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Effect of Farming Practices on Water Quality

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Abstract□Three types of land use were investigated to describe the effect of land use on both surface and ground water quality. Typical land uses of a grazing pasture, Sudan grass field and paddy in Kangwon province were selected and flumes and monitoring wells were installed. Land managements were carefully monitored, water samples were collected periodically and analyzed with respect to nitrate, TP and TKN at a laboratory of Kangwon Provincial Institute of Health and Environment from August, 1993 to May, 1994.

Runoff from the pasture was formed mostly with seeping subsurface flow in the lower areas of the pasture. A few overland flows were observed during heavy storms, and when it occurred, runoff increased sharply. For the Sudan grass field, runoff was formed with overland flow. Nitrate concentration in runoff from both land uses seemed not affected by runoff and ranged from 0.241 to 4.137mg/l. TP and TKN concentrations from the pasture were affected by overland flow. When overland flow occurred, TP and TKN concentrations abruptly increased to 5.726 and 12.841mg/l, respectively, from less than 1.0mg/l. However, these concentrations from the Sudan grass field were quite stable ranging from 0.191 to 0.674mg/l for TP and 0.470 and 1.660mg/l for TKN.

Nitrate concentration was significantly affected by land use(Sudan grass field) and the concentration increase reached about 2mg/l per 100m ground water flow. Nitrate concentration from a well located in the middle of rice fields also was significantly higher than that measured from a well located relatively undisturbed mountain toe area. TP and TKN concentrations in shallow ground water affected by the depth of the monitoring wells. The deeper the monitoring wells, the less TP and TKN concentrations were measured.

Keywords□Nonpoint, pollution, landuse, water quality, nitrate, TP, TKN, ground water, runoff, flume, monitoring well.

I. Introduction

Protection of water resources from pollution has become one of the most important national tasks to be achieved. Point sources of pollution like municipal wastewater treatment plants and various industrial sites have been successfully managed to reduce waste loadings while nonpoint sources of pollution from agricultural areas have been increased. The role of agriculture in water pollution has been targeted by numerous scientists and engineers for a couple of decades in America and research revealed that nonpoint source(NPS) phosphorus from soil erosion and livestock waste run-off has been a significant contributor to water quality degradation and eutrophication of lakes and rivers. In the same period, run-off and leaching from fertilizers and livestock waste are shown to contribute to high nitrate levels in some rivers and ground water wells in agricultural areas (Logan, 1993).

Almost all surface water resources in Korea have been experiencing more or less its water quality degradation in one way or another. Ground water system has not been immunized from contamination. Leaching from livestock feed lots, animal waste dumps, intensively cultivated agricultural areas, and domestic waste drains including septic tank systems which are failing or improperly built are all contamination sources to ground water system(Bouwer, 1978). High nitrate levels exceeding the safe drinking water standard in rural school water supply systems have been reported many times in newspapers(Chosun Ilbo, 7/25/93, 10/7/93 ; Kangwon Domin Ilbo, 7/28/93).

Successful NPS pollution abatement strategies are closely related to understanding of the very basic mechanisms of NPS pollutant generation and transport from various sources and the fate of each pollutant in the soil and water system. Those mechanisms and fate are not well studied and the effect of agricultural land use on surface and ground water quality has not been properly described in Korea. Therefore, objectives of this study are (1) to construct a field scale water quality data base with respect to nitrate(NO_3-N), total phosphorus(TP) and total Kjeldahl nitrogen (TKN), and (2) to analyze water quality variation with respect to land use and management, run-off, and ground water flow by using the collected data. The results could be used by various government agencies to understand the nature of NPS pollution and help develop effective NPS pollution abatement programs to protect and conserve the natural water resources. The results also can be a good educational material to farmers, students and general public.

II. Experimental Procedures

Field experiments were initiated June, 1993 at an agricultural and livestock research farm of the Kangwon National University located at a suburb of Chuncheon, Korea. A grazing pasture(29,700m^2 with 4 to 10° slope), an upland(6,843m^2 with 1 to 3° slope) and a paddy field(7,900m^2) were chosen for this research. Orchard grass(Dactylis Glomerata), Alfalfa(Medicago Sativa), Timothy(Phleum Repens), Clover(Trifolium Repens) and Kentucky blue grass(Poa Pratensis) were dominant species in the pasture. Sudan grass(Sorghum Vulare var. Sudanese) for growing season harvest and Rye(Secale Cereale L.) for winter cover crop have been cultivated for years in the upland. Rice (Il-pum) has been cultivated in the paddies.

A H-flume with stilling well and Stevens water level recorder were installed at each outlet of the pasture and upland for measuring surface runoff and collecting water samples. Runoff samples of about 2 liters were collected by hand from the pasture and upland every other week or when run-off occurred. Total of 9 ground water monitoring wells were constructed to monitor ground water levels and collect water samples. Two were in the pasture, four in the upland and three in the paddy field. A hand auger was used to build

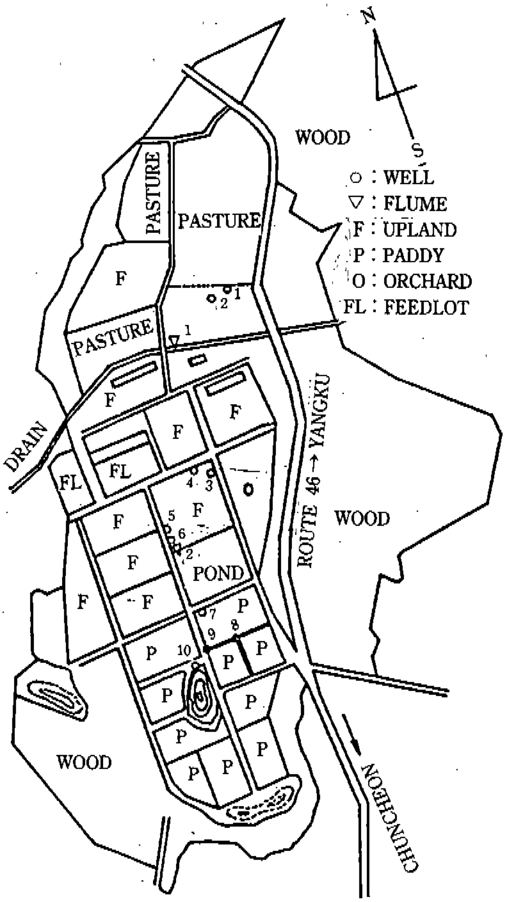

Fig. 1. **Schematic locations of flumes and ground water monitoring wells at a Kangwon National University Research Farm**

the wells and depths of the wells ranged from 1.5m to 2.5m from the soil surface. A vacuum water sampler was built and used to collect ground water samples from the wells. Sampling locations of surface and ground waters were shown in Fig. 1.

Collected water samples were analyzed with respect to nitrate(NO_3-N), total phosphorus(TP), and total Kjeldahl nitrogen(TKN) at a laboratory of the Kangwondo Institute of Health and Environment. TKN is a measure of nitrogen concentration of the form of organic nitrogen and ammonia (NH_4-N) nitrogen in samples by either Macro-Kjeldahl or Semi-Micro-Kjeldahl methods(APHA, 1992), and Semi-Micro-Kjeldahl method was used in this study. Water quality data collected from August, 1993 to May, 1994 were analyzed in this study with respect to different land use.

Table 1. Runoff and water quality measurement from the grazing pasture

Date	Flow rate (l/min)	NO_3-N (mg/l)	TP (mg/l)	TKN (mg/l)
07/29/93	250	3.056	0.191	0.470
08/02/93	60	2.062	0.123	0.157
	220	0.560	0.179	0.470
08/09/93	2,000	3.197	5.726	12.841
08/10/93	220	3.526	0.676	1.910
	115	0.241	0.245	0.658
08/13/93	462	0.632	0.463	0.626
08/16/93	250	3.962	0.216	0.157
08/24/93	60	2.570	0.038	0.125
08/30/93	8	1.824	0.215	0.628

III. Results and Discussion

1. Water Quality from the Grazing Pasture

Runoff and water quality measurement from the grazing pasture are shown in Table 1. Most of rainfall infiltrated into the soil and formed subsurface flow or percolated into ground water body. It seemed that subsurface flow seeped at the lower areas of the pasture. Runoff from the pasture outlet mostly was formed with the seeping subsurface flow. Only a few overland flows caused by heavy storms were observed during the study. It seemed that overland flow began to affect the runoff greater than about 450l/min in the pasture and to dominate the runoff as the overland flow increased. Since seeping water mostly formed runoff, variations of NO_3-N, TP, and TKN concentrations in runoff were relatively small considering that livestock waste residues were on the soil surface. However, when overland flows occurred by heavy storms, runoff rate and TP and TKN concentrations in the runoff increased dramatically. Nitrate concentration did not increase as much. Cattle manure remained on the surface was washed off by the flow's transport capacity to increase TSS in the runoff, which caused the sharp increases of TP and TKN concentrations. Best management practices need to be developed and adopted to curb the sudden surge of waste loadings to receiving water bodies during heavy storms.

Shallow well water qualities were shown in Table 2. Measured nitrate concentrations from the wells did not exceed the safe drinking water standard and no differences were observed between the two wells. The two wells were about 15m apart from each other and Well 1 was installed to measure shallow subsurface flow qualities and Well 2 to measure deeper subsurface flow qualities. Soil texture of the pasture is very sandy with many boulders and cobbles. It was thought that most of infiltrated water percolated deep into the soil profile and drained directly to the lower watershed ground water zone and thus, nitrate did not accumulated in-situ groundwater to cause the low nitrate concentrations. Low nitrate concentration also is contributed because nitrate is an anion and does not retained in the soil profile but move freely with percolating water. TP and TKN concentrations were different between the shallow(Well 1) and deeper(Well 2) wells. Since organic matters in percolating water retained in the soil profile while it moved through the dense soil texture, the deeper well showed less TP and TKN concentrations.

It is thought that nitrate, one of the most notorious pollutants in rural areas and leaching to coarse textured soils like the pasture percolates deep into ground water, easily moves with ground water flow to the lower watershed groundwater zone and ultimately releases to a surface water system. It is necessary to install deep observation wells to describe nitrate leaching quantitatively and assess the impact of land use on surface and ground water qualities.

2. Water Quality from the Upland

Table 3 showed runoff rate and its quality from the upland. Soil in the upland was clayey sand and its hydraulic conductivity was relatively small. Well developed dense Sudan grass covered the

Table 2. Ground water quality measurement from the grazing pasture

Date	NO_3-N (mg/l)	TP (mg/l)	TKN (mg/l)
Well 1			
8/16/93	2.660	0.490	0.282
8/24/93	0.431	0.586	0.470
Well 2			
8/16/93	4.744	0.014	0.094
8/24/93	2.778	0.057	0.031
8/30/93	2.452	0.043	0.125

Note : Well 1 dried before 8/30/93.

Table 3. Runoff and water quality measurement in the upland

Date	Flow rate (l/min)	NO_3-N (mg/l)	TP (mg/l)	TKN (mg/l)
7/29/93	180	3.056	0.191	0.470
8/09/93	2,200	1.793	0.643	1.034
8/10/93	380	4.137	0.541	0.908
	68	2.174	0.614	1.660
8/13/93	300	0.550	0.674	0.971
Average		2.341	0.533	1.009
Std		1.348	0.197	0.426

soil surface well except harvesting periods. Surface residue cover was more than about 60% even right after harvesting. This residue cover helped increase infiltration and reduce runoff and soil erosion. However, some concentrated flows occurred and noticeable ephemeral gullies found in and around the edge of the field where flows were concentrated and local surface slope exceeded 3 to 4°. Most of soil erosion from the field might be originated from these gullies. To protect the soil from erosion, a grassed waterway needs to be built along the edge of the field. Nitrate, TP and TKN concentrations were in the similar ranges but concentration variations were small even in high runoff event when compared to those in runoff from the grazing pasture. High grass litter surface residue cover unlike animal waste residue in the pasture might stabilize the soil surface from erosion to cause relatively stable water quality.

Nitrate concentration changes in the Sudan grass field are shown in Fig. 2. For Wells 4 and 5, only three measurement were done because the wells were dried. Nitrate concentration ranged from 0.023 to 0.192mg/l at Well 3, 0.282 and 1.083 mg/l at Well 4, 1.836 and 3.852mg/l at Well 5, and 0.042 and 3.873mg/l at Well 6, respectively.

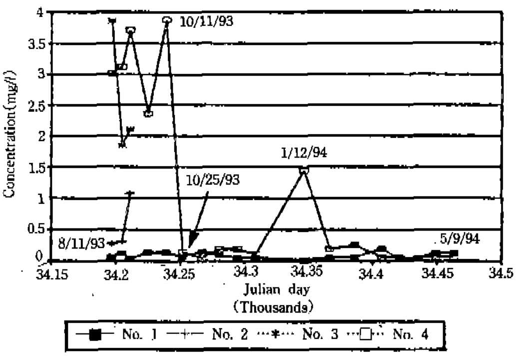

Fig. 2. Nitrate concentration changes with time in the Sudan grass field

The flucturations in Wells 3 and 4 were relatively stable while those in Wells 5 and 6 were not. It seemed that nitrate changes in Wells 5 and 6 varied with seasons while the changes in Well 3 were steadfast. For growing and monsoon season, nitrate concentrations were high and fluctuated much but the concentrations became stabilized after growing season. High nitrate concentration measured January 12, 1994 could be an error caused by either sampling or analyzing processes. Otherwise, the causes of the high concentration should be carefully investigated with more data.

Ground water level measurment revealed that the ground water flows from the upper area(Well 3 and 4) to the lower area(Well 5 and 6). The water level difference measured between Well 3 and 6 were about 4.3m and the distance between the wells was about 120m. Nitrate concentrations between wells at the upper and the lower areas during growing and monsoon season(between 8/16/93 and 10/11/93) were significantly different at the 5% level of significance. The land use affected ground water quality such that nitrate concentration increased about 2.0mg/l per 100m of ground water flow. It is because nitrate was leached with percolating water to the shallow ground water during growing and monsoon season. However, the difference diminished after harvesting Sudan grass and planting winter cover crop.

TKN and TP concentration changes were shown in Fig.s 3 and 4. TKN concentration ranged from 0.063 to 0.626mg/l at Wells 3 and 4, and 0.035 and 1.065mg/l at Wells 5 and 6, respectively. TP concentration ranged from 0.023 to 0.564mg/l at Wells 3 and 4, and 0.022 and 1.949mg/l at Wells 5 and 6, respectively. TKN concentration fluctuated throughout the monitoring but it seemed that magnitude of fluctuation became smaller during

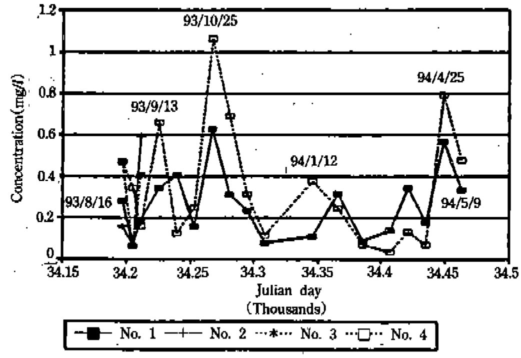

Fig. 3. TKN concentration changes with time in the Sudan grass field

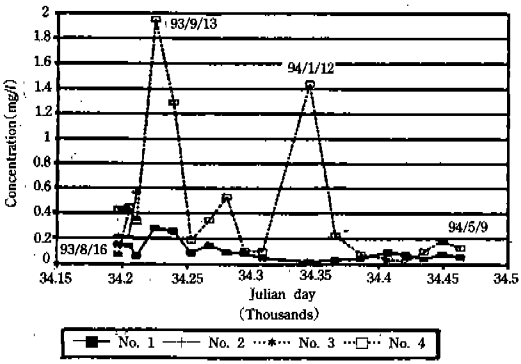

Fig. 4. TP concentration changes with time in the Sudan grass field

the winter season. TP concentration at Well 3 was relatively stable while the concentration at Well 6 fluctuated very much throughout the monitoring. It is not quite clear the cause of the fluctuation and more data is needed to investigate the fluctuation. No statistically significant differences in TP and TKN concentrations between the upper and the lower areas were found.

3. Water Quality from the Paddy

Surface water quality was not measured from the paddy field. However, Shin(1990) reported that TP and TKN losses from paddy watersheds during May and June which was a transplanting season occupied about 85% of the total TP and TKN losses during a growing season. Measured ground water levels between monitoring wells were not much different from each other(Wells 7, 8 and 9). The Differences were about 0.4m at most between wells spaced about 30 to 40m apart each other. By considering adjacent topography and the ground water level, it seemed that ground water flows vertically deep into the soil profile and drains to the lower watershed ground water zone. The ground water monitoring wells were dried early October, 1993 and did not rise to the level which samples could be taken until the end of May, 1994 even though the paddy was filled with water for transplanting.

Table 4 showed nitrate concentration changes around the paddy field. Nitrate concentration mostly ranged from 0.129 to 2.362mg/l except two unusual measurement of 0.018 and 5.231mg/l which might be caused by errors during sampling or analyzing processes. The concentrations in the paddy ground water seemed lower than the other two land uses investigated. Nitrate produced in the paddy water and at the top of the soil layer that can maintain an aerobic zone is either uptaken by rice or moves down with percolating water. The nitrate moving down is subject to denitrification processes at the subsequent anaerobic zone where nitrate transforms to nitrogen gas which

Table 4. Nitrate concentrations(mg/l) from the paddy ground water

Date	Well 7	Well 8	Well 9
8/16/93	0.796	5.231	0.608
8/24/93	1.298	1.435	0.129
8/30/93	1.031	0.018	0.760
9/13/93		0.147	0.342
9/27/93		0.342	2.362

Note : Well 7 dried before 9/13/93.

is released to the atmosphere. The monitoring wells were not installed in the middle of the paddy but installed on small levees between paddies. The distance between the wells and paddies were less than 0.4m. Nitrate produced at the paddy may be diffused to levee side and also subject to denitrification processes while it moves down. Denitrification and diffusion might contribute to the low nitrate concentration. No significant concentration differences between wells were detected. However, it is necessary to install monitoring wells at different depths in the middle of paddies to describe nitrate leaching quantitatively.

Tables 5 and 6 showed TP and TKN concentration changes around the paddies, respectively. TP and TKN concentrations were in the similar range with the ones measured from the other two land uses. TP and TKN concentrations seemed somewhat close to the ones measured from the shallow well of the pasture(Well 1) and Wells 5 and 6 of the lower upland. Paddy TP and TKN concentrations seemed higher than the ones measured from the deep well of the pasture(Well 2) and Wells 3 and 4 of the upper upland. However, these trends need a further study to be statistically proved. Since the water level dropped quickly as dry season began and monitoring wells in paddy dried, water samples were collected and analyzed from a nearby existing well(Well 10) which is about 18m apart from Well 9 and 5m apart from other paddy(Fig. 1). Well 10 is much deeper than the monitoring wells and have been used for drinking and irrigation for many years by the farm workers. The samples were analyzed to monitor water quality changes during Winter season and the analyzed water qualities were shown in Table 7.

Nitrate concentration in Well 10 was significantly higher than the one measured at Well 3 of the upland at the 5% level of significance. Geographically, Well 3 is located at the toe of a mountain where very small artificial disturbances are made and almost no point and nonpoint sources of pollution exist. And Well 10 is surrounded with paddy fields even though it is at least 5m apart from

Table 5. TP concentrations(mg/l) from the paddy ground water

Date	Well 7	Well 8	Well 9
8/16/93	0.393	0.263	1.353
8/24/93	0.384	0.654	0.971
8/30/93	0.624	0.308	0.135
9/13/93		0.691	0.448
9/27/93		0.214	0.772

Note : Well 7 dried before 9/13/93.

Table 6. TKN concentrations(mg/l) from the paddy ground water

Date	Well 7	Well 8	Well 9
8/16/93	0.407	0.313	0.595
8/24/93	0.219	0.188	0.094
8/30/93	0.470	0.157	0.219
9/13/93		0.438	0.689
9/27/93		0.376	1.190

Note : Well 7 dried before 9/13/93.

Table 7. Water quality measurement from Well 10

Date	NO_3-N (mg/l)	TP (mg/l)	TKN (mg/l)
10/11/93	1.275	0.039	0.078
10/25/93	0.962	0.049	0.078
11/08/93	0.962	0.054	0.352
12/06/93	1.093	0.140	0.022
01/12/94	0.785	0.062	0.084
02/01/94	0.928	0.196	0.035
02/21/94	0.805	0.059	0.053
03/14/94	0.737	0.056	0.035
04/25/94	0.756	0.105	0.035
04/11/94	0.735	0.366	0.071
05/09/94	0.675	0.055	n.d
05/23/94	0.988	0.055	n.d

closest paddy. It is very natural that Well 10 water quality is under influence of surrounding land use while Well 3 is not. The nitrate concentration in Well 10 might be affected and thus, showed higher concentration than that in Well 3 although the concentration was less than that of the safe drinking water standard which is 10mg/l.

TP and TKN concentrations in Well 10 were much smaller than other measures except the ones measured at the Well 2 in the pasture. It was thought that as phosphorus and nitrogen compounds moved down, much of the compounds retained in the soil profile to give the low TP and TKN concentrations.

IV. Conclusions

Three types of land use were investigated in this study with respect to surface and ground water qualities and the following conclusions were obtained.

1. Runoff from the pasture was formed mostly with seeping subsurface flow at the lower areas of the pasture. However, a few overland flows occurred by heavy storms and runoff increased sharply(Table 1).

2. Average nitrate concentration in runoff from the pasture was 2.163mg/l with standard deviation of 1.327mg/l. Nitrate concentrations in runoff seemed not affected by runoff rate(Table 1).

3. TP and TKN concentrations in runoff from the pasture increased very sharply to 5.726mg/l (TP) and 12.841mg/l(TKN), respectively, from less than 1mg/l if overland flows occurred by heavy storms. For all other times, the concentrations were in the similar range(Table 1).

4. Measured nitrate concentrations in the ground water of the pasture ranged from 4.744 mg/l to 0.431mg/l and no significant differences in concentration between the shallow and deeper wells were observed(Table 2).

5. TP and TKN concentrations in the ground water of the pasture were different depending on their sources. TP and TKN concentrations from the deeper well(Well 2) were much lower than those from the shallow well(Well 1, Table 2).

6. Nitrate, TP and TKN concentrations in runoff from the upland were similar to those measured from the pasture but concentration variations were smaller than those from the pasture. No sharp increase in TP and TKN concentrations were observed even if a high runoff event occurred(Table 3).

7. Nitrate concentrations in the ground water of the Sudan grass field significantly increased with distance as ground water moved through from the upper(Wells 3 and 4) to the lower(Wells 5 and 6) areas during a growing season(Fig. 2). The increase was about 2.0mg/l per 100m of ground water flow. However, the concentration difference was not significant during a winter season.

8. TP and TKN concentrations in the Sudan grass field did not show any significant differences between the upper and the lower areas. TKN concentrations were very fluctuated throughout the study(Fig. 3). TP concentrations in Well 3 were steadfast while those in Well 4 were very fluctuated(Fig. 4).

9. Nitrate concentrations in the ground water around the paddy seemed lower than the other two land uses. TP and TKN concentrations were similar to the other land uses except Well 2.

10. Nitrate concentrations in Well 10 were significantly higher than those in Well 3. TKN and TP concentrations were similar to Well 2 but lower than those measured from other wells.

Acknowledgements

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