CONTROLLING SOIL AND EUTROPHIC COMPONENT LOSSES WITH SURFACE INLET

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Abstract
This study dealt with controlling soil and eutrophic component losses using the combined measures of surface inlet and buffer strips, and with the estimation of collecting area using surface inlet in upland fields of sloping areas. Field plots *in situ* were employed for this study. Surface inlets were installed at the upper point of buffer strips. The experimental results of field plot indicated that the losses of soil, total nitrogen and phosphorus through surface inlets were 92%, 92% and 86% of total losses by surface flow, respectively. Additionally, the percentage of total discharge through surface inlets indicated almost 100% up to the total rainfall of 49.42 mm and up to the EI_{30} value of 13.75 MJ□m/hour□km^2, although the percentage varied widely according to the rainfall events. It was judged that the combined measures of surface inlets and buffer strips were effective for controlling soil and eutrophic component losses from surface runoff. For the estimation of collecting area with surface inlet, the equation was proposed on the basis of rational and orifice equations. It was concluded that the collecting area with surface inlet combining buffer strips may be designed on the basis of the proposed equation.

Additional Keywords: buffer strips, soil erosion, conservation, nitrogen, phosphorus

Introduction
In upland fields of sloping area, a heavy rainfall causes erosion phenomena, such as sheet, rill or gully erosion. Also, severe soil erosion affects not only the productivity of upland fields but also the water environment in streams further down the catchments (eg. Mihara, 2001). A large number of investigations have been made for soil and water conservation, and then many conservation measures have been developed and adapted by farmers. Especially, buffer strips were employed broadly to control soil and eutrophic component losses. It was known that buffer strips have functions to trap sediments and to decrease energy of surface runoff. However, a few investigations reported that the increase in surface runoff and slope degree decreased dramatically the trapping efficiency of buffer strips in erosion processes (Magette *et al.,* 1989; Jin and Römkens, 2001). Therefore, research interests were focused on soil and water environment conservation measures taking account of the trapping efficiency of buffer strips.

Surface inlet is one of the effective measures for controlling surface runoff and soil losses from upland fields. Surface inlet is a vertical drain with orifices. It is connected to underground pipe conveying the water from surface inlet to settling pond or constructed ditch. Also, there are reports concerning soil erosion and sediment control with surface inlet (Caldwell, 1984; Mielke, 1985). However, little work has been done to evaluate the combined measures of surface inlet and buffer strips for controlling not only soil loss but also eutrophic component losses. So, the objectives of this study were to evaluate the controlling soil and eutrophic component losses using the combined measures of surface inlet and buffer strips and to estimate the collecting area using surface inlet in upland fields of sloping area.

Materials and Methods
Field plot was constructed in upland field, covering with Andosol, located in hilly area of Tama, Tokyo. The dimension of the plot was 2 m wide and 6 m long on 1.9 slope degree. The plot was set up under bared soil condition except for 0.5 m wide buffer strips in slope toe with surface inlet as shown in Figure1. Gyokuryu grass (*Ophiopogon japonics Ker-Gawl*) was transplanted for buffer strips at the density of 1550 stems m^{-2}. The PVC pipe of 11.4 cm outer diameter under 2234 holes m^{-2} density was employed for surface inlet. Every hole has 1 cm in diameter. Weeds and fallen leaves were removed regularly for keeping bared soil condition. Physical properties of soil in field plot are shown in Table 1. The soil texture was CL (clay loam), and the dispersion ratio was 13.3%. Chemical properties of soil in field plot are shown in Table 2. There was no certain tendency in chemical properties of soil during the experiment.

After each rainfall event, discharge of surface runoff and collected water through surface inlet was measured with water tank attaching triangular weir. Soil loss, total nitrogen and phosphorus in surface runoff and collected water through surface inlet was analysed in laboratory. Total nitrogen were analysed by means of the absorption spectrophotometry after decomposition with potassium peroxodisulphate. The observation was conducted for 2 years from August 2001 to July 2003.

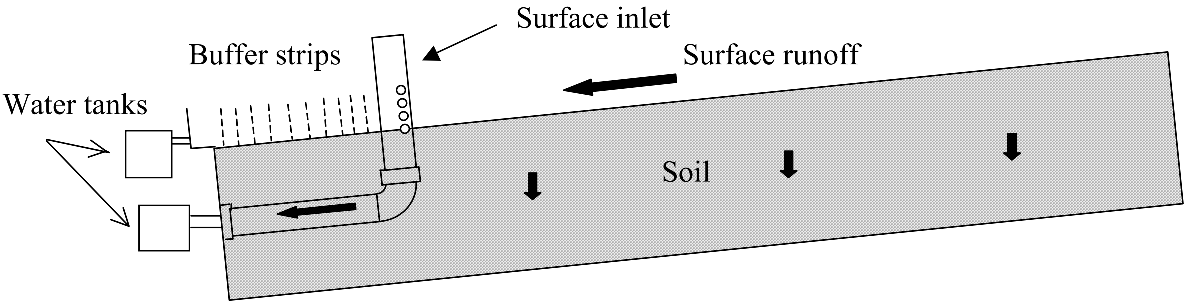

Figure 1. Field plot

Table 1. Physical properties of soil in field plot

Specific gravity	Particle size distribution (%)					Soil texture	Dispersion ratio (%)	Ignition loss (%)	Saturated permeability (cm s^{-1})
	Gravel	Coarse sand	Fine sand	Silt	Clay				
2.66	0.9	16.7	30.4	36.6	15.4	CL	13.3	15.5	1.96×10^{-3}

Table 2. Chemical properties of soil in field plot

Sampling date	Total nitrogen ($\times 10^{-5}$ kg kg^{-1})	Total phosphorus ($\times 10^{-5}$ kg kg^{-1})	NH4-N ($\times 10^{-5}$ kg kg^{-1})	NO3-N ($\times 10^{-5}$ kg kg^{-1})	NO2-N ($\times 10^{-5}$ kg kg^{-1})
Jul 2001	262.2	24.6	14.0	10.0	0.04
Dec 2001	187.5	14.3	7.2	14.0	0.04
Jul 2002	208.0	17.6	14.5	15.0	0.04
Dec 2002	229.6	21.0	13.5	12.0	0.04
Jul 2003	210.	19.5	14.2	11.0	0.03

Results and Discussion

Field plot

Changes in total discharge, soil and eutrophic component losses by surface flow of field plot were shown in Figure 2. In most events of rainfalls, total discharge through surface inlet was much higher than that in surface runoff, and was counted for 82% of total discharge by surface flow. Also, the losses of soil, total nitrogen and phosphorus through surface inlet occupied 92, 92 and 86% of total losses by surface flow, being much higher than those in surface runoff as same as total discharge. Figure 3 shows the relationships among the percentage of total discharge through surface inlet, the total rainfall per event, and the rainfall factor of EI_{30} defined in Universal Soil Loss Equation.

Although the percentage of total discharge through surface inlet varied widely according to the rainfall events, the percentage indicated almost 100% up to the total rainfall of 49.42 mm and up to the EI_{30} value of 13.75 MJ m $hour^{-1}$ km^{-2}. It was conceivable that buffer strips worked as grass barrier under low rainfall condition, all soil particles and eutrophic components in surface runoff were collected by surface inlet installed at upper point of buffer strips. Thus, it was judged that the combined measures of surface inlet and buffer strips were effective for controlling soil and eutrophic component losses from surface runoff.

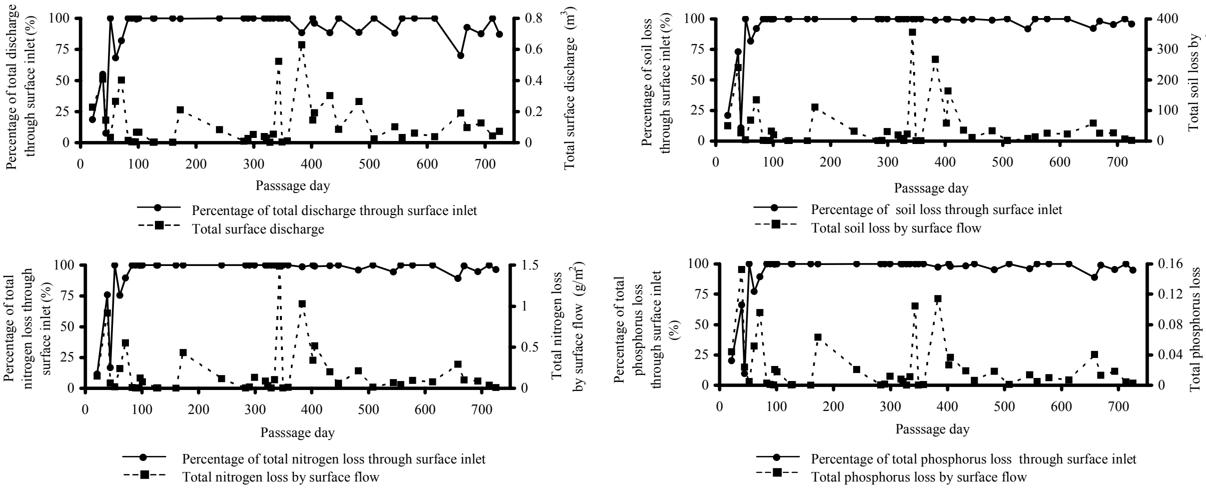

Figure 2. Changes in total discharge, soil and eutrophic component losses by surface flow in field plot

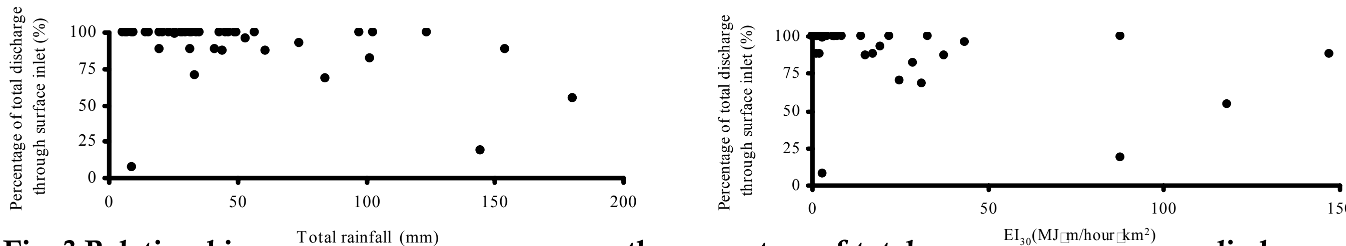

Fig. 3 Relationships among the percentage of total discharge through surface inlet, the total rainfall per event, and the rainfall factor of EI_{30}

Estimation of collecting area with surface inlet

In the estimation of collecting area with surface inlet, following equation was proposed on the basis of rational and orifice equations.

$$H = H_E + H_B \quad (1)$$

where h = effective water depth of buffer strips (m), H_E = height of embankment (m) and H_B = limited water depth of buffer strips (m).

$$A = \frac{3.6\times10^{-6}}{f \cdot I} \sum Ca\sqrt{2gh_i} \quad (2)$$

where A = collecting area with surface inlet (m^2), f = peak runoff coefficient, I = rainfall intensity (mm h^{-1}), C = orifice flow constant, a = cross sectional area of orifice (m^2), g = acceleration caused by gravity (m s^{-2}), h = height from top water to centre of orifice (m) and I = number of each orifice.

Estimated results of collecting area with surface inlet in field plot were shown in Table 3. There was a tendency for collecting area with surface inlet to increase with the limited water depth of buffer strips and to decrease with rainfall intensity and peak runoff coefficient. It was considered that the collecting area with surface inlet depended on the density and the kind of buffer strips, rainfall intensity and hydrological property.

Table 3. Estimated results of collecting area with surface inlet in field plot

Constant	Variable of H_B, I and f	Variable of A
H_E = 0.022 m	H_B = 0.005 m	A = 60.04 m^2
f = 0.6	H_B = 0.01 m	A = 77.18 m^2
I = 25.28 mm/h	H_B = 0.02 m	A = 115.36 m^2
a = 7.85×10^{-5} m^2		
H_E = 0.022 m	I = 25.28 mm/h	A = 60.04 m^2
H_B = 0.005m	I = 29.04 mm/h	A = 52.26 m^2
f = 0.6	I = 34.87 mm/h	A = 45.53 m^2
a = 7.85×10^{-5} m^2		
H_E = 0.022 m	f = 0.6	A = 60.04 m^2
H_B = 0.005m	f = 0.7	A = 51.46 m^2
I = 25.28 mm/h	f = 0.8	A = 45.03 m^2
a = 7.85×10^{-5} m^2		

Conclusion

This study dealt with the controlling soil and eutrophic component losses using the combined measures of surface inlet and buffer strips, and with the estimation of collecting area using surface inlet in upland fields of sloping area. From the experimental results of field plot, it was judged that the combined measures of surface inlet and buffer strips were effective for controlling soil and eutrophic component losses. Additionally for the estimation of collecting area with surface inlet, the equation was proposed on the basis of rational and orifice equations. It was concluded that the collecting area with surface inlet combining buffer strips may be designed on the basis of the proposed equation.

Reference

Caldwell, L.W. (1984). SCS procedures for determining storage requirements for underground outlet terraces in the Midwest. *ASAE paper*, No. 84-2541.

Mielke, L.N. (1985). Performance of water and sediment control basins in northeastern Nebraska. *Journal of Soil and Water Conservation* 40(6), 524-528.

Mihara, M. (2001). Nitrogen and phosphorus losses due to soil erosion during a typhoon, Japan. *Journal of Agricultural Engineering Research* 78(2), 209-216.

Magette, W.L., Brinsfield, R.B., Palmer, R.E. and Wood, J.D. (1989). Nutrient and sediment removal by vegetated filter strips. *Transactions of ASAE* 32(2), 663-667.

Jin, C.-X. and Römkens, M.J.M. (2001). Experimental studies of factors in determining sediment trapping in vegetative filter strips. *Transactions of ASAE* 44(2), 277-288.