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Differences in Soil Properties of Dry Evergreen and Dry Deciduous Forests in the Sakaerat Environmental Research Station

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ABSTRACT To clarify the soil-plant relationship in the Sakaerat Environmental Research Station (SERS), northeast Thailand, soil survey was conducted in the two major types of forest, *i.e.*, dry evergreen forest (DEF) and dry dipterocarp forest (DDF). In addition, DDF with fire protection treatment since 1967 (FPDDF) was also selected as a study plot to know the effect of protection of land cover during dry season on both soil and vegetation. As a result of the soil analysis, such as soil hardness, soil morphological, physical, chemical, and mineralogical properties, the current vegetation in the SERS seemed to be affected greatly by the strength of the impacts (fire) given to the forest. If no fire protection is attempted in the DDF, soil erosion due to loss of organic matter on the surface soil is easily brought about. Soil properties such as clay content and associated properties (water holding capacity, cation exchange capacity, water permeability, and moisture content) become worse easily and shortly, after soil erosion.

The various soil properties of the FPDDF can be considered in the intermediate condition between those of DDF and DEF. The stronger the impact of fire is, the more the soil erosion occurs. On the basis of soil properties, the following mechanism can be suggested to explain the current vegetation; once the original vegetation was destroyed, DEF type forest could not regenerate easily in such a dry and infertile soil condition, and therefore, the other type of vegetation, *i.e.*, DDF, is found elsewhere in northeast Thailand at present. The extremely dry soil condition currently found in the DDF is not intrinsic property of a forest soil. It is created by the removal of the vegetation which used to be there. The fire protected DDF suggests it.

Key words: soil-plant relationship / soil fertility / soil hardness / soil environment / dry dipterocarp forest / dry evergreen forest / fire protection / forest structure

Soil-plant relationship is a quite important aspect persistently occurring in the natural environment. However, both vegetational distribution and soil material distribution are quite complex under the actual condition, it is still very difficult to understand them clearly. If we focus on some specific plant species, we can evaluate the difference in soil properties and geomorphology as a site quality (*e.g.*, Hirai *et al.*, 1997). They showed that the segregated distributions of two dipterocarps were mostly controled by the soil moisture regime and the related soil properties. This type of analysis may be helpful to understand one of the mechanism to regulate the tree distribution in the forest ecosystem, and should be paid more attention to. Another type of approach is to evaluate the site index using a specific value of soil properties. Yamakura & Pongsak (1990) used the soil carbon/nigrogen ratio to evaluate the several forest types in the tropical countries. Bunyavejchewin (1985) analyzed the tropical dry deciduous forest of Thailand, with special reference to vegetation in relation to topographic and soil gradients. Both of the approaches are quite recommendable for the comprehensive understanding of the site related properties of the forests.

At present, the destruction of the tropical forest is one of the world wide concern. We have to try to discriminate whether the changes in vegetation type is man-induced one or not. This aspect should be analyzed in terms of soil-plant relationship. In the Korat plateau of northeast Thailand, a desertification problem caused by salt accumulation in the lowland and surface erosion at the upland crop field adjacent to the lowland becomes serious more and more. Since the mountainous or hilly region is mainly located on the southern and western edges and some of the northern part of Korat basin and the flood plain is located along the Mun and Chi rivers, the rest of the area is characterized by the hilly or undulating upland. Salt affected land is mainly located at the lowest slopes of undulating area to lowland, and it occupies about 30 % of the total area of northeast Thailand. On the other hand, soil erosion hazard occurs on the undulating to hilly upland and it occupies about 30 %. The preceding studies tried to show the source of salt that appeared in the lowland (Miura *et al.* 1994). However, they did not mention the soil erosion problem in connection with the salt accumulation problem on the lowland, neither directly nor indirectly. In order to understand these phenomena comprehensively, we should know the soil-vegetation relationship in the mountainous region and hilly upland surrounding the lowland. Especially, one of the most important things to keep in mind is that both low land and upland used to be covered by the natural vegetation before cleared. Besides, the human impact should be taken into consideration to discuss the difference in the current vegetation.

In the Sakaerat Environmental Research Station (SERS), Kanzaki *et al* (1995a) studied the structure of dry evergreen forest. Sahunalu and Dhanmanond(1995) studied the structure and dynamics of dry deciduous forest. These two different forest types are found within 3 km distance, and the local climate and geomorphology are quite similar.

Bos & Thunduan (1968) carried out detailed soil survey of the north-eastern portion of the SERS. They prepared a soil map of this area by means of air-photo interpretation and field reconnaissance and recommended the further detailed soil studies including chemical and mineralogical analyses to supplement the observations made in their survey. However, their work lacked in the view point of soil-plant relationship. Thus we try to elucidate the causes which determine the two forest types with reference to soil related properties. This approach may lead to the understanding of the soil related problems of the forest and/or crop land in the northeast Thailand, and eventually lead to the development of the technology to prevent from further degradation of the agricultural land and the local communities.

MATERIALS AND METHODS

Study sites

Sakaerat Environmental Research Station is located on the southwestern edges of Korat plateau,

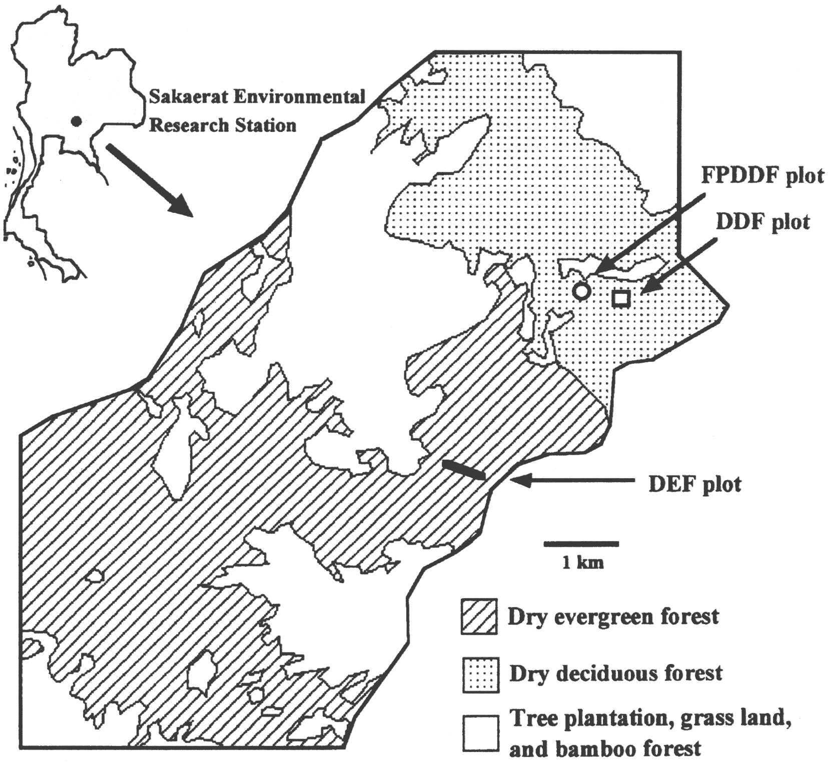

Fig. 1. Map showing the location of research sites and the vegetation map of the Sakaerat Environmental Research Station. (Modified, after Watcharakitii *et al.* 1980)

Nakorn Ratchasima province, northeast Thailand, about 180 km northeast of Bangkok (lat. 14°30' N, long. 101°56' E). The station was established in 1967 and consists of 29.5 km^2 of seasonal evergreen forest and 12.2 km^2 of drought-deciduous forest (Wacharakitti *et al.*, 1980). In Thailand, these forests are called dry evergreen forest (DEF) and dry dipterocarp forest (DDF), respectively (Kanzaki *et al.*, 1995a). Location is shown in Fig. 1.

The site is in the tropical monsoon climate zone. Mean annual temperature at the station is 26.2 °C. Annual rainfall is 1240 mm, and monthly rainfall is less than 50 mm during the dry season, from December to February. The site is located on a cuesta-like table mountain which is composed of sandstone classified into the Phra Wihan formation of the Khorat group (Methikul & Silpalit, 1968). This area occupies the north-easterly part of this surface, with highest elevation (650 m) in the south-west and lowest elevation (250 m) in the north-east. The surface can be represented as a series of tilted steps resulting from block-faulting of the limb of the anticline. The steps are found at elevations of about 390, 470, and 530 meters (Bos & Thunduan, 1968). According to them, red-yellow podzolic soil covers the site and is more than 60 cm deep. These soils are equivalent to Orthic Acrisols (FAO/UNESCO 1974) or Tropustults (USDA, 1990).

A study plot was set up by Kanzaki *et al.* (1995a) in the most strictly preserved *Hopea ferrea*

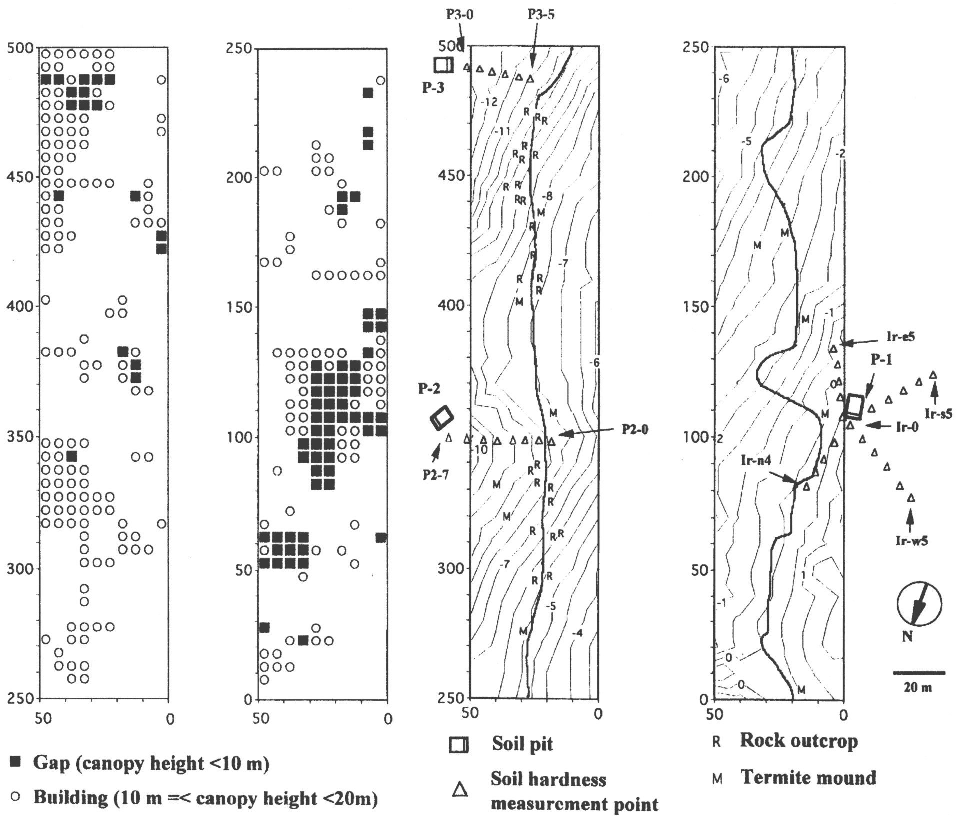

Fig. 2. Canopy stature (left) and the location of the observation (right) in the DEF plots. The canopy stature was measured at every 5 m × 5 m grids, and was classified into one of three categories, i.e., gap, building, and mature phase. Marked area indicates the gap or building phase canopy, and non-marked area indicates the mature phase canopy taller than 20 m high. The thick line in the right map indicates trail in the forest. Rock outcrops and termite mounds were marked only for those found along the trail.

forest. They showed the forest structure using a 2.63 ha study plot (50 m × 526 m) (Fig. 2) and divided into three developmental phases such as gap, building, and mature phases, and a mosaic structure of three different phases was shown in a map. In 2.63 ha, 2889 trees and 384 woody climbers over 5 cm dbh were enumerated until August 1994. Tree density (dbh > 5 cm) was 1309 trees ha^{-1} and total basal area at 1.3 m height was 33.6 m^{2} ha^{-1}, including climbers. Above ground biomass was 273 ton ha^{-1} (for trees only), indicating the high stock of biomass in the forest. Among them, 2768 trees were identified at least to the genus level and 92 species were recorded in Department of Forest Biology, Kasetsart University. The most dominant species was *Hopea ferrea* and some common canopy and sub-canopy species, such as *Lagerstroemia duppereana*, *Shorea henryana*, *Irvingia malayana*, *Hydnocarpus ilicifolius*, *Memecylon ovatum*, and *Walsura trichostemon* associated with (Kanzaki *et al.*, 1995b).

This plot is on the gentle slope facing north-east with mean inclination of 4 degrees. Along with the longer axis of the plot, we selected three sites (P-1, P-2, and P-3) for the analyses of soil properties based on the topography. Altitude of the plot ranges from c.a. 520 to 530 m above sea level. The P-1 site was located at +1.0 m, P-2 was located at -10.0 m, and P-3 was located at -12.0 m from the standard level of the plot. Topograpically, P-1 was on the small hill, P-2 was on the shallow valley, and P-3 was on the mid-slope to escarpments. According to Kanzaki *et al.* (1995a), P-1 was located on the building phase of vegetation, P-2 was between the mature and building phase, and P-3 was on the mature phase.

Two types of study plot in the Dry Deciduous Forest (DDF) were selected in the SERS. One was the DDF without fire protection, and the other was DDF with fire protection treatment (FPDDF) from 1967. Fire protection can be accomplished rather easily and effectively by making a fire protection belt where underground cover of dead plants are removed and prescribed burning was made at the beginning of the dry season. The FPDDF plot is located near the DDF plot within 500 m distance. Generally speaking, the ground fire in the dry season is almost inevitable because of the extremely dry condition for some months a year and also the activity of local people to collect some mammals or lizards for food using small fire. Trees in the DDF often and regularly suffer from ground fire, and thus, they should have endured and adapted to this severe stress. Tree selection may have occurred at first, and adaptation of tree to the environment, e.g., enthickened bark, may have successively occurred. A comparison between DDF and FPDDF was made in terms of the soil characteristics. The census was conducted in a 100 m × 100 m plot in the DDF for trees over 4.5 cm dbh in 1993 (Sahunalu & Dhanmanonda, 1995) and in a 50 m × 50 m plot in the FPDDF for trees over 1 cm dbh in 1994. One pedon from each forest was described in detail. The P-4 was located on the DDF without fire protection with an altitude of 340 m and P-5 was on the DDF with fire protection (FPDDF) with an altitude of 360 m. Both of the sites were situated on the similar geomorphological position, i.e., on the mid-slope. The slope at the P-4 site is 10 degree while that at P-5 is 5 degree. Surface outcrop of rocks was found everywhere. In the DDF plot, there was no definite canopy cover because of the frequent ground fire. On the other hand, the FPDDF plot was covered by the canopy and some ground vegetation. The current difference in surface cover between DDF and FPDDF would be brought by the practice of fire protection, which may have affected the amount of solar radiation reaching to the ground, and thus, will have affected the soil temperature and moisture, and eventually the vegetation.

In the DDF plot, 875 trees over 5 cm dbh were enumerated in 1 ha plot. Total basal area at 1.3 m height was 15.4 m^2 ha^{-1} and above ground biomass was 73.2 ton ha^{-1}. Among the 875 trees, 871 trees were identified at least to the genus level, and 49 species appeared. *Shorea obtusa*, *Dipterocarpus intricatus*, *Pterocarpus macrocarpus* were dominant tree species, and *Bauhinia* sp., *Cratoxylum formosum*, *Lannea wodier*, and *Morinda coreia* were dominant as shrub species. In the FPDDF plot, tree density over 5 cm dbh was 1592 trees ha^{-1}, and was higher than 1309 trees ha^{-1} in the DEF plot. Total basal area at 1.3 m height was 22.5 m^2 ha^{-1}, which is lower than in the DEF plot but higher than the DDF plot.

Soil samples and analytical methods

From every pedon (P-1 to P-5), we collected soil samples for analyzing physical properties at the depths of 0 to 5 cm, and 5 to 10 cm, and 20 to 25 cm when possible. Three phase distribution, bulk density, and true density were evaluated by the Three Phase Meter (Daiki, DIK-1120) at the SERS. Saturated permeability coefficient was analyzed by the falling head permeability technique using Permeameter (Daiki, DIK-4000). Soil moisture was measured by soil tensiometer (Daiki, DIK-3130).

Table 1. Morphological properties of the soils studied.

Pedon	Horizon	Depth (cm)	Color	Structure[a]	Consistency[b]	Root	Gravel	Boundary[c]
P-1	A	0-4	5YR3/4	w f sbk	s/p	many	few	as
	AB	4-8	5YR4/6	w f sbk	vs/p	common	few	as
	BA	8-20	5YR4/8	m f sbk	vs/p	common	few	as
	Bw	20-31	5YR4/8	m m sbk	vs/p	few	few	aw
	C1	31-55	5YR4/8	no	vs/p	few	many	as
	C2	55-76	2.5YR4/8	no	vs/p	few	abundant	as
	C3	76-100+	5YR4/8	no	vs/p	very few	abundant	
P-2	A	0-5	5YR4/4	w f sbk	s/p	common	few	as
	AC	5-12	5YR4/6	no	vs/p	abundant	abundant	as
	C1	12-25	5YR5/8	no	vs/vp	few	GL[d]	as
	C2	25-50	5YR4/8	no	vs/vp	few	GL[d]	as
	R	50-55+						
P-3	A	0-5	5YR4/4	w f sbk	s/p	many	very few	as
	AB	5-15	5YR4/6	m m sbk	s/p	common	few	aw
	BA	15-25	5YR4/8	m m sbk	s/p	few	no	as
	Bt1	25-38	5YR4/8	m m sbk	s/p	few	no	as
	Bt2	38-57	5YR4/8	m c sbk	vs/vp	few	few	cs
	BC	57-80	5YR4/8	m f sbk	vs/p	few	few	cs
	C	80-100+	2.5R3/6	no	vs/p	few	GL	
P-4	A	0-7	10YR4/2	m m sbk	ns/np	common	common	aw
	AC	7-10/15	7.5YR6/3	m f sbk	ns/np	common	abundant	ci
	C	10/15-17/51	7.5YR5/6	no	s/p	few	abundant	ai
	R	17/51+						
P-5	A	0-10	7.5YR5/3	m m sbk	ns/np	many	no	as
	AB	10-21	7.5YR6/4	m m sbk	ns/np	common	abundant	cs
	B	21-31	7.5YR5/8	s f sbk	s/p	few	few	cs
	C	31-75+	5YR5/8	no	vs/vp	few	few	

[a] Abbreviation used for soil structure. Grade: w, weak; m, moderate; s, strong. Class: f, fine; m, medium; c, coarse. Type: sbk, subangular blocky; no, no structure.

[b] Abbreviation used for consistency. Stickiness: ns, non sticky; s, sticky; vs, very sticky. Plasticity: np, non plastic; plastic; p, plastic; vp, very plastic.

[c] Abbreviation used for boundary: as, abrupt smooth; aw, abrupt wavy; ai, abrupt irregular; cs, clear smooth; ci, clear irregular.

[d] GL, gravel layer.

Soil hardness was measured by Hasegawa type cone penetrometer (Daito Green, H-60) around the soil pits.

Soil samples were also collected from every horizon for physicochemical and mineralogical properties, and air dried fine soil particle (less than 2 mm) were prepared. The pH was measured in a soil to water or 1 M KCl ratio of 5 g to 25 mL after reciprocal shaking for 1 h (designated as pHw and pHK, respectively). Electric conductivity was measured using the supernatant solution after pHW analysis. Exchangeable cations were extracted twice with 1 M ammonium acetate (pH 7) for Ca, Mg, Na, and K, by reciprocal shaking and centrifugation in a soil to solution ratio of 5 g to 25 mL. The amounts of Ca, Mg, and K were determined by atomic absorption spectrophotometry, and that of Na by flame photometry (Shimadzu AA-610S). After extraction of exchangeable bases, the residue was washed once with 20 mL of water and twice with 20 mL of 990g L^{-1} EtOH to remove the excess salt, and then ammonium ion was extracted with 30 mL of 100 g L^{-1} NaCl twice by reciprocal shaking for

1 h. The amount of ammonium ion was determined as cation exchange capacity (CEC) by a common distillation method. Exchangeable Al and H were extracted once with 1 M KCl, and their contents was determined by the titration method. Available phosphorus (Av-P) was extracted with 0.001 M H_2SO_4 for 30 min and the content was determined by the molybdenum blue method. Total carbon and nitrogen contents (T-C and T-N) were determined with a NC-analyzer (Sumigraph NC-80). Soil texture was determined by the pipette method after wet decomposition of organic matter with 60 g L^{-1} of hydrogen peroxide and dispersion with the addition of 1 M NaOH to raise the solution pH to 9.2.

RESULTS AND DISCUSSION

Soil morphological properties

Although the difference in elevation is small (14 m in 500 m distance), soil morphological properties of P-1, P-2, and P-3 pedons differed greatly (Table 1). Generally, strongly weathered red soils were found in this site. A red soil in the relatively higher elevation (P-1) contained a lot of gravels at 31 cm in depth, while, at the lower elevation than P-1 by 10 m (P-3), these gravels were found in more deeper part of the solum (80 cm in depth). At the P-2 pedon, a lot of big rocks were found at the ground surface and gravels were abundant from 5 cm to 50 cm. Below 50cm, there were parent rocks (moderately to strongly weathered sand stone). The effective soil depth was 31, 5, and 80 cm for the P-1, P-2, and P-3, respectively. Thus, topography may roughly determine the soil depth. In case of the dominance of surface rock, the soil depth is very shallow, while, in case of the absence of surface rock, soil depth depends on the topographic position, i.e., at the higher elevation, a shallower soil, on the contrary, at the lower elevation, a deeper soil can be found.

In the pedons in DDF plot and FPDDF plot, a lot of big rocks were found in the shallow depth, and tree roots could elongate into deeper part of the solum only along the space between rocks. Although both of the soils showed a very sandy texture in the surface A horizon, the most significant difference between them was the color and thickness of the A horizon. In the P-4 pedon, surface A horizon was only 7 cm in thickness with a pale color of 10YR4/2 (grayish yellow brown). On the other hand, in the P-5 pedon, surface A horizon was 10 cm with a color of 7.5YR5/3(dull brown). Since the color of subsurface horizon did not differ greatly (7.5YR6/3 and 7.5YR6/4 for P-4 and P-5, respectively), this difference in color and thickness of surface horizon might be brought about by the relative accumulation of organic materials in FPDDF plot during the 25-year fire control. Fire deprives the surface soil organic matter and might have caused a severe erosion during the rainy season in the DDF.

These soils can be classified into the following Thai soil series;

P-1: Khao Yai series (Ky),

P-2: Kao Yai series, shallow phase (Ty-c),

P-3: Tha Yang series, colluvial phase (Ty-c),

P-4 and P-5: Tha Yang series (Ty).

According to the survey by Bos & Thunduan (1968), Khao Yai series (Ky) are the deep soils and occur only on shallow slopes where the flatness and vegetation prevent erosion of the top soil. Concretions may be found at depths of more than 60 cm. This term covers small amounts of sandstone gravel and shale fragments of the same size and color as well as true concretions, with rounded, red in color, and an average diameter of 10 mm. Tha Yang series (Ty) are characterized by the few boulders and/or rock outcrops and differs from the Ky series in the shallowness of the soil, the content of boulders and stones at the surface and in the soil, and the occurrence of concretions at shallow depths.

Now, we try to compare the DEF and DDF in terms of five factors for soil genesis, i.e., parent materials, topography, biology, time, and climate. Biologically, there are clear difference in these two vegetational types. Since both of the forests were located within a relatively short distance (about 3 km apart from each other), there may not be a definite difference in climate and geological time for long term weathering. The soil materials found in DEF (P-1 to P-3) were the weathering product of the sand stone with partial interbedding of shale, while those in DDF (P-4 and P-5) were mostly derived from a sand stone. Surface rockiness was similar between the P-2 in the DEF and the P-4 and P-5 in the DDF. The soil depth was very shallow for all these pedons. Topographically, the P-2 was located on the shallow valley with a gentle slope (2 degree), on the other hand, the P-4 and P-5 were located on the middle slope of undulating hill, with a relatively steep slope of 10 and 5 degree, respectively.

Once the vegetation is removed by some causes, the weathering product of shale on the soil surface can be broken into pieces within a short period. Provided that the shale was overlying the sand stone in the DEF and DDF, it may be weathered immediately after exposure to the atmosphere. In addition, the steeper the slope is, the more severe the erosion is. Accordingly, the P-4 had many gravels even at the surface and showed a less accumulation of the clayey materials in the deeper horizon, because of the severe surface erosion. While in the P-5, clayey materials are translocated into the deeper part along the root elongated on the rock surface, as is seen in P-2 in DEF.

Soil erosion can be brought about easily even by one severe rain. After erosion, some of finer particles such as clay, silt, and fine sand from the upper part of the slope also can be carried and supplemented. Thus, complete loss of finer particles from soil surface takes longer time than one-rain-erosion. Translocation of finer particles in the deeper part of the pedon through the rock surface can occur within a short time, which takes longer time than the erosion. The formation of clay in situ takes much longer time and can not be discussed here. Except this, all of the phenomena are so called short time change in this area. Thus, the destruction of vegetation and the resultant erosion of surface soil were considered as the principal mechanism to cause the difference in soil morphological properties.

The current status of soils in DDF and DEF, on the other hand, is very different in morphology, which can be one of the influential factors to cause the difference in vegetation. Furthermore, once ground fire is protected and the vegetation is kept throughout the year, soil erosion may be prevented significantly. Thus, the difference in soil morphological properties between FPDDF and DDF may be created within several decades.

To the contrary, the difference in vegetation can cause a great difference in the surface soil properties between DDF and DEF. Because of more sparse tree density in DDF than in DEF, the supply of organic materials from the vegetation and the retention of them by soils is little contributed to the prevention of soil erosion. This mechanism can also be applicable to the difference between DDF and FPDDF. Once fire is protected even in DDF, more supply of organic matter and its retention by soil can be expected through prevention of soil erosion. These changes can be cosidered reversible between DDF and FPDDF within several decades. At present, it is uncertain whether these changes between DEF and DDF are reversible or not because no definite data are available. However, they can

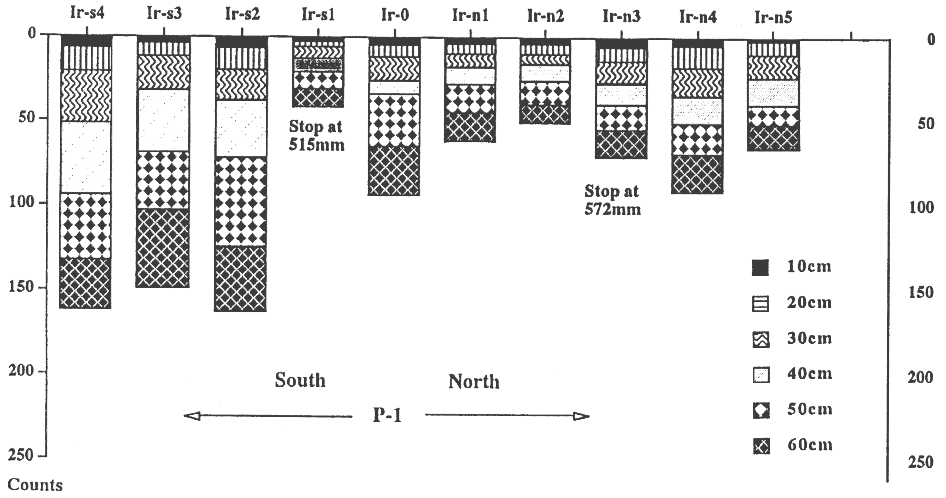

Fig. 3. Counts for penetrating 60 cm by soil penetrometer.
3a. Transect along P-1 site. (south to north)

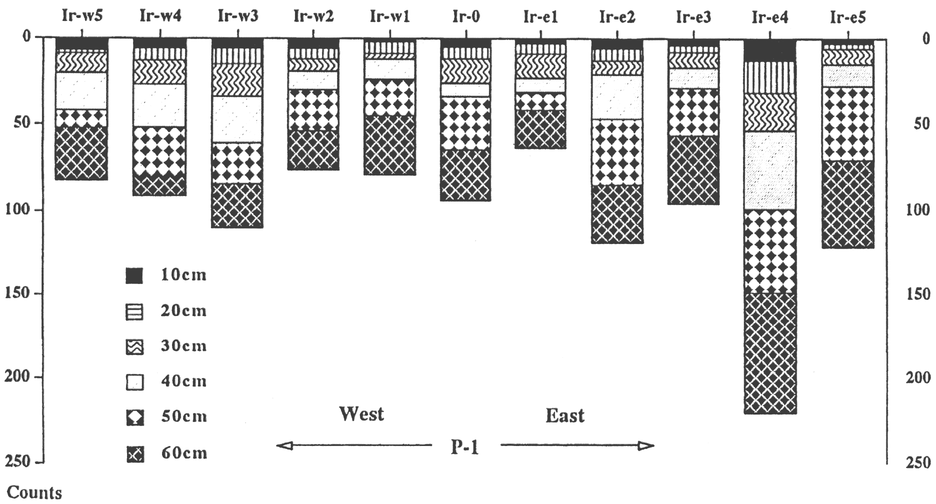

Fig. 3b. Transect along P-1 site. (west to east)

between DEF and DDF are reversible or not because no definite data are available. However, they can be considered as a probable mechanism to determine the current vegetational type in this area.

The distribution of termite mounds was quite dense in the DEF (Kagotani *et al.* 1995). It was mostly composed of the finer soil particles, and its texture corresponded to heavy clay (clay content of fine earth more than 45 %). Therefore, once a big and wide termite mound is abandoned, it can be utilized as a thick soil material for tree roots without facing a physical disturbance by the gravels. The rate of formation and breakdown of termite mound, therefore, can cause the turbation of soils (pedoturbation) and therefore, "rejuvenation of soils" significantly. An accumulation of finer materials overlying the gravel layers were found everywhere on the top of high terrace and/or middle terrace

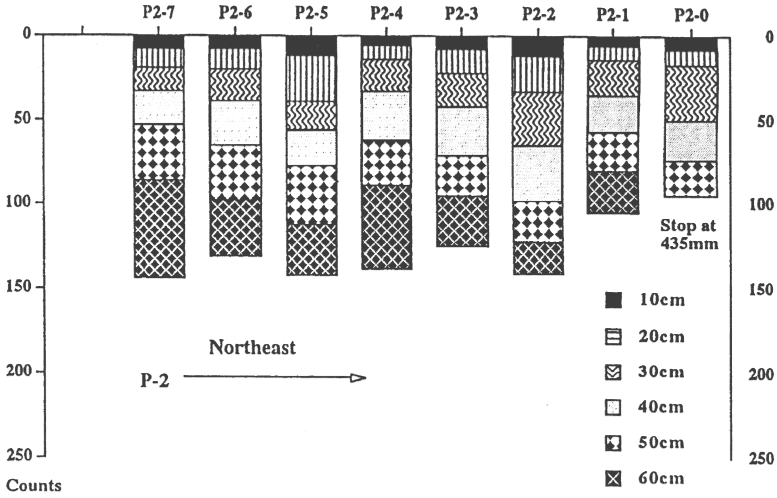

Fig. 3c. Transect along P-2 site (southwest to northeast)

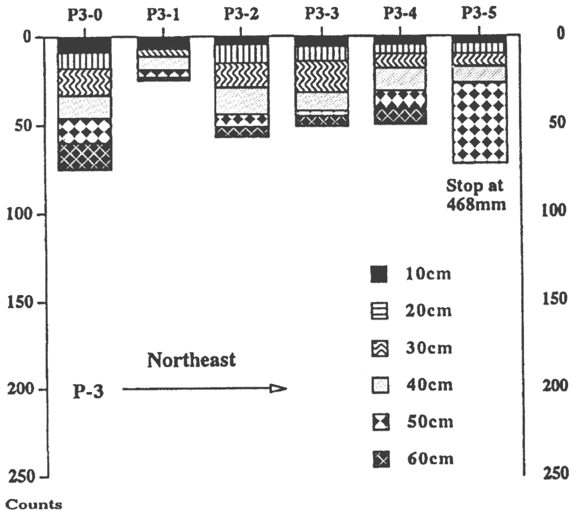

Fig. 3d. Transect along P-3 site. (southwest to northeast)

(Tamura 1991). This layering was most probably formed by the intensive termite activity. Thus, we need more study on the stratigraphy of the soil materials in terms of termite activity, and eventually, on the changes of vegetation types in the SERS.

Soil hardness measurement

The analysis of soil hardness enables us to seize the material distribution in the shallow part of soils, where most of the roots concentrate. In particular, gravel layer or C horizon with abundant gravels can be easily discriminated without digging a soil pit and without disturbing the vegetational stand greatly (Sakurai *et al.* 1995). If a gravel layer is found in a shallow depth, tree root may suffer greatly from

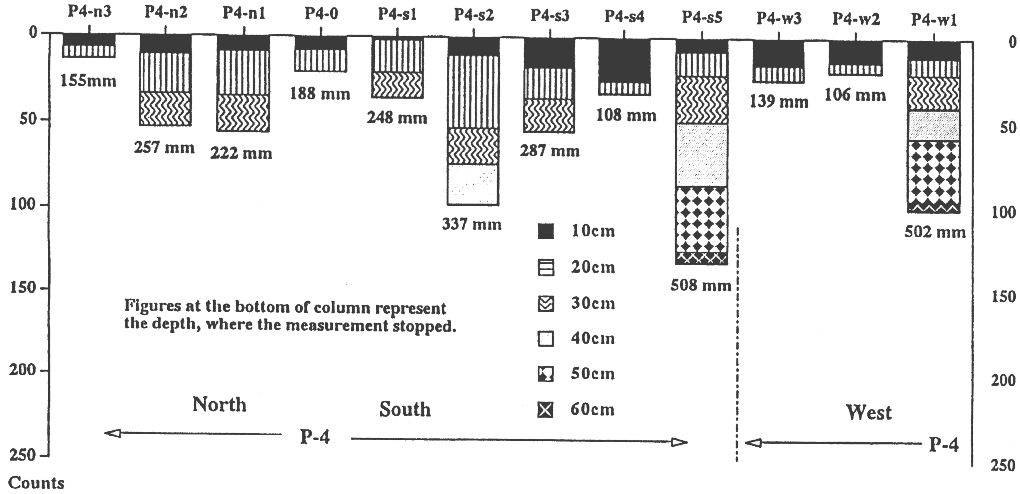

Fig. 3e. Transect along P-4 site. (north to south, and east to west)

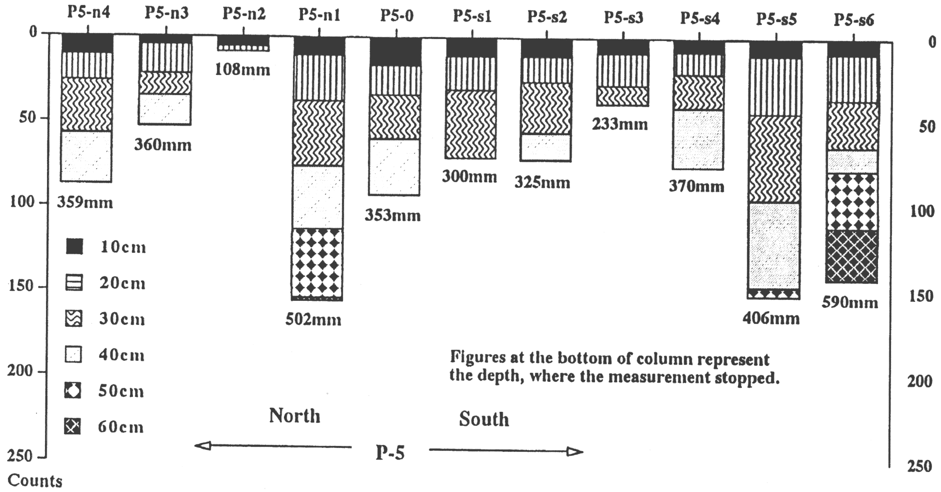

Fig. 3f. Transect along P-5 site (south to north)

the
physical hazard.

Examples of the vertical distribution of soil hardness around the soil pit are depicted for each site (Fig. 3). At the P-1, the surface soil was soft from the surface to 10 cm depth, and it became harder gradually, then became very hard below 40 cm. At the P-2, the soil was hard except surface 3 cm. Especially the deepest part of the P-2 (below 40 cm) was extremely hard, where a gravel layer was found. The soil hardness of the P-3 showed a relatively uniform distribution below 17 cm, representing the absence of the gravel layer, in other words, indicating the presence of the finer soil materials with a similar texture. Contrary to the results in the DEF, we could not complete the soil hardness measurement down to the depth of 60 cm at the P-4 and P-5 in the DDF, because of the

Soil hardness was also examined systematically along the selected transect around the soil pit to show the spatial variability of soils in both DEF and DDF. Location of the examined point is shown in Fig. 2. In Fig. 3 (a to f), the counts for penetrating 60 cm are depicted schematically at every 10 cm. In these figures, the more the count for penetrating 10 cm is, the bigger the area is, therefore, the harder the soil is.

In the higher position of the DEF, soil hardness measurement was conducted toward four directions around a big tree, *Irvingia malayana*, at every 5 meter interval. The P-1 pedon was located closely of this tree. In Fig.3a and 3b, the results of south-to-north and west-to-east transects are shown, respectively. In the vicinity of the tree (Ir-0), the hardest soil below 30 cm was found, whereas, in the southern transect, the material seemed to be soft and its distribution was uniform from 10 cm to 60 cm in depth. In the east to west transect, there existed an extremely hard soil at Ir-w4. The other points showed a similar nature, i.e., soft surface soil and the hard subsurface soil composed of gravels below 30 cm. There were few rocks which made it impossible to complete the measurement to 60 cm. The depth of the gravel layer could be estimated easily in these transects.

On the other hand, in the lowest position around the P-2 in the DEF, the presence of rocks sometimes made it impossible to complete the measurement (Fig. 3c), where, in many cases, a gravel layer was found below 10 or 20 cm. Thus we selected the results in Fig. 3c, where we could complet the measurement down to 60 cm, to show the characteristic of soils excluding big rocks. Surface outcrop of rocks in the DEF, thus, indicated the abundance of rocks in a shallow depth overlaid by a gravel layer.

Along the P-3 transect (Fig.3d), the soil was very soft except P3-5 where surface outcrop of rocks was found. This transect seemed to be located on the colluvial materials transported from the slightly higher position around. Since there was a gravel layer below 80 cm at P-3 pedon, colluvium would be the parent material between the range of P3-0 to P3-4 (about 20 m in distance).

Similar to the transect along the P-2 pedon, in the DDF with or without fire protection, we found the outcrop of rocks everywhere. Measurement of soil hardness, therefore, was often not possible even to the shallow depth (Fig. 3e and 3f). We tried many times to know the soil hardness distribution down to 60 cm, but it was almost impossible to select such a place in both around the P-4 and P-5 pedons.

Compared with the DEF, the slope of the DDF was steeper and its effective soil depth was shallower because of the presence of the gravel layer and big rocks. Once the original vegetation is removed by the human impact, the soil of the DDF may be easily degraded mostly due to soil erosion caused by a heavy rain fall in the rainy season. The loss of the finer soil material, in turn, would cause the serious deficiency in soil moisture in the dry season. This would be the main reason for the poor regeneration of the secondary DDF.

We can now conclude that the prediction of the distribution of physically poor soil in the Sakaerat forest can be accomplished successfully by the simple technique using a soil penetrometer.

Soil physical properties

In Table 2, results of three phase distribution and moisture content are summarized. For the P-1 soil, solid percent was less than 50 % for the upper two layers and 54 % for the subsurface layer. Liquid percent was almost identical throughout three layers. The P-2 soil showed the same tendency as the P-

Table 2. Physical properties of the soils studied.

Sample	Three phase distribution (%)			Moisture content (%)	Saturated water permeability (cm s^{-1})
	Solid	Liquid	Gaseous		
P-1 (0-5cm)	47.15	20.73	32.13	15.10	3.6 E-03
(5-10cm)	47.68	20.60	31.73	14.25	5.3 E-03
(20-25cm)	54.03	19.58	26.40	12.55	6.0 E-04
P-3 (0-5cm)	36.38	14.48	49.15	13.50	1.7 E-02
(5-10cm)	40.23	14.95	44.83	12.18	2.0 E-02
(20-25cm)	43.23	14.88	41.90	11.43	8.7 E-03
P-4 (0-5cm)	41.10	5.15	50.75	4.23	1.1 E-02
P-5 (0-5cm)	43.58	5.50	50.93	4.45	4.0 E-03

1, but solid percent was lower than the P-1 soil, resulting in the higher gaseous phase. Since the soil materials of the P-3 were colluvium, finer clayey particles had been lost through soil erosion, whereas, those of the P-1 were kept as it had been. Even though the difference in elevation was only 10 m, the data on three phase distribution of the P-1, located on the higher position and less slope than the P-3, reflect clearly the more stable condition in terms of soil formation, and less affected by the soil erosion. On the other hand, three phase distribution of the surface soils of P-4 and P-5 was almost same. Soil physical properties in the DDF seemed to be very similar to those of the FPDDF although the thickness of the surface A horizons was deeper and the coverage by the canopy was denser in the P-5 than in the P-4. This means that, irrespective of the particle size, only mineral particles are present without an accumulation of organic matter which makes the porous soil structure.

The most prominent difference between the DEF and DDF is the moisture content, which was more than 10 % in the DEF while less than 5 % in the DDF and FPDDF. This aspect will be discussed in more detail in a section to follow.

Water permeability (n=2) of the P-1 was 3.6 × 10-3 (cm s^{-1}) and slower than the P-3. It became slower toward the deepest part of the solum. This slower water permeability may result from the accumulation of clayey materials by the stable, natural weathering process at the P-1. On the other hand, water permeability of the surface soil of the P-3 was very fast, representing the less clay content. Only the deepest layer (20-25cm) showed a relatively slow value of 8.7 × 10-3 (cm s^{-1}). Thus, we can confirm that the material at the P-3 was derived from colluvium, the clay of which had been lost in the past.

Compared with the DEF, water permeability of the surface soils of DDF was not always faster. Among the soils in DDF, the water permeability of the P-4 is faster than the P-5 (FPDDF). Fire protection for 27 years would keep the root system of the surface vegetational cover even in the dry season, and would be more effective to protect the clayey material against the surface soil erosion. There was no significant difference in water permeability between the soils under the DDF and DEF, and thus, the parent material of these sandy soils would be very similar.

The pF value was monitored using tensiometer in both FPDDF (in the vicinity of the P-5 pedon) and DEF (in the vicinity of the P-1). Air temperature in the morning (mostly between 9 to 10 o'clock), maximum and minimum air temperature, soil temperature (5 cm and 10 cm in depth) were also recorded (Fig. 4).

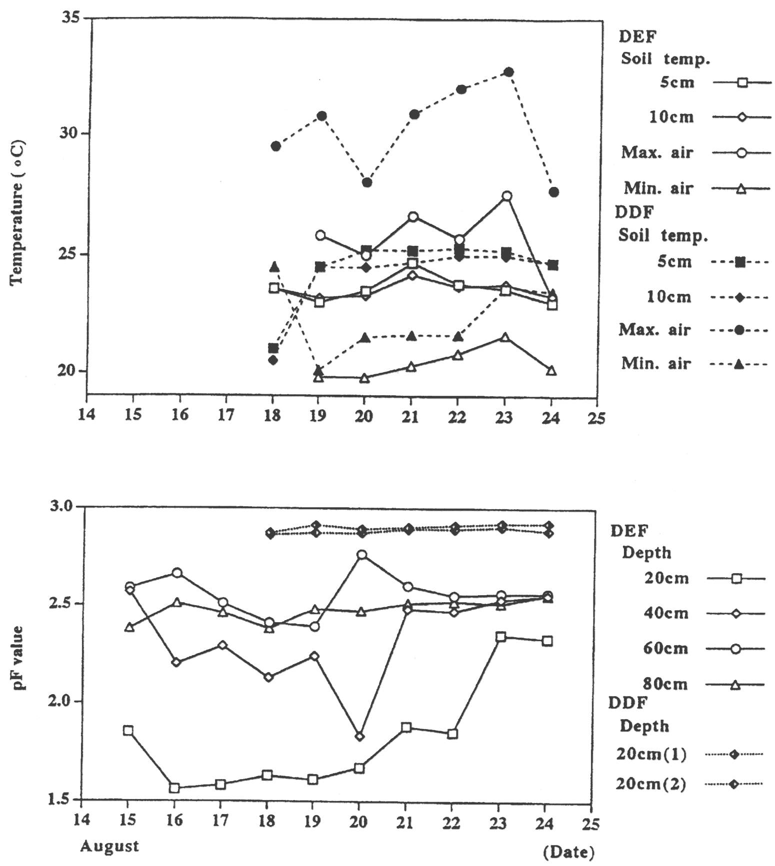

Fig. 4. Changes in temperature of soil and air and pF in DEF and DDF.
Upper: Soil temperature. (5 cm and 10 cm) and maximum and minimum air temperature. Lower: Soil pF values at the different depths.

The pF value at 20 cm depth in P-1 pedon (Fig. 4b) was less than 2.0 from August 15 to 22 and the lowest among the values at the other depths. The occurrence of frequent rain and the cool temperature (Fig. 4a) and dense crown cover were the major cause for it. In addition, an accumulation of litter fall might contribute to keep·the soil moisture of the surface layer. As the maximum air temperature went higher until August 23, the surface soil (20 cm) became drier gradually. A significant change in temperature due to a heavy rain fall (August 15), however, may not affect the pF value of 60 and 80 cm of the DEF soil. On the other hand, in the FPDDF, the pF value of the surface soil (20 cm) was supposed to be more than the upper limit of the equipment (pF 2.9) during the monitoring period. Max. and Min. air temperatures and soil temperature at 5 cm and 10 cm (Fig.4a) were always higher in the FPDDF than the DEF. Thus, high soil temperature and low moisture characterized the soil conditions in the FPDDF, would be the significant factors for the maintenance and/or regeneration of the vegetation. These aspects may be more clearly shown if the monitoring was carried out around P-4 pedon in the DDF.

Table 3. Physicochemical properties of soils studied.

Soil sample	Horizon	Depth cm	EC μ S m^{-1}	pHW	pHK	Exchangeable cations Ca	Mg	K	Na	Al	H	CEC	ECEC	B.S.	Al.S.	Av.P	T-C	T-N	C/N	Clay	Silt	Sand
						cmol(+) kg^{-1}								%		mg kg^{-1}	%		ratio	%		
P-1	A/AB	0-5	112.5	5.17	3.54	0.28	0.40	0.34	0.03	0.99	1.06	5.74	2.03	18.27	17.17	11.9	36.3	3.74	9.7	34.1	15.2	50.7
	AB/BA	5-10	67.1	5.07	3.64	0.09	0.12	0.18	0.03	1.28	0.96	5.15	1.70	8.21	24.89	6.5	20.9	1.67	12.5	36.5	13.0	50.5
	BA	10-20	52.5	4.91	3.70	0.09	0.06	0.13	0.04	1.58	0.98	5.15	1.89	6.16	30.64	4.4	10.3	0.87	11.8	39.1	16.2	44.8
	Bw/C1	20-40	28.3	5.17	3.69	0.07	0.04	0.08	0.03	1.68	0.90	5.15	1.90	4.32	32.55	1.1	7.2	0.62	11.5	44.7	12.1	43.2
	C1/C2	40-60	33.5	5.04	3.65	0.03	0.04	0.07	0.03	1.94	0.88	5.54	2.11	3.14	34.97	2.2	5.1	0.51	10.1	30.6	5.6	63.7
	C2/C3	60-80	32.0	5.21	3.67	0.03	0.03	0.07	0.02	2.15	0.71	5.35	2.31	3.01	40.26	0.0	4.2	0.55	7.7	19.5	5.5	75.1
P-2	A	0-5	72.4	5.33	3.66	0.21	0.34	0.38	0.02	0.99	0.86	5.94	1.93	15.90	16.59	19.5	29.1	1.87	15.6	34.9	13.4	51.7
	AC	5-10	42.5	5.27	3.70	0.03	0.24	0.34	0.03	1.33	0.83	5.94	1.97	10.76	22.40	9.8	13.4	1.21	11.1	44.0	12.1	43.8
	C1	10-20	33.3	5.21	3.72	0.05	0.14	0.26	0.04	1.58	0.98	5.54	2.07	8.91	28.45	9.8	11.0	1.07	10.3	50.1	11.0	38.9
	C2	25-50	30.5	5.45	3.68	0.05	0.11	0.26	0.03	1.72	1.02	5.94	2.18	7.58	29.04	9.8	6.2	0.62	10.0	49.6	10.5	39.9
P-3	A	0-5	45.2	5.61	3.84	0.72	0.50	0.17	0.04	0.16	0.33	3.96	1.59	36.12	4.15	17.3	24.2	1.55	15.6	42.1	12.1	45.8
	AB	5-10	62.9	4.94	3.52	0.17	0.15	0.14	0.02	1.41	0.37	4.36	1.89	10.98	32.43	20.6	17.7	1.10	16.1	28.9	9.0	62.1
	AB/BA	10-20	65.1	4.86	3.58	0.10	0.06	0.14	0.03	1.45	0.71	4.36	1.78	7.47	33.38	8.4	12.9	1.00	12.9	29.1	9.4	61.5
	BA/Bt1	20-40	57.1	4.80	3.63	0.05	0.04	0.11	0.03	1.51	0.98	4.36	1.74	5.30	34.70	8.4	9.3	0.81	11.5	32.2	8.9	58.8
	Bt2/BC	40-60	30.6	4.96	3.63	0.05	0.03	0.07	0.02	1.48	0.98	5.54	1.64	2.95	26.67	3.2	6.2	0.56	11.1	35.6	10.0	54.4
	BC	60-80	27.8	5.00	3.61	0.09	0.04	0.07	0.02	1.61	0.75	5.74	1.83	3.76	28.04	4.3	5.8	0.46	12.4	36.8	10.0	53.2
	C	80+	24.6	5.07	3.61	0.09	0.04	0.07	0.03	1.56	0.77	4.95	1.78	4.52	31.53	4.3	6.9	0.56	12.3	39.0	10.2	50.7
P-4	A	0-7	63.5	6.09	4.36	0.89	0.91	0.25	0.04	0.05	0.08	4.75	2.15	44.23	1.04	20.8	19.8	1.02	19.4	10.6	15.7	73.7
	AC	7-10/15	36.4	5.96	4.01	0.09	0.57	0.14	0.01	0.05	0.51	4.36	0.85	18.49	1.13	11.5	4.4	0.26	17.1	11.3	16.6	72.2
	C	10/15-17/51	21.8	5.95	3.79	0.19	1.03	0.35	0.03	0.82	0.45	3.29	2.41	48.33	24.99	16.7	5.3	0.44	12.1	30.4	13.8	55.8
P-5	A	0-10	141.3	4.99	3.61	0.70	0.34	0.18	0.02	0.76	0.45	4.75	2.00	26.23	15.90	13.6	53.0	3.41	15.5	26.9	9.3	63.8
	AB	10-21	37.8	5.33	3.80	0.10	0.26	0.08	0.02	0.53	0.33	2.77	0.99	16.67	18.96	18.8	6.5	0.39	16.9	17.8	15.0	67.2
	B	21-31	30.7	5.56	3.74	0.12	0.79	0.11	0.02	0.76	0.43	3.17	1.79	32.59	23.85	19.8	4.9	0.39	12.6	20.2	15.3	64.5
	C	31-75+	22.5	5.76	3.72	0.30	1.23	0.13	0.01	0.90	0.57	3.17	2.57	52.62	28.52	8.4	4.7	0.39	12.1	28.4	15.4	56.2

Abbreviations: EC, electric conductivity; pHW and pHK, pH measured in water and 1N-KCl solution; CEC, cation exchange capacity; ECEC , Ca+Mg+K+Na+Al; B.S., base saturation ((Ca+Mg+K+Na)/CEC × 100) ; Al.S., Aluminum saturation(Al/CEC × 100); Av. P., available phosphorus ; T-C and T-N ; total carbon and total nitrogen ; C/N, (T-C)/(T-N).

Chemical and mineralogical properties

Among the chemical properties, soil acidity showed most significant difference between DEF and (FP)DDF soils. Soils at P-1, P-2, and P-3 showed pH values lower than 5.6 and its average is about 5.1. On the contrary, DDF soils (P-4) showed pH values more than 6.0. The pH value of FPDDF soils (P-5) ranged from 5.0 to 5.8. In the DEF forest, surface soils are always covered by the vegetation all the year, and therefore, affected by the organic matter supplied from the vegetation. This leads to the acidification of surface soils. On the other hand, the subsoils of DEF showed the higher exchangeable Al content than those of DDF and FPDDF, which can be a source of strong acidity. In the DDF, surface vegetational cover is burnt out every year, which provides exchangeable Ca to raise the pH value and suppress the acidity produced by exchangeable Al. Soils at FPDDF showed an intermediate nature between those at DEF and DDF.

The effect of burning is also observed in the available phosphorus content (Av-P) in the DDF soils. As generally accepted, phosphorus is supplied only through the decomposition of the organic matter derived from vegetation and phosphate anion is very difficult to leach out chemically from the pedon. The Av-P can be detected only at the surface soil of DEF because there is no fire and the nutrient cycle is limited only at the very surface of the land. In the shallow soils (P-2 from DEF, P-4 from

Table 4. Charge and mineralogical properties of the soils studied.

Soil sample	Horizon	Depth cm	Alo	Sio	Feo	Ald	Sid	Fed	Alo/Ald	Feo/Fed	ZPC	σ p	Mt.	HIV.	It.	Kt.	Gb.	Gt.	Qz.
			%									$cmol_{(+)}kg^{-1}$							
P-1	A/AB	0-5	0.09	0.01	0.02	0.26	0.03	1.87	0.35	0.01	3.96	1.06		±	±	++++	±	±	+
	AB/BA	5-10	0.12	0.01	0.04	0.27	0.08	2.03	0.44	0.02	4.03	0.54		±	±	++++	±	+	+
	BA	10-20	0.14	0.01	0.02	0.32	0.06	2.60	0.43	0.01	4.19	0.39		+	±	++++	±	+	+
	Bw/C1	20-40	0.12	0.01	0.02	0.34	0.06	2.69	0.37	0.01	3.79	1.40		+	±	++++	±	±	+
	C1/C2	40-60	0.14	0.01	0.01	0.42	0.07	3.54	0.33	0.00	3.70	1.77		±	±	++++	±	±	+
	C2/C3	60-80	0.12	0.01	0.01	0.21	0.05	2.57	0.56	0.00	4.09	0.75		+	±	++++	±	±	+
P-2	A	0-5	0.12	0.01	0.02	0.23	0.07	1.71	0.53	0.01	3.75	1.50		±	±	++++	±	±	+
	AC	5-12	0.15	0.01	0.03	0.27	0.05	2.00	0.57	0.01	3.85	1.08		±	±	++++	±	±	+
	C1	12-25	0.17	0.01	0.02	0.40	0.07	2.88	0.42	0.01	4.07	0.50		±	±	++++	±	±	+
	C2	25-50	0.17	0.01	0.04	0.40	0.05	3.31	0.43	0.01	4.05	0.75		±	±	++++	±	±	+
P-3	A	0-5	0.05	0.01	0.04	0.04	0.09	0.64	1.23	0.06	4.28	0.71		±	±	+++	±	±	++
	AB	5-10	0.10	0.01	0.03	0.17	0.08	1.44	0.58	0.02	3.55	1.14		+	±	++++	±	±	+
	AB/BA	10-20	0.11	0.01	0.02	0.19	0.07	1.66	0.57	0.01	3.57	1.07		+	±	++++	±	±	+
	BA/Bt1	20-40	0.14	0.01	0.02	0.19	0.06	1.73	0.72	0.01	3.75	0.79		+	±	++++	±	±	+
	Bt2/BC	40-60	0.12	0.01	0.01	0.22	0.05	2.00	0.54	0.01	3.87	0.50		+	±	++++	±	±	+
	BC	60-80	0.11	0.01	0.01	0.21	0.23	1.90	0.52	0.01	3.64	0.64		+	±	++++	±	±	+
	C	80+	0.11	0.01	0.01	0.22	0.05	2.63	0.48	0.00	3.64	0.66		±	±	++++	±	±	+
P-4	A	0-7	0.06	0.01	0.02	0.05	0.09	0.90	1.21	0.02	2.72	1.40	±	±	±	++++	±	±	++
	AC	7-10/15	0.04	0.01	0.02	0.06	0.04	1.16	0.60	0.01	2.86	1.50	±	±	+	+++	±	±	++
	C	10/15-17/51	0.08	0.01	0.02	0.14	0.06	1.95	0.56	0.01	3.35	1.93	±	+	±	++++	±	±	+
P-5	A	0-10	0.09	0.01	0.02	0.14	0.06	1.18	0.64	0.02	3.23	2.08	±	+	±	++++	±	±	+
	AB	10-21	0.05	0.01	0.02	0.05	0.04	0.65	0.96	0.03	3.54	0.71	±	±	±	+++	±	±	+++
	B	21-31	0.07	0.01	0.03	0.07	0.05	0.95	1.01	0.03	3.09	1.54	±	+	±	++++	±	±	++
	C	31-75+	0.08	0.01	0.02	0.13	0.06	1.53	0.62	0.01	3.14	1.01	±	+	+	+++	±	±	+

Abbreviations: Alo, Sio and Feo, acid-oxalate extractable Al, Si and Fe.
Ald, Sid and Fed, dithionite-citrate-bicarbonate extractable Al, Si and Fe.
ZPC and σ p, zero point of charge and remaining charge at ZPC determined by the STPT method.
Clay minerals: Type; Mt., Montmorillonite; HIV., Hydroxy-interlayered vermiculite; It., Illite; Kt., Kaolinite; Gb., Gibbsite; Gt., Goethite; Qz., Quartz; Abundance; ±, 0-5(%); +, 5-20; ++, 20-40; +++, 40-60; ++++, >60

DDF, and P-5 from FPDDF), which contained a lot of rocks in the shallow position of the profile, the Av-P content is higher than the other soils down to the depth of 50 cm. This is probably due to the transport of surface soil particles with phosphorus into the deeper part of the solum along the rock surface. Even though the Av-P content is very low for all soils studied here, we can evaluate the site characteristics.

Cation exchange capacity (CEC) is clearly corresponding to the amount of clay for all soils. This means the mineral particles themselves show a very similar nature. The surface soils of P-4 (A and AC layers) showed a higher CEC/Clay ratio. Since the clay content of these layers is much lower than other soils, organic matter can be an important source of cation exchanger. Thus, discussion will be included in clay content mentioned below.

Clay content are higher in DEF soils than DDF and FPDDF soils. Among them, the soils at P-3 shows the highest clay content throughout the profile. This shows the soil materials at P-3 is colluvium. Finer particle has been continuously supplied by the surroundings and accumulated here. Another cause of the relatively uniform soil particle distribution can be termite activity. Termite uses only finer particles to build up their nest up to the soil surface. No gravels at the upper part of P-3 pedon may be one of the proof of termite activity. On the other hand, the layer at depth of 60-80 cm showed a lower content of clay in the P-1 pedon. This layer may not be strongly weathered yet and remains the nature of the parent materials, becasue this position has little slope and relatively stable condition for weathering and no proof of soil erosion was observed. In the shallow soils (P-2 from DEF and P-4 from DDF), the clay content is higher in the deeper part of the solum. As mentioned above, clay particles was transported into the deeper part along the rocks. Soils at FPDDF (P-5) showed the clay content from 18 to 28 % and almost equivalent to that of C layer of P-4 (DDF). Without surface erosion under the naked soil surface such as at P-4, clay particles remains as high as this level. However, clay content of P-5 soils was lower than that of P-1 soils. The parent materials of P-1 and P-5 is rather similar but the content of shale interbeded with or overlying sand stone may be different because the weathering of shale would produce more clay than sand stone. On the other hand, the former soil erosion would be more severe in P-5 than P-1.

Aluminum and iron extracted with acid-oxalate (Alo and Feo) showed very low values of less than 0.2 % and 0.4 %, respectively, for all soils. On the other hand, iron extracted with dithionite-citrate-bicarbonate (Fed) is in the moderately higher range more than 1.0 % (except some surface soils), even though the parent materials are mostly acidic sand stone. Activity ratio of iron (Feo/Fed) is also very low (less than 0.03). Clay minerals are mostly kaolins with significant amounts of quartz. These data indicate that the soil materials (derived from sand stone) here are strongly weathered. On the other hand, ZPC values are very low and the remaining charge at ZPC (σ p) also not as large as 2.0 cmol (+) kg^{-1}. Especially, the ZPC values of soils at P-4 and P-5 were very low (lower than 3.5). Sakurai *et al.* (1988, 1996) determined the ZPC values of several Thai forest soils and showed that very low ZPC values represented the strongly weatherd nature of the sandy soils. On the other hand, ZPC values of P-1, P-2, and P-3 soils were slightly higher than those of P-4 and P-5. Depletion of iron and aluminum, which block the permanent negative charge of the clays and shift the ZPC value into higher pH range (Sakurai *et al.* 1989), are more intense for DDF soils than DEF soils. These results can be ascribed to the erosion of the surface soil particles and depletion of the surface coatings of aluminum and iron due to direct influence of the alternative wet and dry moisture conditions in the DDF. ZPC value of sandy silicious soils will become lower value in pH as the weathering proceeds (Sakurai *et al.* 1990).

CONCLUSION

As a result of the soil analysis from various aspects, such as soil hardness, soil morophological, physical, chemical, and mineralogical properties, the current vegetation in the SERS seems to be affected greatly by the strength of the impacts given to the forest. The DDF and FPDDF are located close to the highway and the road condition is good because these forests are on the way to the SERS office. While, the DEF is 3 km apart from the DDF and the road condition is much worse. Thus, the DDF and FPDDF may have been affected continuously by the human activity than the DEF. Once the vegetation was destroyed by fire or some other causes, forest fire might have occurred every dry season. If no fire protection is attempted, soil erosion due to loss of organic matter on the surface soil is easily brought about. The stronger the impact of fire is, the more the soil erosion occurs. Since the in-situ formation of fine soil particles is much slower than the loss of soil prticles through erosion, soil physical properties such as clay content and associated properties (water holding capacity, cation exchange capacity, water permeability, and moisture content) become worse easily and shortly.

On the basis of soil properties, the following mechanism can be suggested to explain the current distribution of the vegetation; once the original vegetation is destroyed, DEF type forest could not regenerate easily in such a dry and infertile soil condition. As a result, the other type of vegetation, i.e., DDF, will be established. The extremely dry soil condition currently found in the DDF during dry season is not intrinsic property of a forest soil. It is created by the removal of the vegetation which used to be there. The fire protection treatment may contribute to recover the appropriate amount of the soil moisture and organic matter for the maintainance of vegetation through prevention of soil erosion. This mechanism may partly explain the current broad distribution of DDF in northeast Thailand. At present, fire protection treatment is not common practice in the local area, and thus, we can not confirm it in the field efficiently. However, the various soil properties of the FPDDF can be considered in the intermediate condition between those of DDF and DEF. We shoud had better survey this area again in the future to confirm the mechanism above mentioned.

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櫻井克年，田中伸一，石塚悟史，神崎護　サケラート環境研究所の乾性常緑林と乾性落葉林の土壌の性質の違い

東北タイにあるサケラート環境研究所 (SERS) において土壌ー植物間の関係を明らかにするために，２つの主要な森林タイプ，すなわち，乾性常緑林 (DEF) と乾性落葉林 (DDF) において土壌調査を行った。乾季に植被が存在することによる土壌・植生への保護効果を調べる目的で，1967 年から防火措置が行われている乾性落葉林 (FPDDF) も調査対象に加えた。土壌の硬度，断面形態，物理性，化学性，鉱物性，などの解析の結果，SERS内の現在の植生は，森林に及んだインパクト（主に火災）の期間の長さに大きく左右されているようであった。もしDDFで防火措置が行われていなければ，表土からの有機物の流失によって土壌侵食は容易に起こる。土壌侵食の後には，土壌の粘土含量とそれに関わる性質，すなわち，保水力，陽イオン交換容量，透水性などは，容易かつ速やかに劣悪化する。

FPDDF 内の土壌の種々の性質は，DDF と DEF の中間的な状況にあると考えられた。火災のインパクトが強いほど，土壌侵食はより強くなる。そこで，得られた結果を基に，現在の植生タイプの分布を説明するメカニズムを次のように考えた：乾燥した低肥沃度の土壌では，一度DEFタイプの森林植生が破壊されると容易には再生不能である。そのため，他のタイプの植生，すなわち，DDF が現在，東北タイの至る所にみられるようになった。DDF にみられる極端に乾燥した土壌条件は，森林土壌の本質的な性質ではない。かつて存在した植被の除去によって創り出されるものである。防火措置の行われている DDF がそのことを示唆している。