A STUDY OF SS SIZE DISTRIBUTION DURING RUNOFF AND FRACTIONATION OF PHOSPHATES DEPENDING ON SOIL SIZE IN AGRICULTURAL WATERSHED

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ABSTRACT
The characterization of the differences and algal-available fractions of P in soils, suspended solid, and bottom sediments have been the main topics of research during the past decade. However, the size distribution and property of particulate matter according to runoff characteristic has not been much studied. The purpose of this study is to discuss about size distribution during runoff and the chemical characteristics of P in each soil size fraction depending on land use and watershed. There is a different temporal variation of particulate matter size distribution during the rain event in each watershed. When considering particle amount by area, most of particles have the size in the range of 10 ~ 100 µm. Also, the percentage of BAP in TP as well as percentage of PCOD in SS also varies temporally and spatially during runoff. To investigate the effect of characteristics of soil particles depending on land use and particle size on water quality, soil samples from two watersheds are examined. For particle size distribution and specific gravity, no significant difference among watersheds is found. However, C, N, and P contents vary soil particle size and watershed. C, N, and P contents are also indirectly proportional to the particle size, which means smaller particle size results in larger. H_2O-extracted P, NH_4Cl-extracted P, NAI-P, Apatite-P, Organic-P, and TP contents in each soil particle sample vary depending on particle size, land use, and watershed. It is possible that the available portion of phosphorus in SS varies according to its origin and characteristics and as a result, the eutrophication of aquatic system also varies.

KEYWORDS: agricultural watershed, fractionation of phosphate, particles matter, size fraction

INTRODUCTION
Soil erosion is the major cause of diffuse pollution which is generally identified as one of the major factors of water quality deterioration in lakes and reservoirs in the world (Water National Quality Inventory, 1994), and sediment is also the most visible pollutant (Clark et al., 1985). The effect of sediment loading on receiving waters is the deterioration of water quality. Due to the sorption of phosphorus to soil, several studies have reported that the major portion of P loading of runoff is sediment bound. Nutrient carried by the sediment can stimulate algae growths and, consequently, accelerate the process of eutrophication (Abrams, 1995; Hakanson et al., 1983; Forstner, 1979; McDowell et al., 1989; Jin et al., 1990; Gaynor and Findlay, 1995; Krovang et al., 1996; Tonderski, 1996; Yan et al., 1999). Sedimentation flux in a lake and effect to water quality of receiving water bodies depend on the concentration or the amount of particles, soil type, and type of runoff events (Sharpley and Smith, 1989; Sharpley et al., 1992), as well as particle characteristics such as size, shape, and density and ambient physical and chemical characteristics.

Recently, concern about eutrophication has spurred a considerable amount of research related to the proportion of soil and sediment P that is algal-available. The main objective has been to assess the ability of soils and sediments to supply biologically available P(BAP)to aquatic ecosystems (David, 1983). For index of BAP, there are many chemical method that a procedure of sequential chemical extractions in an attempt to remove P in different categories. The extracting solutions and the fractions they remove are; 1*N* NH_4Cl, weakly bound P; 0.5*N* NH_4F, Al-bound P; 1*N* NaOH, Fe-bound P; citratedithionite-bicarbonate, occluded P; 1*N* HCl, apatite P (Chang ad Jackson, 1957). Recently, there is a trend to use simply 1*N* NaOH and 0.5*N* HCl as extraction solution (Sharpley et al., 1991). This information can be one of the reference parameters that are used as an input data for the most of models to simulate aquatic systems, to plan a prospect of long-term water quality or water quality management strategy. There are many researches about size fraction of sediment, runoff characteristics of SS loading, and fractionation or bioavailability of P. However, the size distribution and property of particulate matter according to runoff characteristic has not been much studied.

The objective of this study is to survey and characterize the size distribution of particulate matter during the storm event. Also, this study considers the potential bioavailability of soil phosphorus under natural physical and chemical conditions in water.

METHODS
Samples were collected from five small watershed of Lake Koyama, which is located in the eastern part of Tottori prefecture, Japan. Each watershed shape is long and narrow and consists of forest and agricultural area (fig.1). To survey the size distribution of particle matter from the storm water, intensive sampling was performed every 1 hour during two runoff events, on Aug. 21-22, 2001 and on Dec. 12-13, 2001. The distribution of particle size in storm water was analyzed by laser diffraction particle size analyzer. (Simazu SALD 2000A). The analyzed result of the particle size distribution was described by relative percentage by particle area. Soil samples to examine phosphorus contents were collected at Nagara watershed and Obatake watershed from 27th June ~ 9th Aug. 2002. The sampling areas of these watersheds were classified according to the land use into paddies, fields, and forest. For each of these watersheds, several different locations

were selected randomly at 6 different paddy, 6 different field and 2 different forest sites. Soil samples were collected up to 10 cm from surface.

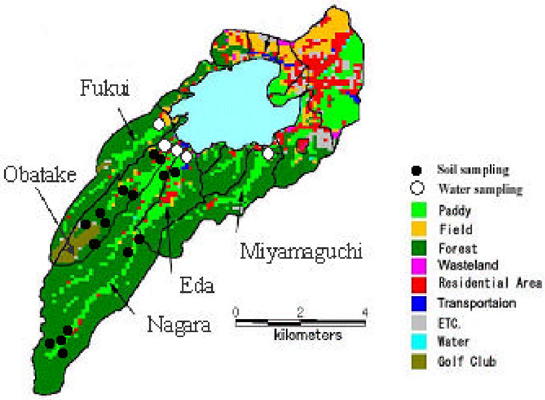

Fig.1 Map of Lake Koyama watershed and sample sites.

Soil samples were prepared by air-drying that is commonly used in soil science (McKeague, 1978). Grinding of soil samples was a batch operation carefully reducing bulk sample of the powder during grinding. Then, these soil samples were classified 2mm-355ìm; 355ìm-212ìm; 212ìm-106ìm; 106ìm-45ìm; 45ìm-20ìm; 20ìm> by vibratory sieve shaker (Fritsch, Analysette 3). After sieving, each sample was dried for determining size fraction in soil on heating to 105-110°C in a dry oven.

Table 1. Summary of land use in study watersheds

Watershed	Miyamaguchi		Eda		Nagara		Obatake		Fukui	
	ha	%	ha	%	ha	%	ha	%	ha	%
Paddy	76.8	21.9	79.2	28.2	179.1	16.3	66.4	20.9	49.6	14.3
Field	1.5	0.4	5.2	1.9	4.2	0.4	8.4	2.6	4.9	1.4
Forest	262.3	74.7	166.3	59.2	883.6	80.6	171.3	53.9	261.5	75.6
Residual area	8.7	2.5	28.2	10.0	22.4	2.1	10.3	3.2	4.6	1.4
Golf field	0.0	0.0	0.0	0.0	7.6	0.7	60.0	18.9	22.2	6.4
Etc.	2.0	0.6	2.0	0.7	0.0	0.0	1.7	0.5	3.0	0.9
Total	351.3	100.0	280.9	100.0	1096.9	100.0	318.0	100.0	345.9	100.0

Fractionation of phosphates in soil sample by the extraction media used the following (Hieltjes and Lijklema, 1980);
Adsorbed-P;
H_2O-extracted Adsorbed-P: shaking by Distilled water during 6 hour,
NH_4-Cl-extacted Adsorbed-P: shaking by Ammonium chloride 1.0M solution, under pH7.2 during 1day,
NAI-P: shaking by Sodium hydroxide 0.1M solution during 16 hour,
Apatite-P: shaking by Hydrochloric acid 0.5M solution, during 1day,
Residual-P: TP- (a+b+c)
H_2SO_4-P as BAP in SS during runoff extracts by shaking in 0.2*N* H_2SO_4 solution during 1day. TP analyses used peroxodisulphate digestion with sulfuric acid and nitric acid. All analyses were done according to Standard Methods (APHA, 1995).

RESULTS AND DISCUSSIONS

There are temporal variations in the percentage of BAP as 0.2N H_2SO_4 extracts P in TP as well as in the percentage of PCOD in SS during runoff (fig. 2). This trend is found in every watershed. There is a different temporal variation of particulate matter size distribution during the rain event in each watershed (fig. 3). Most of particles have the size in the range of 10 ~ 100µm.

The percentage of very fine sand (0.1~0.05µm) and silt (0.05~0.002 µm) discharged from each watershed is greater in December and in August. For example, the particle sizes that correspond to 90% by area in the cumulative size distribution curves in August and December are 89µm and 34µm in Miyamaguchi, 114µm and 16µm in Eda, 107µm and 75µm in Nagara, 88µm and 39µm in Obatake, and 49µm and 26µm in Fukui watersheds respectively. This variation found in December's survey is caused by the fact that the paddy surface is dried up in winter and very few smaller particulate matters flow out during runoff. In addition, it is assumed that removal of the weir and the Watergate, which was temporally set to intake irrigation water, has caused a change in the condition of stream. Despite of the similar variation of flow rate in each watershed, SS loading shows different runoff pattern (Figure 4). Relative amount by area in the size distribution of SS also shows different temporal variation.

For the samples from Nagara and Obatake watersheds, more precise investigation was carried out. The characteristic of soil particle in Nagara and Obatake watershed depending on land use and soil particle size is also exa mined (Figure 5).
In case of particle size distribution, small but not significant differences in each watershed are found. The percentage of larger particles (2000~212μm) is highest in forest and lowest in paddy fields. Also, the percentage of small size particle (45μm >) of paddy is higher than those of the others. The distribution of particle size for different land uses has a similar trend as explained above for every watershed. This is because of agricultural activities such as harrowing to soften soil before a rice-seedling transplanting.

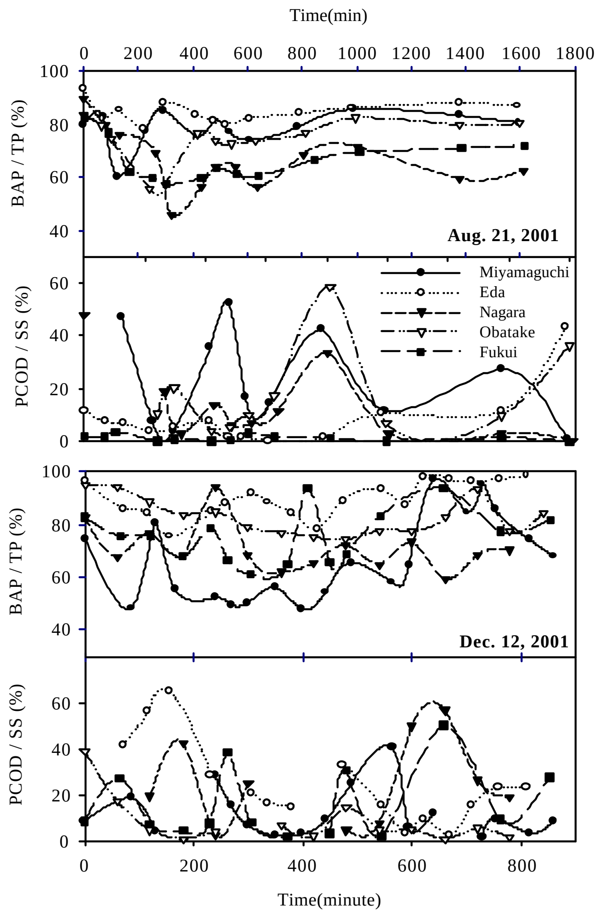

Fig. 2 Variation of POC and BAP percent in SS and TP during runoff event at each stream.

Regarding specific gravity of soil particles, there is no significant difference among three land uses and watersheds. However, the specific gravity is proportional to the particle size, which means smaller particle size results in smaller specific gravity. Average soil specific gravity in field, paddy, and forest are 2.58, 2.52, and 2.54 in Nagara and 2.54, 2.54, 2.58 in Obatake. In general, inorganic soil is known to be 2.6-2.8g/cm^3. However, when the inorganic soil contains a large amount of mineral, the specific gravity becomes large. When it contains organic matter, the value of specific gravity is small (Analysis Method for Soil Environment, 2000).

Carbon and nitrogen (N, P) contents in each soil particle showed varied values. It shows the trend the soil particle size gets smaller, the carbon and nutrient contents get larger. Specially, it seems that there is large change in C and N contents at soil size of under 106μm. It also shows different carbon and nitrogen contents value depending on watershed. It shows the value of C and N contents at Nagara watershed is larger than that of Obatake watershed. The value of C and N contents in forest soil is much larger than that of soil in other land use. Despite the very different C and N contents value of each size fraction, C/N ratio does not show significant difference.

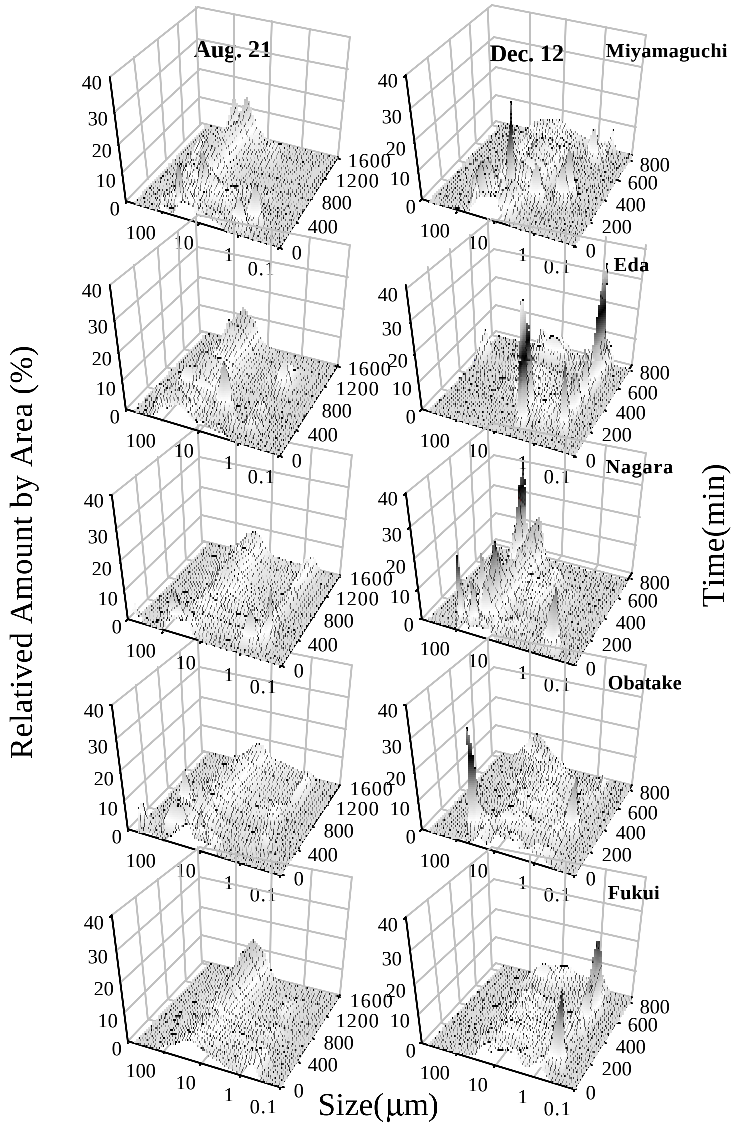

Fig.3 The variation of size distribution of SS as relative amount by area percentage during runoff event on Aug. 21 and Dec. 12, 2002.

H_2O-extracted P, NH_4Cl-extracted P, NAI-P, Apatite-P, Organic-P, TP contents in each soil particle sample showed varied values (Figure. 6). It also shows the trend the soil particle size gets smaller, each P portion contents get larger. It also showed different each P portion contents depending on land use.

The amount of TP is largest in fields and smallest in forest. The smaller the particle size in soil becomes, the more TP is found. For each fractionation of phosphates, the percentage of Org-P is highest for all land uses, and the percentage of NAI-P is the second highest. 10~20% of NH_4Cl-P is found in field soil sample. Other than that, the percentage of other fractionation in soil is significantly low. There is an insignificant difference in fractionation of phosphates for any particle size.
Given that r-BAP (Rapidly Bioavailable Phosphorus) refers to H_2O-P and NH_4Cl-P, s-BAP (Slowly Bioavailable Phosphorus) refers to Org-P, and c-BAP (Conditionally Bioavailable Phosphorus) refers to NaOH-P, then, most of r-BAP is present in field soil but only small amount can be found in the others. Although many have used c-BAP and r-BAP as a combined form known as BAP until now, in this case, most of the phosphorus in field soil is in the form of rapidly bioavailable phosphorus

Considering the phosphorus' availability to algae since bacteria decompose Org-P, therefore it can be referred to s-BAP. In this case, the content ratio of s-BAP in field and paddy soil is both similar and in forest, most of TP is s-BAP. Although these s-BAP's are not available immediately to algae, in an aquatic system, after sedimentation and decomposition, it is slowly being used. In general, release of pollutants from sediment under anaerobic condition is a well-known problem. However the amount of release under aerobic condition is similar to the anaerobic condition (Bostrom et al., 1982).

Different contents of fractionation of phosphates in soil by land use and SS size distribution in runoff can change the potential influence to eutrophication of aquatic system.

Using the above result, potential of P availability in SS loading is estimated (Figure 7). SS loading ratio in each land use is calculated using USLE's soil erodibility factor K, vegetative cover factor C as well as the area ratio. Assumptions that August's size distribution is measured in volumetric relative amount and that SS concentration is $1gL^{-1}$ are made and applied to the above SS loading ratio. The result explains that although the area ratio of dry field is relatively low, the potential percentage of phosphorus loading is significantly high compared to the others. It is because the possibility of SS loading runoff is very high as well as the content of phosphorus contained in SS loading is also high. It is possible that the amount of BAP in SS that is discharged from watersheds is proportional to area of field (Sa, 2003).

CONCLUSION

There is a different temporal variation in particulate matter size distribution in storm water during the rain event. Agricultural activities and change of watershed conditions may have affected a temporal and spatial size distribution of particle matter during runoff. It is possible that the available portion of phosphorus in SS varies according to its origin and characteristics and therefore, the eutrophication of aquatic system also varies. When estimating influence of diffuse pollution to water body, the information such as the size distribution of particle matter as a runoff characteristic, property of particle matter such as existance form, and the contents of C, N and P are necessary.

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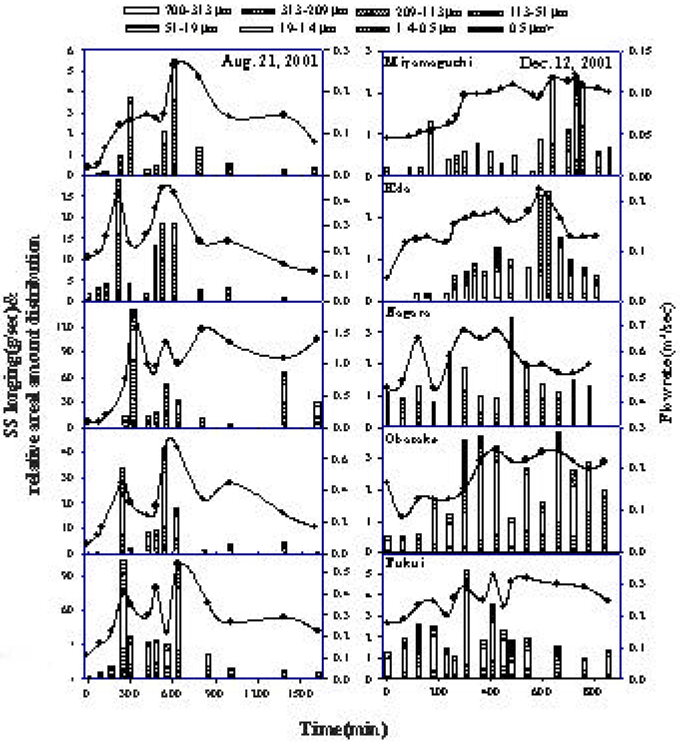

Fig.4 The variation in Flow rate and SS loading with size distribution as relative amount by area

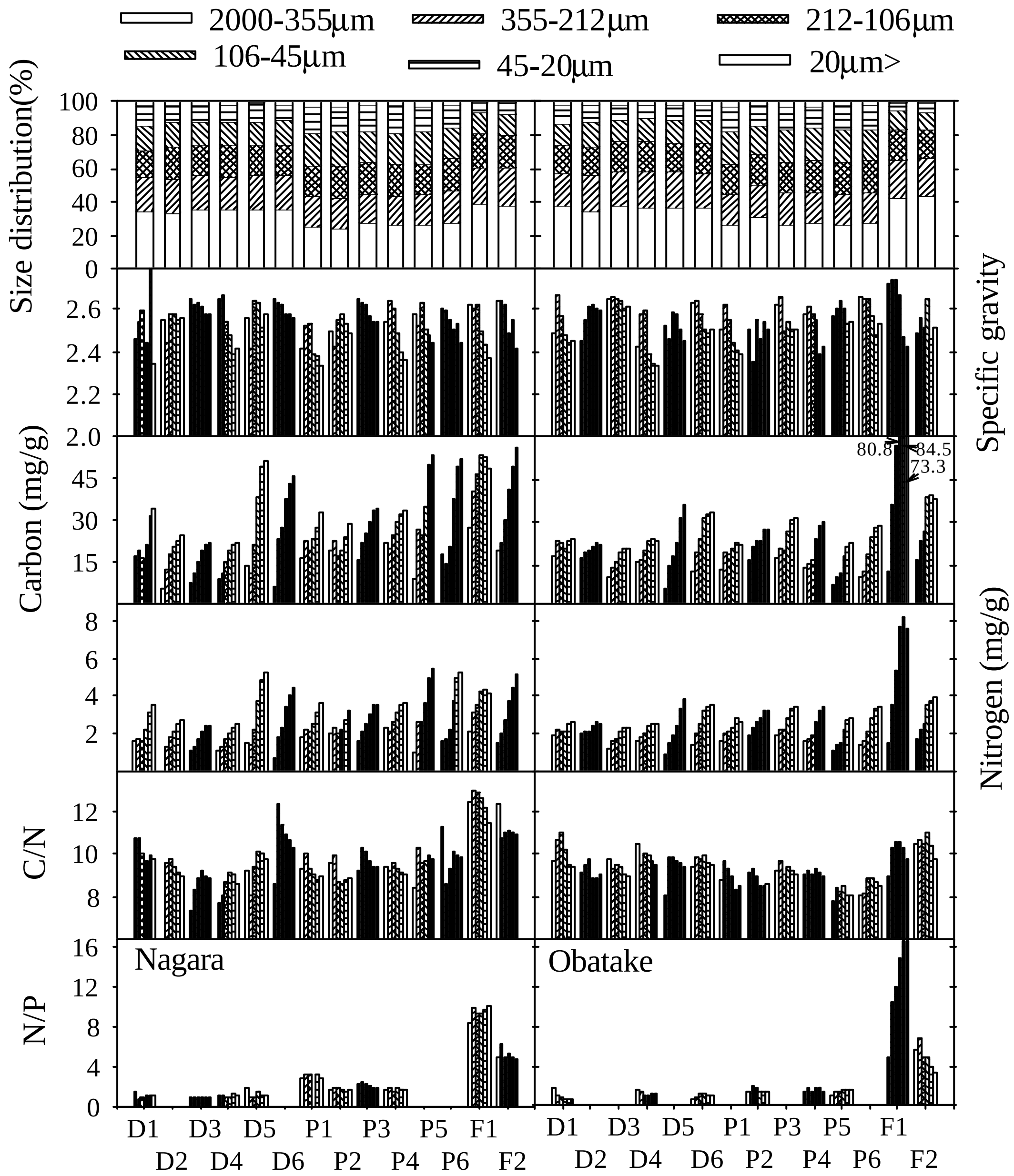

Fig. 5 Distribution of size, specific gravity, C and N contents, C/N ration, and N/P ratio in Nagara watershed and Obatake watershed.

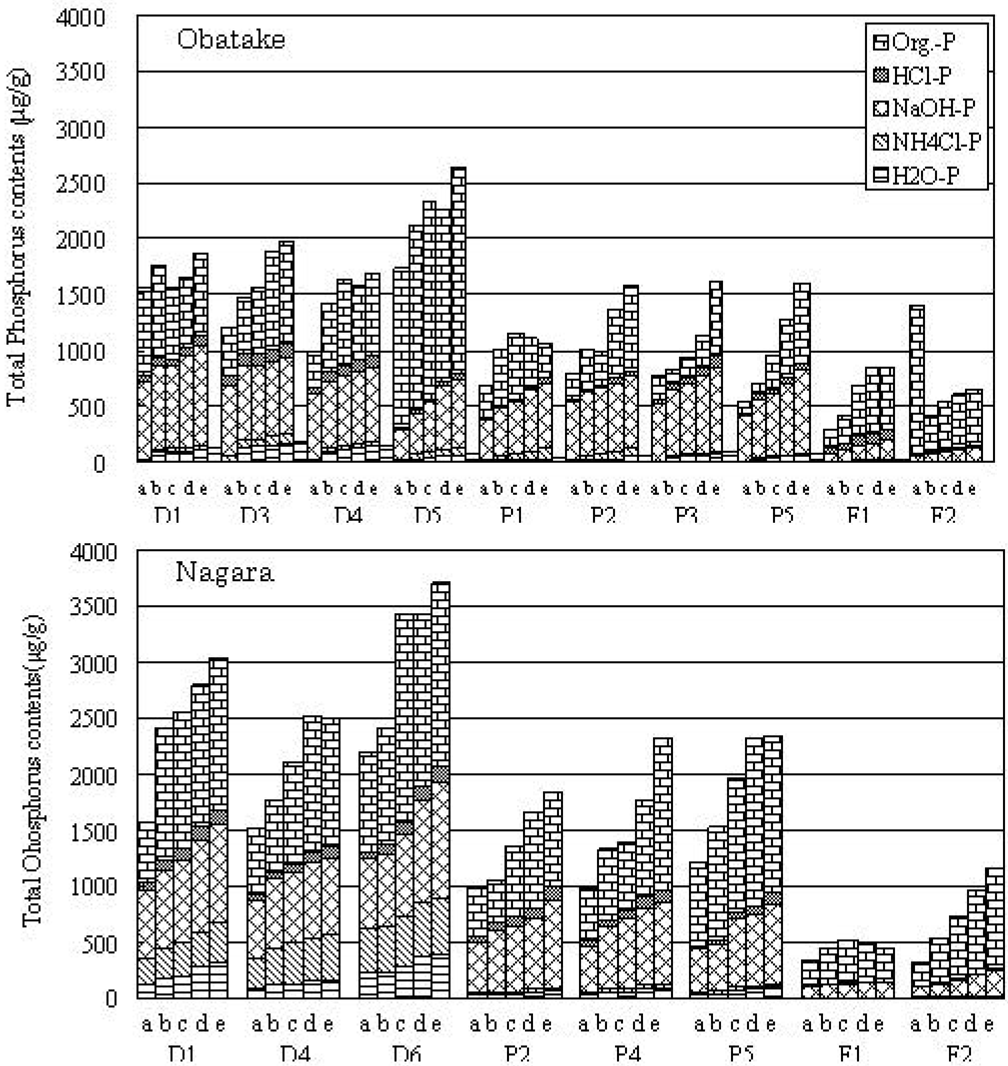

Figure 6 Fraction composition of phosphorus in soil particles of Obatake and Nagara watersheds (D-Dry field, P-Paddy, F=Forest)

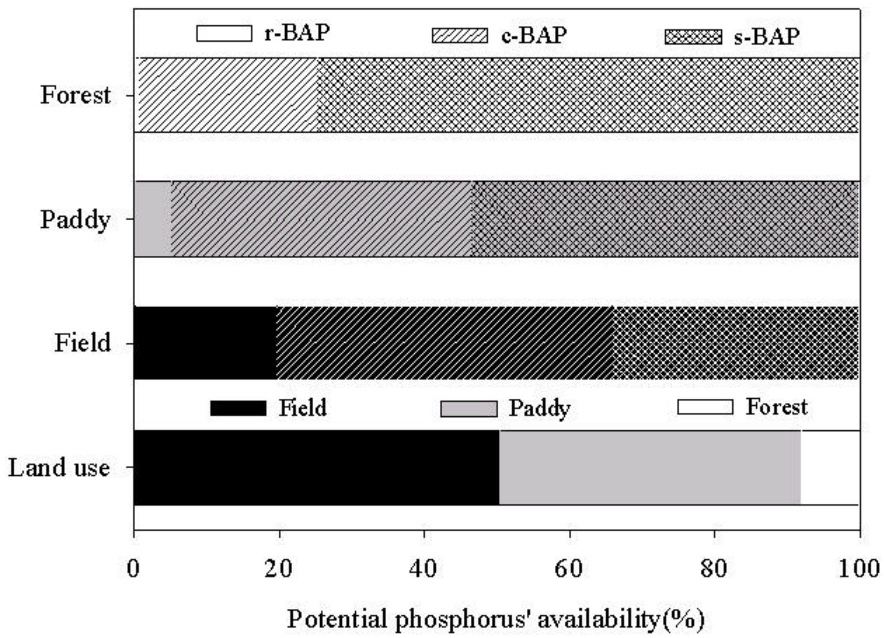

Figure 7 The potential phosphorus' bioavailability, considering land use, fractionation of phosphate, and size distribution of SS in storm water.