Loads of Nitrogen and Phosphorus from the Agricultural Watershed in Central Korea

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Water quality monitoring network was established at the agricultural watershed located at the Namdae-chon watershed of Seolchon-myon, Muju-gun, Chollabuk-do, Korea which is 22,560 ha in size. Based on total amount of stream flow loads of nitrogen and phosphorus from the agricultural watershed were estimated. About 4.48 (1,011 ha), 7.02 (1,585 ha), and 86.82% (19,609 ha) of the site were used for paddy fields, upland fields, and forests, respectively. During the period of 6 months from May 1 to October 31, 1999, the total amounts of precipitation and stream flow were 993.2 mm and 148,533,000 m^3, respectively. The loads of agricultural non-point sources accrued by land use were 83,526 kg, 24,508 kg, 49,705 kg, and 215 kg for total-N, ammonia-N, nitrate-N, and total-P, respectively. Results showed that 23.4 and 0.1% of the applied nitrogen and phosphorus fertilizers, respectively, were estimated to load into the streams as agricultural non-point sources.

Key words: *agricultural watershed, land use, nitrogen, phosphorus, water pollution.*

Deterioration of water quality has recently been observed in many water bodies due to the potential impacts of pollution from various point and non-point sources (NPS). The impact of point source pollution can be localized and well established, whereas the influence of non-point pollution cant be characterized easily because of the insufficiently defined direction and intensity of its activity.[1-3] In Korea, little information is available about the extent to which NPS participates in the deterioration of the quality of water resources in a specific area.

Agricultural activities such as row crop production and animal manure application have known to increase concentrations of pollutants though the runoff such as nitrogen, phosphorus, organic matter, sediment, and bacteria relative to ambient levels. Excessive inputs of such pollutants to downstream can accelerate eutrophication.[4]

Nitrogen and phosphorus exist as various chemical species in water and are often associated with suspended particles. Suspended particles carry nutrients and many other pollutants, and cause turbidity, which are undesirable for water quality. In many regions, however, there is still limited information on the amounts and forms of nutrients which are exported from agricultural catchments.

In this study, the water quality monitoring network was established at the agricultural watershed located at the Namdae-chon watershed of Seolchon-myon, Muju-gun, chollabuk-do, Korea which is 22,560 ha in size in order to find out the potential NPS of pollutants in this region. Based on total amount of stream flow, loads of nitrogen and phosphorus from the agricultural watershed were estimated.

Materials and Methods

Watershed. Water quality was monitored at the Namdae-chon watershed of Seolchon-myun, Muju-gun, Chollabuk-do, Korea (Fig. 1). Livestock wastes from the

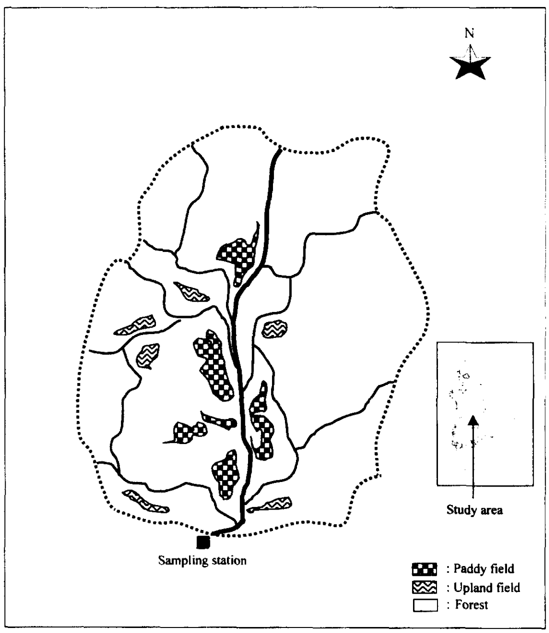

Fig. 1. Map the Namdae-chon watershed and sampling site.

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Abbreviation: NPS, non-point sources.

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

Land use (ha)		Livestock (heads)		Population	Channel slope (m/m)	Shape factor
Paddy	1,011	Pig	1,892			
Upland	1,585	Korean cattle	1,873			
Forests	19,609	Diary cattle	121			
Others	355	Poultry	2,513			
Total	22,560		6,399	8,397	46.97	0.288

watershed have been directly discharged into small streams without any treatment. To understand factors influencing hydrology and water quality of the site, followings are determined: a) exact boundary of the watershed through topography maps (1/25,000) and field surveys; b) topography and land use; and c) population, arable lands, and kinds and numbers of livestock. Total area of the site was 22,560 ha without any influence factor of industrial activity. The 4.48 (1,011 ha), 7.02 (1,585 ha), and 86.82% (19,609 ha) of the site were used as paddy fields, upland fields, and forests, respectively. The stream length was 27.98 km with channel slope of 46.97, and shape factor of 0.288. The population of the watershed was 8,397. The number of pigs, Korean cattle, dairy cattle, and poultry were 1,892, 1,873, 121, and 2,513, respectively (Table 1).

Precipitation and flow measurement. The precipitation data throughout the experimental period were obtained from the Precipitation Observation Station of Moopoong-myun, Muju-gun, Chollabuk-do. Levels of the stream were recorded automatically using a 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.

Sampling and sample analyses. Water samples were collected at down stream of watershed with one week interval from May 1 to September 30, 1999, and analyzed for the water quality parameters. The parameters of water quality selected in this paper were total-N, ammonia-N, nitrate-N, and total-P. Bottles containing sample composites were placed in insulated chests filled with crushed ice and refrigerated at 0 to 4°C soon after collection until analyses. Stream water samples were shaken to obtain homogeneous aliquots for total-N and total-P analyses. Ammonia-N, nitrate-N, and soluble phosphorus were determined in aliquots which were centrifuged and filtered through 0.45 μm Millipore filters. Chemical analyses for total-N, nitrate-N, and ammonia-N were conducted using standard methods as described in the USDI manual.[5] All P determinations were made using the isobutanol extraction method described by Golterman and Clym.[6] Loads of nitrogen and phosphorus caused by agricultural activity were calculated by multiplying total stream flow with the mean concentration of chemical components in down stream water of watershed.

Results and Discussion

Hydrology and total stream flow quantity. The precipitation data of the Precipitation Observation Station at Mupoong-myun, Muju-gun, Chollabuk-do was employed to the experimental site. During the 6 months, from May 1 to October 31, 1999, total amount of precipitation was 993.2 mm. The respective monthly precipitations were 197, 163, 156, 153, 268, and 56.2 mm in from May to October. The maximum daily precipitation was recorded on September 23 as of 77 mm. About 60% of annual precipitation was observed from late June to middle of July in Korea. However, the greatest monthly precipitation of 268 mm was recorded in September during the study period.

The total quantity of stream flow was 148,533,000 m^3, resulting from the respective monthly stream flows of 13,755,000 m^3, 15,357,000 m^3, 20,383,000 m^3, 28,341,000 m^3, 55,795,000 m^3, and 14,898,000 m^3 from May to October. The maximum and minimum daily stream flow, 11,051,000 m^3 and 208,000 m^3, were recorded on September 24 and July 20, respectively (Fig. 2).

Changes in concentrations of nitrogen and phosphorus. The changes in the concentrations of nitrogen and phosphorus in stream water at the experimental field for 6 months (from May 1 to October 30, 1999) are shown in Fig. 3 and 4.

The concentrations of total-N, ammonia-N, and nitrate-N were 1.8~4.0 (average = 2.6 mg L^{-1}), 0.6~1.4 (0.9 mg L^{-1}), and 0.8~2.6 mg L^{-1} (1.3 mg L^{-1}), respectively. The nitrogen concentrations were increased at the time corresponding to the basal fertilization (late May), tillering fertilization (mid-

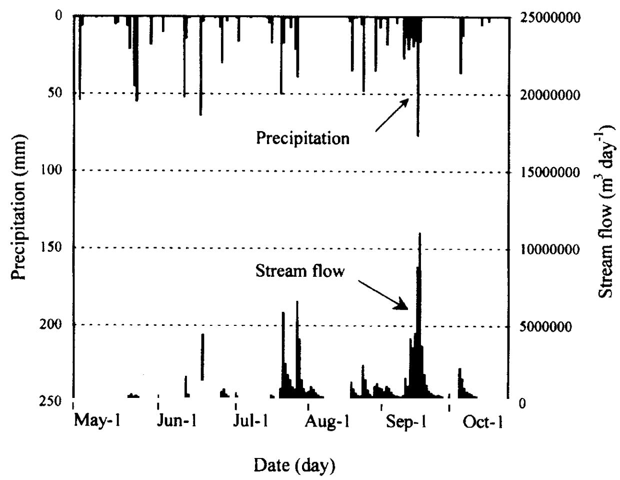

Fig. 2. Precipitation-stream flow during the study period.

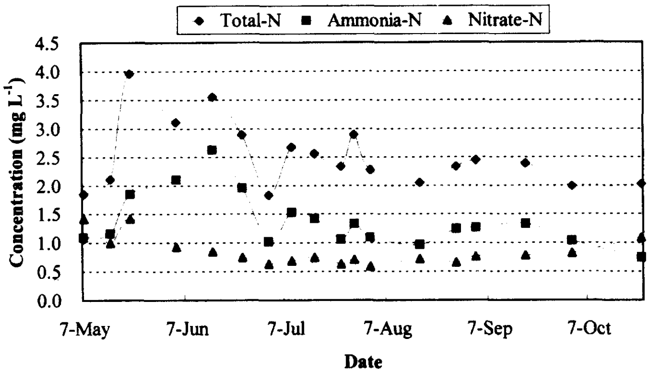

Fig. 3. Concentration changes of nitrogen in the stream during the monitoring.

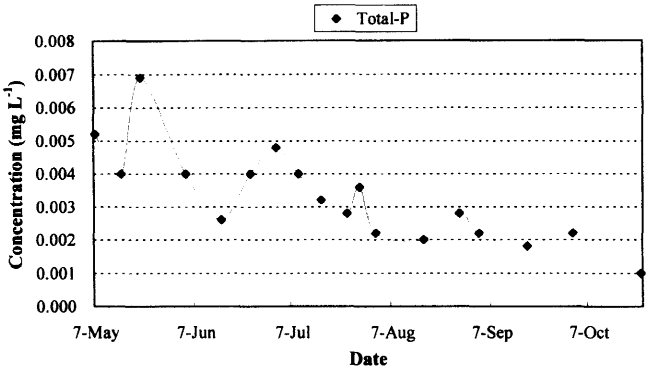

Fig. 4. Concentration changes of phosphorus in the stream during the monitoring.

June), and panicle fertilization (late July) to the arable lands. This suggests that agricultural activity might contribute the nutrients to the stream water. The proportions of ammonia-N and nitrate-N to total-N were 60~70% and 20~30% by late-June, and then changed to 40~50% and 50~60% after mid-July. Jung *et al.*[2] reported that the concentrations of ammonia-N and nitrate-N in stream water of agricultural watershed (total area: 3,210 ha, forest: 1.906 ha, upland: 557 ha, paddy: 652 ha, others: 95 ha) were 1.24~2.52 and 6.86~12.04 mg L^{-1}, respectively. Chung *et al.*[1] also found that concentrations of ammonia-N and nitrate-N in stream water of agricultural watershed (total area: 1,412 ha, forest: 1,063 ha, upland: 166 ha, paddy: 122 ha, others: 70 ha) were 0.07 ~2.37 and 0.40~17.57 mg L^{-1}, respectively. They suggested variations in N and P concentrations were influenced by agricultural activity.

The concentration of total-P was ranged from 0.002 to 0.007 mg L^{-1} (average = 0.003 mg L^{-1}), 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 were assumed to be high. However, any soluble-P was not detected in the study area for the rest of period. Jung *et al.*[2] measured changes of phosphorus source concentrations in stream water of agricultural watershed, showing the concentrations of total-P were 0~2.20 mg L^{-1}, while soluble-P was hardly detected.

Total-N, ammonia-N, and nitrate-N in precipitation were ranged 1.43~4.14 (mean = 1.98), 0.57~2.12 (0.78), and 0.18 ~1.69 mg L^{-1} (0.42 mg L^{-1}), respectively, referring the data from precipitation at Chinan, Chollabuk-do 50 km away from the survey site during the same periods with our study. Comparing the concentrations of nitrogen sources in precipitation and stream water, the concentrations of ammonia-N and nitrate-N in stream water were two times higher than those in precipitation. This suggested that stream water was contaminated by high nitrate-N and ammonia-N due to agriculture, livestock farming, and domestic activities.

Since the agricultural non-point sources are diffusible and have a vast range of outlets, the loading amount may play a role as a pollution source at any time. Therefore, proper managements of fertilizers, cropping system, and water use are needed in order to minimize nutrient loss by soil erosion and runoff from upland fields. Furthermore, improved methods of fertilization and water management are necessary to decrease runoff from paddy fields during the rainy seasons. Thus further studies are needed to quantify the effects of land use and treatments on the water quality at a watershed scale.

Loads of nitrogen and phosphorus caused by agricultural activity. During the study period, total stream flow was 148,533,000 m^3. The loads of total-N, ammonia-N, nitrate-N and total-P caused by agricultural activity in this study area were 339.697, 163.419, 125,289, and 392.5 kg, respectively. Assuming that stream flow mostly occurred by precipitation, loads of nitrogen and phosphorus caused by precipitation could be calculated by multiplying concentration of nitrogen and phosphorus in precipitation by stream flow amount. The amount of total-N, ammonia-N, nitrate-N, and total-P were 256,171 kg, 138,911 kg, 75,498 kg, and 177 kg, respectively.

Excluding the influx amount by precipitation from runoff in stream, the load by agricultural non-point sources was estimated to be 83,526 kg, 24,508 kg, 49,705 kg, and 215 kg for total-N, ammonia-N, nitrate-N, and total-P, respectively. Runoff amount of nitrate-N measured in streams (125,289 kg) was much greater than that (75,498 kg) by precipitation.

The loads of nitrogen and phosphorus into streams from the arable lands could be different with the type of land use. The major crops cultivated at the study site were pepper and Chinese cabbage. The recommended amounts of chemical fertilizers for these crops were 24.2 kg $10a^{-1}$ of nitrogen and 20.5 kg $10a^{-1}$ of P_2O_5. However, 0.8 times less than the recommended nitrogen and 3 times less than the recommended phosphorus had been applied to upland fields at the study site. The recommended amounts of nitrogen and phosphorus fertilizers to paddy fields were 11 kg $10a^{-1}$ and 8 kg $10a^{-1}$ in Korea. The applied amount of nitrogen was 1.1 times less than the recommended amount while the applied amount of phosphorus was nearly the same as the recommended amount. [7] Based on the above data, applied amounts of nitrogen and phosphorus to arable lands at the study site were estimated to 357,298 kg yr^{-1} and 168,427 kg yr^{-1}, respectively.

When losses of chemical fertilizers as an agricultural non-point sources were compared with input amounts of chemical fertilizers to arable lands in watershed, those were equivalent to 23.4 and 0.1% of nitrogen and phosphorus applied. According to Chung *et al.*[1], the nutrient amounts caused by agricultural non-point sources at agricultural watershed were 25,000 kg yr^{-1} of total-N and 500 kg yr^{-1} of total-P. They reported that these were 80 and 12% of applied nitrogen and phosphorus, respectively.

The loads of nitrogen and phosphorus discharged into streams from watershed were estimated to be 5.03 kg ha^{-1} for total-N and 0.01 kg ha^{-1} for total-P. Chung *et al.*[1] measured that the loads of nitrogen and phosphorus drained into streams from small agricultural watershed were 17.58 kg ha^{-1} yr^{-1} for total-N and 0.41 kg ha^{-1} yr^{-1} for total-P.

From the monitoring result, it is extremely difficult to separate the specific share of point source from the non-point source pollution. The most important parameters are precipitation/runoff ratio and conditions such as land cover, amount of fertilizers, and erosion danger, and so on in the particular areas of the watershed. Further studies are needed to quantify the effects of land use and treatments at a watershed scale.

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