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Run-off Impact Assessment of the Steeped Cornfield to Small Stream

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ABSTRACT: This experiment was conducted to evaluate the nutrient loss and to assess the eutrophication into small stream by intensive rains in the steeped cornfield during cultivation. The crop cultivated was a soiling corn (DW5969), and the experimental plots were divided into two parts that were 10 and 18% of slope degrees. The amount of T-N and T-P loss was calculated by analysis of surface run-off water quality, and was investigated the effect of eutrophication to small stream as a part of life cycle assessment (LCA) methodology application. For the surface run-off water quality, EC and T-N values were highest in first runoff event as compared to the other events and maintained the stage state with litter variations at every hour during the runoff period except for EC in the slope 18%. However, T-P concentration has been a transient stage after runoff event of July 27. Total surface run-off ratio was not significantly different with slope degrees, but amount of T-N and T-P losses at 18% of slope were high as 5.96 kg ha^{-1} and 0.65 kg ha^{-1} as relative to 10% of slope degree, respectively. Furthermore, T-N losses from run-off water in the sloped cornfield 10 and 18% were approximately 9.8 and 12.5% of the N applied as fertilizer when the fertilizer applied at recommended rates after soil test, respectively. For the eutrophication impact to the small stream, it was shown that PO_4 equivalence and Eco-indicator value at 18% of slope degree were greater as much 6.11 kg ha^{-1} and 0.81 as compared to the slope angle 10%, respectively. Therefore, it was appeared that each effect of nutrient losses, eutrophication and Eco-indicator value was enhanced according with higher slope degree.

Key Words: Non-point source pollutants, equivalence factor, Eco-indicator 95 method

INTRODUCTION

Sustainable agricultural practices should be based on the appropriate management of water and soil. Point sources of water pollution are relatively easy to identify and statistics indicate that, to a large extent, there have been substantial improvements in control[1)]. A number of factors have been contributed to the reduction of pollution from agriculture, including the introduction of regulations[2)] and the provision of clear agricultural guidelines[3)]. Nevertheless, surface water quality remains a major concern and excess nutrients, through diffuse pollution, can lead to eutrophication and the occurrence of toxic algal blooms. In areas with intensive rainfall, it tends to be non-point source pollutants that nitrogen and phosphorous in and soil are conveyed into the water flowing system. These effluence rates are determined by rainfall and its intensity. In Korea, an intensive rainfall tends to be occurred in summer from June to early September. Yun *et al.*[4)] reported that NPS pollutants from agricultural practices are comprised only 5% of total pollutants entering into bulk water body. Kim *et al.*[5)] indicated that the concentrations of nitrogen and phosphorous in the drainage water was highest when fertilizer was applied during cropping season. NPS pollutants are

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mainly transported from the steeped cropland by surface run-off with rainfall, and responsible for the eutrophication. Isermann[6] estimated that agriculture accounted for between 37 and 82% of nitrogen (N) emission and between 27 and 38% of phosphorus (P) emission into surface waters in Western Europe. Nutrient monitoring of 270 Danish streams indicated that 94% of the N Loading and 52% of P loading arouse from non-point source pollution, primarily from agricultural activities[7]. Werner[8] concluded that diffuse pollution from agriculture was responsible for about 44 and 28% of total N and P inputs into surface water, respectively, in Germany. Lowrance[9] has shown that in the U.S. agriculture contributes over 70% of T-P discharges to rivers. In order to examine the entire small stream burden connected with agricultural production systems, it is necessary to consider all non-point sources pollutants at the same time. Life Cycle Assessment (LCA) is a methodology to assess all the environmental impacts associated with a product, process or activity by identifying, quantifying and evaluating all the resources consumed, and all emissions and wastes released into the environment. Furthermore, the results show that LCA methodology is basically suitable to assess the environmental impact associated with agricultural production[10]. It appeared that the LCA methodology is available tool to assess the environmental impact associated with different fertilizer applications for rice cultivation[11]. Objective of this study was to establish the potential attributed indicators by evaluating the nutrient loss and by assessing the eutrophication when run-off flowed into the small stream by rainstorm in the steeped cornfield during cultivation season.

MATERIALS AND METHODS

The crop cultivated was a soiling corn (DW5969), and the experimental plots were divided into two partial block areas that were 10 and 18% of slope degree by block. At the bases of sloped cornfield that directly connected into the small stream, two gauges were installed for measurement of run-off, and surface run-off samples were collected every hour by auto-samplers for an analysis of water quality. Soil chemical characteristics of the steeped cornfield were presented in Table 1. Application amount of fertilizer based on data of soil test before sowing the corn seed was determined.

Fertilizers are applied with 15.6-0-13.0 kg $10a^{-1}$ (N-P_2O_5-K_2O) and 500 kg $10a^{-1}$ (composted manure) in the fine sandy loam soil. For results of the soil test, Concentration of available P_2O_5 in the cornfield was relatively higher than the proper range (300~500 mg kg^{-1}) recommended by RDA (Rural Development Administration). Therefore, phosphorus fertilizer was not applied in the steeped cornfield. Chemical properties of organic material used in this experiment were given in Table 2.

The pH was determined by using an Orion Research EA-940 pH meter, electrical conductivity by EC meter (Y.S.I model-30), total nitrogen, NH_4-N and NO_3-N by Kjeldahl method[13], available phosphate by Lancaster method[14], and exchange cations by using ICP-AES (Inductively Coupled Plasme-Atomic Emission Spectrometry, GBC INTERGRA XMP, Australia. For assessment of eutrophication to small stream by surface run-off water in the steeped cornfield, the inventory data for eutrophication are aggregated to effect scores using the equivalence factors shown in Fig. 1. The higher the equivalence factor, the higher is its contribution. PO_4 equivalence was calculated by modifying the Eco-indicator 95 method as follow:

Also, Eco-indicator values were induced by following equation[15]:

Table 1. Chemical characteristics of the steeped cornfield soil used

pH	O.M (g kg^{-1})	T-N (%)	Av. P_2O_5 (mg kg^{-1})	K	Ca	Mg	CEC
				cmol$^+$ kg^{-1}			
6.7	3.8	0.14	879.1	2.82	6.32	1.03	13.2

Table 2. Chemical properties of composted manure used in the experiment (Unit : %)

T-N	P_2O_5	K_2O	CaO	MgO
1.3	1.42	0.17	0.18	0.17

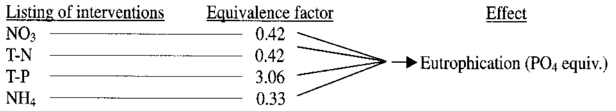

Fig. 1. Characterization of emissions for eutrophication in the Eco-indicator 95 method.

Eco-indicator value of eutrophication = $(\Sigma_{n=i}\ PO_4\ equiv./NV)*WF$, where normalization value (NV) and weighing factor (WF) for eutrophication were 38.2 and 5, respectively.

For the above equation, the normalization, the contributions of the analyzed system to the total extent of the environmental impacts examined in Europe were used. Taking eutrophication as an example, normalization was done by dividing the eutrophication potential of the system under investigation by the total eutrophication potential in Europe. However, the normalized and dimensionless data do not allow any conclusion about the potential of the different impacts to harm the environment. Therefore, an additional weighting step is required to consider the different level of severe of the environmental effects. According to the Eco-indicator value for an eutrophication, multiplying the normalized effect value by a weighing factor developed for its environmental effect done this.

RESULTS AND DISCUSSIONS

Characteristics of run-off water

Monthly rainfall rates are given in Table 3. Runoff losses were different according to the amount and distribution of rainfall, cultivation crops and the slope. Bhardwaj *et al.*[16] reported about 30-35% runoff ratio under maize cultivation on four percent slope. In the present studied field, it appeared that the run-off ratios at 10 and 18% of slope degrees ranged from 12% to 43.2% and from 12.7% to 44.5%, respectively.

N and P concentrations in runoff water

Surface runoff water quality in surface runoff at cornfield was influenced by the hydrological characteristics and the chemical inputs of natural or anthropogenic origin, in the base catchments. The patterns of EC, T-N and P concentrations in the runoff water from the different steeped cornfields at every one-hour interval with runoff events during crop cultivation were presented in Fig. 2 and 3. Concentrations of EC and T-N were highest in first runoff event as compared to the other events and maintained the stage state with litter variations at every hour during the runoff period except for EC in the slope 18%. However, T-P concentration has been a transient stage after runoff event of July 27. It was released with low concentration until July 23 and then with about five times higher concentration after this runoff event irrespective of the slope.

Apart from the total load nutrients in surface runoff, their concentrations were also relevant from the viewpoint of impact into the small stream water quality on ecosystem. The primary growth limiting nutrient in most freshwater systems is not N but P[17] and consequently the framework of most eutrophication management has been focused predominantly on the control of P loading[18]. In this context, though there is a lack of consensus on the concentration of T-P in agricultural runoff that is considered eutrophication, it is generally accepted that runoff water is degraded if T-P concentration contains more than 100 μg ℓ^{-1}[19]. For the monitoring periods, the average concentrations of T-P in run-off water were 2.36 mg ℓ^{-1} and 3.30 mg ℓ^{-1} for slope 10 and 18% on August 27, respectively. The present study, showed that concentration of T-P exceeded that guideline of 100 μg ℓ^{-1} in the all run off events through crop cultivation irrespective to the different slopes (Fig. 2 and 3). However, T-P is not the sole nutrient limiting eutrophication in streams and river. Enrichment with both N and P has been shown to produce higher algal yields than addition

Table 3. Characteristics of run-off in the steeped cornfield with different slope degrees during cultivation

Parameters	Slope 10%			Slope 18%		
	June	July	Auust	June	July	August
Rainfall (mm) (A)	126.0	422.0	170.0	126.0	422.0	170.0
Run-off ($m^3\ ha^{-1}$) (B)	151.2	1321.0	734.6	160.1	1381.2	756.8
Run-off ratio (%) (B/A)	12.0	31.3	43.2	12.7	32.7	44.5

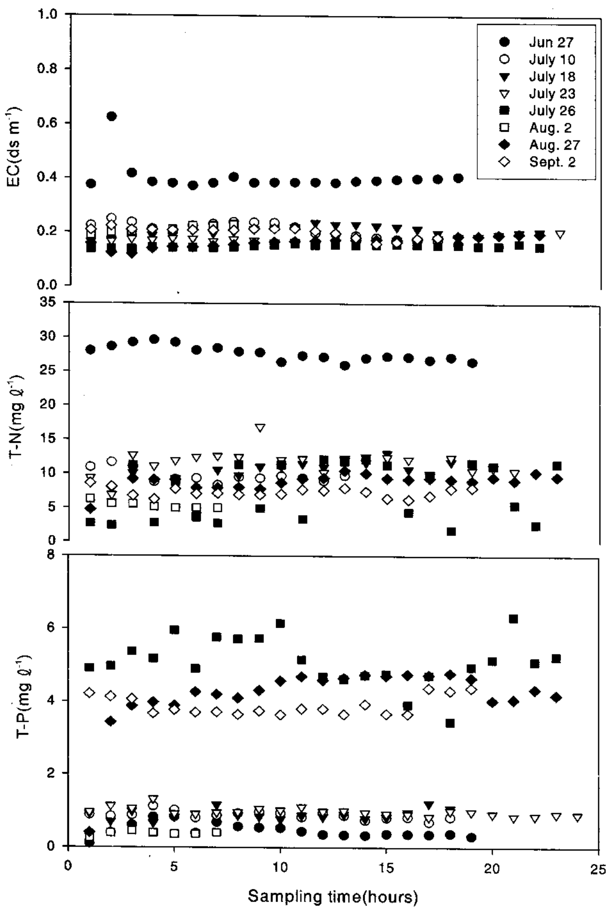

Fig. 2. Electrical conductivity and concentrations of nitrogen and phosphorus in the surface water from the steeped cornfield with slope 10% during cultivation.

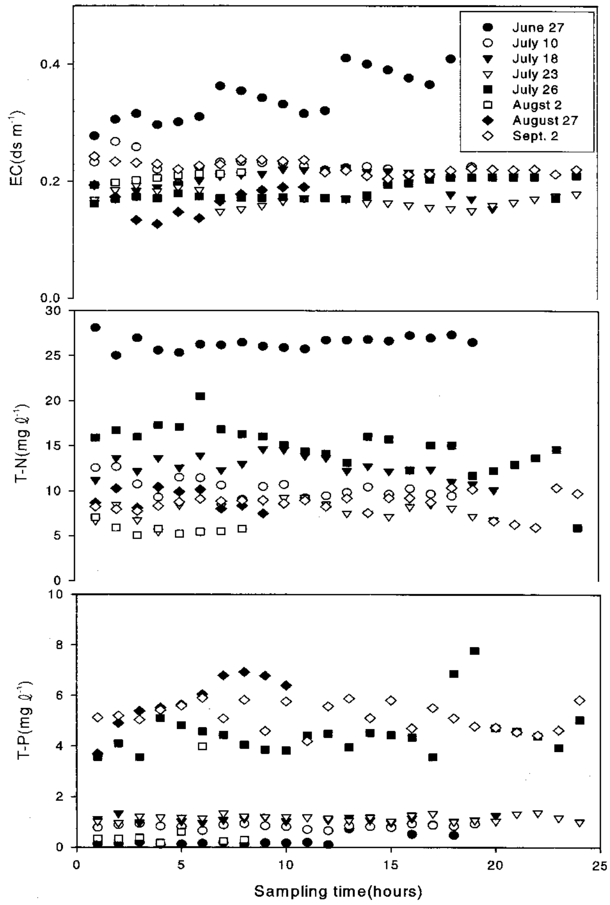

Fig. 3. Electrical conductivity and concentrations of nitrogen and phosphorus in surface flowing from the steeped cornfield with slope 18% during cultivation.

of P alone thereby indicating that both N and P can be co-limiting to algal communities in freshwater systems[16]. In fact, the maintenance of a total N concentration of <350 μg ℓ^{-1} in freshwater has been recommended to keep algal biomass below the nuisance level of 100 mg m^{-1} [18]. Through the monitoring periods, the average concentrations of T-N in run-off water were 27.67 mg ℓ^{-1} and 26.09 mg ℓ^{-1} or slope 10 and 18% on June 27, respectively. The present study showed that both N and P concentrations in runoff water were high (Fig. 2 and 3) and their transport to the small stream where N is generally the limiting nutrient[17] would only serve to stimulate eutrophication in the ecosystem.

T-N and T-P load in surface run-off water

The movement of agro-chemicals from agricultural fields of the temperate region has shown that the amount, intensity and timing of first rainfall event after application of the chemicals are the most important factors affecting their load in surface run-off water[20]. Furthermore, the fate and transformation of the nutrients in soil plays a crucial role with regard to their behavior and hazard as water pollution. In the present study, the first run-off event occurred almost 9 weeks after sowing of corn. Losses of T-N (except for July 26) and T-P (for July 26 and August 27) via run-off did not significantly different between slope 10 and 18%.

For the nutrient loss, the amount of T-N and T-P in the steeped cornfield with 10% of slope degree was 21.74 and 6.73 kg ha^{-1} for the slope 10%, and was 27.70 and 7.38 kg ha^{-1} for the slope 18%, respectively (Fig. 4). Therefore, T-N and T-P losses at slope 18% were high as 5.96 and 0.65 kg ha^{-1} as compared to slope 10%, respectively. T-N losses from run-off water in the sloped cornfield 10 and 18% were approximately 9.8 and 12.5% of the N applied as fertilizer when the fertilizer applied at recommended

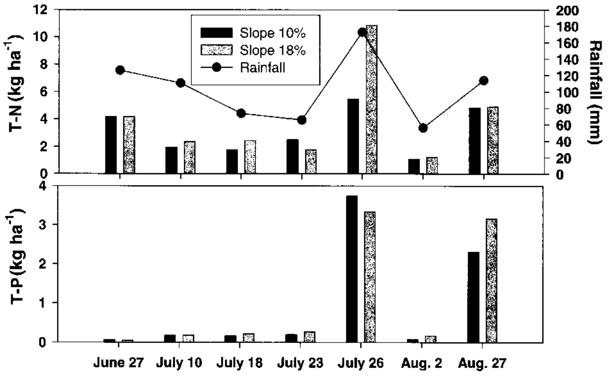

Fig. 4. Total nitrogen and phosphorous moved by surface runoff from the steeped cornfield during cultivation.

rates after soil test, respectively. These results were not agreement with Isermann's estimation[6] between 37 and 82% of nitrogen (N) emission in Western Europe and about 44% of total N input into surface water, as fertilizer would be lost in runoff when the fertilizer was applied at recommended rates and at optimum time in Germany[8]. However, Douglas *et al.*[21] noted that only a small percentage of the N and P applied as fertilizer would be lost in runoff when the fertilizer was applied at recommended rates and optimum times.

Eutrophication impact assessment of surface run-off water

For the eutrophication impact assessment of surface run-off water into the small stream for the steeped cornfield, the observation values of parameters related with PO_4 equivalence are given in Table 4. For the slope 18% as well as surface run-off loads, the T-N was higher except June, but T-P was lower as compared

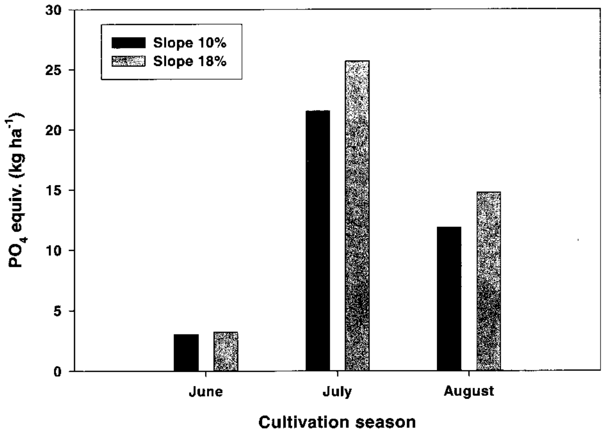

Fig. 5. Effects of eutrophication for run-off in the steeped cornfield with different slope degrees during crop cultivation.

with the slope 10% through the crop cultivation periods. NO_3-N was the dominant form of N moved in surface run-off water. It observed that the composition rates of T-N and T-P were 48 and 13%, and contribution order of chemical compositions for the eutrophication was T-N > NO_3-N>T-P>NH_4-N at both slopes.

For the eutrophication impact assessment, PO_4 equivalence values of run-off water from the steeped cornfield during crop cultivation were presented in Figure 5. It appeared that the equivalence values of the surface run-off water on July were greatest as compared to the other month in both slopes. Also, PO_4 equivalence values at slope 18% were greater at 16 and 20% on July and August, respectively, than the slope 10%. In respective to the assessment of eutrophication in the steeped cornfield, the loading amount based on PO_4 equivalence is calculated with 35.6 and 41.72 kg ha^{-1} at each slope (Fig. 5).

Table 4. Important emissions (kg ha^{-1}) in the steeped cornfield with different slopes during cultivation

Slopes (%)	Parameters (kg ha^{-1})	Cultivation periods			
		June	July	August	Total
10	T-N	4.18	11.65	5.91	21.74
	T-P	0.07	4.27	2.39	6.73
	NO_3-N	3.16	8.03	4.74	15.92
	NH_4-N	0.05	0.64	0.19	0.88
18	T-N	4.18	17.42	6.11	27.70
	T-P	0.05	4.00	3.33	7.38
	NO_3-N	3.00	13.97	4.59	21.56
	NH_4-N	0.08	0.83	0.26	1.18

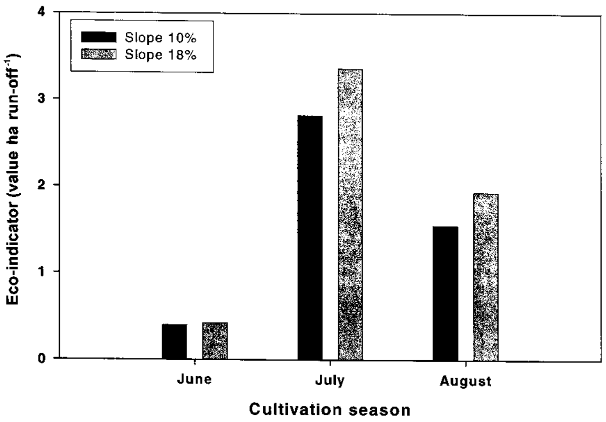

Fig. 6. Eco-indicator values for environmental effect by run-off in the steeped cornfield with different slope degrees during crop cultivation.

Eco-indicator values were calculated with an equation established by Goedkoop[15)]. Eco-indicator values in two steeped cornfields with 10 and 18% of slope degrees were 4.66 and 5.47, respectively (Fig. 6). So Eco-indicator value at 18% of slope degree was greater at 0.81 than the slope degree 10%.

In respect to Eco-indicator value, it appeared that there were predominated at 59.1 and 70.6% of the total eutrophication effect on July at the slope 10 and 18%, respectively.

Overall, for the nutrient losses, eutrophication and Eco-indicator value into the small stream were higher at the cornfield of slope 18%.

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