SUSTANZA™ FARM ENVIRONMENT MAPS: A PRACTICAL TOOL TO ASSESS AND MANAGE RISK OF NUTRIENT LOSSES FROM AGRICULTURE TO SURFACE AND GROUNDWATER

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INTRODUCTION

One of the major current issues facing the agricultural industry in general is the loss of nutrients from farmland to streams, rivers and lakes, and the problems of eutrophication, algal blooms, excessive weed growth etc. that this causes. Phosphorus (P) is usually considered the main limiting nutrient in freshwater ecosystems, and has been the main focus of this project to date. Very small concentrations of dissolved P are all that are needed for eutrophic conditions to develop, with the threshold levels specified by the Ministry for the Environment for New Zealand being 0.015 – 0.03 mg P/litre (MfE, 2001).

The amount of P transferred from pasture to waterways is influenced by a range of factors including grass cover, slope, soil properties (e.g. P status, infiltration rate, erodibility), riparian management and climate. Although some of these factors cannot readily be managed to reduce P losses, others are more amenable to management strategies. One such factor is fertiliser, where losses of P from recently applied soluble fertiliser can be a major component of total annual P losses, constituting as much as 50% or more of the overall loss (P. M. Haygarth; C.J.P. Gourley, pers. com.). Although typically less than 5% of applied fertiliser is lost in runoff (Sharpley *et al*., 1993), this may still be more than enough to cause environmental problems. For example, experiments in New Zealand in the late 1970s showed a large increase in dissolved inorganic (equivalent to dissolved reactive) P losses in surface runoff immediately after application of single superphosphate, followed by a gradual decline over the next two months back to background levels (Sharpley *et al*., 1978).

Similar results were also found in more recent work using micro-plots in a field experiment on a hill-country pasture in New Zealand (Nguyen *et al*., 1999). This trial also included two direct application phosphate rock (DAPR) treatments (Gafsa and Kosseir). Dissolved reactive P (DRP) lost over the same initial period of the experiment from the DAPR-treated plots was orders of magnitude less than that from the superphosphate-treated plots, and only slightly higher than the control plots' losses. Approximately 1.7 2.2% of the applied P was lost as DRP from the superphosphate-treated plots, compared to 0.07–0.08% from the DAPR treatments. Whilst caution should be applied in extrapolating these findings to other situations, nevertheless, the size of the differences in DRP losses between the two different types of P fertiliser, i.e. fully water-soluble vs. slow release, is very significant in the context of P losses to the environment in surface runoff.

It was considered that the best way to utilise these research findings was to devise a practical farm management tool that farmers could use to strategically manage their fertiliser applications in a way that would minimise the risk of loss of P from recently applied fertiliser, as well as taking other potential sources into consideration. For reasons of cost and to facilitate application on as wide a basis as possible, a simple approach, such as that of the P Index developed by the USDA (Lemunyon and Gilbert, 1993; Gburek *et al*., 2000) was decided on. This would enable the relative risk of P loss to water over different areas of a farm to be assessed, provide a visual guide to these areas in the form of a farm map, and would be relatively easy and cost-effective to produce, i.e. the necessary input data would be readily available, or if not, then at least easy to generate. With this in mind, a simple model that could be run in a Geographical Information System (GIS) environment was constructed to produce such a tool (Stroud *et al*., 2001, 2002; Hart *et al*., 2002).

SOURCES OF INFORMATION

Information that was needed to build up an individual farm map and provide input data for the model was sourced from a number of commercially-available national databases. These included the 1:50,000 NZ Topographic Vector Database produced by Land Information New Zealand, from which the position of rivers, streams, canals and lakes were obtained, as well as other geographical features such as contour lines, roads, tracks, forests, scrub, etc. Information on soil types and characteristics was obtained from the 1:63,360-50,000 New Zealand Land Resource Inventory (NZLRI) Soils Database produced by Landcare Research Ltd. Data at the soil series level utilised in the model consists of P retention class (5) and internal drainage class (5) (Webb and Wilson, 1995; Milne *et al*., 1995), and a soil erodibility factor determined empirically by Summit-Quinphos. A few examples are shown in Table 1.

A digital elevation model (DEM) of New Zealand, with a grid cell size of 30 m x 30 m, was computed from 20 m contour lines and used to calculate a grid of slope values used in the model calculations. All other input data grids were aligned with this slope grid, which was divided into classes using the slope factor in the Revised Universal Soil Loss Equation as a guide (<7° = 1, 7-12° = 2, 12-17° = 3, 17-22° = 4, 22-28° = 5, >28° = 6). A rainfall intensity factor was incorporated, based on the average number of days per year with greater than 10, 20, 30, 40 or 50 mm of rain. These were calculated from data from all rainfall monitoring stations in the country with 10 or more years of complete data record over the last 30 years. The values for each station were interpolated to produce grid maps for New Zealand. The value of each grid cell was used as an index of the likelihood of a runoff-producing rainfall event occurring at that location. The level of intensity about 16.6%. Considered with the large concentration of non-point pollutant in initial rainfall runoff, the installation of infiltration receiving box makes the burden of non-point pollution lessened by more than 18.5%.

Table. 3. Peak flow reduction effect by installing infiltration receiving box

Rainfall (mm)	General Receiving Box		Infiltration Receiving Box		Reduction Effect	
	Runoff (m^3)	Peak Flow (cms)	Runoff (m^3)	Peak Flow (cms)	Runoff (%)	Peak Flow (%)
70.5	150526.2	33.69	122817.6	28.09	18.4	16.6

CONCLUSIONS

Since the characteristic of pollutant runoff by rainfall shows relatively high concentration in early runoff. More than 80% of the entire rainfall are 20mm and below in Korea(MOCT, 2001), the storm runoff treatment facilities for the reduction of non-point pollution may be designed to cover approximately 20mm rainfall. It will be able to treat more than 80% of the entire rainfall and contribute to reduce considerably the non-point pollution burden(Choi and Shin, 2002). However, when establishing the storm runoff treatment facilities in certain area, the geomorphologic peculiarities and hydrological characteristics as well as the climate and applicable technologies must be taken into consideration when determining the scale of the facilities. Moreover, the peculiarity of Korean climate, which has more than 70% of ra infall in the rainy spell in summer, shall also be considered when selecting the storm runoff treatment technology and designing the facilities.

There are many types of storm runoff treatment facilities applicable to each local peculiarity. In Korea, where the use of land is limited, the size of land required for the treatment facilities shall be the main consideration in selecting the location. Generally, the urban areas where wide area is not usually unavailable, adopt infiltration facilities that occupy relatively small area. Especially, the appropriate measures are needed to enable the control of non-point pollution by supplementing existing manhole and to improve the rainwater detention pond to make it possible to treat the early rainwater non-point pollution. The installation of apparatus type facilities such as Stormceptor, Stormfilter and Swirl/Vertex(John C. Clausen. 2002). needs sufficient preliminary study in terms of their effectiveness in peculiar climate and geographical features of Korea.

Moreover, increased impermeable rate accompanied by urbanization changed the characteristics of storm runoff. It added to the damage from flood due to rapid storm runoff seen from the water volume aspect. Seen from the aspect of water quality, it caused the water quality to be deteriorated with the runoff of various polluting materials into the water system along with the storm runoff. Therefore, immediate action shall be taken to properly control the storm runoff to reduce the risk of flood by rapid storm runoff and to improve the water quality.

REFERENCES

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John C. Clausen. (2002). *Stormwater Treatment Devices Section 319 Project Project #99-07 Final Report*, Department of Natural Resources Management and Engineering, University of Connecticut, Storrs, CT06269-4017. 65p.

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As rainfall is increased, the runoff of general receiving box is also linearly increased. However, the runoff of infiltration receiving box is less reduced than the runoff of general receiving box. Average runoff reduction at each point is 73.32% in Sungnam, 75.1% in Osan, or 73.4% in Cheongju.

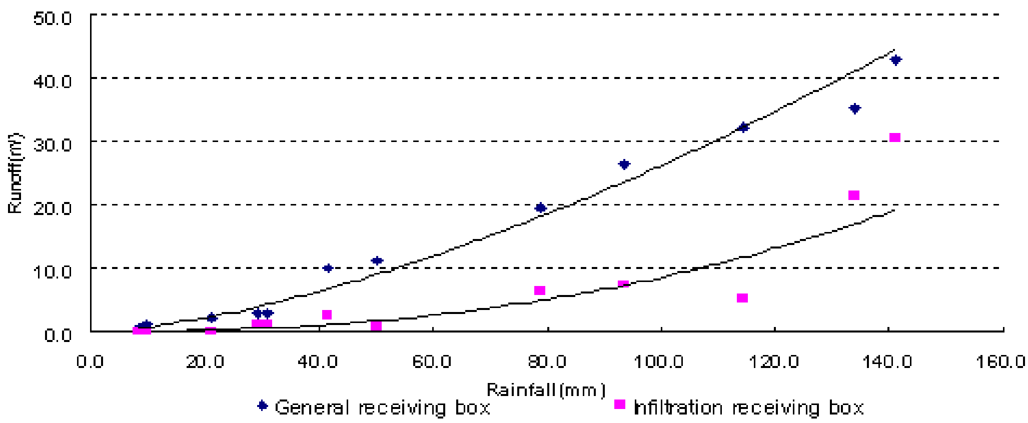

***Figure 9.** Runoff characteristics of general receiving box and infiltration receiving box (Sungnam)*

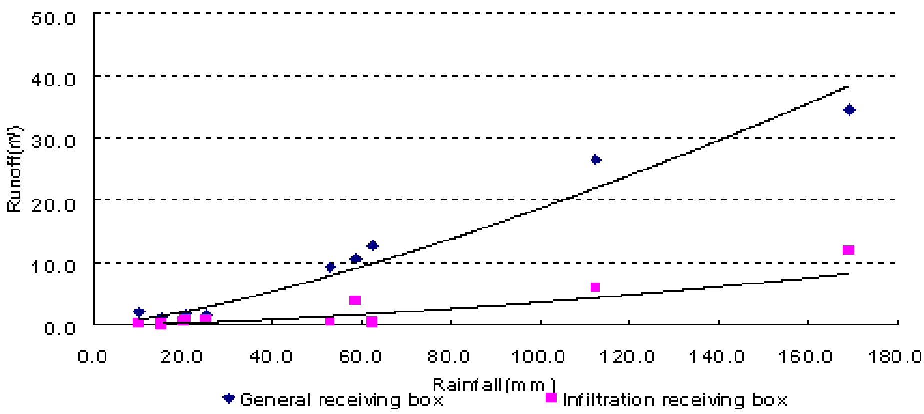

***Figure 10.** Runoff characteristics of general receiving box and infiltration receiving box (Osan)*

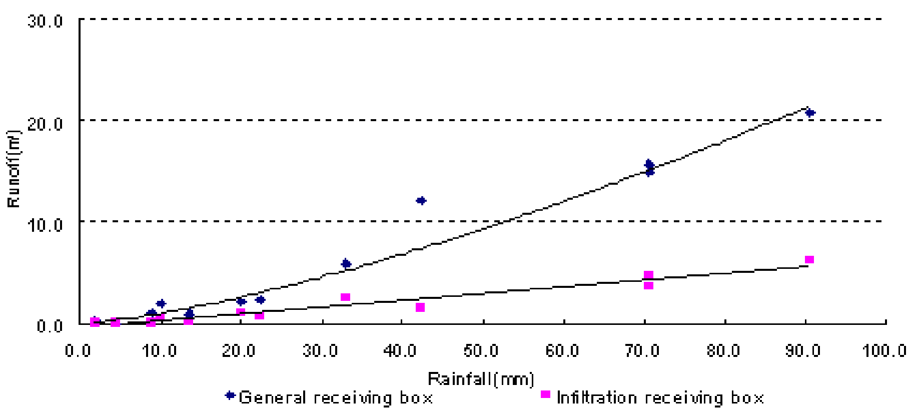

***Figure 11**. Runoff characteristics of general receiving box and infiltration receiving box (CheongJu)*

To study the effect of infiltration receiving box in entire drainage region on runoff reduction, it is considered that infiltration receiving box is applied to the road of entire drainage region and its effect on the reduction of rainfall runoff is checked. Experimental area is CheongJu. Runoff is used to analyze 70.5mm rainfall of July 21, 2001 by ILLUDAS model. In the simulation result of rainfall runoff, the reduction of total runoff is about 18.5% and the reduction of peak flow is

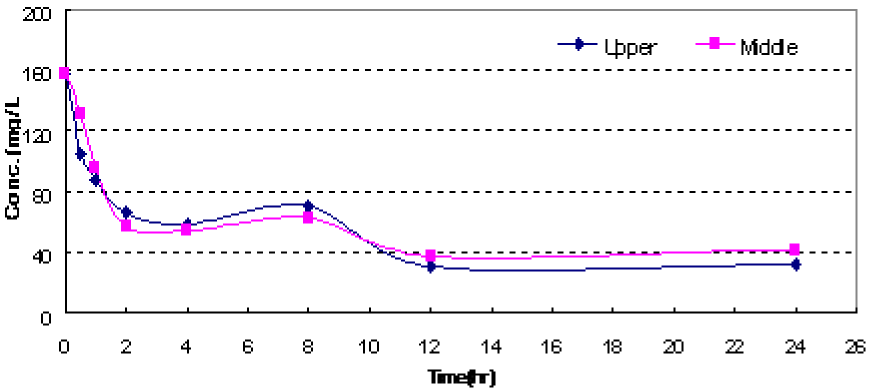

Figure 6. *Settlement characteristics of COD of storm runoff (commercial area)*

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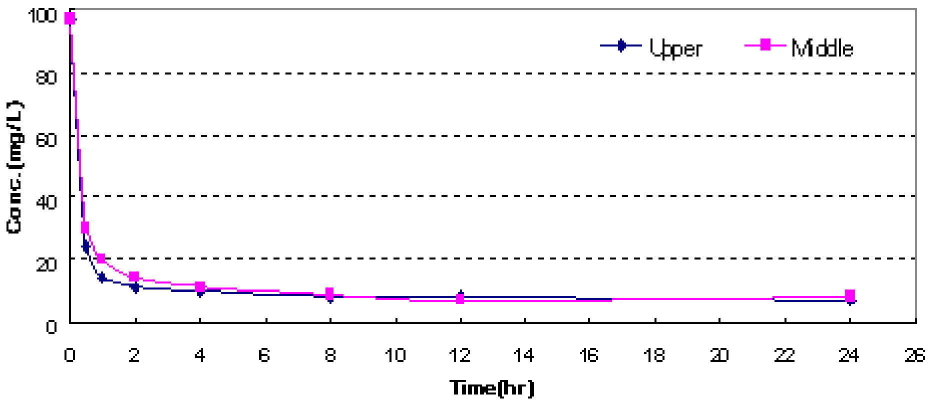

Figure 7. *Settlement characteristics of SS of storm runoff (Motorway)*

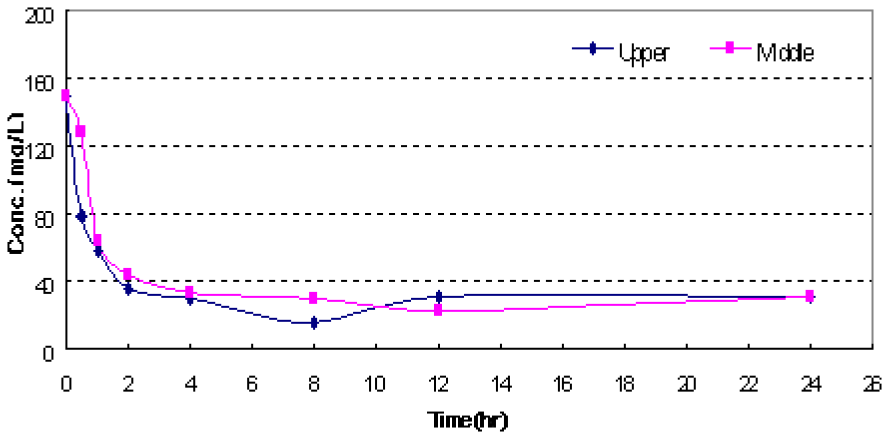

Figure 8. *Settlement characteristics of COD of storm runoff (Motorway)*

Reduction analysis of rainfall runoff and non-point pollutant by infiltration receiving box

Infiltration receiving box has a structure, of which bottom is packed by sand and rubble and pierced to infiltrate water, and is consisted of 10cm sand and 90cm rubble layer. Infiltration receiving box has been installed to prevent the inundation damage of heavy rain in urban area. It can be recently considered to reduce non-point pollutant by the underground infiltration of rainfall runoff.(ASCE, 1998). While rainfall runoff flew into infiltration receiving box passes infiltration layer and ground layer, its contaminant is removed and replaced with underground water.

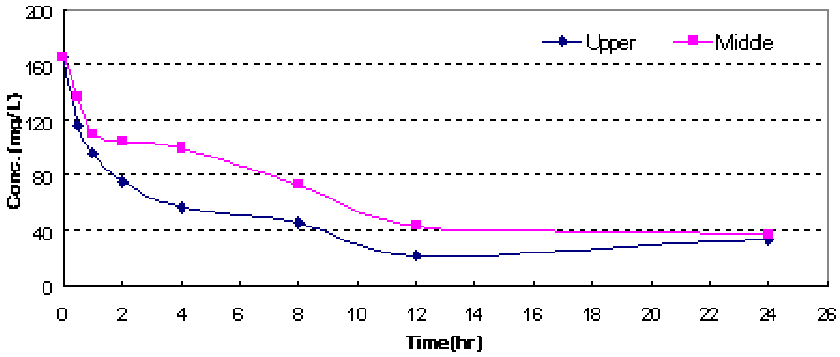

Figure 3. *Settlement characteristics of SS of storm runoff (residential area).*

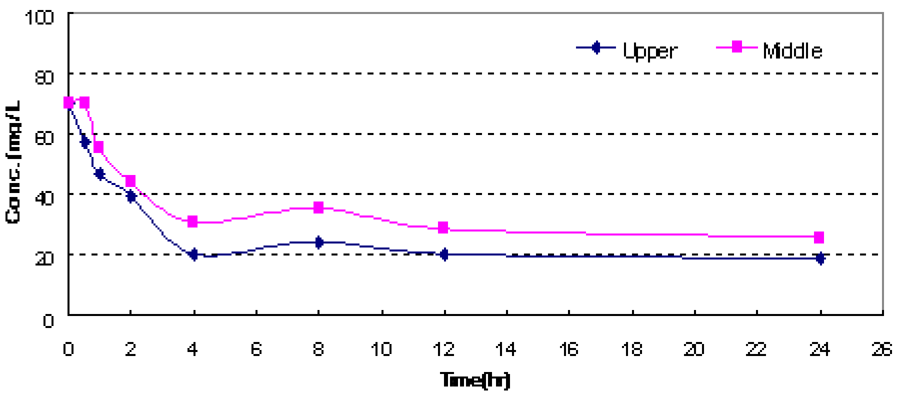

Figure 4. *Settlement characteristics of COD of storm runoff (residential area)*

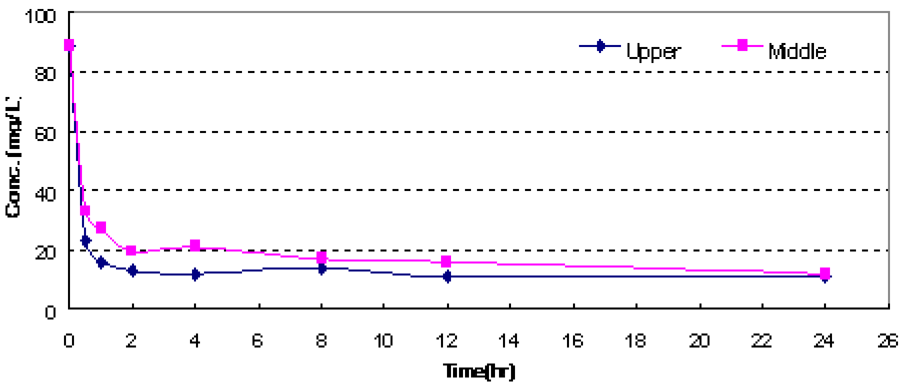

Figure 5. *Settlement characteristics of SS of storm runoff (commercial area)*

Initial SS concentration of rainfall runoff at motorway is 97.0mg/L and is reduced to 8.0mg/L at discontinuance point after 24 hours settlement. Initial COD concentration is 149.0mg/L and is reduced to 30.3mg/L at discontinuance point after 24 hours settlement.

Generally, settlement characteristics of rainfall runoff are good. It is possible that settlement for only 12 hours remove more than 60% of both COD and SS. When water reservoir of pumping station is used as water treatment facility, rainfall runoff must be stored and settled for at least 12 hours and drained from the top of the reservoir. Muddy water at its bottom must be treated and drained.

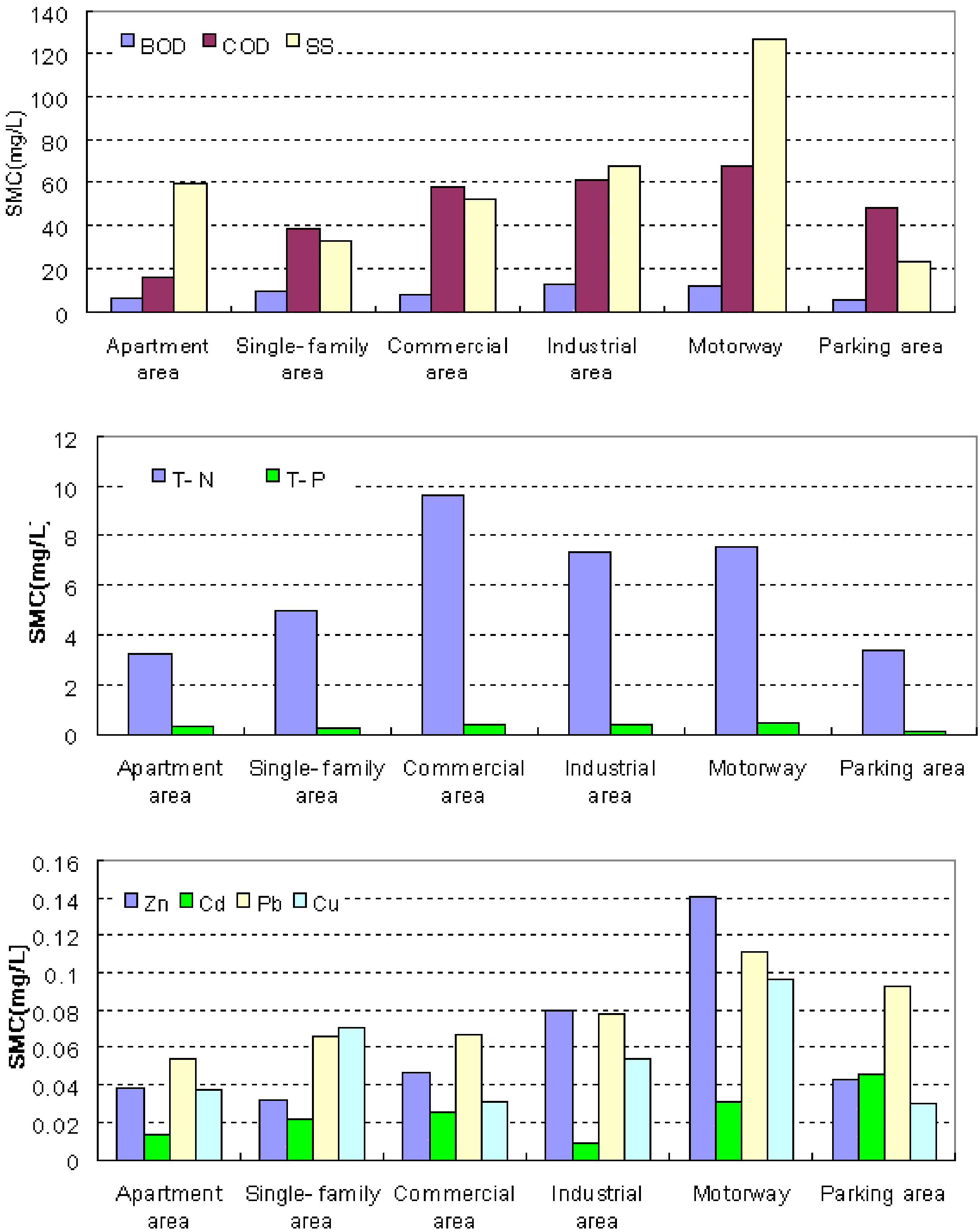

***Figure 2**. Comparison of SMC according to the use of land*