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Forest soil fertility in Okinawa Island, subtropical region in Japan

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Abstract

This study investigated the influence of soil types on the forest soil fertility in the subtropical region. Three sampling points were established for each soil type (limestone, marlstone and silicate). Samples were taken from surface and subsurface soils in each site and analysed for total C, total N, total P, organic P and soil pH. The main objectives were; (1) quantification and comparison of nutrients distribution and cycling in forests under different soil types. (2) Evaluation of impact of acidic soils on the forest soil fertility.

The soil pH showed that limestone and marlstone soils were neutral to alkaline with pH range (5.84-7.81), while that from silicate rock was strongly acidic with pH range (3.41-4.99). The quantities of nutrients availability are different within these three geological sites of soil formation. Limestone soils shows to have much more nutrients availability followed by marlstone and silicate soils. In comparison to soil layers, surface soils (0-10 cm) also have much nutrients availability than subsurface soils (10-20 cm) in all sampling stations. All three types of soils show to be more favourable with C/N ratio than C/P ratio. The C/N ratio in this study varied between 10 to 70; while C/P ratio varied between 150 to 2070.

Key words : Forest soil, nutrients, subtropic

Introduction

Soil organic matter (SOM) is an important factor in evaluating management system of the forest (Doran and Parkin, 1994). When plant litter enter the mineral soil, soil-inherent stabilization mechanisms such as inclusion into aggregates or protection due to the interaction with soil minerals are operative (Soilins et al., 1996). Organic matter can be transported downward by a soil animals. Earthworms, for example, can completely mix soil to depths of a meter or so, transferring organic matter downward in the process. Burrowing animals move soil material low in organic matter from the deeper horizons to

the surface and vice versa (Anderson et al., 1989). Yeates et al., (1982) reported that soil micro- and macrofaunal organisms can have significant effects on soil development by affecting litter decay, nutrient dynamics, and microbial ecology.

SOM is a fundamental for many reasons. It improves the structure of the soil and its resistance to erosion, and allows the storage of nutrients, the ion exchange and nutrient support to microflora (Campbell 1978). In tropical and subtropical regions, rapid SOM (~ 58% C) decline occurs under conventional management systems involving intensive soil disturbance (Tiessen et al., 1992; Parfitt et al., 1997). In tropical and subtropical regions, where soils are strongly weathered and contained variable charged mineral, interaction of SOM and these soils can result in increasing SOM protection from microbial attack compared with that found in less-weathered temperate soils (Martin et al., 1982; Parfitt et al., 1997). Great stability of mineral-associated SOM in highly weathered soils, which may be an important in maintaining and restoring soil quality, determines the soil potential for acting as an atmospheric CO₂ sink in tropical and subtropical regions (Parfitt et al., 1997).

The forest soil fertility depends on the acidic condition of the forest soil among other factors. The soil pH has an important effect on chemical and biological processes that occur in the soil. Organisms responsible for decomposition of residue, nodulation of legumes, and nutrient transformations such as oxidation of ammonium to nitrate have optimum pH's similar to plants. In acidic forest soils, the abundance of macrofauna, biological activity and rates of litter decomposition are low (Kautz and Topp 1998). Nitrogen, phosphorus, and carbon are the most important nutrients in soil. Nitrogen availability in forest soils is determined by the rates of N mineralization, microbial conversion of organic N to NH₄⁺ and possible further oxidation to NO₃⁻ (Pastor et al., 1987). Forest productivity and N turnover rates can exert strong controls, both together and individually, on nitrification and net mineralization in forest soils (Pastor et al., 1987; Wedin and Tilman, 1990). Nutrients mineralization is regulated by abiotic factors (example, soil fertility, moisture, temperature and texture) and biotic factors such as changes in microbial activity with soil depth, rates of litter inputs (Pastor et al., 1984; Binkley and Hart, 1989; Wedin and Tilman, 1990), and the quality of organic matter (Pastor et al., 1987). Although plants take up inorganic NH₄⁺ and NO₃⁻, they produce organic N compounds that are returned to the soil as litterfall. Therefore, vegetation influences N mineralization and nitrification through competition with microbes for nutrients, and through litter quality and quantity (Pastor et al., 1984).

On other hand, phosphorus (P) is an important nutrient element which limits productivity in forest soils because it is chemically reactive and always exists as insoluble phosphate mineral in nature. Our understanding of the role of P in forest ecosystem is however severely hampered by difficulties in identifying and quantifying available P fractions in forest soils. P forms in soil cover a wide range of forms and include both

organic and inorganic forms (Tiessen et al 1984). In tropical and subtropical soils which are acidic and contain a large amount of Fe and Al, available P is readily precipitated as the highly insoluble iron and aluminium phosphates or adsorbed to oxides surface. Both forms are poor sources of P for plants (Stevenson, 1986). In calcareous soils which contain a large amount of Ca, most of the inorganic P precipitates as calcium phosphates.

In Okinawa one of the major phenomenons of environmental pollution affecting forest ecosystems is acidic soil forming processes. Vuai et al., (2003) reported that central to northern parts of Okinawa Island are abundantly affected by acidic soils. Hence, determination of soil acidity and sensitivity to acidification is an important for our knowledge of state of soil health. It was also reported that forest in the limestone areas has higher diversity than that from silicate areas (Feroz, 2003). The difference in forest productivity may indicate difference in soil fertility. Therefore the purposes of this study were to quantify and compare the nutrient distribution and cycling in the forest under different soil types. The second objective is to determine the soil acidity and sensitivity to acidification. We examined the hypothesis that: (1) are there significant differences in soil C, N and P stocks and dynamics between three geological types of rocks (i.e. limestone, marlstone and silicate rocks)? And (2) are soils fertility affected by acidic soils condition in the forest?

Materials and methods

Study sites and Sampling

Okinawa Island is located in the monsoon region of Asia and has a humid subtropical climate. The annual average rainfall is 2,200 mm and average temperature is 22°C. Therefore, the properties of the soils in this district reflect the climatic factors. The soil types in Okinawa Island are classified into four major groups (Fig.1); (1) Kunigami Mahji, red-yellow color and are regarded as a problem soils from the point of view of erosion. The soils are low in nutrients, dominated with exchangeable aluminum (Tokashiki, 1993) and have pH range of 4.5 to 5.5 (Ooshiro and Hamagawa, 1983). According to US taxonomy, they are classified as Typic Paleudults and some are Typic Dystrochrepts (Tokashiki, 1993). (2) Shimajiri Mahji (dark-red soil), (3) Jahgalu (grey terrace soil) and (4) Chuseki soil (Alluvial soil). The Island consists of gently sloped terrain in the central to the southern parts, but in the northern parts the slope is steep with many valleys. The predominant soil in Okinawa Island is Kunigami Mahji, which distribute from the central to the northern area of the Island and cover about 55% of the total land area of 1,225 km². The soils are red and yellow color and readily erosible due to high rainfall (Onaga, 1986).

The study was conducted from three different geological rocks, corresponding to three soils types (Fig.1); these are Shimajiri Mahji (limestone), Jahgalu or Kucha

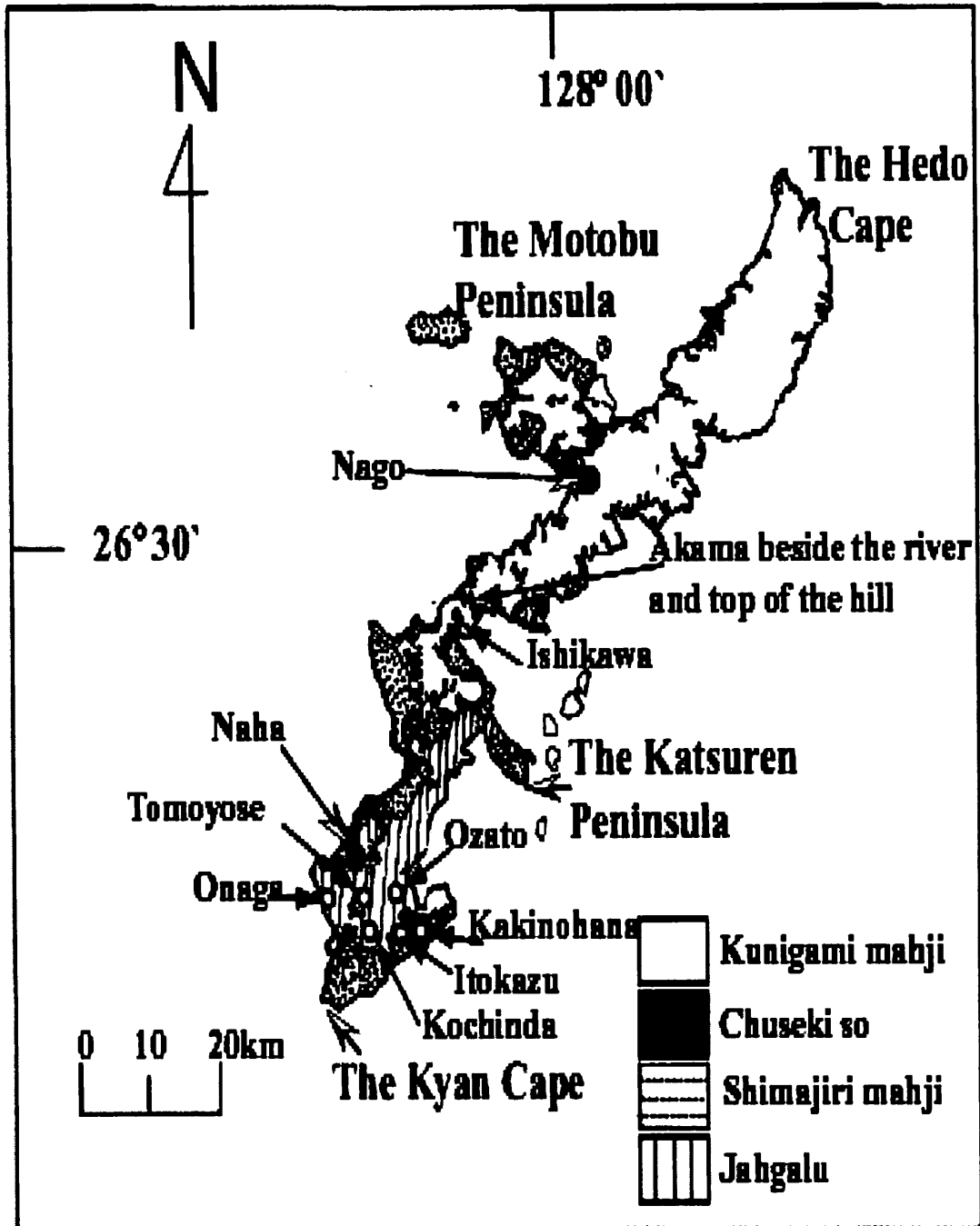


Fig. 1. Map of Okinawa Island showing soil distribution and sampling sites.

O Sampling location.

Table 1. Location and Some characteristics of the forest at the sampling sites.

Area code	Region	Altitude (a.m.s.l)	Rock type and location	Dominant trees
1	Ozato (Ozato village)	155		<i>Cinnamomum pseudo-pedunculatum.</i> + <i>Elaeocarpus sylvestris.</i>
2	Kakinohana (Tamagusuku village)	136	Limestone	<i>Bischofia javanica, Ficus virgata,</i> <i>Ficus microcarpa+Celtis boninensis.</i> <i>Cinnamomum pseudo-pedunculatum,</i>
3	Itokazu (Tamagusuku village)	193	(Southern area)	<i>Rhus succedanea,</i> <i>Celtic boninensis + Ficus virgata.</i>
4	Kochinda (Kochinda Town)	40		<i>Bischofia javanica.</i>
5	Tomoyose (Kochinda Town)	56	Marlstone	<i>Mallotus philippensis +</i> <i>Acacia Confusa.</i>
6	Onaga (Tomishiro City)	57	(Southern area)	<i>Erythrina orientalis.</i>
7	Akama-riverside (Onna village)	80		<i>Castanopsis sieboldii</i>
8	Akama-top the hill (Onna villege)	100	Silicate	<i>Castanopsis sieboldii</i>
9	Ishikawa (Ishikawa City)	150	(Central area)	<i>Castanopsis sieboldii</i>

(marlstone) and Kunigami Mahji (silicate soils). The two studied sites are located at the southern part of the Island, which underlain by limestone and marlstone. The third studied site is located at the central part of the Island, in which trees are varied in age and the vegetation cover is relatively scarce at forested soils, which are typically in the red soil area. The vegetation dominant for each studied site is shown in Table 1. Soil sampling was performed at the end of October 2003. Three sampling points were established for each soil type. Soil samples from surface (0-10cm) and subsurface mineral layers (10-20cm) were collected at each site. Samples were placed in polyethylene bags and stored at room temperature or freezed depending on the experimental purpose. In the studied site of central Okinawa, two topographic positions were sampled within Akama top of the hill and beside the river.

Sample preparation and elemental analyses

The oven dry (50°C) samples were sieved in order to remove the fraction > 2mm. The dried sample was crushed into powder using an agate mortar. Total organic C and total N were determined by the dry combustion methods (Nelson and Sommers, 1996) using Micro Corder JM10 CHN analyzer. Combustion was at 950°C for 5.5 min, which is standard for the analyzer. The bridge current for the detector was set at 75 mA for C and 130 mA for N. Detection range under these settings was 3 - 2600 micro-g for C and 1 -

1000 micro-g for N. Antipyrine was used as a calibration standard. Six concentrations were measured to obtain a linear calibration ($r^2 = 0.997$) for both elements.

The total P content was determined after digestion of the soils with Sulphuric acids-Hydrogen Peroxide-Hydrofluoric acid methods (Bowman, 1988), and the total organic P was estimated as the difference between the 1N H_2SO_4 extractable P in a soil sample ignited at 550°C and unignited sample (Oslen and Sommers, 1982). The P concentration after all digestion was determined by the molybdenum blue method (Murphy and Riley, 1962). Soil pH was measured in 0.01 M $CaCl_2$, using a 1:2.5 (w/v) soil: solution ratio for both surface and subsurface mineral soils (McLean 1982).

Results and discussion

pH and Sensitivity to acidification

The pH measured in $CaCl_2$ solution have lower values than those measured in water (Vanmechelen et al. 1997). The pH values ($CaCl_2$) of the surface and subsurface mineral layers are shown in Fig.2 and in Table 2(b). Values below 4.0 were found in site number 7 and 8 under silicate rocks for both surface and subsurface soils, suggested that the soil were highly acidic. The pH values in the silicate soils (sites number 7, 8 and 9) were below 5.0 similarly to those obtained in the soils of CONECOFOR Permanent Monitoring Plots in Italy (Alianiello et al.2002). The optimal pH value was 7.81 at site number 2 under limestone area. Generally, the values of pH obtained in the limestone and marlstone of this study lie between 6.00 and 7.81, which are favorable for soil animals. Baath (1989); and Anderson and Joergensen (1997) reported that the microbial biomass and enzyme activity are strongly reduced in very acidic soils.

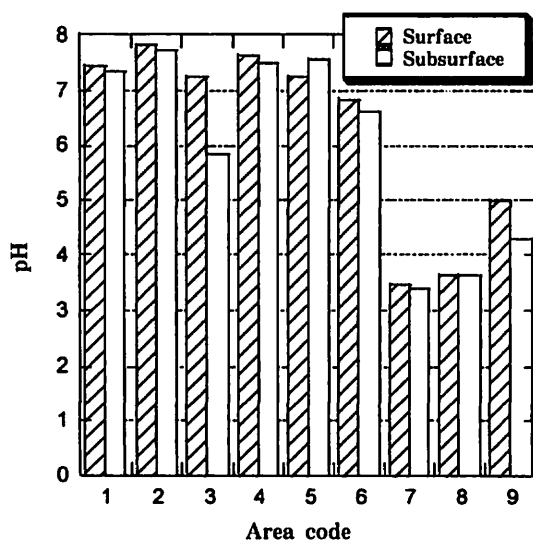


Fig. 2. pH (0.01M $CaCl_2$) values for surface and subsurface mineral soils.

For the knowledge of the fertility of forest soil, sensitivity to acidification is also important. An indication of this sensitivity is provided by the difference between the pH of the surface and that of the subsurface layer. If the difference is very high (more than 1 pH unit), the sensitivity of the soil to acidification is high (Vanmechelen et al. 1997). This was observed only on the site number 3 under limestone area. In general, no clear sensitivity to acidification was observed. The difference in pH values ranged from (0.12-1.40), (0.14-0.23) and (0.02-0.71) for limestone, marlstone and silicate rocks, respectively.

Table 2(a). Total Organic Carbon (TOC) and Total Nitrogen (TN) concentrations (mean with standard deviations) and C: N ratio in surface and subsurface mineral soils.

Area code	TOC (g/kg)	*TOC (g/kg)	TN (g/kg)	*TN (g/kg)	C/N	*C/N
1	102.9 ± 1.30	34.4 ± 0.47	8.72 ± 0.10	3.03 ± 0.03	11.8	11.4
2	100.1 ± 0.46	82.6 ± 2.01	6.48 ± 0.25	4.12 ± 0.75	15.4	20.0
3	77.9 ± 0.83	17.2 ± 2.27	7.69 ± 0.20	1.55 ± 0.24	10.1	11.1
4	52.6 ± 1.59	21.7 ± 0.58	3.48 ± 0.48	0.79 ± 0.70	15.1	27.6
5	56.7 ± 0.34	18.7 ± 2.07	5.48 ± 0.43	0.80 ± 0.70	10.3	23.3
6	44.2 ± 2.38	15.2 ± 0.86	4.29 ± 0.27	1.56 ± 0.27	10.3	9.8
7	104.4 ± 4.63	15.0 ± 1.84	5.10 ± 0.17	0.00 ± 0.00	20.5	0.0
8	52.1 ± 2.17	10.9 ± 0.38	2.49 ± 0.18	0.00 ± 0.00	20.9	0.0
9	62.0 ± 1.47	18.1 ± 1.09	2.65 ± 0.22	0.25 ± 0.44	23.4	71.4

Table 2(b). Total Phosphorus (TP) and Organic Phosphorus (OP) concentrations, TOC: TP ratio and soil pH (CaCl₂) values in surface and subsurface mineral soils.

Area code	TP (mg/kg)	*TP (mg/kg)	OP (mg/kg)	*OP (mg/kg)	C/P	*C/P	pH	*pH
1	49.7	44.24	3.74	0.05	2071	778	7.45	7.33
2	229	103.8	225	0.73	436	795	7.81	7.71
3	445	48.12	25.0	0.06	175	358	7.24	5.84
4	341	114.1	6.32	0.72	154	190	7.64	7.50
5	237	65.00	13.7	1.03	239	287	7.24	7.55
6	99.1	88.08	5.32	0.34	445	173	6.85	6.62
7	75.2	49.91	1.39	4.48	1387	300	3.48	3.41
8	54.0	20.81	4.70	1.28	965	524	3.62	3.64
9	115	80.03	0.25	0.21	539	226	4.99	4.28

*For subsurface mineral soils.

Nutrients availability

1) Total Organic Carbon

Results of total organic carbon in the surface layers and in the subsurface mineral layers are given in Fig.3. All surface layer samples show total organic carbon values greater than those of subsurface layers. The surface soil (0-10 cm) C stocks were 3 to 4 times greater than those in the subsurface soil (10-20 cm). This suggests that the upper 0-10cm are highly affected by the litter quantity and the microbial community both through

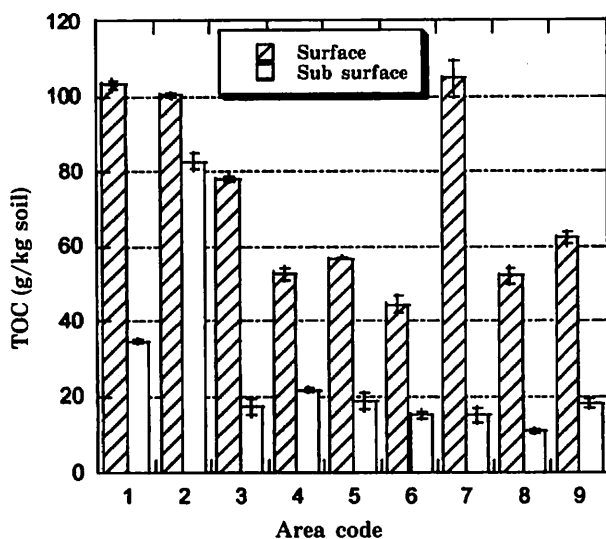


Fig. 3. Total organic carbon (TOC) in surface and subsurface mineral soils.

mixing with fragments of litter and through leaching of litter solutes. Alianiello et al.(2002) reported that carbon concentration always decreases with depth.

The effect of topography on surface soil C stocks was significant. The highest value of total organic C was 104.4 gkg^{-1} in soil at site no.7 (beside the river), suggesting that it was influenced by physical processes. According to Aguilar and Heil (1988), physical processes such as water and wind erosion can result in losses of soil C and N from one landscape position, and additions to another position by deposition. This might be more pronounced in the area with different topography. Central to the northern area of Okinawa Island is mainly distribute with red soil and contained steep sloped hills. The soil is very erosible and is a major environmental problem in that area (Onaga, 1986). In addition to that heavy rainfalls with high erosive power falling in Okinawa (Onaga, 1986) may enhance the accumulation of organic matter in low land near the streams. As the consequence, they increase intra-variation of nutrients even in the same rock lithology, as it was observed in Akama bottom (area code 7) and top (area code 8) of the hill.

With exception of this topographic influence, generally the values of total organic C obtained in the limestone areas (sites no.1,2,3) are relatively higher compared with those obtained in marlstone and silicate rocks (Fig.3). On the other hand, the lowest value of total organic C for surface soil was $44.2 \text{ gkg}^{-1}\text{soil}$ at site no.6 under marlstone area, and $10.9 \text{ gkg}^{-1}\text{soil}$ for subsurface mineral soil under silicate rocks. Parent material affects the C content of the soil through its influence on texture and adsorptive properties. The fixation of humic substances as organic mineral complexes serves to preserve organic matter. Thus, heavy-textured soils with a high clay and silt content contain more organic C than coarser textured (sandy) soils (Feller et al., 1993). In the southern part of Okinawa

where soil parent materials is Shimajiri Mahji (limestone), the soils have high contents of silt and clay (Adachi and Yokoda 1981), and high annually rates of litterfall (14t/ha/y) (Kuba, 1976; and Abe, 1980), that might be a reason for a relatively high concentration of TOC in this site.

2) Total Nitrogen

Figure 4 shows the values of total N of the surface and subsurface mineral layers. Similarly as total organic C, all values of N content obtained in the surface soils are greater than those in the subsurface mineral soils. It is probably due to the uppermost soil is largely affected by the litter quality and the microbial community of the litter layer. This may result an increase in SOM decomposition and rates of N mineralization at surface layer than subsurface mineral layer which is less affected by litter quality. The SOM degradation has negative effects mainly on cation exchange capacity, nutrient availability, aggregate stability and microbial activity (Bayer and Mielniczuk, 1999).

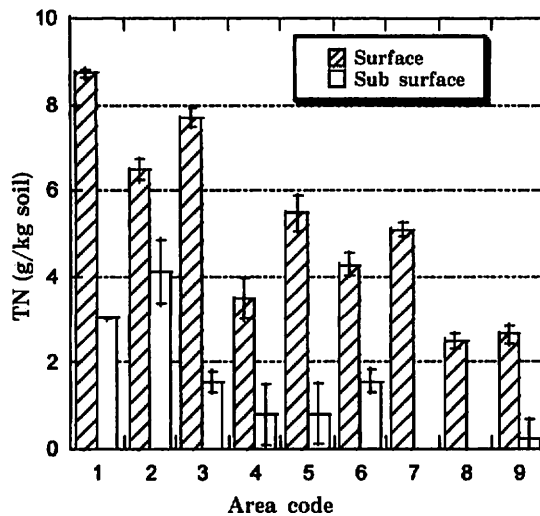


Fig. 4. Total Nitrogen (TN) in surface and subsurface mineral soils.

The highest N concentration in surface soil is 8.7 gkg^{-1} at site number 1 under *Cinnamomum pseudo-pedunculatum* and *Elaeocarpus sylvestris* trees; and 4.1 gkg^{-1} soil in subsurface at site number 2 under *Ficus virgata*, *Ficus microcarpa*, *Celtis boninensis* and *Bischofia javanica* vegetation types. On the other hand the lowest N content in surface layer was 2.5 gkg^{-1} at site number 8 in silicate rocks under *Castanopsis sieboldii* trees. In the present study, subsurface layers of two sites (7 and 8) in silicate areas were not detected for N concentrations, suggesting that the activities of microorganisms which are important in the decomposition of soil residues are reduced by low soil pH in this site (Fig.2) results low in nutrient availability. Kautz and Topp (1998) reported that in acidic

forest soils, the abundance of macrofauna, biological activity and rates of litter decomposition are low. In general the values of total C and N content of surface and subsurface layers obtained in the silicate rocks, show the lower values than obtained in the CONECOFOR, in Italian soil (Alianiello et al.2002).

3) Phosphorus

Similarly as the case of N, P availability is determined by the rate of decomposition of the soil organic matter (Waring and Schlesinger 1985), indicated by the C/P ratio. A low C/P ratio is an index of high P availability (Staaf and Berg 1982; Pritcher and Fischer 1987). Other parameters, such as pH, the concentration of some cations (Ca, Al, Fe), and climatic zone, can also assist in the evaluation of phosphorus availability. Calcium phosphate is mainly present in basic soils, Fe and Al phosphates in acidic soils and all of them are largely insoluble.

The highest total P and organic P were 444.7 and 225.3 mgPkg⁻¹ respectively for surface soil, collected from limestone sites (Fig.5). In subsurface mineral soils the highest total P was 114.1 mgPkg⁻¹ recorded at marlstone soil and 4.5 mgPkg⁻¹ for organic P at silicate soil. Stevenson and Cole (1999) reported that total P is usually the highest in the upper A horizon and the lowest in the lower A and upper B horizons due to recycling by plants. The lowest values for total P in surface soils were 49.7 mgPkg⁻¹ recorded at limestone soil and 20.8 mgPkg⁻¹ at silicate soil for subsurface. For organic P the lowest values recorded were 0.3 mgPkg⁻¹ at silicate soil and 0.1 mgPkg⁻¹ at limestone soil for surface and subsurface soils respectively. These results suggest that P cycling is vertical stratified in these soils types. Most of the P in the surface soil is controlled by adsorbed to oxide surface, while in subsurface soil, it is controlled by sorption to amorphous Al and Fe (Phimsirikul and Match 2003). Stevenson (1986); Forth and Ellis (1997) reported that

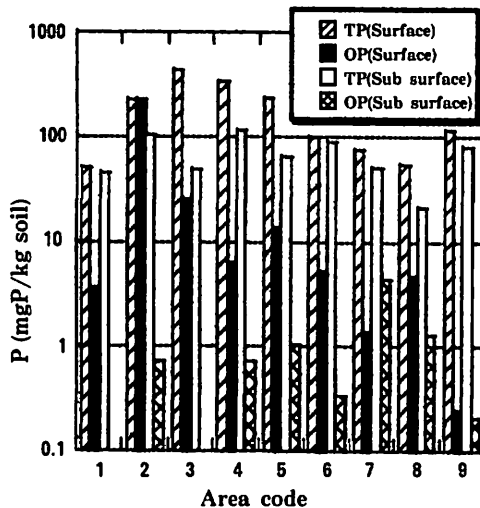


Fig. 5. Results of total and organic P in surface and subsurface mineral soils.

inorganic P in tropical and subtropical acid soils are mostly in the form of iron and aluminium phosphates, and calcium phosphate in calcareous soils.

In the present study, there were no clear differences between the three soil types for P availability (Fig.5). However in the limestone soils availability of P is relatively high. This is probably due to its soil parent material. Soils formed from acidic rocks are generally low in P, and those derived from basic rocks contain moderate to high amounts. In the southern part of Okinawa, soils were neutral to alkaline with pH range 5.84 to 7.81, in connection with calcareous state of soil parent materials; that might be a reason for limestone soils to have high amount of total P. Unweathered calcareous soils of dry region often have high P contents due to the general lack of leaching and the presence of appreciable amounts of P in the form of apatite (Stevenson and Cole 1999). According to Phimsirikul and Matoh (2003), the fraction of inorganic and organic P depends on the kinds of major cations (Ca, Fe and Al) in soil.

Mineralization of nutrients

Nutrient mineralization is regulated by abiotic factors (example, soil fertility, moisture, temperature, and texture) and biotic factors such as changes in microbial activity with soil depth, rates of litter inputs (Pastor et al., 1984; Binkley and Hart, 1989; Wedin and Tilman ,1990), and the quality of organic matter (Pastor et al., 1987).

A low C/N ratio in the surface layer indicates rapid mineralization of the organic matter, and hence a higher availability of N. In the present study (Fig.6a and Table 2), the C/N ratio almost decreases from the subsurface mineral to surface layers. The highest C/N ratios for both surface and subsurface layers are 23.4 and 71.4 respectively, which are found at site number 9 in silicate soil. In comparison between three geological sites, silicate rock contained relatively higher C/N ratios corresponding with low pH. This

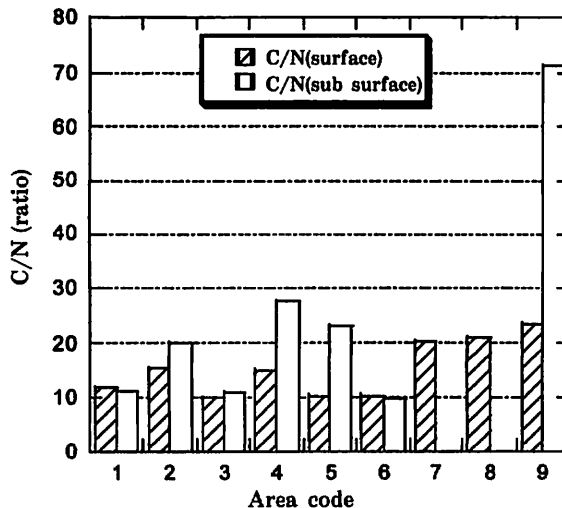


Fig. 6a. The C/N ratio in surface and subsurface mineral soils.

suggest that the activities of microorganisms which are important in the decomposition of soil residues are reduced by low soil pH. Hagvar (1988) found that pH had a positive influence on litter decomposition rates. This result also confirms the low nutrients availability present in the acidic soils. The average C/N ratio in the surface layers of the present study lies between 10 and 24 that are generally equivalent to the mean CONECOFOR values, which are mostly between 10 and 31.

The highest C/P ratios are 2070 and 795 for surface and subsurface soils respectively, both were found in limestone soils (Fig.6b). The lowest ratios were recorded in marlstone soils which are 154 for surface and 173 for subsurface soils. These results are inconsistent with the study of the status of P in Thai soils (Phimsirikul and Match 2003), which reported that the C/P ratio varied from 40 to 189. According to Brady and Weil (1996); Stevenson and Cole (1999) an initial net mineralization will occur at C/N ratios of less than 20: 1 and at C/P ratios of less than 200: 1. In contrast, an initial net immobilization of N will occur at C/N ratios of 30: 1, and of P at C/P ratios over 300: 1. Intermediate ratios lead to neither a gain nor a loss of the nutrients.

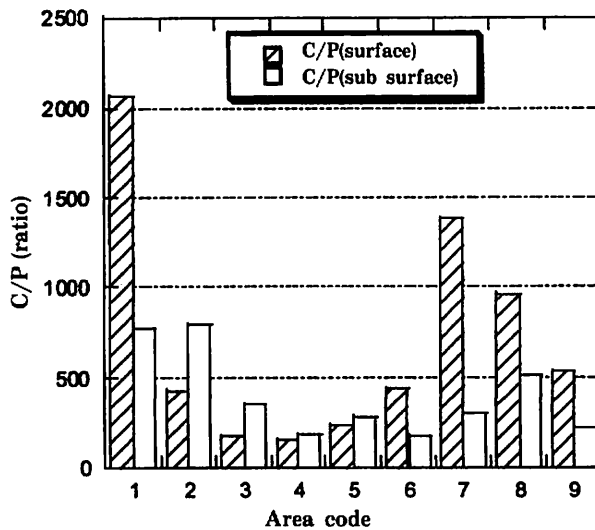


Fig. 6b. The C/P ratio in surface and subsurface mineral soils.

Generally, the variations for C/N (Fig.6a) and C/P (Fig.6b) ratios in our results are similarly to that from different region of the world (data not shown), in which ratios recorded for C and P are somewhat more variable than for C and N. One explanation for the wider range of C/P ratio is that, unlike N, P is not a structural constituent of humic and fulvic acids (Stevenson and Cole, 1999).

Mobilization of nutrients

Nutrients dynamics in forest soils may also be studied by evaluating nutrient

transportation from surface to subsurface soil. Figure 7 shows the average ratio of nutrients (C, N and P) in surface to subsurface mineral soil. In general the ratios are low in limestone soil, increased in marlstone soil and relatively high at silicate soil. This depicts that vertical transportation of organic matter is higher in the limestone area due to both high porosity and activities of soil animals. Soil in limestone area mainly infiltrated downward resulting to alluviation of constituents from the surface, whereas in silicate rock, soil penetration capacity is relatively low, and in conjunction with steep

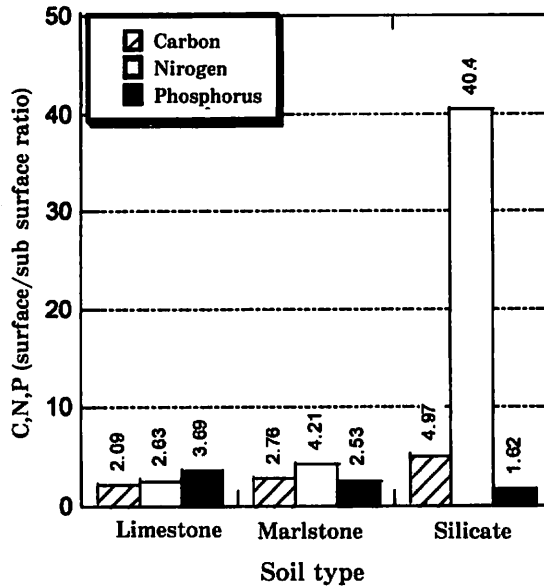


Fig. 7. The average ratios of C, N, and P in surface to subsurface mineral soils.

slopes, incoming water drain in the surface and subsurface resulting to horizontal distribution of nutrients. According to Stevenson and Cole (1999), in soils formed under deciduous forests on sites that are well drained and well supplied with Ca; the litter becomes well mixed with the mineral layer by earthworms and other fauna. In this case, the 10-15cm of soil becomes coated with humus. On other hand, on sites low in available Ca, the leaf litter is not mixed with the mineral layer but forms a mat on the soil surface. An organic-rich layer acid (mor) humus accumulates at the soil surface, and humus accumulates only in the top few centimeters of soil. In addition to that, chemical composition of red soil (silicate rock) has been reported to have very low content of Ca (Tokashiki, 1993; Vuai et al., 2003).

Sources of nutrients

The amount of C and N in the soil at a given location is important for biological and physical processes. Biological processes affecting the amount of C in soil include additions from plant residues and losses by respired CO₂, while the amount of N in soil

is determined by the balance between gains from microbial N-fixation and losses by denitrification, volatilization of NH_3 gas, and NO_3^- leaching (Jenny, 1980). According to Joergensen (1987) and Sparrow et al. (1992), an increase in N is caused by wet deposition and immobilization by microbes. On the other hand, the native P in soil was derived from the apatite of soil-forming parent materials. From a mineralogical point of view, apatite is a complex compound of tricalcium phosphate. The compound is highly insoluble in water, and the P in them is not readily available to plants (Stevenson and Cole 1999).

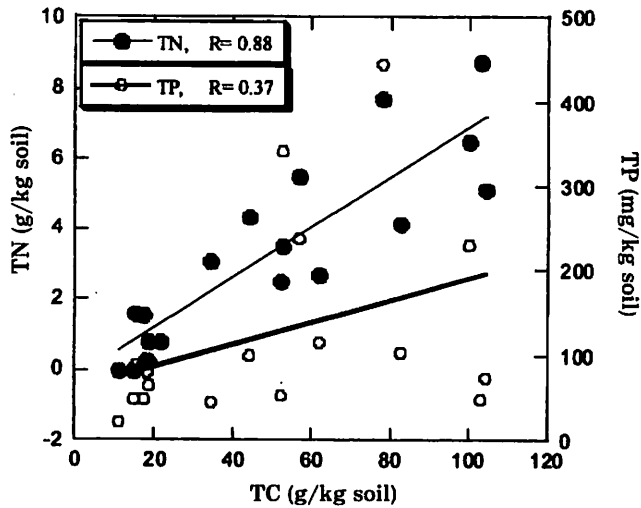


Fig. 8. Relationship between total carbon (TC), total nitrogen (TN), and total phosphorus (TP).

The relationship between total organic C and N in our study (Fig.8) is relatively good compared to C and P. This indicates that decomposition of soil organic matter is the main contributor of nitrogen pool in the studied samples. While, the P of apatite is liberated and subsequently; absorbed by plants and recycled, incorporated into the organic matter of soils and sediments, and also redeposited as sparingly soluble mineral forms, such as Ca-, Fe-, and Al-phosphates and the occluded P of Fe- and Al-oxides during weathering and soil development (Stevenson and Cole, 1999).

Conclusions

Quantities of nutrients availability are different within three geological sites of soil formation. Limestone (area codes,1,2,3) soils shows to have much more nutrients availability followed by marlstone (area codes, 4,5,6) and silicate (area codes, 7,8,9) soils. In general, the higher values of total organic C and N were found in the limestone areas; however, the highest value of total C (104.4 gkg^{-1} soil) was obtained from low land area in

silicate soils at site 7. Similarly as the case of total organic C and N concentrations, the total P and organic P concentrations are higher in the limestone soils and lower in the silicate soils. All three types of soils show to be more favourable with C/N ratio than C/P ratio. The C/N ratio in this study varied between 10 to 70; while C/P ratio varied between 150 to 2070.

The result of soil pH also shows the effect to fertility of forest soils in this study. The lowest soil pH is 3.48 at surface and 3.41 at subsurface soils, both in the silicate rocks which imply that the soil is highly acidic and the lowest in nutrients availability.

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