INTEGRATED WATER RESOURCES AND QUALITY MANAGEMENT SYSTEM USING GIS/RS TECHNOLOGIES

Kyu-Cheoul Shim[1], Soon-Bo Shim[2], and Yo-Sang Lee[3]

[1]Project Manager, Sustainable Water Resources Research Center, Koyang, Kyounggi 411-712, Korea
[2]Professor and Director of Institute of Water Resource and Quality Management, Department of Civil Engineering at Chungbuk National University, Cheongju, Chungbuk, 361-763, Korea
[3]Senior Researcher, Water Resources Research Institute, Korea Water Research Corporation, Tae-Jeon, Korea

Abstract: There has been continuous efforts to manage water resources for the required water quality criterion at river channel in Korea. However, we could obtain the partial improvement only for the point sources such as, waste waters from urban and factory site through the water quality management. Therefore, it is strongly needed that the best management practice throughout the river basin for water quality management including non-point sources pollutant loads. This problem should be resolved by recognizing the non-point sources pollutant loads from the upstream river basin to the outlet of the basin depends on the landuse and soil type characteristics of the river basin using the computer simulation by a distributed model based on the detailed investigation and application of Geographic Information System (GIS). The purpose of this study is consisted of the three major distributions, which are the investigation of spread non-point sources pollutants throughout the river basin, development of the base maps to represent and interpret the input and outputs of the distributed simulation model, and prediction of non-point sources pollutant loads at the outlet of a upstream river basin using Agricultural Non-Point Sources Model (AGNPS). For the validation purpose, the Seom-Jin River basin was selected with two flood events in 1998. The results of this application showed that the use of combined a distributed model and an application of GIS was very effective for the best water resources and quality management practice throughout the river basin

Key Words: BMP, Water Resources and Quality Management, GIS, DBMS, River Basin, AGNPS, Non-Point Pollutant Loads, Seom-Jin River Basin

1. INTRODUCTION

Recently, the trend of water quality pollution problems has been changed from the point sources pollutants to non-point pollutant loads that were occurred from the runoff of urban storm water and agricultural areas in Korea. Therefore, it is strongly needed that the establishment of measures for preventing and reducing the non-point sources pollutants throughout the river basin and landuse characteristics to manage the water quality problems effectively (Kim, 1999).

The purpose of this study is consisted of the three major distributions. The first is the investigation of spread non-point sources pollutants throughout the river basin. Second is the development of the base maps to represent and interpret the input and outputs of the distributed simulation model. The last purpose is the prediction of non-point sources pollutant loads at the outlet of a upstream river basin using Agricultural Non-Point Sources Model (AGNPS).

The application of Geographic Information System (GIS) was used to classify the landuse based on landuse characteristics. In addition, GIS can generate input data and recognize the transport of non-point pollutant throughout the river basin and its impacts based on results of AGNPS.

2. AGNPS MODEL

AGNPS was developed by the cooperating work with Agricultural Research Service (ARS), Soil Conservation Service (SCS) and Minnesota Pollution Control Agency (MPCA) for the non-point pollutant load analysis at the single event rainfall in the U.S. The design of AGNPS is consisted of three major sub-models that are Hydrology Model, Sediment Yield Model and Chemical & Biological Model with Graphical User Interface including GIS (Singh, 1995). The detailed layout was represented in Fig. 1.

The mean grid values for rainfall, SCS CN, sediment, soil, fertilizer, and pesticide were used to calculate Runoff volume, Peak Runoff rate, concentration of N, P, COD by AGNPS model.

3. SPATIAL DATABASE

Base Maps

The digital elevation map (DEM), landuse map, soil map and slope map for Seom Jin River Basin were constructed to generate input data and parameters for AGNPS Model. UTM-52n coordinate system was the criterion for base maps, which was performed by Arcview 3.0a. The FORTRAN codes were developed for converting the ASCII form of GIS data into the AGNPS input data and parameters. The ASCII DEM was used to calculate parameters of Flow Direction, Receiving Cell Number, Slope Length and etc. The parameters of SCS-CN, Overland Manning Coefficients, C-factor, S- factor, P-factor, Surface Condition Constant and COD-factor were calculated by analyzing landuse, soil and slope maps.

Flow Routing

AGNPS model can route the peak runoff and pollutant loads at the outlet of river basin by calculating flow routing from a certain cell to the other. In this study, the Flow Direction was calculated using 8-point pour algorithm that was coded by FORTRAN with DEM data. The Flow direction was used to generate the parameter of Receiving Cell Numbers Fig. 2 showed graphical view of the algorithm.

4. APPLICATION

Study Area

Seom-Jin River Basin was selected as a study area, which is consisted of Gwan- Chon River Basin (301.776 km^2) and Ssang-Chi River Basin (117.895 km^2). The Gwan-Chon River Basin has 300 x 300 resolution, which has 3274 cells. The Ssang-Chi River Basin has 200 x 200 resolution, which has 2872 cells. The grid map of Seom-Jin River Basin was represented in Fig. 3.

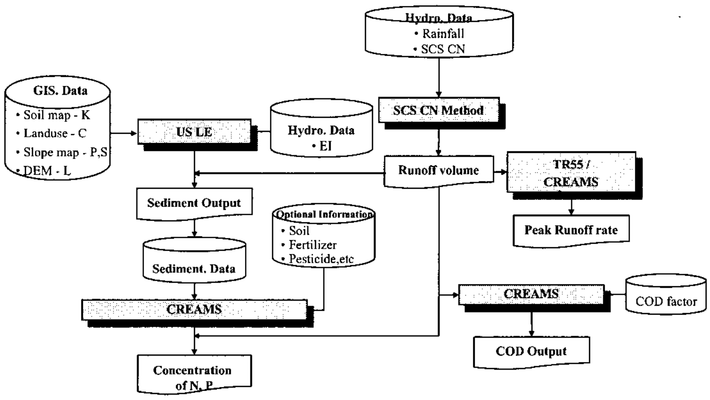

Fig. 1. The Layout of AGNPS Model

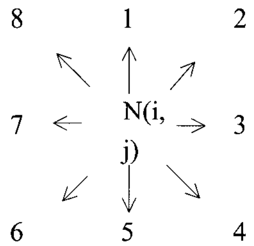

Fig. 2. The Graphical View of 8-Point Pour Algorithm

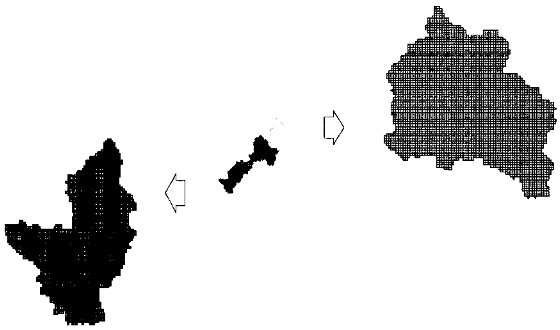

Fig. 3. The Grid Map of Seom-Jin River Basin

The major economic activity is related with the business of farming and livestocks. Therefore, the most landuse types are consisted of forest (74.8 %) and agricultural area (15.3 %), which produce municipal, agricultural and livestock waste water as the non-point sources.

Hydrology

The hydrologic data that were 5 times collected by Korea Water Resources Cooperation (KOWACO) in 1998 were applied in this study. The summary of data was represented in Table 1.

The parameters of hydrology, Overland Manning Coefficients (OMC), Surface Condition Constant (SCC) and SCS Curve Number (SCS-No) were selected and used by user's manual for AGNPS. The FORTRAN code was developed to apply these parameters values into the each cell by landuse characteristics. The results of applying the parameter were represented in Fig. 4.

Erosion and Sediment transport

For applying USLE Equation, the most important factor is energy-intensity (R), which was estimated from rainfall intensity and kinetic energy (Forster et al., 1995). The table 2 represented related rainfall factors for each rainfall event.

The Soil erodibility factor (K) was estimated by using the table of soil classification and soil map. In the slope length steepness factor (LS), the slope steepness (%) was calculated by using derived Slope map from DEM (Singh, 1996). The slope length was calculated by resolution of cell size; the slope length of Gwan-Chon River Basin is 984 ft and the slope length of Ssang-Chi River Basin is 656 ft.

The Cropping management factor (C) was classified by land use activities from landuse map. The soil conservation practice factor (P) was estimated by the slope steepness (%), which was derived slope map from DEM.

The sediment yield and sediment delivery rate were estimated by suing USLE with calculated

Table 1. The applied rainfall events

Watershed	Event	Total Rainfall (inch)	160 Max (inch/hr)	Peak Discharge (CMS)
Gwan Chon	1	2.32	0.39	39.82
	2	3.43	1.22	103.21
Ssang Chi	1	2.32	0.39	42.72
	2	1.57	0.83	38.85

Table 2. Rainfall factor by rainfall event

Watershed	Event	Total Rainfall (inch)	EI	R
Gwan Chon	1	2.32	1549.915	15.49
	2	3.43	2726.301	27.26
Ssang Chi	1	2.32	1557.761	15.58
	2	1.57	1232.991	12.33

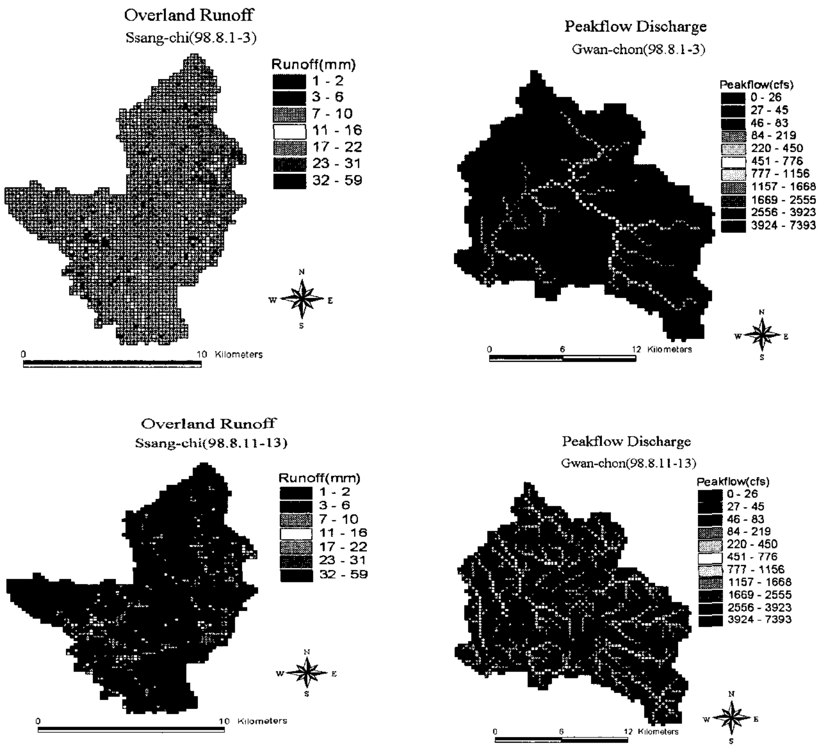

Fig. 4. Results of applying hydrologic parameters

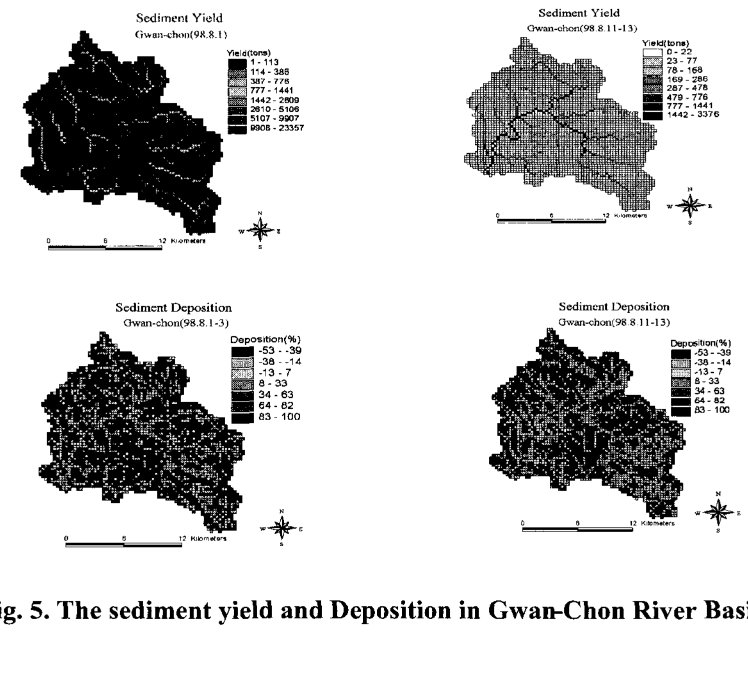

Fig. 5. The sediment yield and Deposition in Gwan-Chon River Basin

parameters above (Morris, 1997). The estimated values ware represented by using GIS and shown in Fig. 5.

Chemicals

The AGNPS model can estimate the yields and concentrations of sediment-attached and soluble chemical at the watershed outlet. However, in this study, only the estimated yields and concentrations of sediment soluble chemical were compared with simulation results and observation at the watershed outlet.

To estimate of total nutrient loads, the total nitrogen, phosphorous and COD loads were required. The total nitrogen and phosphorous were calculated depends on soil information such as concentration of nitrogen and phosphorous in the soil moisture. The concentrations of sediment soluble COD was assumed and calculated from runoff and mean concentration of COD above.

The nitrogen, phosphorous and COD loads of unit area (kg/ha) by landuse as the results of AGNPS run were shown in Fig. 6.

In Gwan-Chon River Basin, the most value of nitrogen loads of unit area was 2.21 kg/ha (37.33%) that was shown at the fallow area. In Ssan-Chi River Basin, the most value of nitrogen loads of unit area was 0.28 kg/ha (21.23%) that was shown at the small grain area. In addition, the mean concentrations of nitrogen by landuse were summarized in the table 3.

In Gwan-Chon River Basin, the most value of phosphorous loads of unit area was 0.76 kg/ha (33.64 %) that was shown at the fallow area. In Ssan-Chi River Basin, the most value of phosphorous loads of unit area was 0.13 kg/ha (21.69 %) that was shown at the small grain area. In addition, the mean concentrations of phos- phorous by landuse were summarized in the table 4.

Table 3. Mean Concentration of Nitrogen by Landuse

(Unit:ppm)

Landuse	Gwan-Chon		Ssang-Chi	
	Event 1	Event 2	Event 1	Event 2
Woodland	0.92	0.82	0.04	0.05
Urban	2.71	1.85	0.21	0.25
Small Grain	1.66	0.98	0.20	0.24
Legumes	2.10	1.05	0.21	0.25
Meadow	2.21	0.44	0.22	0.27
Fallow	3.71	3.66	0.21	0.25

Table 4. Mean Concentration of Phosphorous by Landuse

(Unit:ppm)

Landuse	Gwan-Chon		Ssang-Chi	
	Event 1	Event 2	Event 1	Event 2
Woodland	0.29	0.23	0.003	0.003
Urban	0.79	0.54	0.006	0.006
Small Grain	0.46	0.27	0.009	0.009
Legumes	0.59	0.30	0.007	0.006
Meadow	0.62	0.12	0.006	0.007
Fallow	1.12	1.11	0.007	0.007

Table 5. Mean Concentration of COD by Landuse

(Unit:ppm)

Landuse	Gwan-Chon		Ssang-Chi	
	Event 1	Event 2	Event 1	Event 2
Woodland	0.580	2.275	0.047	0.052
Urban	2.289	1.828	0.296	0.326
Small Grain	1.997	1.411	0.261	0.288
Legumes	2.369	1.714	0.285	0.309
Meadow	1.478	1.096	0.311	0.342
Fallow	3.738	2.870	0.430	0.463

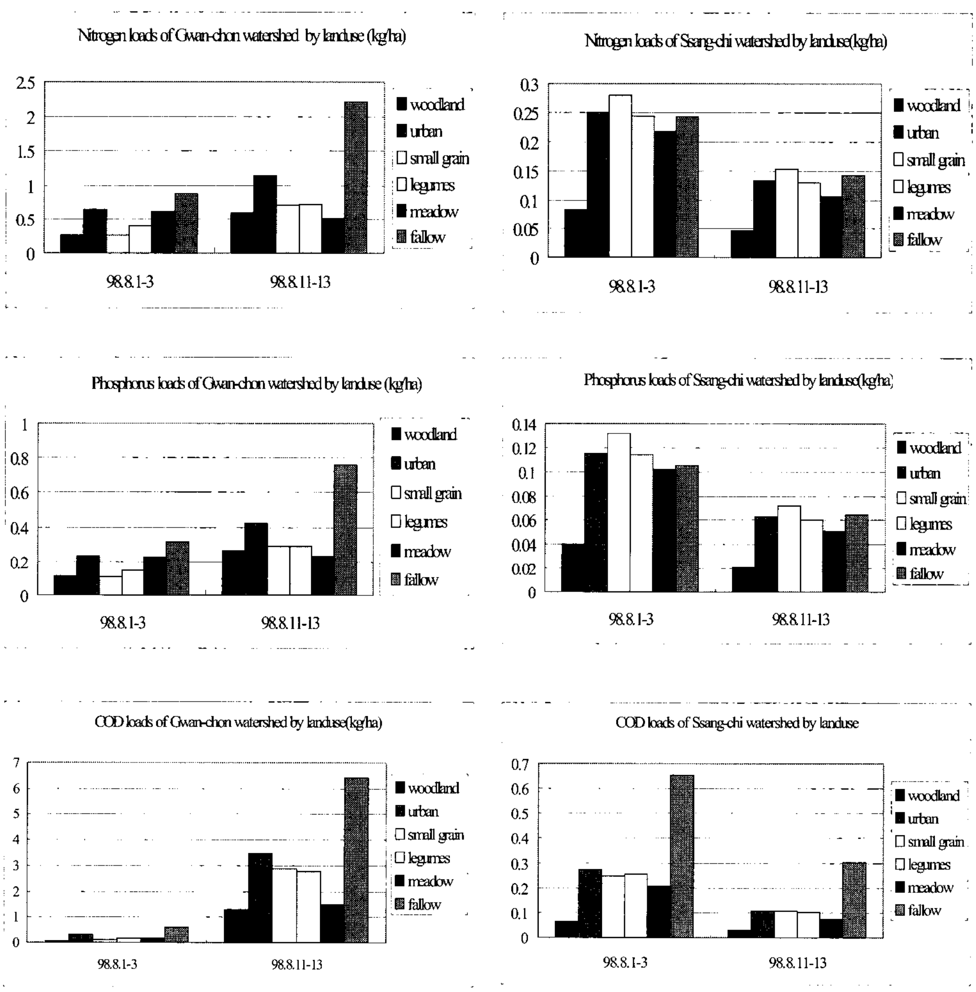

Fig. 6. Results of the estimations of non-point sources pollutant loads

In Gwan-Chon River Basin, the most value of COD loads of unit area was 6.4 kg/ha (34.78%) that was shown at the fallow area. In Ssan-Chi River Basin, the

most value of COD loads of unit area was 0.655 kg/ha (38.47%) that was shown at the fallow area. In addition, the mean concentrations of COD by landuse were summarized in the table 5.

5. CONCLUSION

To the best management practice throughout the river basin for water quality management including non-point sources pollutant loads, the AGNPS model were used based on the detailed investigation and application of Geographic Information System (GIS). Two rainfall events in 1998 were used to estimate the non-point sources pollutant loads at the outlet of river basin depends on characteristics of topology, soil and landuse. The detailed results of simulation were follows:

1) The comparison of AGNPS model results and observation was similar and satisfactory.
2) The soil erosion was proportionally increased by amount of rainfall-runoff and the most yield of erosion was occurred on clay among the five particles type.
3) The most values of pollutant load of N, P and COD on unit area were occurred at the fallow area. However, The least values of the pollutant load were occurred at the woodland.

ACKNOWLEDGEMENT

The work was supported by Korea Research Foundation Grant.

REFERENCE

Maidment, D. R. (1992). *Handbook of Hydrology*, McGraw Hill.

Foster, I., Gurnell, A., and Webb, B. (1995). *Sediment and Water Quality in River Catchments*, John Wiley & Sons Ltd., pp.97-106

Morris, G. L. and Fan, J. (1997). *Reservoir Sediment Handbook*, McGraw Hill.

Singh, V. P. etc. (1996). *Geographical Information System in Hydrology*, Kluwer Academic Publishers.

Singh, V. P. (1995). *Computer Model of Watershed Hydrology*, Water Resources Publication.

Kim, J. H. (1999). *A System Development for Estimating Non-point Source Pollutant Loads from Watershed using Geographic Information System*, A thesis for a doctorate of Chungbuk National University.

Project Manager, Sustainable Water Resources Research Center, Koyang, Kyounggi 411-712, Korea.
(E-mail : skcpj@water21.re.kr)

Professor and Director of Institute of Water Resource and Quality Management, Department of Civil Engineering at Chungbuk National University, Cheongju, Chungbuk, 361-763, Korea.

Senior Researcher, Water Resources Research Institute, Korea Water Research Corporation, Tae-Jeon. Korea.