	0.980

in this area in order to improve the water quality of pipeline water source and to prevent the water contamination of Andong Dam which is the main water resource of Gyeongsang Province.

The results of this research will contribute to establish water quality conservation policy on the characteristic and volume of water pollutants in each watershed. This research also contributes to deciding an appropriate location and treatment capacity of WPPFs in each watershed. But, applications of this research are limited because research site was very wide, considered location decision factors were restricted, and degree of pollution was not considered. Ultimately, this research will contribute the building of nationwide wide environmental management system using the environmental geographic information system and its analysis linkage system. Moreover, this research method which the environment geographic information system links with the analysis program using the SAS Bridge Program will contribute to develop the online and real time analysis system on the web. KAGIS

References

Bang, Seung-Suk, Hyo-June Jeong and Hong-Keun. Lee, 2002. The Site Selection of Small Wastewater Treatment Plant using GIS in the Boryeung-Hongseong Area. Journal of Korean Society on Water Quality 18(6): 621-635.

Bae, Min-Ki and Byeung-Moon Jang. 1998. A Study on Selection of Proposed Waste Facilities Sites using Geographic Information System. Journal of Korean Association of Geographic Information Studies 1(2): 14-26.

Braskerud, B. C. 2002. Factors affecting nitrogen retention in small constructed wetlands treating agricultural non-point source pollution. Ecol. Eng. 18. pp.351-370.

Cho, Jae-Heon, Tai-Jong Yu and Dong-Jin Park. 2001. Development of a Database about Environmental Information of the Youngsan River Basin using Arc / View GIS. Journal of the Korean Society of Water and Wastewater 15(2): 103-114.

Cho, Deokho and Minki Bae. 2004. The Building of Environmental Geographic Information System for Supporting Environmental Policymaking in Korea. 2004 ESRI International User Conference. pp. 120-132.

Goo, Ja-Moon. 2000. A Study of Collaboration between GIS and Census Data for Urban Analysis and Location Analysis. Journal of Korean Association of Geographic Information Studies 3(3): 31-45.

Jo Myung-Hee, Bong-Kyum Kwon and Ki-Dong Bu, 1999. A Spatial Change Analysis of Water Quality Pollutant Using GIS and Satellite Image. Journal of the Korean Association of Geographic Information System 2(3): 60-70.

Lee, Jin-Duk, Sang-Ho Yeon and Sung-Gil Kim. 2000. A Case Study on Suitability Analysis of Solid Waste Landfill Site utilizing GIS. Journal of Korean Association of Geographic Information Studies 3(4): 33-49.

Lee, Tae-Gwan. 2003. The appraisement of the site selection for wastewater treatment plant. Journal of Nakdonggang Environmental Research Institute 8(1): 7-16.

Patra, B and B. Pradhan. 2005. Design of an environmental information system for monitoring water and air quality in urban areas. Disaster Prevention and Management 14(3): 326-342.

Shattri Mansor, Mohammed Abu Shariah, Lawal Billa, Iwan Setiawan, Faisal Jabar. 2004. Spatial technology for natural risk management. Disaster Prevention and Management 13(5): 364-374.

Shin, Sha-Chul. 2001. Land Cover Classification Technique Using Satellite Data. Ind. Technol. Res. Inst. Andong National University. Vol. 8. pp. 167-173.

Sreenivasa Rao Amaraneni, Sarnam Singh, P.K. Joshi. 2004. Mapping the spatial distribution of air and water pollutants in Kolleru Lake, India using geographical information systems (GIS). Management of Environmental Quality: An International Journal 15(6): 584-608.

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