

ASSESSMENT OF AGRICULTURAL NON-POINT SOURCE POLLUTANTS, AND THE MANAGEMENT OF AGRICULTURAL SOILS

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ABSTRACT

Fertilizer is an essential source of nutrients for stable food production. However, the improper management of fertilizer has a harmful effect on water quality in watersheds. Non-point source (NPS) pollutants such as nitrogen and phosphorus which have been applied as fertilizer are brought down into watersheds by soil erosion. There, the dissolved nutrients enter rivers and lakes, causing eutrophication.

However, a case study in Korea revealed that NPS pollutants from agricultural activity comprised only 5% of total NPS pollutants entering the water body. This Bulletin reviews the occurrence of NPS pollutants from different kinds of agriculture (upland and paddy rice), and suggests how to control NPS by proper soil and fertilizer management.

INTRODUCTION

Agriculture can be defined as the industry which utilizes the natural environment for food production by using the water, soil, atmospheric resources and solar energy. Sustainable agricultural practices for crop production must be based on proper management of water and soil. In areas with intensive rainfall, it tends to be non-point source pollutants which enter the water when nitrogen, phosphorous and soil particles are conveyed into the water system.

Non-point source (NPS) pollution comes from many sources. It is caused when rainfall and runoff move over the ground, carrying pollutants with them and depositing them in lakes and rivers. Studies of patterns of nutrient loss and soil erosion with different kinds of land use, and the effect of these on the environment, are very important if we are to develop countermeasures. Such studies

show how to reduce water contamination and protect the environment. They are also important in agronomy, in indicating the best ways to protect the soil and prevent nutrient losses.

There are various differences in non-point source pollution from soil erosion in upland and rice paddy fields during intensive rainfall. The objective of this research was to compare soil erosion and run-off in fields where different agricultural practices were followed, and to see the effect of various countermeasures in controlling the loss of organic matter, nitrogen and phosphorus.

NON-POINT SOURCE POLLUTANTS FORM AGRICULTURE

In non-point source pollution, we can distinguish the outflow of pollutants in irrigation water which drains into rivers and streams, run-off from pastures and livestock

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sheds, the precipitation of air pollutants, and the contamination of reclaimed land by scrap materials, and of the areas surrounding an abandoned mine (U.S. Congress 1987). The effluence (outflow) of non-point source pollutants from agricultural land occurs mainly during and after rainfall. The rate of effluence is determined by the amount of rainfall and its intensity. Therefore, non-point source pollution from agriculture tends to be occasional, and occurs over a relatively short time. The level of non-point source pollutants in a waterway could vary greatly, according to the distance and flow path of water between agricultural land and the waterway.

In Korea, intensive rainfall tends to occur in summer, between June and early September. The amount of water falling as rain is greater than the amount lost by evapotranspiration. On the other hand, a great deal of water is needed at this time to irrigate crops. As a result, there tends to be a water shortage during the cropping season, except during periods of intensive rainfall (Fig. 1).

SOIL EROSION AND NUTRIENT LOSSES

In Korea, as in the rest of Asia, rice paddies are located in the lowlands, where gravity provides plenty of water for irrigation systems. Most upland crops and orchards are

located on slopelands, where irrigation is difficult.

Soil particles in slopeland areas are constantly being moved and rearranged. Soil erosion is caused by the vertical movement after rainfall of water mixed together with soil particles.

The rate of erosion may be high after intensive rainfall. If the soil surface is protected by growing crops or some other vegetation, the erosion rate is lower. However, soil erosion may be very rapid during and after intensive rainfall onto bare soil during the off season. If we consider the water balance in upland areas at the same time as rice cultivation is being cultivated in the lowlands, average inflow from rainfall is 947 m. Evapotranspiration accounts for 395 mm, and infiltration for 188 m. The amount of run-off is 273 mm, or 28% of the total water. The run-off rate varies with different soil types and cropping methods.

Soil erosion causes the surface layer to lose fertile topsoil and nutrients from applied fertilizer. Furthermore, nutrient loss contributes to water contamination. Therefore, counter-measures are needed to intercept soil erosion. Oh *et al.* (1998) tested the effectiveness of various soil conservation measures for four years in a slopeland area at Yangpeong in Gyeonggi province.

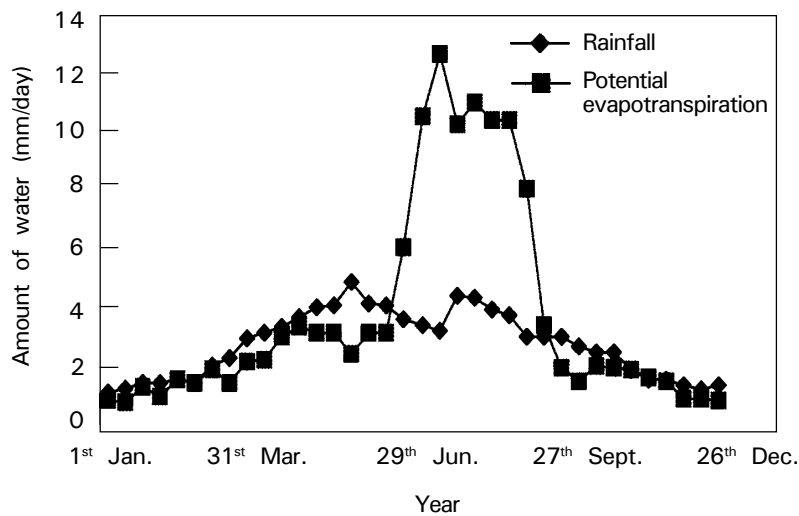


Fig. 1. Seasonal variation in rainfall and potential evapotranspiration in Korea

Table 1. Loss of water, soil, and nutrients from slopeland areas

Treatment	Water loss	soil loss	Loss of nutrients ¹⁾
	mt/ha/year		kg/ha/year
Soil conservation practices ²⁾	642	13.9	26.8
Conventional practices	1,178	85.7	72.8

1) N, P₂O₅, and K₂O

2) Bench terraces, terrace channels, and grass strip

Table 2. Monthly variations in rainfall, runoff and soil loss at the experimental site

	Month							Total
	April	May	June	July	Aug.	Sept.	Oct.	
Rainfall (mm)	58.4	105.2	117.8	273.6	339.3	64.1	55.5	1,014
Runoff (mt/ha) ¹⁾	4.4	85.6	131.5	588.2	831.5	137.5	77.7	1,856
Soil loss (mt/ha) ¹⁾	6	431	431	1,520	1,649	280	31	4,348
Soil loss (kg/ha) ²⁾	-	174.2	188.5	791.4	1,014.2	128.5	11.4	2,308
Soil deposited (kg/ha) ³⁾	5.7	256.8	242.5	728.6	634.8	151.5	19.6	2,039

1) Total soil removed from experimental area.

2) Total weight of soil particles which reached the receiving water body.

3) Total weight of soil particles deposited before reaching the receiving water body.

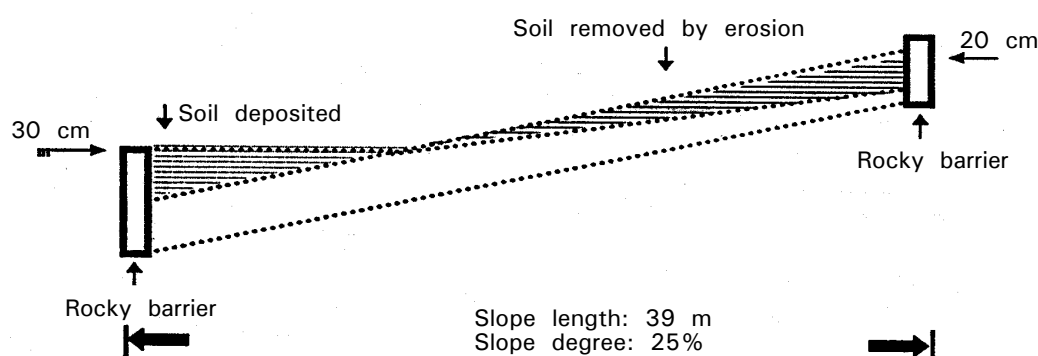


Fig. 2. Pattern of soil erosion on slopeland

The slope of the site ranged from 4 to 40%. The area of the experimental site was 84 ha. Various soil conservation facilities were installed, including bench terraces, terrace channels and grass strips. Compared to these measures, normal farming practices had 6.1 times as much soil erosion. Water loss was 1.8 times higher, and nutrient losses were 2.7 times higher than when conservation measures were practiced (Table 1). The soil lost moved from the upper part of the slope down to the

lower part, washed down by water falling as rain. The run-off water carrying soil particles was intercepted by soil conservation facilities installed in the lower part of experimental sites, so it did not directly flow into the stream.

Table 2 shows the amount of soil erosion and run-off after rain during the summer (April to October) over five years at Yeju, in Gyeonggi province. The experimental sites included forest (22.5 ha), pasture (4.8 ha), upland fields (2.7 ha) and a rice paddy (3.5

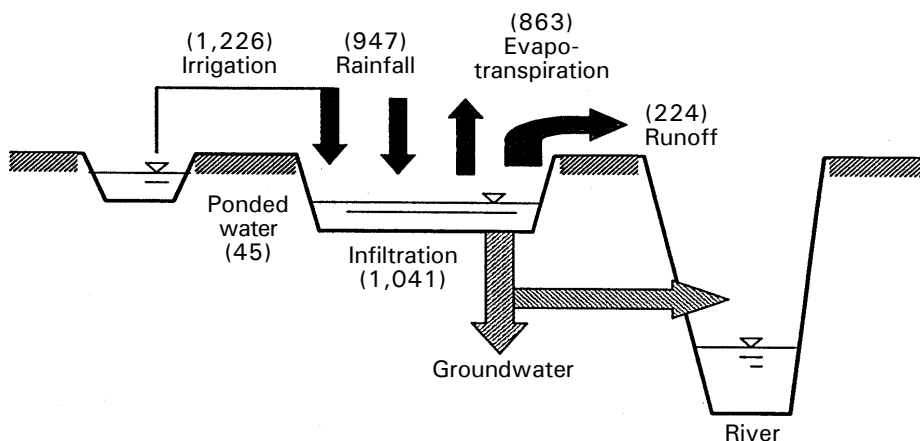


Fig. 3. Water balance of paddy fields (mm)

ha). Slopes ranged from 11 to 42% (Lee *et al.* 1997).

The average amount of inflowing water over the five-year period was 10,139 mt/ha. Water effluence, and soil erosion from rainfall over five years amounted to 1,856 mt/ha, and soil erosion to 4,348 mt/ha. Soil erosion mainly occurred from July to August. Nearly 73% of total soil erosion occurred during this time. Of the eroded sediments, 53.1% (2,039 kg/ha) were deposited before they reached the river. The amount actually flowing into the river was 2,308 kg/ha (46.9%).

Fig. 2 shows the pattern of movement of soil lost from an upland field, with a slope 39 meters long and with a gradient of 29%. In this study, the accumulation of soil in the lower part of the field was only around 120 kg/ha/year (Oh *et al.* 1998). These results show that the rate of soil erosion varies according to the degree of slope, the intensity of rainfall, the soil type, the crop and the cultivation method. However, there is always some loss of soil and nutrients with heavy rain. Such losses can be reduced by applying best management practices (BMP), such as drainage and cultivation along the contours.

WATER PURIFICATION FUNCTION OF PADDY FIELDS

Rice paddies tend to be located on flat ground in lowland areas. Paddy fields need a large quantity of irrigation water. Most of this water flows down from higher slopes. The quality and quantity of water in the lowlands largely depend on farming practices on higher ground.

Fig. 3 shows the water balance of paddy soils in Korea (Eom *et al.* 1993). The amount of irrigation water needed to supply a rice paddy during the rice cultivation period is approximately 122.6 cm/ha. This is provided through an irrigation channel from an irrigation reservoir, or by pumping water from a river into the rice paddy.

Of the total irrigation water, 947 mm was supplied by rainfall and 2,173 mm from the annual inflow of water during the rice cultivation period. If we consider the water leaving the paddy during the cropping season, 863 mm evaporated into the atmosphere, 1,041 mm infiltrated into the groundwater, and 224 mm overflowed over the levee into the river. Therefore, the total amount of water leaving the field was estimated to be 2,128 mm.

Fig. 3 shows the water balance estimated on the basis of samples of runoff water from forest, slopeland and rice paddy one day after heavy rain at Nonsan in Chungnam province. The irrigation water pumped from the river, amounting to 1,226 mm, originating as run-off from the mountainous watershed and the slopeland. It contained various point or non-point source pollutants when it reached the irrigation channels around the rice paddy. When this water irrigated the paddy, the paddy soil accomplished a purification function through the mechanisms of uptake, absorption and accumulation of pollutants in the irrigation water.

Kim *et al.* (1999) indicated that the concentration of nitrogen and phosphorous in the drainage water was highest at the times when fertilizer was being applied during the cropping season. The efficiency of the

purification of nitrogen in the irrigation water ranged from 52.1 to 66.1%. The efficiency of phosphorous purification was 26.7 to 64.9% (Eom *et al.* 1993)

Paddy rice fields have the additional function of preventing flooding, since they store water flowing down from higher ground after rain (Eom *et al.* 1993). In doing this, they also play a role in reducing the inflow of non-point source pollutants from slopeland into rivers.

In view of the fact that the average height of levees is about 27 cm, and the flooding depth for rice culture is 4 cm, while irrigation water infiltrates to an average depth of 4 cm, the actual depth of water contained in a rice paddy is approximately 27 cm. It is estimated that there are 367 billion mt of water contained in rice paddies all over Korea. This means a considerable potential ability to protect rivers from non-point source pollution.

COUNTERMEASURES TO REDUCE THE OCCURRENCE OF AGRICULTURAL NON-POINT SOURCE POLLUTION

When soil erosion occurs in slopeland areas during and after rain, it plays a role in transferring non-point source pollutants, as water and soil particles carrying absorbed nitrogen and phosphorous flow down into water courses. There are various ways of reducing environmental contamination with agricultural non-point source pollutants.

Correct fertilizer management is essential. Only the critical amount of fertilizer needed by each crop should be applied. The amount of nutrients required should be based on soil chemical analysis. With respect to soil management, the soil should be kept covered with crop residues, so that bare soil is not exposed during fallow periods. Run-off after rain should be reduced by planting crops along the contours, constructing bench terraces, digging drainage channels along terraces, and planting grass strips. In this way the horizontal flow of water can be controlled, and the vertical flow of water can be reduced.

In cases where run-off is flowing directly into a stream, there may be a need to dig a pond at the bottom of the slope to catch run-off water before it reaches the stream, in order to reduce non-point source pollutants and maintain the quality of irrigation water flowing from slopeland. In summary, what is needed is

to apply best management practices in slopeland areas.

CONCLUSION

Environmental problems do not just affect the part of the country where they occur. They affect other parts as well, and may also affect trade and other international relationships. These are important to all countries in the world today. Furthermore, what begins as an environmental problem in a certain area may become a social problem which affects the whole community.

It is very difficult to control non-point source pollution. The best way is to begin with a precise assessment of what non-point source pollution exists, and where it comes from. Efficiency in reducing non-point source pollution from agriculture can be maximized if it is integrated with other policies, and if suitable incentives are found for agricultural producers to adopt best management practices, especially in slopeland areas.

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