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Changes of Stream Water Quality and Loads of N and P from the Agricultural Watershed of the Chooryung-chon Tributary of the Sumjin River Basin

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ABSTRACT : At this study, the monitoring network of water quality was established in the agricultural watershed an area 14,960 ha of the central southwest of Korea. Loads of nitrogen and phosphorus by agricultural land use were quantified bases on total amounts of stream flow. The land were used as a lowland paddy, an upland and a forest about 12.14 % (1,815 ha), 5.17 % (773 ha) and 80.31 % (12,015 ha) of the area, respectively. For six months, from May 1 to October 31, 1999, the total precipitation was 970 mm and the total amount of stream flow was 80,281,000 m^3. In the load of agricultural non-point sources relevant to land use, total-N was 138,413 kg, then ammonia-N 13,362 kg, nitrate-N 124,629 kg, and total-P 157 kg. The loss of nutrient which from application of chemical fertilizer were 38.0% in nitrogen and 0.1% in phosphorus to input chemical fertilizer in the watershed.

Key words : Agricultural watershed, Land use, Load, Water pollution,

INTRODUCTION

The impact of point source pollution can be localized and well established, whereas the influence of non-point pollution is still a problem because of the insufficiently defined direction and intensity of its activity. In spite of the evident presence of non-point pollution sources in Korea, there are no sufficient data on them, nor there is adequate information about the extent to which they participate in the deterioration of the quality of water resources in an area [1, 3, 4].

Studies on pollutant loads at watershed are needed because some of non-point pollution loads discharged from pollution sources are sediments in transport process, some are used by bio-chemical factors and the actual amount of pollution loads in streams is very little. As the control of nutrient export from point sources has become more rigorous, research has shifted to the movement into streams of nutrients from non-point sources. In many regions there is still limited information on the amounts and forms in which nutrients are exported from agricultural catchments with different characteristics.

The pollution from agricultural watersheds has been brought into attention as a potential pollutant to streams and tributaries, since majority of them cause water quality degradation, eutrophication of reservoir and bad effect on agricultural environment. To prevent the pollution from agricultural watersheds, it is necessary to find out the source of the pollution and the quantity of pollutant.

At this study, the monitoring network of water quality was established at the agricultural watershed and loads of nitrogen and phosphorus from the agricultural watershed by land use were quantified.

MATERIALS AND METHODS

Watershed. To understand factors influencing hydrology and water quality of the area, a) exact boundary of the area was lined through topography maps (1/25,000) and field surveys, b) topography and land use were investigated, and c) data of population, arable lands and livestock were collected. Watershed of Chooryung-chon (North Longitude 35° 50′ ~ 35° 20′), Ssangchi-myun, Sunchang-gun, Chollabuk-do, Korea was selected for the study (Fig. 1). The total area of the area was 14,960 ha where no industrial activity occurred. Paddy fields, upland fields and forests were used about 12.14 % (1,815.8 ha), 5.17 % (773.7 ha) and 80.31 % (12,015.3 ha), respectively. The total area of the watershed was 14,960 ha, the stream length 28.32 km, channel slope 19.70 and shape factor 0.187. The population of the watershed was 4,500. The numbers of pig, Korean cattle, dairy cattle, poultry were 335, 2,680, 12 and 12,155, respectively. Livestock wastes from the

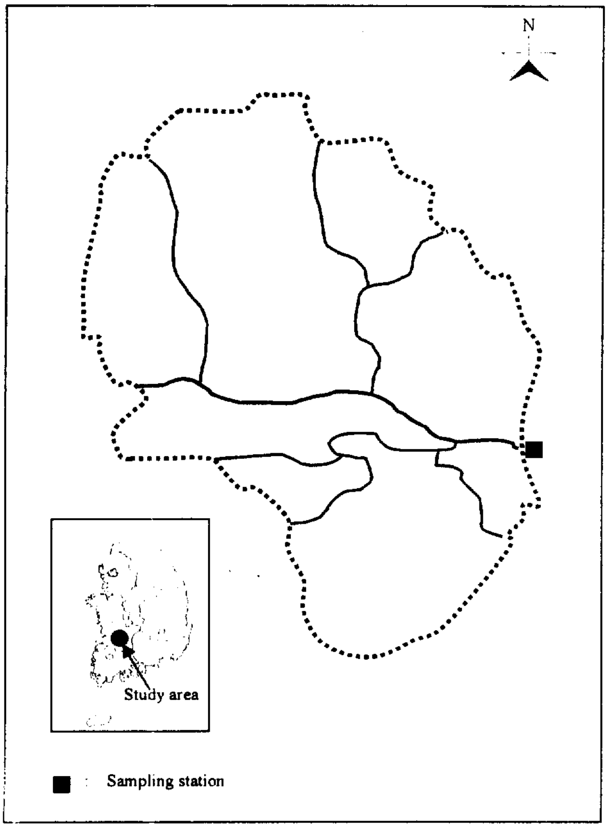

Fig. 1. The investigated area and water sampling site in Chollabuk-do, Korea

two watersheds had been directly flowed into small streams through outlets without any purification equipment.

Precipitation and measurement of water flow. The precipitation data of the Precipitation Observation Station of Ssangchi-myun, Sunchang-gun, Chollabuk-do was used to the study area. Levels of the stream were automatically recorded using the water level meter (Hydro Logic Co., Model L24A). The flow velocities, along with the cross-sectional areas of the riverbed, were measured to estimate total amounts of water flow at monitoring sites in this tributary.

Table. 1. Status of the watershed areas for land use, population, livestock and physiographic factor.

Land use(ha)		Livestock (heads)		Population	Channel slope($m \cdot m^{-1}$)	Shape factor
Paddy	1,815	Pig	335			
Upland	773	Korean cattle	2,680			
Forest	12,015	Diary cattle	12			
Others	357	Poultry	12,155			
Total	14,960		6,399	4,500	19.70	0.187

Sampling and sample analyses. Water samples were collected at down stream of watershed with one-week interval from May 1 to October 31, 1999 and analyzed for the water quality parameters. The parameters of water quality selected in this paper are total-N, ammonia-N, nitrate-N and total-P. Bottles containing the sample were placed in insulated chests and crushed ice was added to fill the chests. The bottles were refrigerated at 0 to 4 ℃ soon after collection until analyses. The water samples were shaken to obtain homogeneous aliquots for total-N and total-P analysis. Ammonia-N, nitrate-N, and soluble phosphorus were determined in aliquots which were centrifuged and filtered through 0.45 μm Millipore filters. Chemical analysis for total-N, nitrate-N, and ammonia-N were conducted using standard methods as described in the FWPCA manual (USDI, 1971). All P determinations were made using the isobutanol extraction method described by Golterman and Clym (1969).

Loads of nitrogen and phosphorus caused by agricultural activity were calculated by multiplying total stream flow and the concentration of each one.

RESULTS AND DISCUSSION

Hydrology and total stream flow. The climate of the western part of the province has southern coast climate, and mountainous area of eastern part belongs to southern inland climate. By the effect of the Yellow Sea, the western plain has less yearly temperature variation and precipitation distribution is less than that of mountainous area. Even in the peninsula, the annual temperature variation of the inland is greater than that of the coast area. The precipitation data which applied to this study area were collected from the Precipitation Observation Site of SSangchi-myun, Sunchang-gun, Chollabuk-do. For the period of 6 months from May 1 to October 31, 1999, the total precipitation was 970 mm. Monthly precipitation was 149 mm, 163 mm, 240 mm, 247 mm, 334 mm, and 45 mm in May, June, July, August, September and October, respectively. The maximum daily precipitation was 123 mm on September 23. About 60 % of annual precipitation poured during Korean monsoon (changma) from late June to late July, however, the heaviest precipitation was in September 1999.

The total amount of stream flow was 80,281,000 m^3. It was 6,349,000 m^3, 5,865,000 m^3, 10,196,000 m^3, 14,010,000 m^3, 30,663,000 m^3, and 10,725,000 m^3 in May, June, July, August, September and October, respectively. The maximum daily stream flow was 7,296,000 m^3 on September 23. The minimum of daily stream flow was 9,000 m^3 on July 20 (Fig. 2).

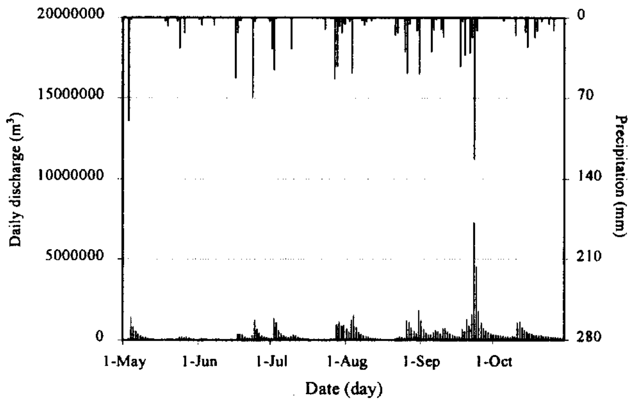

Fig. 2. Seasonal distribution of precipitation-stream flow

Changes in concentrations of nitrogen and phosphorus. The changes in the concentrations of nitrogen and phosphorus in stream water at the investigated area for 6 month (from May 1 to October 30, 1999) were as shown on Table 2.

The concentrations of total-N, ammonia-N, and nitrate-N were 1.9~4.3 mg·L^{-1} (average =2.8 mg·L^{-1}), 0.7~1.7 mg·L^{-1} (0.9 mg·L^{-1}), and 0.9~3.3 mg·L^{-1} (1.6 mg·L^{-1}), respectively. The high concentrations of nitrogen sources were between late-May (when applied basal fertilization) and the mid-June (when applied fertilization for tillering) and in late-July (when applied panicle fertilization), when chemical fertilizers were applied to arable lands. This suggested that agricultural activity was given a great influence on the amount of detected nutrients in stream water. Ammonia-N in stream water occupied 60~70 % in total-N and nitrate-N did 20~30 % in total-N until late-June. However, 40~50 % of total-N was ammonia-N and 50~60% of total-N was nitrate-N after the mid-July. Ammonia-N applied to arable lands seemed to be flowed into water without proper nitrogen mineralization process and was given influence on water quality because of frequent rainfall-runoff from arable lands during the changma in Korea.

Table. 2. Changes in the concentrations of nitrogen and phosphorus in stream water

	Total-N	Ammonia-N	Nitrate-N	Total-P
Mean	2.8	0.9	1.6	0.006
S.D.	0.6	0.2	0.4	0.002
Min	1.9	0.7	0.9	0.004
Mix	4.3	1.7	3.3	0.010

Unit : mg·L^{-1}
Number of sample : 34
S.D. : standard deviation

Jung *et al.* (1998) measured nitrogen sources concentrations in the stream water of agricultural watershed where 1,906 ha in forest, 557 ha in upland, 652 ha in paddy, and 95 ha in others, in 3,210 ha of total area. The concentrations of ammonia-N and nitrate-N were 1.24~2.52 mg·L^{-1} and 6.86~12.04 mg·L^{-1}, respectively. And Chung *et al.* (1999) measured nitrogen sources concentrations in the stream water of agricultural watershed (total area: 1,412 ha, forest: 1,063 ha, upland: 166 ha, paddy: 122 ha, others: 70 ha) and the concentrations of ammonia-N and nitrate-N were 0.07~2.37 mg·L^{-1} and 0.40~17.57 mg·L^{-1}, respectively. They suggested it was influenced by agricultural activity. When the results of Jung *et al.* (1998) and the current study were compared, nitrate-N of this study was lower than that of Jung *et al.* (1998).

The concentration of total-P was 0.004~0.010 mg·L^{-1} (average = 0.006 mg·L^{-1}). It was the highest in the period from the mid-May to early-June when the amount of applied chemical fertilizer to arable lands and runoff from sediments was high. Any significant amount of soluble-P may be not detected in the area because farmstead and livestock complex was relatively rare around the area.

Jung *et al.* (1998) measured changes of phosphorus source concentrations in the stream water of agricultural watershed (3,210 ha). The concentrations of total-P were 0~2.20 mg·L^{-1} but soluble-P was hardly detected. When the results of Jung *et al.* (1998) and this study were compared, total-P of this study was lower than that of Jung *et al.* (1998). Maybe it was that this investigated site was five times greater than that of Jung *et al.* (1998) and the dilution effect by great amount of precipitation and stream water made the concentration lower.

The chemical composition of precipitation was not analyzed in this study but the chemical composition data of precipitation were gotten at Chinan, Chollabuk-do. There was 50 km away from the investigated area. The concentration of total-N, ammonia-N and nitrate-N in the precipitation was ranged 1.43~4.14 mg·L^{-1} (mean=1.98 mg·L^{-1}), 0.57~2.12 mg·L^{-1} (0.78 mg·L^{-1}) and 0.18~1.69 mg·L^{-1} (0.42 mg·L^{-1}), respectively.

When the concentration of nitrogen sources in the precipitation and the stream water were compared, ammonia-N and nitrate-N in stream water was greater two times of those in precipitation. This suggested that stream water be gathered nitrate-N and ammonia-N from arable land, livestock farm and domestic activities. Therefore, optimistic fertilization, reasonable cropping system and water purification equipment is needed in order to minimize nutrient loss by soil erosion and surface water from upland. And improved methods of fertilization and water management are necessary to reduce runoff from paddy fields in rainy seasons.

Loads of nitrogen and phosphorus by agricultural activity. Since agricultural Non-point sources had obscure sources and vast range of outlets; they can be converted into pollution sources at any time.. So, the load needs to be estimated. During the study period, total stream flow was 80,281,000 m³. The amount of total-N, ammonia-N, nitrate-N and total-P was 218,696 kg, 56,896 kg, 148,290 kg and 212 kg, respectively. Assuming stream flow was mostly occurred by precipitation, load of nitrogen and phosphorus by precipitation could be calculated by multiplying the concentration of nitrogen and phosphorus in precipitation. The amount of total-N, ammonia-N, nitrate-N and total-P was 80,283 kg, 43,534 kg, 23,661 kg and 55 kg, respectively. When influx amount by precipitation was excluded from runoff in stream, the load by agricultural non-point sources was 138,413 kg, 13,362 kg, 124,629 kg and 157 kg for total-N, ammonia-N, nitrate-N and total-P, respectively (Table 3).

Since the survey area was influenced by only agricultural activities, the pollutants load at the area was caused by agricultural non-point sources such as activities of arable land and livestock farming, domestic wastes and loss from forest areas. Because load of nitrogen and phosphorus in arable lands could be different according to land use, further researches are necessary on loads caused by different non-point sources.

The major cultivated crops in the investigated area were red pepper and Chinese cabbage. The recommended amount of chemical fertilizer for those crops was 242 $kg \cdot ha^{-1}$ for nitrogen and 205 $kg \cdot ha^{-1}$ for phosphorus. However, 0.7 times less than in nitrogen and 2 times less than in phosphorus of the amount of recommended fertilization had been applied to upland fields. The recommended amount of chemical fertilizer to paddy fields was 110 $kg \cdot ha^{-1}$ for nitrogen and 80 $kg \cdot ha^{-1}$ for phosphorus in Korea. The applied amount of nitrogen was 1.4 times than the recommended amount while the applied amount of phosphorus was nearly the same to the recommended amount (Statistical Yearbook of Agriculture & Forestry, 1998). Based on the such recommend fertilization, applied amount of chemical fertilizers to arable lands in the study area was estimated to 367,245 $kg \cdot yr^{-1}$ for nitrogen and 181,775 $kg \cdot yr^{-1}$ for phosphorus.

When loss ratio of chemical fertilizer by agricultural non-point sources was compared with input amount of chemical fertilizer to arable lands in watershed, it was 38.0% and 0.1% of applied chemical fertilizer for nitrogen and phosphorus, respectively. According to Chung *et al.* (1999), the nutrient amount caused by agricultural non-point sources at agricultural watershed (1,421 ha) was 25,000 $kg \cdot yr^{-1}$ for total-N and 500 $kg \cdot yr^{-1}$ for total-P. And they reported that this amount was 80 % and 12 % of applied nitrogen and phosphorus, respectively. There was considerable difference between results of this study and Chung *et al.* (1999). Maybe, it was that nutrients were diluted with stream water (dilution effect) at this study area where the watershed was contributed largely with forest area.

Assumed the land use was ignored and the whole study area was considered to be total watershed area, the load per watershed area by agricultural activity was estimated to be 9.25 $kg \cdot ha^{-1}$ for total-N and 0.01 $kg \cdot ha^{-1}$ for total-P. The amount of nitrogen was relatively larger than that of phosphorus. Chung *et al.* (1999) measured the load of nitrogen and phosphorus flowed into streams from small agricultural watershed and reported that the annual load amount per watershed area was 17.58 $kg \cdot ha^{-1}\ yr^{-1}$ for total-N and 0.41 $kg \cdot ha^{-1}\ yr^{-1}$ for total-P. This result was larger than that of this study.

Extract large-area specification of the share of point and non-point sources of pollution only on the basis of the results

Table. 3. Input-output of nitrogen and phosphorus in the watershed area.

	Input		Loads of agricultural activity*	Applied amounts of chemical fertilizer	Loss ration of chemical fertilizer(%)
	Precipitation	Stream water			
Total-N	80,283	218,696	138,413	367,245	38.0
Ammonia-N	43,534	56,896	13,362		
Nitrate-N	23,661	148,290	124,629		
Total-P	55	212	157	181,775	0.1

Unit : kg

* : Input amount by precipitation was excluded from amounts of stream water

of monitoring is very difficult. The most important parameters are precipitation/runoff ratio and other conditions such as land cover, amount of fertilizers and erosion danger etc. in the particular areas of the watershed.

To solve water pollution problem caused by agricultural non-point sources, standard of chemical fertilizer application for crop is needed to be set and then continuous awakening is necessary to help farmers to keep the recommended standard when they apply fertilizer to crops. And in order to minimize the loss of nutrients to streams and to maximize the efficiency of fertilization for crops, farmers need to consider fertilizer application time, formula of chemical fertilizer, and application method.

A number of researches related to tillage have been carried to search and keep sustainable agriculture. Less frequent plowing is desirable to keep fertility of soil since plowing usually brings clay erosion and inhibits rapid decomposition of organic matter in soil. Numbers of researches were reported there was a positive correlation between soil erosion and loss of nutrients and organic matter. Especially, when arable lands were plowed in traditional way, a great deal of phosphorus adsorbed to soil was lost with surface soil erosion. This explained that excessive plowing practice could accelerate nutrients loss. In order to minimize surface and ground water pollution by nutrient loss from arable lands, lots of researches in other related fields are also recommended.

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