A STUDY OF THE MORPHOLOGICAL, PHYSICAL AND CHEMICAL CHARACTERISTICS OF SOILS AS INFLUENCED BY TEAK VEGETATION

By

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THESIS

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CERTIFICATE

This is to certify that the thesis herewith submitted contains the results of bonafide research work carried out by Shri. A. I. Jose under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

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INTRODUCTION

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It has long been recognised that vegetation exerts a decisive influence on the morphological, physical and chemical properties of soils. Considerable amount of work has been done on vegetation as a soil-forming factor in the temperate regions, but very little information is available regarding the influence of vegetation on soil characteristics under tropical and sub-tropical conditions.

Jenny (1941) in his discussion on organisms as a soil-forming factor, treats vegetation both as an independent and as a dependent variable. In order to ascertain the role of vegetation as an independent variable it should be possible to study the properties of the soil as influenced by the vegetation, while all other soil-forming factors such as climate, parent material, topography, and time are maintained at any particular constellation. Hence, under natural conditions, it is often difficult to estimate reliably the influence of vegetation on soil properties. But this aspect becomes particularly simple and easily evaluated whenever Man controls the vegetational cover, as in all agricultural and many silvicultural practices. A classic example of this problem is provided by the teak(<u>Tectona grandis</u> Linn.)

plantations of the Nilambur Range, Calicut District, where teak plantations of varying stages of growth and natural forests exist adjacently in areas of apparently identical climate, parent material, topography and age.

The teak plantations at Nilambur date back to the year 1846 when the systematic planting of teak was begun. It may be mentioned here that the oldest teak plantation in the world (Conolly's Teak Plantation) is situated in this area. Further, plantations of any age from 1 year to more than 120 years are also available in this region. Hence the Nilambur forest area presents an excellent site for a scientific study of the influence of teak on the morphological, physical and chemical characteristics of soils.

In the Nilambur plantations, with which the present study is mainly concerned, the best quality teak occurs along the banks of the rivers and the quality deteriorates as one moves away from the riverain alluvium, particularly on hill slopes. It has been suggested that the soil gets deteriorated during the course of forming and maintaining a teak plantation away from the riverain alluvium. Observational evidence indicates that this deterioration of soil is mainly due to the hardening of the surface soil under pure teak, probably from exposure and surface erosion. It is also believed that clear-felling of forests and planting of teak will hasten the process of laterization, making the soil unfavourable for the growth of teak. This process of laterization is not clearly detected in the first rotation crop but becomes pronounced afterwards.

From theoretical considerations, it would appear that some changes in soil conditions are bound to occur following the removal of natural forests and planting of teak, for the equilibrium between the vegetation and soil is affected as a result of these silvicultural operations. But a general survey of literature shows that practically no scientific work has been done along this line to prove that any deterioration of the soil takes place under pure teak. The situation, therefore necessitates the carrying out of a systematic study of this controversial problem. This work was, therefore, undertaken with the following objectives:

1. To study the extent to which the morphological, physical and chemical properties of soils are affected by the clear-felling of trees followed by the planting of teak.

2. To assess the deterioration, or otherwise, of the nutrient status of the soils consequent on deforestation and replanting.

3. To find out the effect of silvicultural activities on the chemical composition of the clay.

The details of the investigation undertaken with the above objectives are presented and discussed in the following pages.

REVIEW OF LITERATURE

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It is now universally accepted that the soil is a natural historic body reflecting the influence of various soil-forming factors.

According to Dokuchaev (1889) "the soil is the result of the combined activity and reciprocal influence of parent material, plant and animal organisms, climate, age of the land, and topography".

Joffe (1936) classified the factors involved in the process of soil formation into two, active and passive. According to him the passive factors (or soil formers) represent the constituents which serve as the source of the mass (mineral matter) and some environmental conditions which affect it. They comprise the parent material, the topography, and the age of the land (the time factor). The active factors of soil formation are represented by agents supplying the energy that acts upon the mass and furnish reagents for the process of soil formation. The elements of the biosphere, the atmosphere, and the hydrosphere are representatives of this class of factors.

Jenny (1941) gave a new concept of soil-forming factors. He divided the factors involved into two groups - the independent variables and the dependent variables and only the independent variables were treated as the soil-forming factors or the soil formers. Thus climate, organisms, topography, parent material, and time were recognised as independent variables while soil reaction, organic matter, soil colour etc. represented the dependent variables.

Vegetation as a Soil-forming factor

Marbut (1932), in his notes on the relation of soil type to environment, considered vegetation as the most important soil-forming factor.

According to Nikiforoff (1935) the more important profile features are mainly determined by the nature of the plant cover. But Robinson (1935) has treated vegetation only as a dependent factor, since it is itself closely governed by situation, soil, and climate.

In his discussion on biosphere as a factor of soil formation, Joffe (1936) stated that plants acted directly and indirectly as a factor of soil formation. The type of vegetation - grassland or timber - and the physiological functions of the plants and their composition influenced the profile constitution.

Jenny (1941) recognised vegetation both as an independent and as a dependent variable. To illustrate the role of vegetation as an independent variable he referred the prairie-timber transition zone where two divisions of vegetation namely virgin forest and virgin prairie lived adjacently, although other factors like parent material, climate, topography, and age did not differ much. From this study he observed the following.

i. The total nitrogen and organic matter were more abundant in prairie than in forest soil. The carbon:nitrogen ratio was wider for the forest. In the forest an abrupt change of organic matter with depth was noted.

ii. The silica:alumina ratio was slightly higher under forest than under prairie, indicating that translocation of alumina had been hastened.

iii. The base:alumina ratio was high for prairie and low for timber, especially in the lower horizons. The amount of exchangeable bases and degree of base saturation were invariably higher in the grassland profiles.

iv. Under timber there was a great translocation of minerals and a lower pH.

Based on these observations he concluded that under equal climatic circumstances a deciduous forest cover stimulated leaching and accelerated soil development more than a prairie vegetation.

Solovev (1954) reported that the properties of a light chestnut soil were modified under the influence of forest plantations. The thickness of the humus horizon was increased by 10 to 12 cm. and leaching of carbonates was hastened. The soil in the forest cover still showed more exchangeable calcium than in steppe soil, perhaps due to the addition of calcium in the leaf fall. He believed that a forest altered a light chestnut soil so that it came to resemble a chernozem soil.

Duchaufour (1954) compared analogous climax soils under oak in the Atlantic region and under fir in Vosages. Both were brown soils with mull humus. The regression of soils under oak led to rendzina on calcareous parent material, and to gleyed peat on compact clayey material. There was an accelerated degradation to podzol on soils under fir. Regeneration of degraded soils containing raw humus into brown forest soils was possible by mixed stands of deciduous and coniferous trees, provided podzolization was not too far advanced at the time of reforestation.

Nakata (1954), from his comparison between forest soil in natural forests and in forests cleared and planted with fir, reported that both soils showed almost the same mechanical composition, but chemical composition was poorer and pH, carbon:nitrogen ratio, absorptive capacity, organic matter content, and exchangeable calcium were lower in the planted area which had been clear cut thirty three years before.

From a comparison of young and old forest stands, Ovington and Madgwick (1957) suggested that in the forest soil the greatest change in soil acidity occurred in the first 25 years after planting.

Skorodumov (1959) evaluated the chernozem soils under two different vegetations, the forest and the steppe. The fields surrounded by forests were free of carbonates, chlorides, and sulphates down to the ground-water level while chernozem in the steppe was rich in carbonates, sulphates, and water soluble salts.

Pathak et al. (1964), in a catena study of the physical and chemical properties of soil under cultivation and under forest cover, found that porosity, water holding capacity, sticky point moisture, and hydraulic permeability of soils under forest cover were higher than those of soils under cultivation. The forest soils exhibited more aggregation than the cultivated normal soils. The aggregates were also larger in size. The cation exchange capacity was higher for soils under timber while the silica:sesquioxide ratio showed a decreasing tendency. The data for dispersion ratio of soils under cultivation indicated that these soils were more susceptible to erosion.

Robinson et al. (1966) observed no significant differences in physical properties of soils under indigenous forest and under a 16 year old tree plantation while he obtained distinct differences in chemical properties, particularly between the two top soils.

Effects of clear-felling

Muller (1887) found that soils having a mor type humus layer benefited frequently by deforestation. It led to decomposition of organic matter, decreased acidity and hastened nitrification by activating soil fauna.

Ehrenburg (1922) stated that the removal of forest canopy and burning resulted in erosion and the subsequent removal of fertile surface soil. Substantial amounts of calcium, magnesium, potassium, and phosphorus were lost by leaching. The favourable effects noticed were a decrease in acidity and the quick oxidation of organic matter.

In a 21 year experiment to determine the effect of the removal of litter and duff on tree growth, Delovoy (1926) showed that the removal of forest soil covering retarded the growth, the loss being greatest when the litter was removed every year.

Davidson (1926) concluded that clear-cutting caused the washing away of lime, increased leaching and resulted in complete destruction of forest organisms.

Trimble and Tripp (1949) reported that removal of timber resulted in erosion and humus destruction. Opening the stand increased air movement and facilitated the oxidation of soil humus and compaction of soil. In cleared areas, after 30 years, all the organic matter disappeared from the surface which accompanied active sheet erosion. They observed that a humus layer began to form, when 30 to 40 years elapsed after establishing a new stand. After 50 years the organic matter was still patchy and the mineral soil layer still compact. Stands of 100 year old developed a good humus layer and the mineral soil was loose and moist.

Shibata et al.(1951) compared the properties of soil in a 65 year old Hinoki forest and in an adjoining clear-felled area. In the cleared area litter decomposed more rapidly, soil acidity was less and the contents of total nitrogen and exchangeable calcium were higher in the lower horizons than in the forested area.

They concluded that the favourable effects of clear-felling were likely to disappear within a few years.

Duchafour (1953) reported that the destruction of forest cover led to heavy leaching and loss of plant nutrients.

Riquier (1953) concluded that clearing of forests destroyed organic matter and checked its subsequent accumulation, increased the pH and the quantity of assimilable nutrients, and induced erosion. The improvement noticed in physical properties was only temporary. Two crops after clear-felling impoverished the soil of its nutrients to such an extent that reforestation or regeneration of such areas became difficult.

Fuller (1955) found that deforestation caused loss of nitrogen, while the other nutrients got concentrated and changed to more soluble forms. The removal of soluble salts by leaching raised the pH of the soil. A decrease in the carbon:nitrogen ratio to a depth of 8 to 12 inches was also noted.

Referring to the clear-felling of old coniferous stands, Maran (1955) stated that the removal of forest cover reduced the active and exchangeable acidity of the soil. Calcium and potassium became more available to plants in semi-arid regions while the reverse took place in the case of humid slopes.

McDonald (1955) obtained no change in the physical properties of soil as a result of clear-felling. The soils from forests and cleared area showed no difference in their moisture contents.

Coltharp (1960), in a study of the effects of commercial type clear-cutting on soil, found no marked change in soil texture, bulk density, porosity, and permeability after clear-felling trees in the woodlands.

Pathak et al.(1964) obtained a reduction in the cation exchange capacity of the soil consequent on clear-felling and cultivation while the silica:sesquioxide ratio tended to increase after clear-felling.

Nye and Greenland (1964), in a study of the changes in the soil after clearing tropical forests observed that the loss of organic matter was very rapid during the first year after deforestation followed by burning.

Yamaya (1965) obtained morphological changes in the forest litter and changes in the properties of soil organic matter by partial deforestation. After clear-cutting the decomposition of litter was quicker, reducing the thickness of the organic matter layer.

In a study on some forest soils of Kerala, Thomas and Brito-Mutunayagam (1966) reported that the chemical constitution of clay was not altered to any significant extent as a result of deforestation and no depletion in nutrient capital of soil was noticed 2 years after deforestation. But they observed marked changes in the physical conditions of the soil. The favourable structure of the natural forest soil had been adversely affected by deforestation and the soil was subjected to severe erosion.

Chaly and Koshy (1967), in their studies on the effect of deforestation on organic carbon, nitrogen, and potash status of some forest soils of Kerala, found that the organic matter in the surface layer was reduced substantially with increase in the period of denudation. The level of this constituent increased in lower horizons after deforestation, presumably due to increased leaching. Soil denuded for 5 years contained higher amounts of total and exchangeable potassium than in the forest soil, perhaps due to the addition of this element in the form of ash as a result of the burning of the tree stumps. In the profiles denuded for 10 to 15 years there was considerable reduction in the amounts of total and exchangeable potassium in the surface layer. The increased potassium content of the lower horizons of these soils showed that there was enhanced downward movement of this element consequent on denudation.

Growth of teak as influenced by soil conditions

Troup (1921) observed better growth of teak on well drained deep alluvial soils. According to him it required a good subsoil drainage and did not endure stiff soil or one which was liable to inundation or water-logging. Along dry ridges it became stunted and this was also the case on shallow soil. In Madhya Pradesh he noticed a superior growth of teak on soils formed from trap formation, metamorphic rocks and Vindhyan sandstones. Teak performed well on these sedimentary rocks which were leached least by the action of water.

In his studies on the teak soils of Java, Newland (1922) obtained no direct correlation between the chemical properties of soil and the growth of teak, while some of the physical factors in the soil showed a correlation with teak quality. A soil with a high water holding capacity and low permeability in the top as compared with the second layer appeared to be conducive to good teak growth.

Castens (1927) found no justification for planting teak any where but in the alluvial valley soil and on the rarely occurring deep loamy sand and loam on the broader ridges. Teak planted on clay did not grow well, while on the narrow ridges and moderate to steep slopes it died in later years.

Newman (1930) emphasised the necessity of avoiding water-logged soils in selecting sites for planting teak.

Champion (1931) reported that soil aeration caused marked improvement in the growth of teak, partly by prolonging the growing season.

Diebold (1935) found that a deep well drained soil with an alkaline influence in the subsoil was best for the natural hard wood forests, whereas shallow soils and those with poor internal drainage were of low quality for hardwoods.

Davis (1940), from his studies on Nilambur soils with special reference to their suitability for teak, noted that the riverain alluvium was most suited for maintaining good quality teak. Teak plantations away from the riverain alluvium supported only teak of poor quality.

Taggarse (1945) observed that the growth of the teak plantation, after the first 10 years, depended mainly on the nature of the subsoil and the level of the water table. Crop failures occurred due to the hardness of the subsoil.

Based on a detailed study of soil deterioration under teak, Griffith and Gupta (1947) came to the following conclusions.

i. The availability of water influenced the growth of teak even where the composition of the soil and aspect did not markedly change. In Nilambur teak plantations drainage and proximity to main rivers exercised considerable influence on the quality of teak.

ii. General topography and aspect appeared to affect the growth of teak. The hill-top topography was most disadvantageous while the cool northerly aspect and foot-hill alluvium sites were most suitable.

iii. The immaturity of soil helped the growth of teak.

iv. The dispersion coefficient was low in the soils of the areas where the quality of the teak was poor.

Afanasiev (1948) found that soils with high clay content were unsuitable for tree growth. Some soils with 1 ppm. nitrogen, phosphorus or potassium maintained vigorous plantations; the presence of these elements in larger amounts did not necessarily correlate with good or even fair growth. The pH over the range of 4.9 to 8.8 showed no marked effect on tree behaviour. When other factors were favourable, the presence of mottlings within a depth of 36 inches indicated a site of poor quality.

Bhatia (1954) obtained direct correlation between teak growth and soil fertility factors, such as hydrogen ion concentration, exchange capacity, calcium, magnesium, and phosphorus; but no direct correlation was found for nitrogen, organic matter, and carbon:nitrogen ratio.

Boonkird et al. (1960) suggested that the site quality for teak was not clearly related to differences in hydrogen ion concentration, organic matter content, or readily extractable phosphorus in the 15 cm. of top soil or in the 30 to 35 cm. subsoil layer. Impeded drainage, coarse texture, or the occurrence of bed rock at a shallow depth were associated with poor site quality, whereas profiles permitting deep penetration of roots and containing moderate to high quantities of bases were of superior site quality. The site quality increased with increasing moisture storage capacity.

In North Bengal, Ghosh (1965) observed that the suitability of site for teak was determined primarily by the depth of soil and drainage, though the surface conditions varied widely within a restricted zone.

Yadav (1968) reported that teak attained better quality on moist soils developed from basalt, which was acidic and had adequate amount of exchangeable calcium and satisfactory levels of available phosphorus.

Soil deterioration under teak

According to Newland (1922) teak was likely to cause soil deterioration as the site of plantation become old. In Java he found that the site quality decreased as a result of regular planting of teak after the felling of the old woods.

Richmond (1928), from a study of soil deterioration and lowering of site quality under teak, suggested that good aeration of the soil promised to be the solution to this difficulty with second rotation teak.

Champion (1932, 1939) stated that deterioration of soil under teak was not proved but observational evidence indicated that the surface soil hardened under pure teak, probably from exposure and drip action, and that surface erosion occurred on slopes sometimes resulting in fire injury to exposed roots.

Davis (1940), in his preliminary note on

Nilambur soil, reported that the soil got deteriorated during the course of forming and maintaining a teak plantation away from the riverain alluvium and it either caused a poor quality teak or became entirely unsuitable for it. He believed that laterite rock was either exposed or formed consequent on the clear-felling and planting of teak.

Teak, being a light-demander and intolerent of crown friction, Mirchandani (1941) stated that the ground under pure teak remained sufficiently exposed. This deciduous plant shed all foliage quickly early in dry weather, and for nearly six or seven months the forest floor was exposed to burning sun and wind.

Laurie and Griffith (1942), in a study of the problems of pure teak plantation, found that deterioration of soil under teak took place reducing increment and total volume production. Soil erosion was unduly rapid resulting in damage to roots of the trees and in loss of increment. Experimental proof for any deterioration of the soil taking place under pure teak plantation was lacking, though theoretical considerations led them to believe that some such changes were likely. The soil moisture relations appeared to be some what changed under pure teak crop, possibly on account of lower permeability of soil. Occasionally such areas turned swampy after clear-felling.

Taggarse (1945) reported that exposure of soil by the removal of natural forests led to soil erosion, and epicormics were produced by hard subsoil in pure teak plantation. He urged the need of growing another species in the second rotation to avoid the deterioration of soil. Some others have observed that the growth of teak appeared to be influenced by the accumulation of sesquioxides in deteriorating soils of teak plantations, and by the tendency of silica to leach out in such soils. The molecular ratio of silica:sesquioxides appeared to be correlated with the quality of the teak (Anonymous, 1946).

Griffith and Gupta (1947), referring to the problem of laterization in Nilambur teak plantations, reported that the deterioration of soil under pure teak took place not due to the formation of laterite, but perhaps by the hardening of the lateritic type of soil which was detrimental to teak. The molecular ratio of silica:sesquioxides seemed to be correlated with the quality of teak unless some factors eg. existence of a laterite under a shallow depth of soil, excessive boulders in soil, or extra high water table occurred.

MATERIALS AND METHODS

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Profile sites were selected to represent the following 6 types of vegetation.

(1) Natural forests
(Profiles 1, 2, 3 and 4)

(2) 1 year old teak plantation
(Profiles 5, 6, 7 and 8)

(3) 15 year old teak plantation
(Profiles 9, 10, 11 and 12)

(4) 30 year old teak plantation
(Profiles 13, 14, 15 and 16)

(5) 60 year old teak plantation
(Profiles 17, 18, 19 and 20)

(6) 120 year old teak plantations
(Profiles 21, 22, 23 and 24)

In each of the above areas profile pits were made to a depth of 180 cm. The morphological features of each profile were noted and soil samples collected from the different horizons. In cases where the horizon differentiation was not sufficiently clear samples were collected from depths of 0 to 30, 30 to 90 and 90 to 180 cm.

As indicated above the profiles from the natural forests were numbered from 1 to 4, whereas profiles 5 to 8, 9 to 12, 13 to 16 and 17 to 20 were from teak plantations of age 1, 15, 30 and 60 years respectively. Profile 21 was collected from Conolly's Teak Plantation Preservation

Plot where teak trees as old as 120 years are still preserved. Profile 22 was from an area where teak was planted 120 years ago as in the case of the preservation plot, but where the trees failed to come up satisfactorily. The site now presents only a few old teak trees grown here and there. Profile 23 and 24 were from areas where planting began 120 years ago but the present vegetation consists of second rotation teak of very poor quality. With these reservations, profiles 21 to 24 were treated as from teak plantations of age 120 years. In the selection of the profile sites special care was taken to see that the areas selected were of uniform topography and free from local influences.

Laboratory investigations

The soil samples collected from each profile were brought to the laboratory, ground, and passed through a 2 mm. seive. The samples thus prepared were stored in 1 kg glass bottles and used for the following studies.

(i) Physical determinations

The mechanical composition of the soils was determined by Troell's method as described by Wright (1939). Apparent density, absolute specific gravity, maximum water holding capacity, pore space and volume expansion of the soils were also determined in the manner described by the above author using a Keen-Raczkowski box. The moisture equivalent was calculated by the indirect method using the formula:

$$\text{Moisture equivalent} = (\text{Moisture holding capacity} - 21) \times 0.635$$

(ii) <u>Chemical analysis of the soils</u>

The chemical analysis of the soil samples was carried out by adopting standard analytical procedures as given by Jackson (1958).

(iii) <u>Separation and analysis of clay fraction</u>

The clay fraction from the two upper layers of each profile was separated and analysed for silica, alumina and iron oxide by following the methods suggested by Sankaram (1966).

RESULTS

RESULT

MORPHOLOGICAL CHARACTERS OF SOIL PROFILES

The morphological features of the profiles studied are described below.

Profile I

Location:	Natural forests, Karulai Range, Nilambur Division.
Elevation:	300 to 375 m.
Topography:	Level
Vegetation:	Trees like *Xylia xylocarpa* (Xylia), *Dalbergia latifolia* (rose wood), *Swietenia mahogony*, *Lagerstroemia speciosa*, *Lagerstroemia lanceolata* etc; and surface covered by herbaceous perennials and annuals.
Depth (cm.) 0 to 10	Dark reddish brown (5 YR 3/2); sandy clay; crumb; noncalcareous; well drained; abundant fibrous roots; few gravel of diameter up to 8 mm.; clear and wavy boundary.
10 to 30	Dark reddish brown (5 YR 3/3); clayey; compact; noncalcareous; fairly well drained; abundant roots; few gravel of diameter up to 5 mm.; diffused boundary.
30 to 90	Dark reddish brown (5 YR 3/4); clayey; blocky; poorly drained; few roots; very few concretions; clear and wavy boundary.
90 to 180	Reddish brown (5 YR 4/4); sandy clay loam; granular; noncalcareous; moderately drained; roots absent; no concretions; large stones present.

Profile 2

Location:	Natural forests, Karulai Range, Nilambur Division.
Elevation:	300 to 375 m.
Topography:	Level
Vegetation:	Trees like *Terminalia paniculata*, *Terminalia tomentosa*, *Grewia teliaefolia*, *Calophyllum inophyllum* etc.; surface covered by *Cleistanthus collinus*, *Desmodium* spp. *Calycopteris floribunda* and *Helicteres isora*.
Depth (cm.) 0 to 10	Very dark brown (10 YR 2/2); loam; crumb; noncalcareous; well drained; abundant roots; few gravel of diameter up to 6 mm.; boundary not distinct.
10 to 30	Dark brown (10 YR 3/3); clay loam; compact; noncalcareous; moderately drained; abundant roots; few concretions of diameter up to 5 mm.; diffused boundary.
30 to 90	Dark reddish brown (5 YR 3/4); loam; granular; fairly well drained; few large roots; few concretions; irregular and broken boundary.
90 to 190	Reddish brown (5 YR 4/4); loam; granular; well drained; roots absent; very few concretions; noncalcareous.

Profile 3

Location:	Natural forests, Karulai Range, Nilambur Division.
Elevation:	300 to 375 m.
Topography:	Level
Vegetation:	Trees like *Dalbergia latifolia*, *Lagerstroemia flos-reginae*, *Swietenia mahogony*, *Xylia xylocarpa*, *Artocarpus hirsuta*, *Dysoxylum malabaricum*, *Terminalia* spp. etc. and undergrowths like *Calycopteris floribunda*, *Eupatorium odoratum*, *Helicteres isora*, *Glycosmis pentaphylla* and *Desmodium* spp.

Depth (cm.)
0 to 10 — Dark reddish brown (5 YR 3/2); sandy clay loam; crumb; noncalcareous; well drained; abundant roots; pebbles and quartz grains up to size 10 mm. diameter; highly diffused boundary.

10 to 30 — Dark reddish brown (2.5 YR 3/4); sandy clay loam; granular; noncalcareous; well drained; few roots; few gravel up to diameter 1 cm.; boundary not clear.

30 to 90 — Dark reddish brown (2.5 YR 3/4); sandy clay loam; granular; noncalcareous; moderately drained; few roots; very few concretions; occasional yellow mottlings; boundary smooth and clear.

90 to 180 — Reddish brown (5 YR 4/4); sandy clay loam; blocky; fairly well drained; roots absent; quart grains of diameter of 0.25 to 0.5 cm. distributed throughout.

Profile 4

Location: Natural forests, Karulai Range, Nilambur Division.

Elevation: 300 to 375 m.

Topography: Level

Vegetation: Trees like Grewia tiliaefolia, Dillenia pentagyna, Bombax malabaricum, Lagerstroemia spp. Dalbergia latifolia etc.; surface covered by various shrubs, herbs and grasses.

Depth (cm.)
0 to 10 — Very dark greyish brown (10 YR 3/2); loam; crumb; noncalcareous; well drained; abundant fibrous roots; quartz grains and gravel up to diameter 1 cm.; boundary gradual and diffused.

10 to 30 — Dark reddish brown (5 YR 3/3); sandy clay loam; structureless; abundant roots; noncalcareous; well drained; no mottlings; clear and well defined boundary.

30 to 90 — Dark reddish brown (2.5 YR 3/4); sandy clay loam; structureless; noncalcareous; moderately drained; few large roots; dark red and yellow mottlings prominent; boundary wavy.

90 to 180	Reddish brown (5 YR 4/4); sandy clay loam; no structure; friable; few iron concretions; red and yellow mottlings common; roots absent; few pieces of granite and gneiss.

Profile 5

Location:	Kanhirakadavu, Karulai Range, Nilambur Division.
Elevation:	150 to 200 m.
Topography:	Level
Vegetation:	1 year old teak plantation (Teak planted in 1966).
Depth (Cm.) 0 to 30	Very dark grey (5 YR 3/1); sandy clay loam; granular; compact; noncalcareous; gravel up to diameter 1 cm. abundant; few fibrous roots; well drained; few mottlings; boundary clear and wavy.
30 to 90	Dark reddish brown (5 YR 2/2); sandy clay; granular; noncalcareous; well drained; very few roots; yellow and red mottlings present; diffused boundary.
90 to 180	Dark brown (7.5 YR 4/4); sandy clay loam; blocky; noncalcareous; moderately drained; yellow and red mottlings prominent; small rock pieces present; roots absent.

Profile 6

Location:	Kanhirakadavu, Karulai Range, Nilambur Division.
Elevation:	150 to 250 m.
Topography:	Level
Vegetation:	1 year old teak plantation (Teak planted in 1966).

Depth (cm.) 0 to 30	Very dark brown (10 YR 2/2); sandy clay loam; granular; well drained; few fibrous roots; concretions abundant; yellow mottlings common; noncalcareous; friable; highly diffused boundary.
30 to 90	Dark brown (7.5 YR 3/2); sandy loam; structureless; extremely well drained; noncalcareous; roots absent; quartz grains many; definite and wavy boundary.
90 to 180	Dark brown (7.5 YR 4/2); sandy clay loam; granular; well drained; yellow mottlings prominent; few rock pieces (gneiss and granite) present; roots absent.

Profile 7

Location:	Kanhirakadavu, Karulai Range, Nilambur Division.
Elevation:	150 to 200 m.
Topography:	Level
Vegetation:	1 year old teak plantation (Teak planted in 1966).
Depth (cm.) 0 to 30	Dark reddish brown (5 YR 2/2); loam; granular; well drained; few fibrous roots; concretions abundant; well drained; gravel up to size 5 mm. diameter; boundary clear and wavy.
30 to 90	Dark reddish brown (5 YR 3/4); sandy clay loam; blocky; moderately drained; noncalcareous; very few roots; few concretions; diffused boundary.
90 to 180	Light yellowish brown (2.5 YR 6/4); sandy loam; structureless; loose and friable; extremely well drained; quartz grains abundant; yellow and red mottlings common; mixed with lateritic stones; roots absent.

Profile 8

Location:	Kanhirakadavu, Karulai Range, Nilambur Division.

Elevation:	150 to 200 m.
Topography:	Level
Vegetation:	1 year old teak plantation (Teak planted in 1966)
Depth (cm.) 0 to 30	Very dark grey (10 YR 3/1); loam; granular; well drained; roots abundant; noncalcareous; few iron concretions; occasional mottlings; boundary gradual and diffused.
30 to 90	Dark brown (10 YR 3/3); clayey; blocky; poorly drained; few large roots; concretions absent; boundary wavy.
90 to 180	Very pale yellow (10 YR 7/3); sandy clay; granular; moderately well drained; no roots; red and yellow mottlings highly prominent; mixed with lateritic stones and weathered parent material in the process of laterization; merges with the laterite bed below.

Profile 9

Location:	Karulai Range, Nilambur Division
Elevation:	150 to 200 m.
Topography:	Level
Vegetation:	15 year old teak plantation (Teak planted in 1952).
Depth (cm.) 0 to 30	Dark reddish brown (5 YR 2/2); sandy clay loam; structureless; well drained; roots abundant; noncalcareous; large sized gravel of diameter up to 1 to 2 cm.; boundary highly diffused.
30 to 90	Dark reddish brown (5 YR 3/4); sandy loam; granular; well drained; few roots; few medium sized concretions; boundary not clear.
90 to 180	Strong brown (7.5 YR 5/8); loamy sand; granular; friable; large stones and rock pieces present; no roots; well drained.

Profile 10

Location:	Karulai Range, Nilambur Division.
Elevation:	150 to 200 m.
Topography:	Level
Vegetation:	15 year old teak plantation (Teak planted in 1952).
Depth (cm.) 0 to 30	Dark reddish brown (5 YR 3/2); sandy loam; structureless; well drained; noncalcareous; loose and friable; few gravel up to size 5 mm. diameter; diffused boundary.
30 to 90	Dark reddish brown (5 YR 3/4); loamy sand; quartz grains abundant; excessively well-drained; few roots; small sized iron concretions many; boundary broken and irregular.
90 to 180	Reddish brown (5 YR 4/4); loamy sand; granular; well drained; few lateritic stones; abundant concretions; red and yellow mottlings prominent; roots absent.

Profile 11

Location:	Karulai Range, Nilambur Division.
Elevation:	150 to 200 m.
Topography:	Level
Vegetation:	15 year old teak plantation (Teak planted in 1952).
Depth (cm.) 0 to 25	Dark reddish brown (5 YR 3/3); sandy clay loam; structureless; pebbles and quartz grains of diameter up to 2 cm.; noncalcareous; abundant fibrous roots; boundary clear and wavy.
25 to 90	Yellowish red (5 YR 4/6); sandy clay loam; granular; well drained; concretion few and large sized; boundary gradual and diffused.

90 to 180	Reddish yellow (5 YR 6/6); sandy loam; granular; moderately well drained; occasional yellow and red mottlings; stones and granite rock pieces present; no roots; noncalcareous.

Profile 12

Location:	Karulai Range, Nilambur Division.
Elevation:	150 to 200 m.
Topography:	Level
Vegetation:	15 year old teak plantation (Teak planted in 1952).
Depth (cm.) 0 to 30	Dark brown (7.5 YR 4/2); sandy clay; granular; loose and friable; quartz grains up to 5 mm. size distributed throughout; few iron gravel; abundant roots; fairly well drained; non-calcareous; boundary highly diffused.
30 to 90	Yellowish red (5 YR 4/6); clay loam; blocky; well drained; very few concretions; occasional yellow mottlings; few large roots; clear and wavy boundary.
90 to 180	Reddish yellow (5 YR 6/6); sandy clay loam; granular; abundant lateritic stones; highly mottled; roots absent; moderately drained; noncalcareous.

Profile 13

Location:	Karulai Range, Nilambur Division.
Elevation:	175 to 200 m.
Topography:	Level
Vegetation:	30 year old teak plantation (Teak planted in 1937).
Depth (cm.) 0 to 30	Very dark brown (10 YR 2/2); granular; well drained; noncalcareous; iron gravel of diameter up to 1 cm. abundant; yellow and black mottlings common; gradual and diffused boundary.

30 to 100	Very dark brown (10 YR 2/2); clayey; blocky; poorly drained; very few concretions; few large roots; noncalcareous; boundary clear and distinct.
100 to 180	Yellowish brown (10 YR 5/6); sandy clay; blocky; moderately well drained; roots absent; mixed with partially weathered rock pieces of gneiss and granite and lateritic stones.

<u>Profile 14</u>

Location:	Karulai Range, Nilambur Division.
Elevation:	175 to 200 m.
Topography:	Level
Vegetation:	30 year old teak plantation (Teak planted in 1937).
Depth (cm.) 0 to 25	Dark brown (7.5 YR 3/2); sandy clay loam; structureless; abundant roots; fairly drained; few gravel up to diameter 0.5 cm.; noncalcareous; boundary well defined.
25 to 85	Dark brown (7.5 YR 3/2); clay loam; granular; well drained; occasional mottlings; few iron concretions of size 0.25 to 0.5 cm. diameter; boundary wavy and distinct.
85 to 180	Dark brown (7.5 YR 4/4); clay loam; blocky; friable; moderately drained; red and yellow mottlings prominent; lateritic stones common; no roots; noncalcareous.

<u>Profile 15</u>

Location:	Karulai Range, Nilambur Division.
Elevation:	175 to 200 m.
Topography:	Level
Vegetation:	30 year old teak plantation (Teak planted in 1937).

Depth (cm.) 0 to 30	Dark brown (7.5 YR 4/2); sandy clay loam; blocky; friable; well drained; abundant roots; small iron concretions and quartz grains distributed throughout; yellow mottlings common; diffused boundary.
30 to 90	Light brown (7.5 YR 6/4); clayey, compact; poorly drained; very few concretions; few roots; no mottlings; noncalcareous; boundary not clear.
90 to 180	Reddish yellow (7.5 YR 7/6); sandy clay loam; red and yellow mottlings abundant; no roots; merges with the laterite bed below.

Profile 16

Location:	Karulai Range, Nilambur Division
Elevation:	175 to 200 m.
Topography:	Level
Vegetation:	30 year old teak plantation (Teak planted in 1937).
Depth (cm.) 0 to 30	Dark reddish brown (5 YR 3/2); loam; granular; mixed with quartz grains of 0.25 to 0.5 cm. diameter; well drained; yellow mottlings common; noncalcareous; boundary gradual and diffused.
30 to 90	Yellowish red (5 YR 4/6); sandy clay loam; granular; very few concretions of diameter up to 4 mm.; fairly well drained; mottlings present; very few roots; boundary not distinct.
90 to 180	Yellowish red (5 YR 4/6); loam; structureless; lateritic stones and nodules abundant; well drained; no roots; highly mottled; gradually merges with the laterite bed beneath.

Profile 17

Location:	Karulai Range, Nilambur Division
Elevation:	125 to 175 m.

Topography:	Level
Vegetation:	60 year old teak plantation (Teak planted in 1917).
Depth (cm.) 0 to 30	Very dark grey (5 YR 3/1); clay loam; granular; moderately drained; small quartz grains abundant; gravel very few; fibrous roots many; noncalcareous; boundary poorly differentiated.
30 to 90	Strong brown (7.5 YR 7/6); sandy clay; quartz grains plenty; granular; moderately drained; few roots; few iron concretions up to size 1 cm. diameter; diffused boundary.
90 to 180	Strong brown (7.5 YR 7/6); sandy clay loam; blocky; well drained; loose and friable; mixed with lateritic stones; red and yellow mottlings common; roots absent.

<u>Profile 18</u>

Location:	Karulai Range, Nilambur Division
Elevation:	125 to 175 m.
Topography:	Level
Vegetation:	60 year old teak plantation (Teak planted in 1917).
Depth (cm.) 0 to 27	Black (5 YR 2/1); sandy clay loam; structureless; few large iron gravel; small concretions abundant; well drained; friable; fibrous roots plenty; noncalcareous; boundary clear and distinct.
27 to 85	Yellowish red (5 YR 4/8); sandy clay loam; no structure; well drained; few concretions of size 0.25 to 0.75 cm. diameter; no mottlings; few roots; boundary clear and distinct.
85 to 180	Reddish yellow (5 YR 6/6); clay loam; blocky; few unweathered rock pieces; yellow and red mottlings; lateritic nodules abundant; fairly well drained; roots absent; merges with the more lateritic soil beneath.

Profile 19

Location: Karulai Range, Nilambur Division

Elevation: 125 to 175 m.

Topography: Level

Vegetation: 60 year old teak plantation (Teak planted in 1917).

Depth (cm.)

0 to 25 — Dark reddish brown (5 YR 2/2); sandy clay loam; granular; well drained; few mottlings; concretions of size 0.5 to 1 cm. diameter; many fibrous roots; noncalcareous; boundary wavy and well defined.

25 to 95 — Dark reddish grey (5 YR 4/2); sandy clay loam; granular; occasional mottlings; few large roots; well drained; noncalcareous; boundary smooth and clear.

95 to 180 — Yellowish red (5 YR 4/8); sandy clay loam; blocky; admixture of soft lateritic concretions and clay; prominent yellow and red mottlings; few rock pieces (gneiss and granite); gradually diffuses with the laterite bed beneath.

Profile 20

Location: Karulai Range, Nilambur Division

Elevation: 125 to 175 m.

Topography: Level

Vegetation: 60 year old teak plantation (Teak planted in 1917).

Depth (cm.)

0 to 30 — Dark reddish brown (5 YR 3/2); sandy clay loam; granular; loose and friable; quartz grains abundant; excessively well drained; few fibrous roots; noncalcareous; diffused boundary.

30 to 90 — Dark reddish brown (5 YR 3/4); sandy clay loam; granular; prominent red and black mottlings; well drained; no roots; few iron concretions; boundary not distinct.

90 to 180 — Yellowish red (5 YR 5/8); sandy clay loam; structureless; very loose and friable; large lateritic aggregates present; very prominent red and yellow mottlings; rich in kaolin clay.

Profile 21

Location:	Compartment No.33, Nilambur Range, Nilambur Division. (Conolly's Teak Plantation Preservation Plot; bank of the river Chaliyar).
Elevation:	100 to 150 m.
Topography:	Level
Vegetation:	120 year old teak plantation (Teak planted in 1846 to 1847).
Depth (cm.) 0 to 10	Dark yellowish brown (10 YR 3/4); loam; crumb; very few iron concretions; no mottlings; fibrous roots abundant; excessively well drained; earth worms common; boundary wavy and definite.
10 to 30	Dark brown (7.5 YR 4/4); clay loam; blocky; no concretions; no mottlings; transported rock pieces present; well drained; non-calcareous; diffused boundary.
30 to 90	Reddish brown (5 YR 4/4); clay loam; blocky; moderately well drained; no mottlings; transported gravel and stones distributed throughout; few large roots; noncalcareous; boundary highly diffused.
90 to 180	Dark brown (7.5 YR 4/4); sandy clay loam; mixed with quartz grains; no mottlings; few large roots; well drained and noncalcareous.

Profile 22

Location:	Compartment No.35, Nilambur Range, Nilambur Division (Teak failure area).
Elevation:	100 to 150 m.

Topography:	Level
Vegetation:	120 year old teak plantation (Only a few old teak trees grown here and there).
Depth (cm.) 0 to 30	Dark reddish brown (5 YR 3/3); sandy clay loam; granular; very compact; large boulders; few large sized iron gravel of diameter 1 to 2 cm.; well drained; very few roots; noncalcareous; distinct boundary.
30 to 90	Dark brown (7.5 YR 4/2); very hard laterite, unsuitable for quarrying; excessive iron boulders; no roots; well drained; boundary not clear.
90 to 180	Reddish yellow (7.5 YR 6/6); hard laterite; vermicular; red mottlings prominent with occasional yellow mottlings; unsuitable for quarrying; no roots; noncalcareous.

<u>Profile 23</u>

Location:	Compartment No.31, Nilambur Range, Nilambur Division
Elevation:	100 to 150 m.
Topography:	Level
Vegetation:	120 year old teak plantation (Second rotation crop - teak first planted in 1846 and replanted in 1920 - teak trees of very poor quality).
Depth (cm.) 0 to 25	Reddish brown (5 YR 4/3); sandy loam; granular; laterite stones and gravel abundant; few fibrous roots; well drained; noncalcareous; very distinct boundary.
25 to 100	Reddish yellow (5 YR 7/6); laterite; soft; vermicular and honey-comb like; suitable for quarrying; red and yellow mottlings prominent; no roots; boundary not clear.
100 to 180	Reddish yellow (5 YR 7/6); laterite; soft; vermicular; suitable for quarrying; highly mottled; noncalcareous; no roots.

Profile 24

Location:	Compartment No.31, Nilambur Range, Nilambur Division.
Elevation:	100 to 150 m.
Topography:	Level
Vegetation:	120 year old teak plantation (Second rotation crop - teak first planted in 1846 - clear-felled and replanted in 1920 - teak trees of very poor quality).
Depth (cm.) 0 to 35	Yellowish brown (10.5 YR 5/3); sandy clay loam; granular; lateritic concretions abundant; few fibrous roots; well drained; prominent yellow and red mottlings; boundary wavy and well defined.
35 to 90	Strong brown (7.5 YR 5/6); laterite; vermicular; highly prominent red and yellow mottlings; soft; suitable for quarrying; no roots; fairly well drained; merges with the laterite bed below.
90 to 180	Reddish yellow (7.5 YR 6/6); laterite; vermicular; kaolin clay present in patches; prominent mottlings; suitable for quarrying; no roots; noncalcareous.

LABORATORY INVESTIGATIONS

I. Physical determinations

(1) Mechanical analysis. The results of the mechanical analysis of the soils are given in Tables I to VI and presented graphically in Fig. 1 to 3.

The depth at which the maximum amount of clay occurs in the various profiles is correlated with the age of the teak plantation.

In the profiles from the natural forests the amount of clay varies from 18.5 per cent in the lowest horizon of profile 4 to 49.0 per cent in the second layer of profile 1. In all the four profiles from the natural forests the maximum amount of clay is found at the same range of depth viz., 10 to 30 cm. At lower depths the percentage of clay is found to be less.

In the case of the 1 year old teak plantation the clay content of the soils varies from 14.5 to 47.8 per cent. The highest amount is found in the second horizon of profile 8 and the lowest amount in the third horizon of profile 6. In this plantation the clay content is highest in the second layer (30 - 90 cm.) of all the profiles except profile 6 where the maximum amount of clay is present in the first horizon.

TABLE I

MECHANICAL COMPOSITION OF SOILS FROM NATURAL FORESTS

	Depth (cm.)	Per cent on oven dry basis				
		Organic matter	Clay	Silt	Fine sand	Coarse sand
Profile 1	0 - 10	7.3	36.5	7.3	9.1	39.8
	10 - 30	3.0	49.0	11.3	7.0	29.7
	30 - 90	1.9	44.3	14.3	12.4	27.1
	90 -180	0.9	30.5	16.3	14.7	37.6
Profile 2	0 - 10	6.1	23.5	27.5	29.4	13.5
	10 - 30	2.4	29.8	24.5	19.2	24.1
	30 - 90	1.7	22.3	27.8	25.2	23.0
	90 -180	0.8	19.4	31.0	29.5	19.3
Profile 3	0 - 10	7.8	27.7	14.0	43.3	7.2
	10 - 30	3.8	31.9	12.0	39.2	13.1
	30 - 90	2.2	24.0	20.7	36.3	16.8
	90 -180	1.0	21.3	24.4	33.6	19.7
Profile 4	0 - 10	8.5	22.0	30.1	33.2	6.2
	10 - 30	3.5	30.7	20.5	32.1	13.2
	30 - 90	1.6	25.3	23.9	30.1	19.1
	90 -180	0.8	18.5	24.8	22.2	33.7

TABLE II

MECHANICAL COMPOSITION OF SOILS FROM 1 YEAR OLD TEAK PLANTATION

	Depth (cm.)	Per cent on oven dry basis				
		Organic matter	Clay	Silt	Fine sand	Coarse sand
Profile 5	0 - 30	4.1	30.3	13.5	20.0	32.1
	30 - 90	2.0	36.5	10.0	22.5	29.0
	90 -180	0.5	29.0	19.5	19.3	31.7
Profile 6	0 - 30	4.7	24.5	14.3	34.3	22.2
	30 - 90	2.4	16.8	24.5	31.2	25.1
	90 -180	0.4	14.5	21.3	28.7	35.1
Profile 7	0 - 30	5.8	21.8	25.8	25.2	21.4
	30 - 90	2.6	25.8	17.8	28.1	25.7
	90 -180	0.6	19.0	26.5	19.8	34.1
Profile 8	0 - 30	5.6	23.2	27.0	32.1	12.1
	30 - 90	1.9	47.8	11.0	27.0	12.3
	90 -180	0.3	35.0	14.2	32.7	17.8

TABLE III

MECHANICAL COMPOSITION OF SOILS FROM 15 YEAR OLD TEAK PLANTATION

	Depth (cm.)	Per cent on oven dry basis				
		Organic matter	Clay	Silt	Fine sand	Coarse sand
Profile 9	0 - 30	2.0	22.5	9.0	19.0	47.5
	30 - 90	1.1	11.3	14.5	53.4	19.7
	90 -180	0.2	10.5	7.3	24.5	57.5
Profile 10	0 - 30	2.4	13.7	12.5	27.3	44.1
	30 - 90	0.9	11.5	12.0	26.4	49.2
	90 -180	0.4	6.3	7.1	29.2	57.0
Profile 11	0 - 25	3.5	21.3	20.8	23.3	31.1
	25 - 90	1.0	25.4	18.5	20.9	34.2
	90 -180	0.3	15.3	15.5	27.8	41.1
Profile 12	0 - 30	2.6	35.3	15.5	31.0	15.6
	30 - 90	0.5	36.3	18.0	33.0	12.2
	90 -180	0.4	24.0	19.5	18.0	38.1

TABLE IV

MECHANICAL COMPOSITION OF SOILS FROM 30 YEAR OLD TEAK PLANTATION

	Depth (cm.)	Per cent on oven dry basis				
		Organic matter	Clay	Silt	Fine sand	Coarse sand
Profile 13	0 - 30	2.0	22.1	28.8	24.3	22.8
	30 -100	1.1	45.2	13.8	25.0	14.9
	100 -180	0.1	38.0	7.5	31.0	23.4
Profile 14	0 - 25	2.1	29.1	22.5	30.2	16.1
	25 - 85	1.4	34.6	17.5	21.4	25.1
	85 -180	0.3	35.0	33.8	18.2	12.7
Profile 15	0 - 30	2.7	34.5	13.5	31.6	17.7
	30 - 90	1.0	41.8	14.3	14.0	28.9
	90 -180	0.4	29.5	18.3	11.3	40.5
Profile 16	0 - 30	3.2	17.5	30.5	16.7	32.1
	30 - 90	1.1	23.3	24.6	18.4	32.6
	90 -180	0.4	10.3	43.3	16.5	29.5

TABLE V

MECHANICAL COMPOSITION OF SOILS FROM 60 YEAR OLD TEAK PLANTATION

	Depth (cm.)	Per cent on oven dry basis				
		Organic matter	Clay	Silt	Fine sand	Coarse sand
Profile 17	0 - 30	5.8	40.1	14.3	36.3	3.5
	30 - 90	2.1	35.8	15.8	38.9	7.4
	90 -180	0.9	26.0	19.3	29.1	24.7
Profile 18	0 - 27	5.6	25.5	18.3	45.3	5.3
	27 - 85	2.0	31.3	18.5	37.7	10.5
	85 -180	1.0	31.0	24.0	28.8	15.2
Profile 19	0 - 25	6.0	29.3	14.3	16.8	33.6
	25 - 95	2.6	33.5	11.3	13.7	38.9
	95 -180	0.6	29.8	14.0	13.1	42.5
Profile 20	0 - 30	4.1	28.5	16.0	13.2	38.2
	30 - 90	1.8	31.3	15.0	13.8	38.1
	90 -180	0.5	29.0	12.3	15.3	42.9

TABLE VI

MECHANICAL COMPOSITION OF SOILS FROM 120 YEAR OLD TEAK PLANTATIONS

	Depth (cm.)	Per cent on oven dry basis				
		Organic matter	Clay	Silt	Fine sand	Coarse sand
Profile 21 (Conolly's Teak Plantation, preservation plot - alluvium)	0 - 10	8.2	21.0	32.0	28.1	10.7
	10 - 30	4.8	38.8	36.3	14.0	6.1
	30 - 90	2.0	37.3	33.3	17.6	9.8
	90 - 180	1.0	21.8	23.8	37.8	15.6
Profile 22 (Teak failure area - hard laterite)	0 - 30	2.0	26.5	18.6	22.2	30.7
	30 - 90	0.6	34.0	10.3	22.6	32.5
	90 - 180	0.2	30.3	12.3	28.5	28.7
Profile 23 (Second rotation - laterite)	0 - 25	4.0	17.1	11.0	27.1	40.8
	25 - 100	1.1	32.3	8.4	22.1	36.1
	100 - 180	0.3	28.9	13.3	32.9	24.6
Profile 24 (Second rotation - laterite)	0 - 35	4.2	29.3	13.3	22.3	30.9
	35 - 90	1.4	43.0	10.5	19.0	26.1
	90 - 180	0.4	30.6	11.5	17.1	40.4

The profiles from the 15 year old teak plantation show considerable differences in the amount of clay in the different layers, as well as in the nature of variation in clay content with depth. The percentage of clay in the various horizons of these profiles varies from 6.3 in the third horizon of profile 10 to 36.3 in the second layer of profile 12.

The clay content of the soils from the 30 year old teak plantation ranges from 10.3 per cent in the third horizon of profile 16 to 45.2 per cent in the second layer of profile 13. In all the profiles from this plantation the maximum amount of clay is observed at a depth of 60 to 90 cm.

Three of the profiles (nos. 18, 19 and 20) from the 60 year old teak plantation show a close similarity in the nature of their depth function curves for clay. In these profiles the clay content is slightly high in the second horizons whereas in profile 17 the maximum amount of clay is in the surface horizon.

The translocation of clay in the profile from the preservation plot (120 year old teak plantation) is similar to that of the profiles from the natural forests, the highest amount occurring in the second horizon (10 to 30 cm.). The other three profiles (nos. 22, 23 and 24) in the 120 year old teak plantations show a

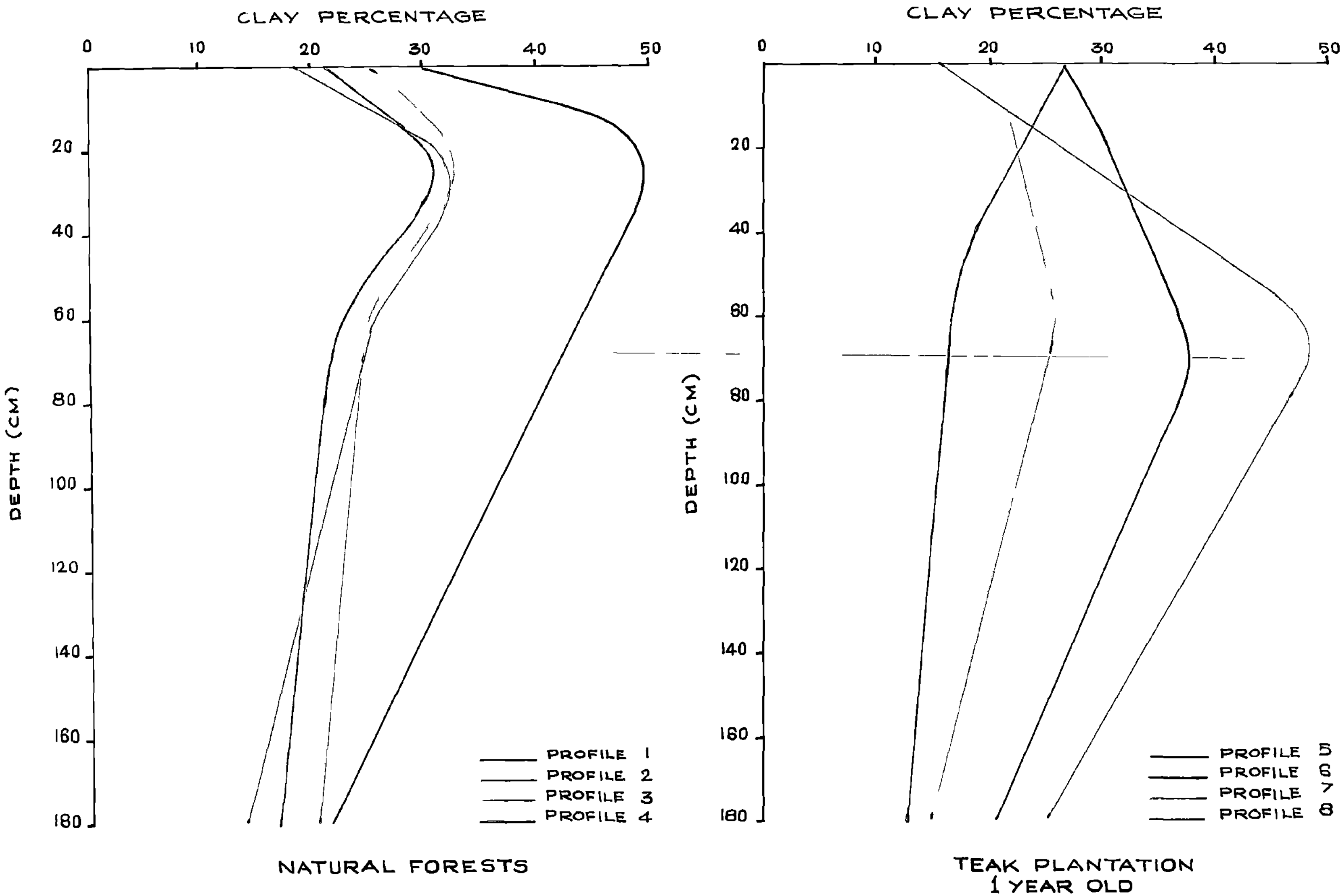

FIG 1

VARIATION IN THE CLAY CONTENT OF SOILS WITH DEPTH IN THE DIFFERENT PROFILES FROM NATURAL FORESTS AND 1 YEAR OLD TEAK PLANTATION

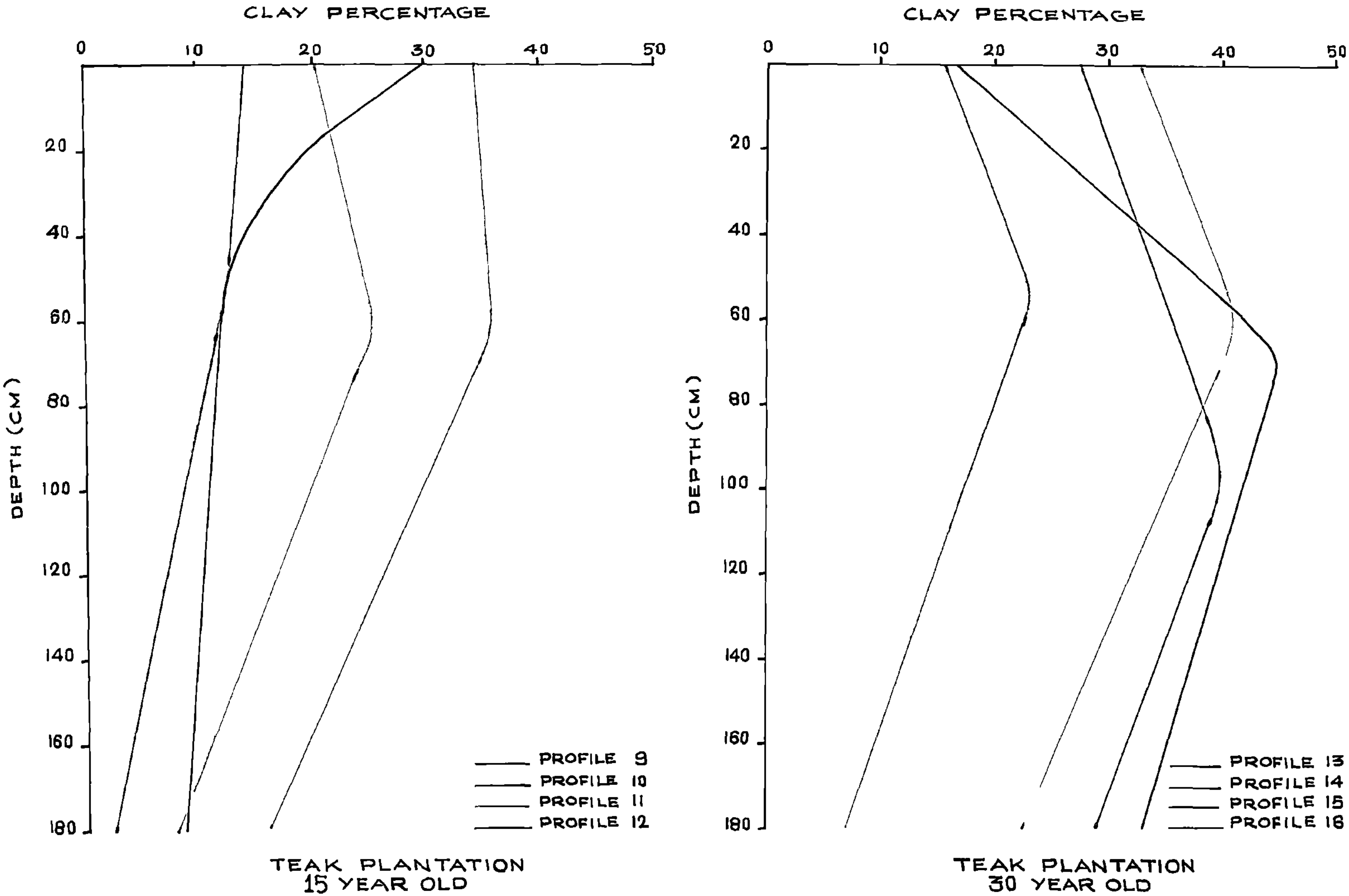

FIG 2

VARIATION IN THE CLAY CONTENT OF SOILS WITH DEPTH IN THE DIFFERENT PROFILES FROM 15 YEAR OLD TEAK PLANTATION AND 30 YEAR OLD TEAK PLANTATION

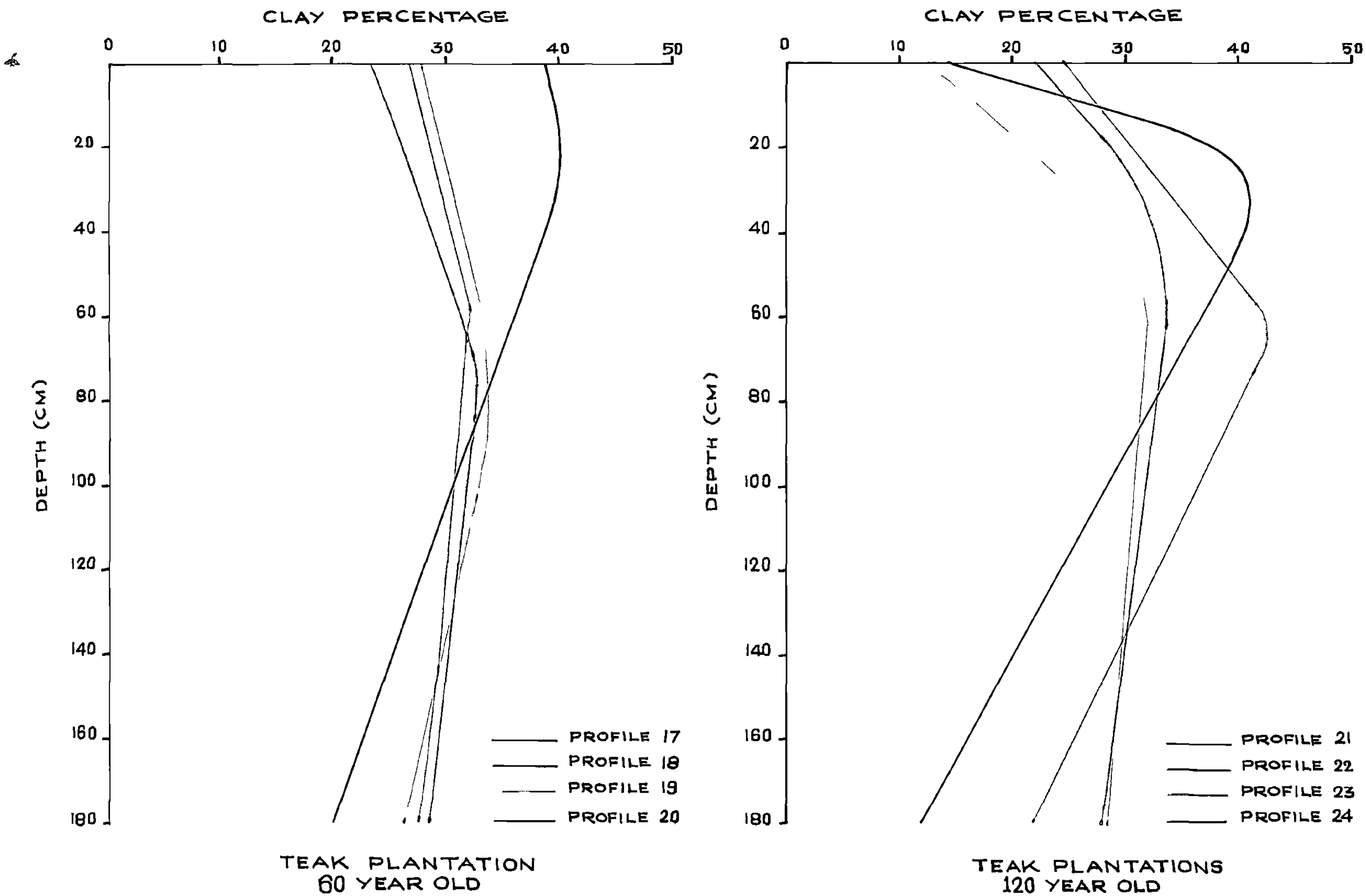

FIG 3

VARIATION IN THE CLAY CONTENT OF SOILS WITH DEPTH IN THE DIFFERENT PROFILES FROM 60 YEAR OLD TEAK PLANTATION AND 120 YEAR OLD TEAK PLANTATIONS higher percentage of clay at a relatively lower depth (60 to 90 cm.).

There is nothing very remarkable in the distribution of silt and sand in the various profiles investigated.

(2) Single value constants

The single value constants of the soils are given in Tables VII to XII.

(a) Apparent density. In all the profiles studied the apparent density of the soil steadily increases with depth, the highest value being generally for the soil from the lowermost horizon. The lowest value (1.02) for this physical constant is recorded for the surface horizon of the profile from the preservation plot and the highest value (1.57) is obtained for the second horizon of the profile from the teak failure area of the 120 year old teak plantation. The value of the apparent density of the soils in the lower horizons of the different profiles varies only within very small limits whereas there is marked variation in this physical constant in the surface horizons. The apparent density of the soils in the surface horizons generally increases with increasing age of the plantation. Thus, this value is found to vary from 1.11 to 1.21 in the surface horizons of the profiles from the natural forests. Under the influence of teak vegetation this value changes from 1.21 to 1.32 in the 1 year old teak plantation, and from 1.25 to 1.38 in the 15 year old plantation. The corresponding values for the 30 and 60 year old teak plantations are 1.29 to 1.34 and 1.20 to 1.34 respectively. In the case of the preservation plot of the 120 year old teak plantation, the apparent density varies from 1.02 in the surface horizon to 1.32 in the lowermost horizon. In the other three profiles (nos. 22, 23 and 24) of the 120 year old teak plantations the apparent density is considerably higher and varies from 1.34 for the surface horizon of profile 23 to 1.57 for the second layer of profile 22 (teak failure area).

(b) Absolute specific gravity. As in the case of apparent density, the specific gravity of the soils from the surface horizons of the different profiles varies with the age of the teak plantation though the variation is not so pronounced as in the case of apparent density. The highest value for specific gravity (2.74) is noted for the second layer of the profile from the teak failure area and the lowest value (2.18) is recorded for the surface horizon of the profile from the preservation plot. The specific gravity of the surface soils is found to vary from 2.34 to 2.43 in the natural forests and from 2.41 to 2.49 in the 1 year old teak plantation. In the case of the 15, 30 and 60 year old plantations the variations are from 2.38 to 2.52, 2.41 to 2.56 and from 2.46 to 2.49 respectively.

TABLE VII

SINGLE VALUE CONSTANTS OF SOILS FROM NATURAL FORESTS

	Depth (cm.)	Apparent density	Specific gravity	Maximum water holding capacity (per cent)	Moisture equivalent (per cent)	Pore space (per cent)	Volume expansion (per cent)
Profile 1	0 - 10	1.16	2.34	51.4	19.3	50.5	6.28
	10 - 30	1.24	2.48	48.6	17.5	50.0	4.04
	30 - 90	1.31	2.51	44.2	14.7	47.9	5.02
	90 -180	1.38	2.48	33.7	8.1	44.1	3.31
Profile 2	0 - 10	1.11	2.38	49.9	18.4	53.3	5.07
	10 - 30	1.32	2.52	44.6	15.0	47.6	4.60
	30 - 90	1.34	2.40	30.4	6.0	44.2	2.98
	90 -180	1.46	2.49	25.4	2.8	41.3	3.11
Profile 3	0 - 10	1.21	2.43	46.8	16.4	50.2	6.75
	10 - 30	1.39	2.48	42.1	13.4	43.9	5.98
	30 - 90	1.41	2.33	39.5	11.7	39.8	4.60
	90 -180	1.38	2.41	30.0	5.7	42.7	2.41
Profile 4	0 - 10	1.18	2.38	48.6	17.5	50.5	5.18
	10 - 30	1.38	2.39	39.8	11.9	42.3	6.12
	30 - 90	1.34	2.42	40.4	12.3	44.7	2.67
	90 -180	1.41	2.47	26.5	3.5	42.8	2.32

TABLE VIII

SINGLE VALUE CONSTANTS OF SOILS FROM 1 YEAR OLD TEAK PLANTATION

	Depth (cm.)	Apparent density	Specific gravity	Maximum water holding capacity (per cent)	Moisture equivalent (per cent)	Pore space (per cent)	Volume expansion (per cent)
Profile 5	0 - 30	1.21	2.41	36.4	9.8	49.4	5.21
	30 - 90	1.33	2.39	37.8	10.7	44.3	4.13
	90 -180	1.40	2.44	38.6	11.2	42.6	2.84
Profile 6	0 - 30	1.28	2.46	35.4	9.1	47.1	4.86
	30 - 90	1.35	2.45	32.7	7.4	44.5	4.21
	90 -180	1.42	2.51	25.4	2.8	43.5	2.41
Profile 7	0 - 30	1.32	2.48	33.8	11.3	46.6	3.84
	30 - 90	1.38	2.54	31.6	6.7	45.6	4.21
	90 -180	1.41	2.45	28.7	4.9	42.6	5.43
Profile 8	0 - 30	1.25	2.49	40.3	12.3	49.8	5.18
	30 - 90	1.41	2.50	36.5	9.8	43.6	4.12
	90 -180	1.40	2.46	39.6	11.8	43.1	2.64

TABLE IX

SINGLE VALUE CONSTANTS OF SOILS FROM 15 YEAR OLD TEAK PLANTATION

	Depth (cm.)	Apparent density	Specific gravity	Maximum water holding capacity (per cent)	Moisture equivalent (per cent)	Pore space (per cent)	Volume expansion (per cent)
Profile 9	0 - 30	1.36	2.51	42.8	13.8	45.8	5.13
	30 - 90	1.38	2.54	31.6	6.7	44.9	5.62
	90 -180	1.41	2.51	29.4	5.3	45.6	3.18
Profile 10	0 - 30	1.38	2.48	35.4	9.1	44.3	4.88
	30 - 90	1.39	2.51	28.6	4.8	44.6	6.43
	90 -180	1.42	2.49	24.8	2.4	42.9	2.98
Profile 11	0 - 25	1.32	2.52	38.1	10.9	47.6	4.41
	25 - 90	1.38	2.53	43.1	14.0	45.4	5.23
	90 -180	1.41	2.56	37.8	10.7	44.9	3.21
Profile 12	0 - 30	1.25	2.38	37.1	10.2	47.5	2.28
	30 - 90	1.41	2.41	38.2	10.9	41.4	5.21
	90 -180	1.40	2.42	29.6	5.5	42.1	3.12

TABLE X

SINGLE VALUE CONSTANTS OF SOILS FROM 30 YEAR OLD TEAK PLANTATION

	Depth (cm.)	Apparent density	Specific gravity	Maximum water holding capacity (per cent)	Moisture equivalent (per cent)	Pore space (per cent)	Volume expansion (per cent)
Profile 13	0 - 30	1.29	2.56	37.4	10.4	49.6	3.16
	30 -100	1.38	2.54	48.6	17.5	45.6	5.12
	100 -180	1.34	2.59	42.1	13.4	48.2	2.18
Profile 14	0 - 25	1.31	2.54	33.4	7.9	48.4	3.84
	25 - 85	1.29	2.50	37.6	10.5	48.4	4.16
	85 -180	1.36	2.51	34.8	8.8	45.9	2.11
Profile 15	0 - 30	1.34	2.44	36.2	9.7	45.1	4.48
	30 - 90	1.28	2.49	41.6	13.1	48.5	5.23
	90 -180	1.36	2.57	33.6	8.0	47.1	3.12
Profile 16	0 - 30	1.33	2.41	40.6	12.4	44.8	5.18
	30 - 90	1.41	2.39	37.4	10.4	41.0	4.88
	90 -180	1.44	2.52	28.6	4.8	42.8	4.11

TABLE XI

SINGLE VALUE CONSTANTS OF SOILS FROM 60 YEAR OLD TEAK PLANTATION

	Depth (cm.)	Apparent density	Specific gravity	Maximum water holding capacity (per cent)	Moisture equivalent (per cent)	Pore space (per cent)	Volume expansion (per cent)
Profile 17	0 - 30	1.20	2.46	49.6	18.2	51.2	5.23
	30 - 90	1.31	2.48	42.7	13.8	47.0	4.12
	90 -180	1.39	2.44	40.4	12.3	43.0	2.84
Profile 18	0 - 27	1.34	2.49	39.8	11.9	46.1	4.16
	27 - 85	1.37	2.51	41.4	13.0	45.4	5.13
	85 -180	1.41	2.53	40.8	12.6	44.2	4.00
Profile 19	0 - 25	1.21	2.48	38.6	11.2	51.0	4.56
	25 - 95	1.28	2.49	43.2	14.1	48.5	6.12
	95 -180	1.39	2.50	29.3	5.3	44.4	3.18
Profile 20	0 - 30	1.26	2.48	36.8	10.0	49.0	3.14
	30 - 90	1.35	2.51	40.4	12.3	46.3	4.18
	90 -180	1.40	2.39	37.8	10.7	41.4	4.23

TABLE XII

SINGLE VALUE CONSTANTS OF SOILS FROM 120 YEAR OLD TEAK PLANTATIONS

	Depth (cm.)	Apparent density	Specific gravity	Maximum water holding capacity (per cent)	Moisture equivalent (per cent)	Pore space (per cent)	Volume expansion (per cent)
Profile 21 (Conolly's Teak Plantation, preservation plot - alluvium).	0 - 10	1.02	2.18	54.7	21.4	53.2	8.44
	10 - 30	1.18	2.21	42.1	13.4	46.6	6.31
	30 - 90	1.23	2.34	40.3	12.3	47.4	4.12
	90 -180	1.32	2.45	36.8	10.0	46.1	2.98
Profile 22 (Teak failure area - hard laterite)	0 - 30	1.46	2.51	34.6	8.6	41.9	2.07
	30 - 90	1.57	2.74	28.8	5.0	42.7	2.60
	90 -180	1.53	2.69	32.4	7.2	43.1	2.98
Profile 23 (Second rotation - laterite)	0 - 25	1.34	2.48	38.6	11.2	45.8	3.75
	25 -100	1.48	2.64	30.1	5.8	43.8	2.98
	100 -180	1.46	2.68	33.7	8.1	45.5	2.60
Profile 24 (Second rotation - laterite)	0 - 35	1.38	2.41	36.7	10.0	42.7	3.18
	35 - 90	1.47	2.58	32.8	7.5	43.0	3.12
	90 -180	1.48	2.59	34.2	8.4	42.9	2.67

Nothing remarkable is noted in the variation of this property with depth in the various profiles.

(c) Maximum water holding capacity and moisture equivalent. The maximum water holding capacity of the soils varies from 24.8 to 54.7 per cent and the moisture equivalent from 2.4 to 21.4 per cent. The surface horizon of the profile from the preservation plot (120 year old teak plantation) records the maximum values for both these constants and the lowest values are given by the third horizon of profile 10 (15 year old teak plantation). The values for these physical constants do not show any regular variation with depth in any of the plantations under study. The soils from the natural forests and from the preservation plot show relatively higher values for these constants and also exhibit a gradual decreasing tendency with depth.

(d) Pore space. The pore space of the soils from the different profiles varies from 41.0 per cent in the middle layer of profile 16 (30 year old teak plantation) to 53.3 per cent in the surface layer of profile 2 (natural forests). In most of the profiles the general tendency is for this constant to decrease with depth. The soils from the surface layers of the natural forests and from the preservation plot show a high percentage of pore space, viz., 50.2 to 53.3 per cent as compared to the surface layers of the teak plantations. In the latter case the percentage of pore space varies from 46.8 to 49.8, 44.3 to 47.6, 44.8 to 49.6 and 46.1 to 51.2 in the 1, 15, 30 and 60 year old plantations respectively. It is noteworthy that the figure for pore space is very low (41.9 per cent) in the surface soil of the teak failure area.

(e) Volume expansion. The volume expansion of the soils studied varies from 2.07 per cent in the surface horizon of the profile from the teak failure area to 8.44 per cent in the surface horizon of the profile from the preservation plot (120 year old teak plantation). In general the tendency for this constant is to decrease with depth, though in a few profiles the subsoils show slightly higher values. The surface soils of the natural forests and the teak preservation plot have relatively higher percentages of volume expansion (5.07 to 8.44) whereas the soils from the different horizons of the teak failure area have markedly low percentage of volume expansion (2.07 to 2.98 per cent).

II. Chemical analysis

(1) Organic carbon. The variation in the organic carbon content of soils with depth in the different profiles is given in Tables XIII to XVIII and is represented graphically in Fig. 4 to 6.

The organic carbon content varies from 0.06 per cent in the third layer of profile 13 (30 year old

TABLE XIII

CARBON:NITROGEN RELATIONSHIPS IN SOILS FROM NATURAL FORESTS

	Depth (cm.)	Organic carbon (per cent)	Nitrogen (per cent)	Carbon: Nitrogen ratio
Profile 1	0 - 10	4.23	0.36	11.8
	10 - 30	1.74	0.21	8.3
	30 - 90	1.08	0.18	6.0
	90 - 180	0.54	0.11	4.9
Profile 2	0 - 10	3.54	0.39	9.1
	10 - 30	1.38	0.19	7.3
	30 - 90	0.96	0.15	6.4
	90 - 180	0.48	0.11	4.4
Profile 3	0 - 10	4.53	0.38	11.9
	10 - 30	2.23	0.23	9.7
	30 - 90	1.26	0.20	6.3
	90 - 180	0.57	0.13	4.4
Profile 4	0 - 10	4.96	0.39	12.7
	10 - 30	2.00	0.20	10.0
	30 - 90	0.93	0.17	5.5
	90 - 180	0.45	0.10	4.5

TABLE XIV

CARBON:NITROGEN RELATIONSHIPS IN SOILS FROM 1 YEAR OLD TEAK PLANTATION

	Depth (cm.)	Organic carbon (per cent)	Nitrogen (per cent)	Carbon: Nitrogen ratio
Profile 5	0 - 30	2.37	0.27	8.8
	30 - 90	1.17	0.19	6.2
	90 -180	0.30	0.07	4.3
Profile 6	0 - 30	2.73	0.33	8.3
	30 - 90	1.38	0.21	6.6
	90 -180	0.24	0.06	4.0
Profile 7	0 - 30	3.36	0.38	8.8
	30 - 90	1.53	0.26	5.9
	90 -180	0.33	0.07	4.7
Profile 8	0 - 30	3.24	0.35	9.3
	30 - 90	1.11	0.19	5.8
	90 -180	0.15	0.04	3.8

TABLE XV

CARBON:NITROGEN RELATIONSHIPS IN SOILS FROM 15 YEAR OLD TEAK PLANTATION

	Depth (cm.)	Organic carbon (per cent)	Nitrogen (per cent)	Carbon: Nitrogen ratio
Profile 9	0 - 30	1.17	0.11	10.6
	30 - 90	0.63	0.10	6.3
	90 -180	0.12	0.03	4.0
Profile 10	0 - 30	1.38	0.18	7.7
	30 - 90	0.54	0.10	5.4
	90 -180	0.24	0.06	4.0
Profile 11	0 - 25	2.04	0.27	7.6
	25 - 90	0.57	0.10	5.7
	90 -180	0.18	0.04	4.5
Profile 12	0 - 30	1.53	0.20	7.7
	30 - 90	0.30	0.06	5.0
	90 -180	0.21	0.05	4.2

TABLE XVI

CARBON:NITROGEN RELATIONSHIPS IN SOILS FROM 30 YEAR OLD TEAK PLANTATION

	Depth (cm.)	Organic carbon (per cent)	Nitrogen (per cent)	Carbon: Nitrogen ratio.
Profile 13	0 – 30	1.14	0.13	8.8
	30 –100	0.66	0.11	6.0
	100 –180	0.06	0.01	6.0
Profile 14	0 – 25	1.23	0.15	8.2
	25 – 85	0.78	0.14	5.6
	85 –180	0.18	0.04	4.5
Profile 15	0 – 30	1.56	0.20	7.8
	30 – 90	0.57	0.09	6.3
	90 –180	0.24	0.06	4.0
Profile 16	0 – 30	1.83	0.21	8.7
	30 – 90	0.63	0.11	5.7
	90 –180	0.21	0.05	4.2

TABLE XVII

CARBON:NITROGEN RELATIONSHIPS IN SOILS FROM 60 YEAR OLD TEAK PLANTATION

	Depth (cm.)	Organic carbon (per cent)	Nitrogen (per cent)	Carbon: Nitrogen ratio
Profile 17	0 - 30	3.39	0.37	9.2
	30 - 90	1.25	0.21	6.0
	90 -180	0.54	0.11	4.9
Profile 18	0 - 27	3.24	0.35	9.3
	27 - 85	1.17	0.21	5.6
	85 -180	0.60	0.12	5.0
Profile 19	0 - 25	3.45	0.38	9.1
	25 - 95	1.53	0.26	5.9
	95 -180	0.33	0.07	4.7
Profile 20	0 - 30	2.37	0.29	8.2
	30 - 90	1.05	0.19	5.5
	90 -180	0.30	0.06	5.0

TABLE XVIII

CARBON:NITROGEN RELATIONSHIPS IN SOILS FROM 120 YEAR OLD TEAK PLANTATIONS

	Depth	Organic carbon (per cent)	Nitrogen (per cent)	Carbon: Nitrogen ratio
Profile 21	0 - 10	4.77	0.46	10.4
(Conolly's Teak	10 - 30	2.76	0.32	8.6
Plantation,	30 - 90	1.14	0.18	6.3
preservation plot	90 -180	0.57	0.11	5.2
- alluvium)				
Profile 22	0 - 30	1.17	0.16	7.3
(Teak failure area	30 - 90	0.33	0.07	4.7
- hard laterite)	90 -180	0.12	0.03	4.0
Profile 23	0 - 25	2.31	0.28	8.3
(Second rotation	25 -100	0.66	0.14	4.7
- laterite)	100 -180	0.18	0.04	4.5
Profile 24	0 - 35	2.43	0.30	8.1
(Second rotation	35 - 90	0.78	0.13	6.0
- laterite)	90 -180	0.24	0.04	6.0

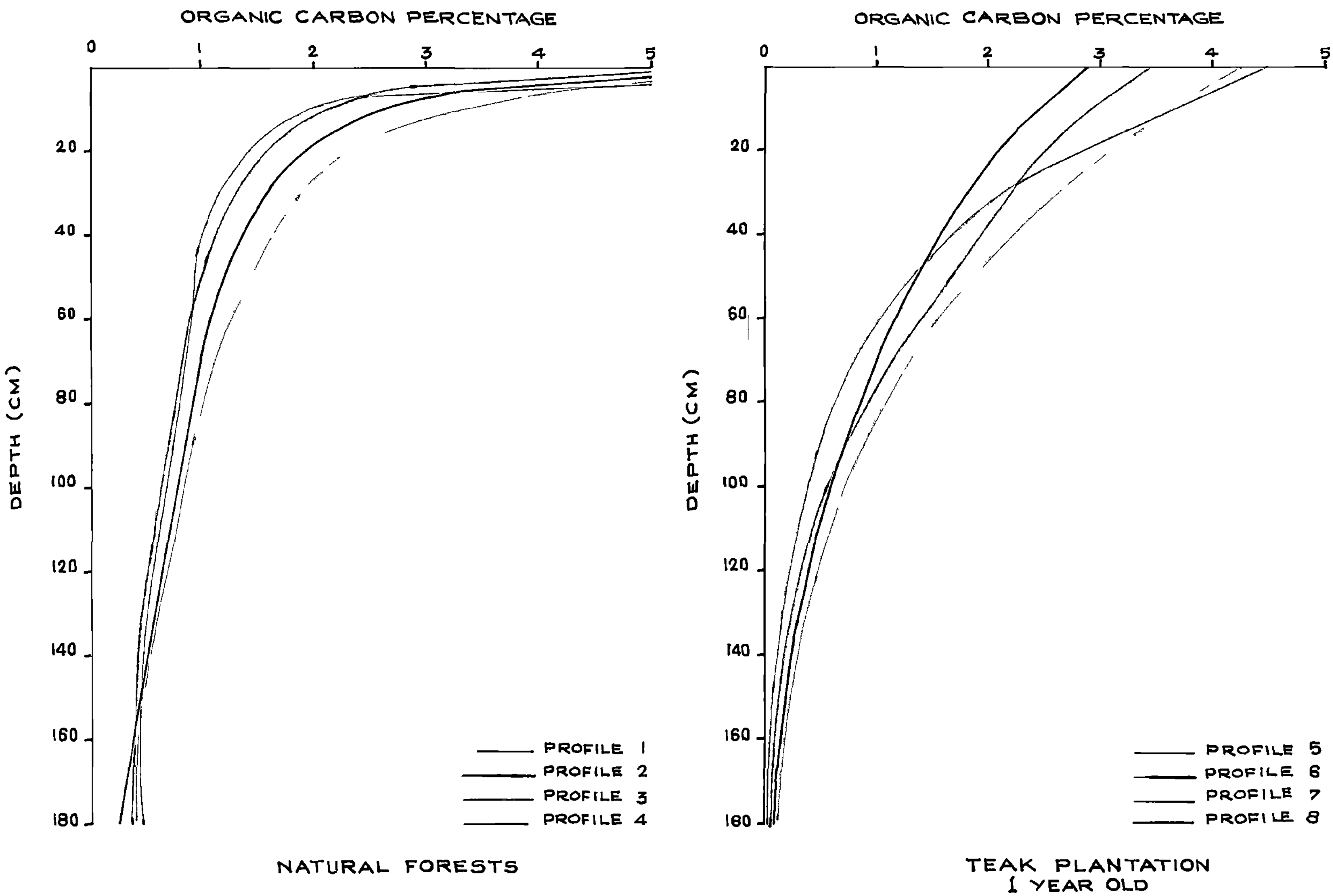

FIG 4 VARIATION IN THE ORGANIC CARBON CONTENT OF SOILS WITH DEPTH IN THE DIFFERENT PROFILES FROM NATURAL FORESTS AND 1 YEAR OLD TEAK PLANTATION

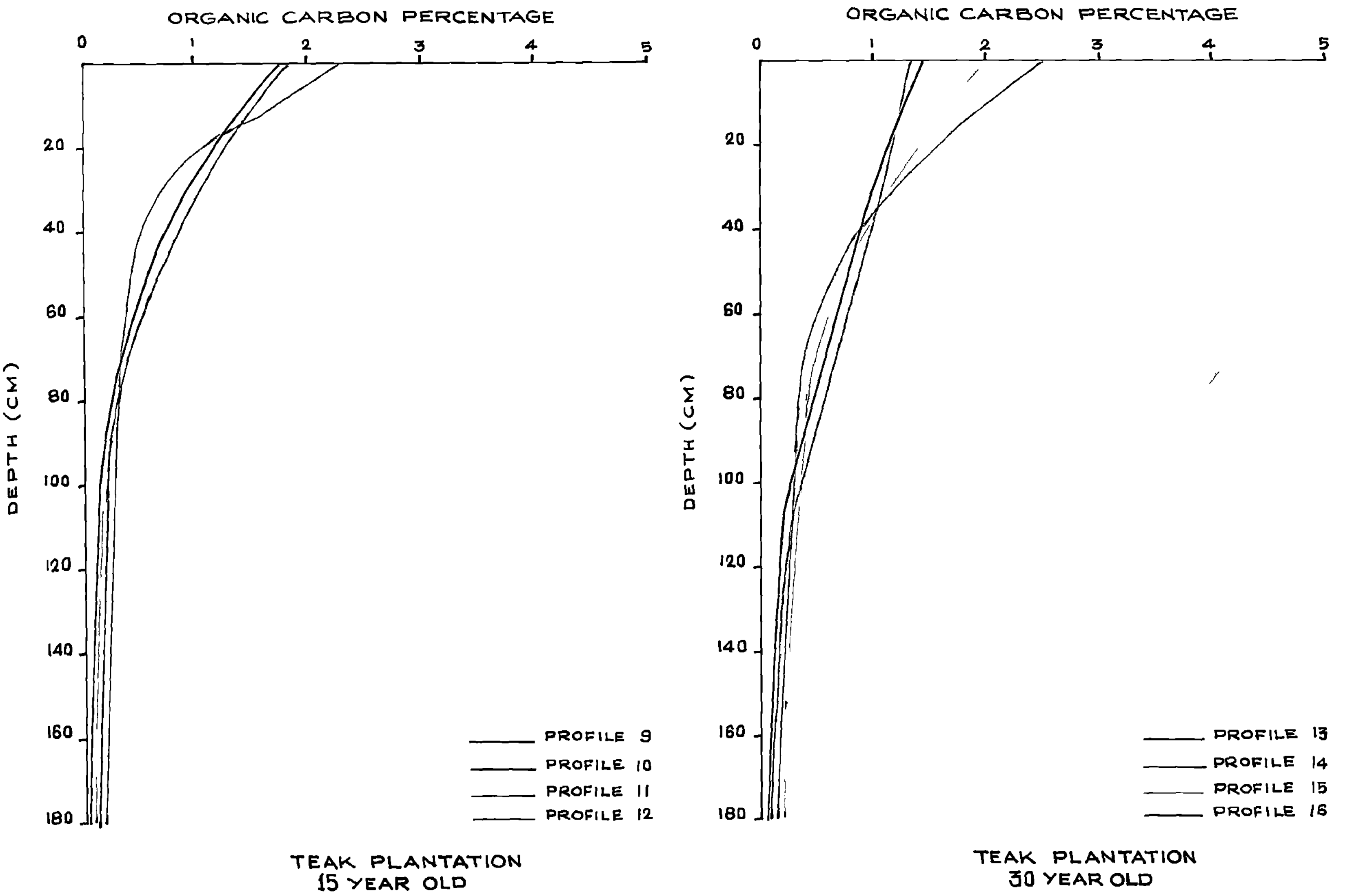

FIG 5

VARIATION IN THE ORGANIC CARBON CONTENT OF SOILS WITH DEPTH IN THE DIFFERENT PROFILES FROM 15 YEAR OLD TEAK PLANTATION AND 30 YEAR OLD TEAK PLANTATION

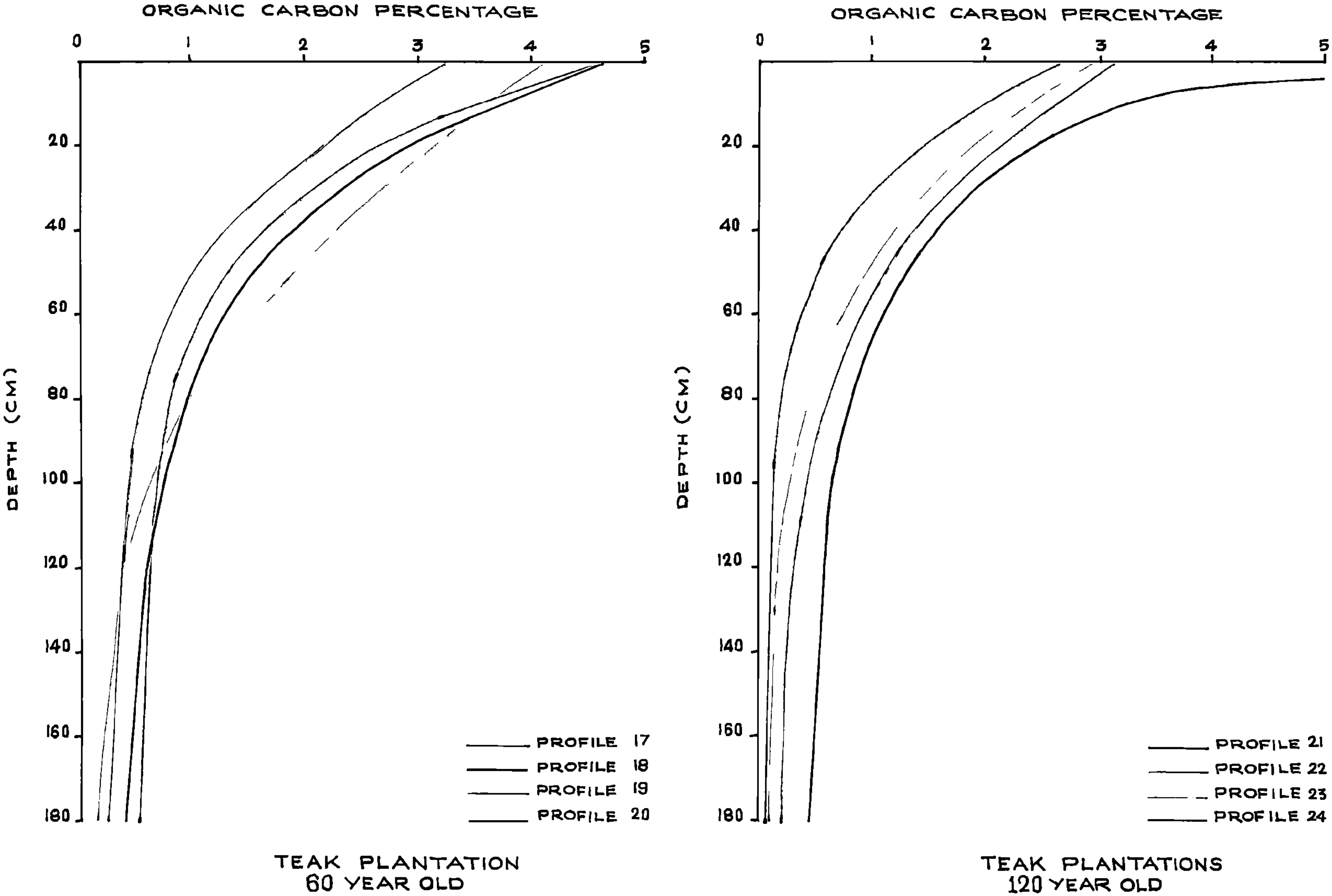

FIG 6

VARIATION IN THE ORGANIC CARBON CONTENT OF SOILS WITH DEPTH IN THE DIFFERENT PROFILES FROM 60 YEAR OLD TEAK PLANTATION AND 120 YEAR OLD TEAK PLANTATIONS teak plantation) to 4.96 per cent in the surface layer of profile 4 from the natural forests. In all the profiles under investigation the highest amount of organic carbon is seen in the surface horizon and it tends to decrease steadily with depth. The highest values for this constituent (3.54 to 4.96 per cent) are obtained in the surface horizons of the natural forests and the preservation plot. As regards the influence of the age of the teak plantation on this constituent it is seen that the organic carbon content decreases with the age of the teak plantation up to 30 years and thereafter it tends to increase in the 60 and 120 year old plantations. The profile from the teak failure area contains relatively a lower level of organic carbon in all its horizons.

(2) Nitrogen. The variation in the nitrogen content of the soils is presented in Tables XIII to XVIII and represented graphically as a function of depth in Fig. 7 to 9.

The nitrogen status of the soils studied ranges from 0.01 per cent in the third layer of profile 13 (30 year old teak plantation) to 0.46 per cent in the surface layer of the profile from the teak preservation plot. The amount of nitrogen in the various profiles studied decreases with depth. The highest values for this element (0.36 to 0.46 per cent) are obtained in the surface horizons of the natural forests and the preservation

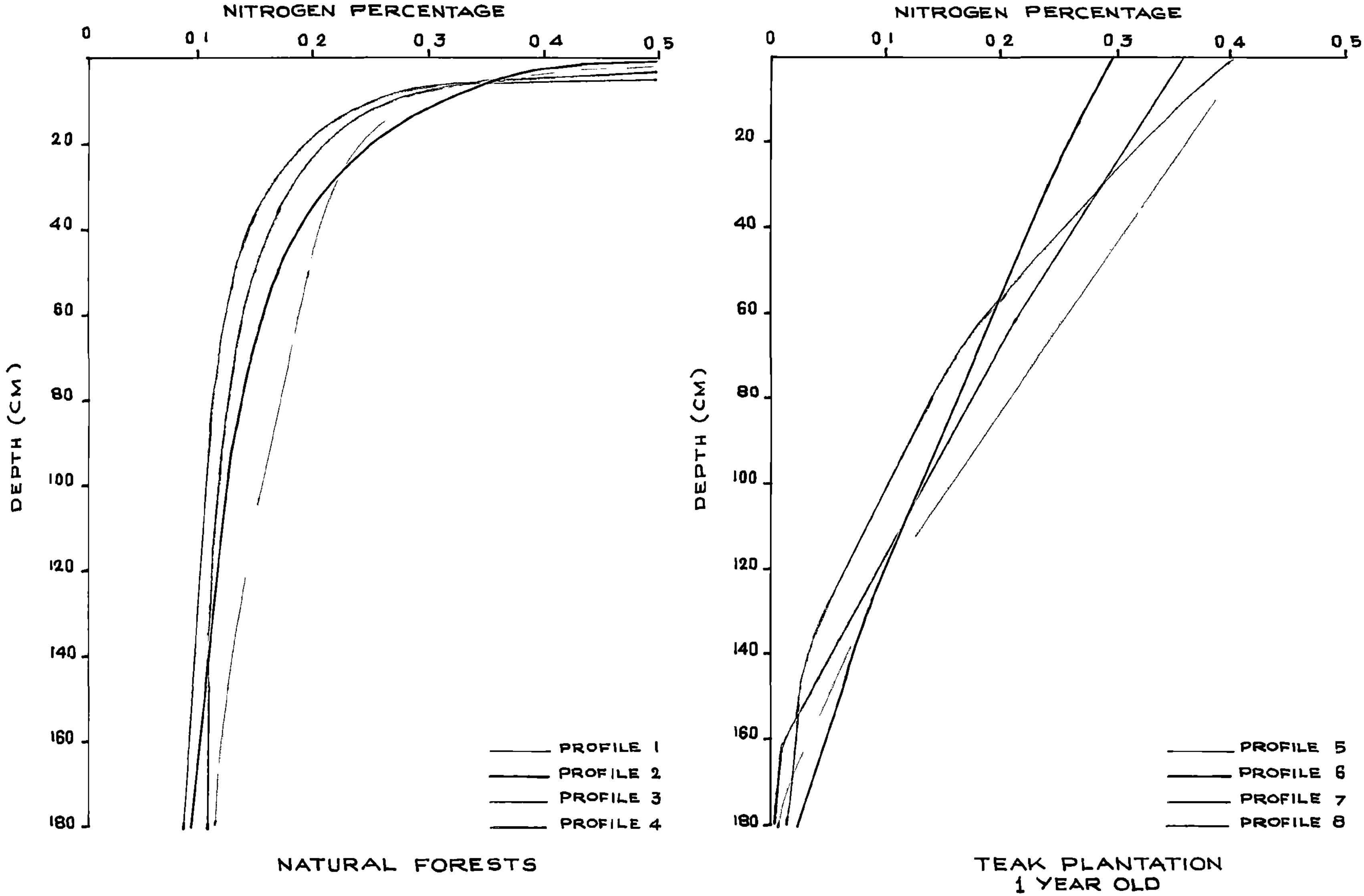

FIG 7

VARIATION IN THE NITROGEN CONTENT OF SOILS WITH DEPTH IN THE DIFFERENT PROFILES FROM NATURAL FORESTS AND 1 YEAR OLD TEAK PLANTATION

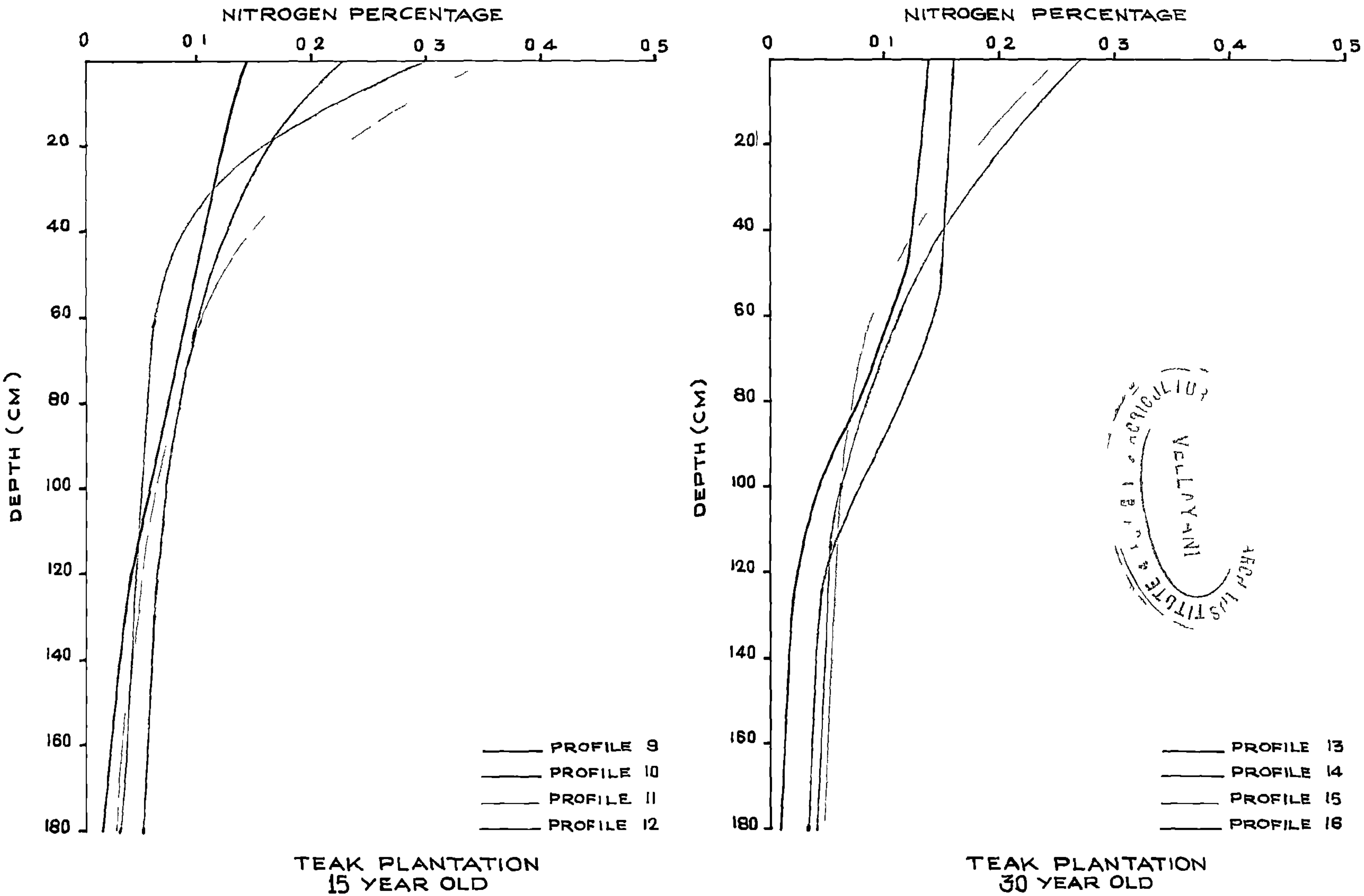

FIG 8

VARIATION IN THE NITROGEN CONTENT OF SOILS WITH DEPTH IN THE DIFFERENT PROFILES FROM 15 YEAR OLD TEAK PLANTATION AND 30 YEAR OLD TEAK PLANTATION

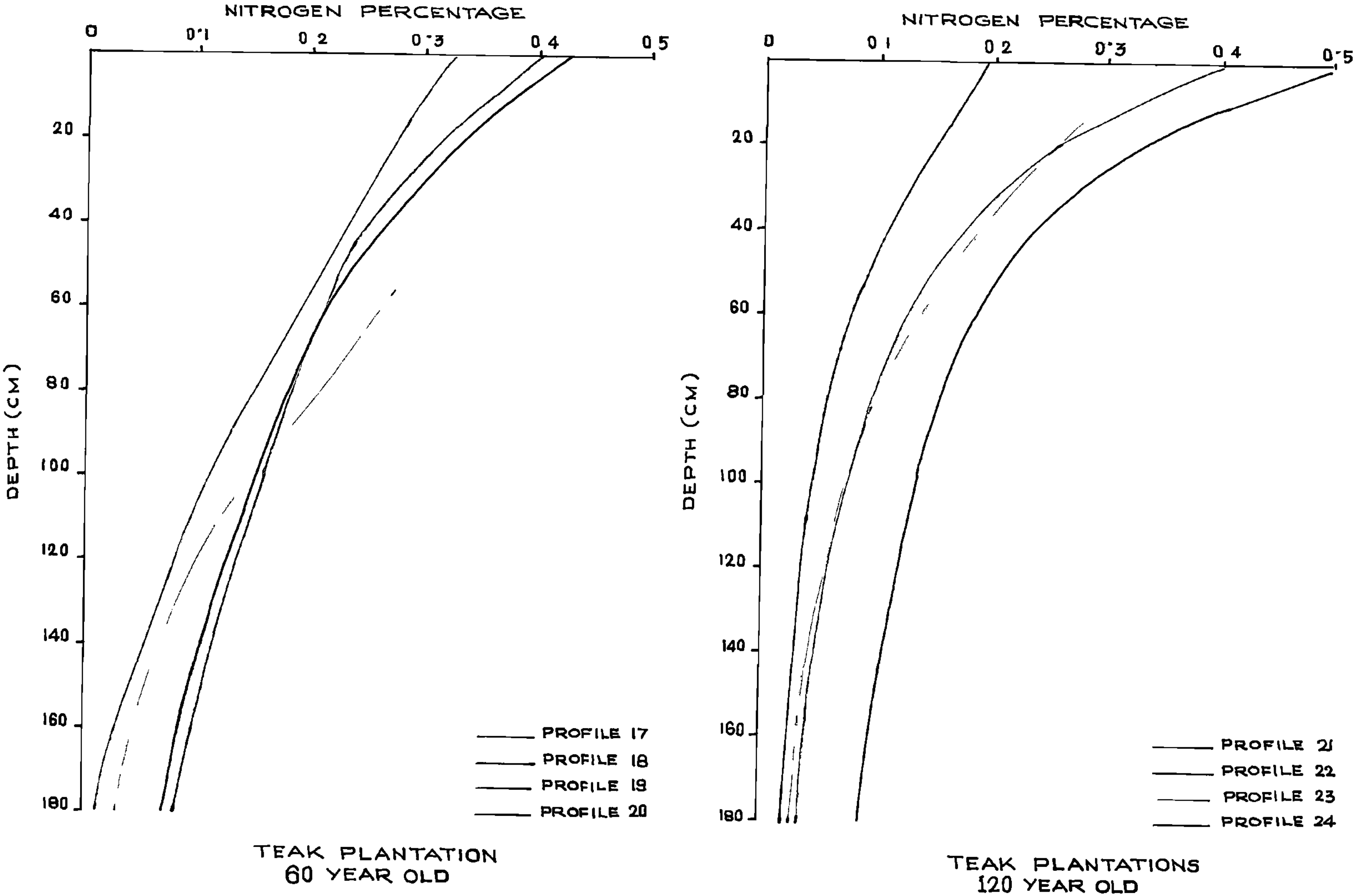

FIG 9 VARIATION IN THE NITROGEN CONTENT OF SOILS WITH DEPTH IN THE DIFFERENT PROFILES FROM 60 YEAR OLD TEAK PLANTATION AND 120 YEAR OLD TEAK PLANTATIONS

plot. As in the case of organic carbon, nitrogen content also decreases with the age of the teak plantation up to the 30th year whereafter it tends to increase in the 60 and 120 year old teak plantations. It is noteworthy that the second layers (30 to 90 cm.) of the profiles from the 1 year old teak plantation contain appreciably higher amounts of nitrogen (0.19 to 0.26 per cent) than the corresponding layers of the other profiles. Profile 22 of the teak failure area gives a low percentage of nitrogen (0.03 to 0.16 per cent) in all the horizons.

(3) Carbon:nitrogen ratio. The variation in the carbon:nitrogen ratio of the soils with depth in the different profiles is given in Tables XIII to XVIII and is illustrated graphically in Fig. 10 to 12.

The carbon:nitrogen ratio varies from 3.8 in the third horizon of profile 8 (1 year old plantation) to 12.7 in the surface horizon of profile 4 from the natural forests. The highest values for this ratio are recorded by the surface layers of profiles from the natural forests (9.1 to 12.7) and the preservation plot (10.4). In all the profiles the ratio tends to decrease down the profile. No regularity in the variation of the carbon:nitrogen ratio with the age of the teak plantation is noticed.

(4) Soil reaction (pH). The data in Tables XIX to XXIV indicate that the pH of the soils ranges from 5.0 in the surface layer of profile 4 from the natural forests

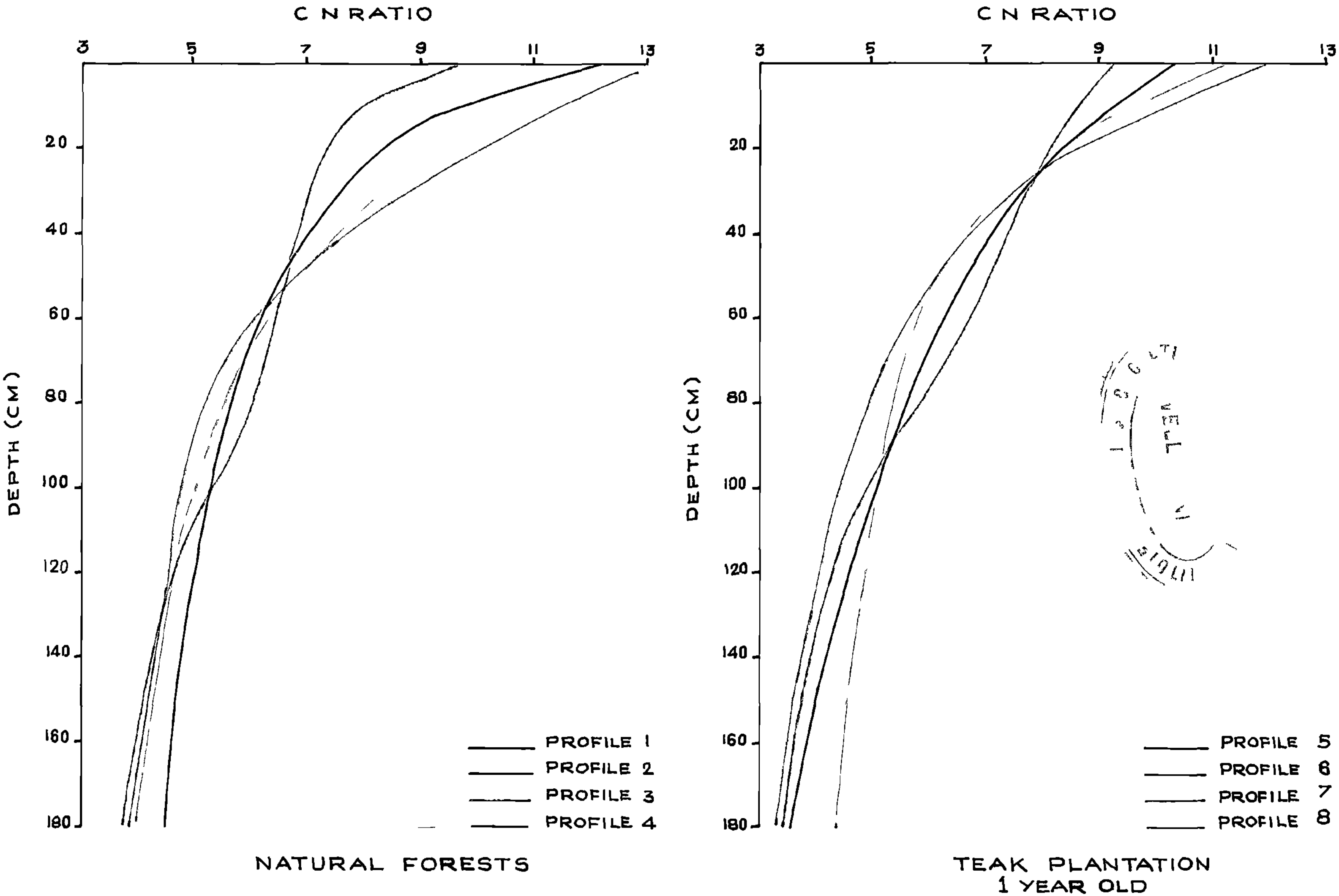

FIG 10

VARIATION IN THE C N RATIO OF SOILS WITH DEPTH IN THE DIFFERENT PROFILES FROM NATURAL FORESTS AND 1 YEAR OLD TEAK PLANTATION

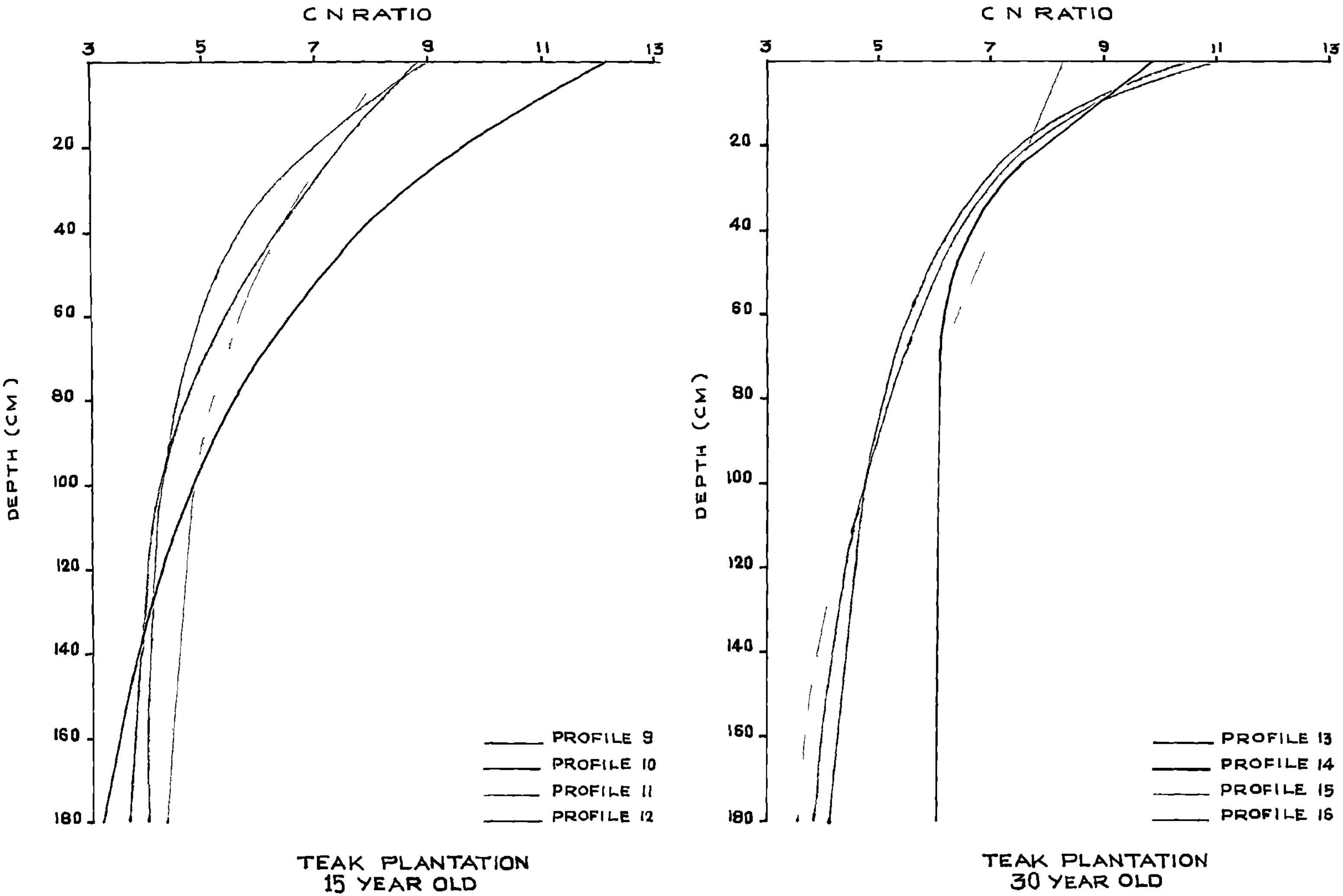

FIG 11

VARIATION IN THE C N RATIO OF SOILS WITH DEPTH IN THE DIFFERENT PROFILES FROM 15 YEAR OLD TEAK PLANTATION AND 30 YEAR OLD TEAK PLANTATION

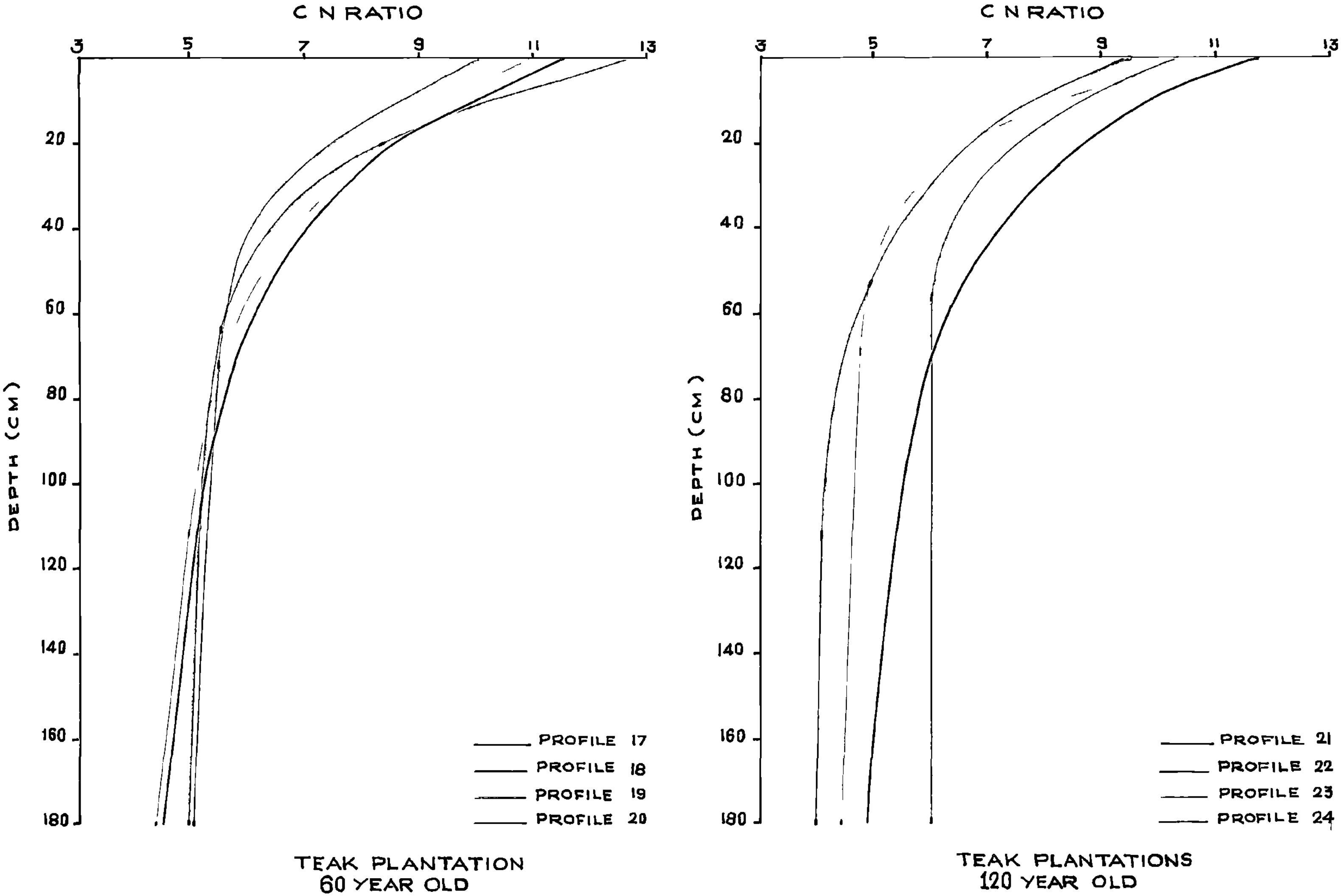

FIG 12

VARIATION IN THE C N RATIO OF SOILS WITH DEPTH IN THE DIFFERENT PROFILES FROM 60 YEAR OLD TEAK PLANTATION AND 120 YEAR OLD TEAK PLANTATIONS to 6.1 in the third layer of profile 5 (1 year old teak plantation). In general it may be stated that the pH values tend to increase with increase in depth. The pH of the soils from the different layers does not show much variation with the age of the teak plantation. However, the surface horizons of the profiles from the natural forests and the preservation plot are relatively more acidic (pH 5.0 to 5.2) than the surface soils of the other profiles (pH 5.1 to 5.9).

(5) Total soluble salts. The conductivity determined in a 1:2 soil-water extract, which is taken as a measure of the total soluble salts, varies from 0 to 0.45 mmhos./cm. (Tables XIX to XXIV). The highest value is recorded for the surface horizon of the profile from the preservation plot. It is clear that there is no toxic concentration of soluble salts in any of the profiles.

(6) Loss on ignition. The loss on ignition of soils ranges from 4.1 per cent in the third horizon of profile 10 (15 year old teak plantation) to 19.2 per cent in the surface layer of the profile from the preservation plot (120 year old teak plantation). It tends to decrease rather steadily with depth in all the profiles. Loss on ignition of the surface soils in the different profiles is found to be related to the age of the teak plantation. In the natural forests it ranges from 15.6 to 18.3 per cent

TABLE XIX

CHEMICAL COMPOSITION OF SOILS FROM NATURAL FORESTS

	Depth (cm.)	pH	T.S.S. (mmhos/cm.)	Per cent on oven dry basis							
				Loss on ignition	Acid insolubles	Fe_2O_3	Al_2O_3	P_2O_5	K_2O	CaO	MgO
Profile 1	0 - 10	5.2	0.30	18.3	54.8	8.1	16.4	0.20	0.15	0.58	0.39
	10 - 30	5.8	0.20	13.9	53.4	8.4	21.8	0.21	0.18	0.44	0.26
	30 - 90	5.5	0.10	11.2	54.2	9.2	23.0	0.13	0.16	0.32	0.18
	90 -180	5.6	0.00	10.2	58.5	9.0	20.5	0.11	0.13	0.30	0.17
Profile 2	0 - 10	5.1	0.25	16.5	52.2	7.9	21.1	0.17	0.14	0.61	0.43
	10 - 30	5.7	0.25	11.8	58.6	6.8	20.4	0.17	0.21	0.34	0.38
	30 - 90	5.4	0.05	10.5	56.7	10.2	20.4	0.11	0.10	0.30	0.21
	90 -180	5.4	0.00	6.5	59.4	10.3	21.8	0.13	0.16	0.31	0.10
Profile 3	0 - 10	5.2	0.25	15.6	57.0	8.2	17.0	0.18	0.12	0.51	0.33
	10 - 30	5.8	0.20	13.1	56.2	9.4	18.9	0.16	0.18	0.58	0.24
	30 - 90	5.9	0.05	10.2	52.6	9.9	24.9	0.10	0.17	0.29	0.12
	90 -180	5.7	0.00	6.8	57.8	10.0	23.2	0.08	0.14	0.33	0.17
Profile 4	0 - 10	5.0	0.20	17.9	48.3	11.1	20.1	0.21	0.10	0.63	0.24
	10 - 30	5.4	0.25	12.9	52.0	10.8	22.0	0.18	0.20	0.61	0.32
	30 - 90	5.7	0.00	9.9	54.0	10.2	23.7	0.11	0.21	0.44	0.20
	90 -180	5.7	0.00	6.2	55.4	11.4	25.0	0.12	0.17	0.21	0.14

TABLE XX

CHEMICAL COMPOSITION OF SOILS FROM 1 YEAR OLD TEAK PLANTATION

	Depth (cm.)	pH	T.S.S. (mmhos/cm.)	Per cent on oven dry basis							
				Loss on ignition	Acid insolubles	Fe_2O_3	Al_2O_3	P_2O_5	K_2O	CaO	MgO
Profile 5	0 - 30	5.3	0.25	14.4	47.2	10.6	25.3	0.11	0.18	0.18	0.09
	30 - 90	5.8	0.25	7.8	59.4	10.4	20.1	0.18	0.21	0.21	0.15
	90 -180	6.1	0.05	6.6	58.1	11.5	21.6	0.16	0.16	0.18	0.12
Profile 6	0 - 30	5.9	0.25	13.4	62.9	7.2	14.0	0.13	0.15	0.24	0.15
	30 - 90	5.8	0.20	6.6	67.4	6.9	16.8	0.20	0.24	0.21	0.21
	90 -180	5.7	0.10	5.3	63.2	8.3	21.2	0.10	0.18	0.15	0.16
Profile 7	0 - 30	5.8	0.20	13.0	59.5	6.2	15.1	0.08	0.12	0.24	0.11
	30 - 90	5.9	0.15	6.9	66.5	5.9	18.3	0.17	0.20	0.39	0.12
	90 -180	5.9	0.00	5.7	63.8	6.3	22.0	0.13	0.23	0.16	0.11
Profile 8	0 - 30	5.7	0.25	15.8	49.4	11.5	20.6	0.13	0.16	0.25	0.20
	30 - 90	5.8	0.05	8.3	58.7	10.7	20.0	0.19	0.29	0.25	0.12
	90 -180	6.0	0.00	8.8	52.0	8.5	28.5	0.12	0.24	0.11	0.08

TABLE XXI

CHEMICAL COMPOSITION OF SOILS FROM 15 YEAR OLD TEAK PLANTATION

	Depth (cm.)	pH	T.S.S. (mmhos/cm.)	Per cent on oven dry basis							
				Loss on ignition	Acid insolubles	Fe_2O_3	Al_2O_3	P_2O_5	K_2O	CaO	MgO
Profile 9	0 - 30	5.6	0.25	9.7	59.6	8.3	19.8	0.13	0.12	0.22	0.29
	30 - 90	5.8	0.05	6.0	64.3	7.1	20.0	0.12	0.19	0.21	0.21
	90 -180	5.9	0.00	5.5	62.1	8.4	21.7	0.08	0.28	0.20	0.13
Profile 10	0 - 30	5.5	0.25	7.4	56.7	10.2	22.9	0.09	0.10	0.29	0.25
	30 - 90	5.5	0.30	4.7	63.2	11.4	18.2	0.10	0.15	0.21	0.18
	90 -180	5.7	0.15	4.1	64.8	8.6	20.2	0.05	0.19	0.12	0.16
Profile 11	0 - 25	5.5	0.20	11.0	56.0	9.8	20.6	0.10	0.14	0.31	0.19
	25 - 90	5.6	0.25	6.4	63.0	10.2	17.9	0.14	0.24	0.18	0.17
	90 -180	5.7	0.10	5.7	63.0	10.3	18.8	0.08	0.19	0.12	0.15
Profile 12	0 - 30	5.7	0.25	12.7	57.0	6.8	20.8	0.12	0.15	0.30	0.20
	30 - 90	5.7	0.00	7.9	63.2	7.3	19.2	0.13	0.22	0.15	0.17
	90 -180	5.8	0.00	6.3	63.0	7.0	21.6	0.07	0.11	0.16	0.09

TABLE XXII

CHEMICAL COMPOSITION OF SOILS FROM 30 YEAR OLD TEAK PLANTATION

	Depth (cm.)	pH	T.S.S. (mmhos/cm.)	Per cent on oven dry basis							
				Loss on ignition	Acid insolubles	Fe_2O_3	Al_2O_3	P_2O_5	K_2O	CaO	MgO
Profile 13	0 - 30	5.4	0.10	11.9	56.0	8.3	21.3	0.14	0.13	0.31	0.26
	30 -100	5.6	0.00	6.2	57.1	10.2	24.2	0.16	0.23	0.27	0.13
	100 -180	5.9	0.00	7.2	58.6	11.9	20.2	0.11	0.18	0.28	0.12
Profile 14	0 - 25	5.4	0.15	9.5	58.1	9.2	20.9	0.10	0.17	0.31	0.27
	25 - 85	5.7	0.05	8.2	56.4	8.6	24.5	0.11	0.16	0.31	0.24
	85 -180	5.6	0.00	7.0	62.8	7.8	20.3	0.10	0.14	0.30	0.21
Profile 15	0 - 30	5.5	0.10	10.6	55.0	10.4	21.7	0.12	0.10	0.29	0.19
	30 - 90	5.6	0.00	8.9	52.5	8.2	27.9	0.14	0.19	0.25	0.20
	90 -180	5.8	0.00	6.9	52.7	11.9	26.3	0.15	0.13	0.22	0.18
Profile 16	0 - 30	5.6	0.00	11.9	57.2	9.1	19.5	0.09	0.12	0.38	0.33
	30 - 90	5.7	0.05	6.3	59.5	10.2	21.7	0.16	0.18	0.21	0.29
	90 -180	5.7	0.00	6.0	57.8	10.6	23.6	0.09	0.20	0.18	0.19

TABLE XXIII

CHEMICAL COMPOSITION OF SOILS FROM 60 YEAR OLD TEAK PLANTATION

	Depth (cm.)	pH	T.S.S. (mmhos/cm.)	Per cent on oven dry basis: Loss on ignition	Acid insolubles	Fe_2O_3	Al_2O_3	P_2O_5	K_2O	CaO	MgO
Profile 17	0 - 30	5.5	0.25	14.3	57.4	9.8	15.9	0.16	0.15	0.32	0.30
	30 - 90	5.6	0.10	8.3	57.6	9.6	22.1	0.17	0.16	0.28	0.32
	90 - 180	5.7	0.00	8.5	60.0	10.2	19.3	0.09	0.12	0.14	0.21
Profile 18	0 - 27	5.2	0.30	11.4	58.0	8.3	19.9	0.13	0.15	0.39	0.24
	27 - 85	5.4	0.15	8.6	53.0	7.5	28.7	0.16	0.20	0.23	0.18
	85 - 180	5.8	0.05	8.7	51.9	9.8	27.4	0.18	0.14	0.12	0.20
Profile 19	0 - 25	5.4	0.25	12.7	61.7	8.6	14.6	0.09	0.13	0.41	0.29
	25 - 95	5.6	0.05	7.9	59.6	8.6	21.7	0.11	0.21	0.32	0.23
	95 - 180	5.8	0.00	7.6	58.8	7.7	23.4	0.06	0.18	0.32	0.18
Profile 20	0 - 30	5.3	0.25	14.4	58.1	10.3	14.9	0.18	0.11	0.37	0.20
	30 - 90	5.5	0.10	8.9	60.2	9.6	19.0	0.16	0.17	0.24	0.22
	90 - 180	5.7	0.00	7.5	60.3	11.2	19.1	0.10	0.21	0.20	0.17

TABLE XXIV

CHEMICAL COMPOSITION OF SOILS FROM 120 YEAR OLD TEAK PLANTATIONS

	Depth (cm.)	pH	T.S.S. (mmhos/cm.)	Per cent on oven dry basis							
				Loss on ignition	Acid insolubles	Fe_2O_3	Al_2O_3	P_2O_5	K_2O	CaO	MgO
Profile 21 (Conolly's Teak Plantation preservation plot - alluvium)	0 - 10	5.1	0.45	19.2	53.0	8.4	16.8	0.25	0.17	0.82	0.98
	10 - 30	5.9	0.20	14.6	52.2	11.5	18.6	0.20	0.20	0.60	0.71
	30 - 90	5.4	0.05	12.1	53.2	10.2	21.5	0.15	0.15	0.42	0.44
	90 -180	5.4	0.00	7.6	59.7	8.3	22.0	0.16	0.19	0.32	0.12
Profile 22 (Teak failure area - hard laterite)	0 - 30	5.1	0.30	14.8	34.3	18.6	29.4	0.15	0.09	0.25	0.20
	30 - 90	5.6	0.05	13.6	33.3	19.2	31.4	0.27	0.22	0.18	0.08
	90 -180	5.6	0.00	10.5	39.7	16.2	31.0	0.13	0.16	0.14	0.06
Profile 23 (Second rotation - laterite)	0 - 25	5.8	0.25	13.5	47.7	13.9	22.8	0.13	0.10	0.28	0.21
	25 -100	5.9	0.00	11.8	41.6	12.2	31.9	0.06	0.15	0.14	0.12
	100 -180	5.9	0.00	11.0	43.6	11.8	31.6	0.05	0.14	0.16	0.11
Profile 24 (Second rotation - laterite)	0 - 35	5.7	0.20	12.7	48.8	10.2	26.0	0.08	0.10	0.28	0.17
	35 - 90	5.8	0.05	9.8	46.7	14.2	25.9	0.04	0.18	0.15	0.13
	90 -180	5.7	0.00	10.4	43.0	13.1	31.5	0.04	0.16	0.15	0.14

while in the teak plantations of age 1, 15, 30 and 60 years it varies from 13.0 to 15.8, 7.4 to 12.7, 9.5 to 11.9, and 11.4 to 14.4 per cent respectively. As regards the soils of the 120 year old teak plantation, the profile from the preservation plot records the highest value for loss on ignition (19.2 per cent) in its surface horizon. In the other three profiles under 120 year old teak plantations loss on ignition varies from 12.7 to 14.8 per cent in the surface layers.

(7) Acid insolubles. The amount of hydrochloric acid insolubles in the soils varies from 33.3 per cent in the second layer of profile 22 (teak failure area) to 67.4 per cent in the second layer of profile 6 (1 year old teak plantation). Acid insolubles show no regularity in variation with the age of the teak plantation. But profiles 22, 23 and 24 of the 120 year old teak plantations are relatively low in acid insolubles in all the horizons (33.3 to 48.8 per cent).

(8) Iron oxide (Fe_2O_3). The Fe_2O_3 content of the soils ranges from 5.9 per cent in the second layer of profile 7 (1 year old teak plantation) to 19.2 per cent in the second layer of the profile from the teak failure area. The variation in the Fe_2O_3 content of the soils with depth and with the nature of the vegetation is rather irregular. However, profiles 22, 23 and 24 of

the 120 year old teak plantations are characterized by significantly higher amounts of Fe_2O_3 (10.2 to 19.2 per cent).

(9) Alumina (Al_2O_3). The amount of Al_2O_3 in the soils under study varies from 14.0 per cent in the surface layer of profile 6 (1 year old teak plantation) to 31.9 per cent in the middle layer of profile 23 (120 year old teak plantation). No regularity is noted in the variation of this constituent either with depth or with the age of the plantation although profiles 22, 23 and 24 contain appreciably higher amounts of Al_2O_3 (22.8 to 31.9 per cent).

(10) Phosphorus. Tables XIX to XXIV show that the P_2O_5 status of the soils ranges from 0.04 per cent in the two lower horizons of profile 24 to 0.25 per cent in the surface soil of the preservation plot (120 year old plantation). In the profiles from the natural forests and the preservation plot the amount of P_2O_5 decreases with depth while in the profiles from the various teak plantations it has a general tendency to accumulate in the second horizon (30 to 90 cm.).

(11) Potassium. The K_2O content of soils varies from 0.09 to 0.29 per cent. The highest value is observed in the second layer of profile 8 (1 year old teak plantation) and the lowest value in the surface horizon of profile 22 (teak failure area). In most of the profiles the maximum

amount of K_2O is found in the second horizon. The upper layers (0 to 30 cm.) of the profiles from the natural forests, as well as the preservation plot, show a slightly higher percentage of K_2O than in the profiles from the various teak plantations. However, compared to the natural forests the profiles from the teak plantations contain higher levels of this constituent in their lower horizons. This accumulation of K_2O in the lower horizons is very marked in the case of the profiles from the 1 year old teak plantation, and it becomes less pronounced by the time the plantations reach the age of 30 years.

(12) Calcium. Tables XIX to XXIV indicate that the CaO status of the soils from the different profiles ranges from 0.11 per cent in the third horizon of profile 8 (1 year old teak plantation) to 0.82 per cent in the surface horizon of the profile from the preservation plot (120 year old teak plantation). Except in a very few profiles, the CaO content of soils tends to decrease with depth. The soils from the natural forests and from the preservation plot contain relatively higher percentage of this constituent throughout the profile, the maximum amount (0.51 to 0.82 per cent) occurring in the upper layers. The amount of CaO in the surface horizons of the profiles from the various teak plantations appears to be influenced by the age of the teak plants. The lowest

values (0.18 to 0.25 per cent) are obtained in the case of the 1 year old teak plantation. As the plantation becomes older the amount of CaO in this horizon gradually increases and the value ranges from 0.22 to 0.31, 0.29 to 0.38 and 0.32 to 0.41 per cent in the 15, 30 and 60 year old plantations respectively. The CaO values for profiles 22, 23 and 24 of the 120 year old teak plantations are comparable with that of the profiles from the 15 year old teak plantation. Very little difference is observed in the CaO content of the deeper horizons of the profiles from the various teak plantations.

(13) Magnesium. The MgO content of the soils varies from 0.06 per cent in the third horizon of profile 22 (teak failure area) to 0.98 per cent in the surface layer of the profile from the preservation plot. The soils of the natural forests and the preservation plot contain relatively higher amounts of this constituent. As regards the influence of the age of the plantation on this element, it is noted that the MgO content is lowest in the 1 year old teak plantation and it tends to increase with the age of the teak trees.

III. Analysis of the clay fraction

The data showing the chemical character of the clay fraction of soils are presented in Tables XXV to XXX.

TABLE XXV

CHEMICAL CHARACTER OF THE CLAY FRACTION OF THE SOILS FROM NATURAL FORESTS

	Depth (cm.)	Per cent on oven dry basis			Molecular ratios		
		SiO_2	Al_2O_3	Fe_2O_3	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3+Fe_2O_3}$
Profile 1	0 - 30	31.1	27.8	15.1	1.89	5.44	1.40
	30 - 90	38.2	27.9	13.9	2.32	7.31	1.76
Profile 2	0 - 30	33.3	29.7	15.0	1.90	5.89	1.44
	30 - 90	34.0	30.6	15.4	1.89	5.84	1.43
Profile 3	0 - 30	34.9	31.2	13.9	1.90	6.68	1.48
	30 - 90	36.1	30.1	15.7	2.04	6.13	1.53
Profile 4	0 - 30	28.8	30.3	16.9	1.61	4.52	1.19
	30 - 90	33.9	29.7	16.4	1.94	5.48	1.43

TABLE XXVI

CHEMICAL CHARACTER OF THE CLAY FRACTION OF THE SOILS FROM 1 YEAR OLD TEAK PLANTATION

	Depth (cm.)	Per cent on oven dry basis			Molecular ratios		
		SiO_2	Al_2O_3	Fe_2O_3	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3+Fe_2O_3}$
Profile 5	0 - 30	34.1	27.9	16.0	2.07	5.67	1.52
	30 - 90	36.6	32.2	16.2	1.93	6.03	1.46
Profile 6	0 - 30	31.2	32.8	16.0	1.61	5.19	1.23
	30 - 90	37.2	32.8	16.4	1.92	6.07	1.46
Profile 7	0 - 30	39.9	28.0	14.1	2.44	7.55	1.83
	30 - 90	36.2	31.8	16.0	1.93	6.02	1.46
Profile 8	0 - 30	38.8	27.9	11.3	2.35	9.08	1.87
	30 - 90	35.6	32.0	16.4	1.89	5.80	1.42

TABLE XXVII

CHEMICAL CHARACTER OF THE CLAY FRACTION OF THE SOILS FROM 15 YEAR OLD TEAK PLANTATION

	Depth (cm.)	Per cent on oven dry basis			Molecular ratios		
		SiO_2	Al_2O_3	Fe_2O_3	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3+Fe_2O_3}$
Profile 9	0 - 30	34.9	30.0	17.1	1.98	5.43	1.45
	30 - 90	39.8	29.9	15.3	2.26	6.90	1.70
Profile 10	0 - 30	33.4	32.8	16.8	1.73	5.30	1.31
	30 - 90	38.8	30.1	18.1	2.19	5.72	1.58
Profile 11	0 - 25	30.1	33.7	16.2	1.52	4.96	1.16
	25 - 90	33.1	34.5	16.4	1.64	5.40	1.26
Profile 12	0 - 30	36.8	28.7	13.5	2.18	7.20	1.67
	30 - 90	38.9	31.2	14.9	2.12	6.96	1.62

TABLE XXVIII

CHEMICAL CHARACTER OF THE CLAY FRACTION OF THE SOILS FROM 30 YEAR OLD TEAK PLANTATION

	Depth (cm.)	Per cent on oven dry basis			Molecular ratios		
		SiO_2	Al_2O_3	Fe_2O_3	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3+Fe_2O_3}$
Profile 13	0 - 30	30.0	33.6	16.4	1.52	4.85	1.16
	30 -100	28.8	35.7	20.5	1.37	3.74	1.00
Profile 14	0 - 25	33.9	29.8	17.1	1.93	5.27	1.41
	25 - 85	38.1	30.9	14.0	2.10	7.20	1.63
Profile 15	0 - 30	35.4	28.1	18.5	2.14	5.08	1.51
	30 - 90	36.8	30.2	17.0	2.07	5.77	1.53
Profile 16	0 - 30	36.1	29.8	14.1	2.06	6.83	1.58
	30 - 90	35.4	32.3	17.3	1.86	5.45	1.39

TABLE XXIX

CHEMICAL CHARACTER OF THE CLAY FRACTION OF THE SOILS FROM 60 YEAR OLD TEAK PLANTATION

	Depth (cm.)	Per cent on oven dry basis			Molecular ratios		
		SiO_2	Al_2O_3	Fe_2O_3	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3+Fe_2O_3}$
Profile 17	0 - 30	34.2	28.1	15.7	2.07	5.81	1.53
	30 - 90	36.3	30.9	16.0	2.00	6.04	1.50
Profile 18	0 - 27	35.0	31.0	14.1	1.92	6.61	1.49
	27 - 85	38.5	31.7	13.8	2.07	7.45	1.62
Profile 19	0 - 25	33.9	30.2	15.9	1.91	5.70	1.43
	25 - 95	32.1	36.0	16.8	1.52	5.09	1.17
Profile 20	0 - 30	33.9	28.4	15.7	2.03	5.76	1.50
	30 - 90	35.9	31.2	16.1	1.96	5.97	1.47

TABLE XXX

CHEMICAL CHARACTER OF THE CLAY FRACTION OF THE SOILS FROM 120 YEAR OLD TEAK PLANTATIONS

	Depth (cm.)	Per cent on oven dry basis			Molecular ratios		
		SiO_2	Al_2O_3	Fe_2O_3	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3+Fe_2O_3}$
Profile 21 (Conolly's Teak Plantation, preservation plot - alluvium)	0 - 30	33.0	26.9	13.1	2.09	6.70	1.59
	30 - 90	38.4	27.2	12.4	2.41	8.18	1.86
Profile 22 (Teak failure area - hard laterite)	0 - 30	28.8	34.3	15.9	1.43	4.84	1.10
	30 - 90	26.4	36.2	17.4	1.24	4.03	0.95
Profile 23 (Second rotation - laterite)	0 - 25	29.1	34.4	15.4	1.45	5.04	1.12
	25 - 100	27.6	38.3	17.1	1.22	4.29	0.95
Profile 24 (Second rotation - laterite)	0 - 35	30.0	34.9	15.2	1.47	5.26	1.15
	35 - 90	25.6	39.6	18.8	1.10	3.63	0.84

(1) Silica (SiO_2). The SiO_2 content of the clay from the various profiles under examination ranges from 25.6 per cent in the second layer of profile 24 (120 year old teak plantation) to 39.9 per cent in the surface horizon of profile 7 (1 year old teak plantation). The variation in the SiO_2 content of clay from various profiles does not follow any regular pattern and is not seen to be correlated with the age of the teak plantation. But the clay from profiles 22, 23 and 24 of the 120 year old teak plantations are relatively poor in the SiO_2 content, especially, in the lower horizons (25.6 to 27.6 per cent).

(2) Alumina (Al_2O_3). The amount of Al_2O_3 in the clay from various profiles ranges from 26.9 per cent in the first layer of profile 21 (preservation plot) to 39.6 per cent in the second layer of profile 24 (120 year old teak plantation). The variation in the Al_2O_3 content of the clay fraction from various profiles does not appear to be affected by the nature of the vegetation. However, profiles 22, 23 and 24 contain higher levels of Al_2O_3 (34.3 to 39.6 per cent) in both the horizons.

(3) Iron oxide (Fe_2O_3). The data in Tables XXV to XXX indicate that the Fe_2O_3 content of the clay fractions from the various profiles ranges from 11.3 to 18.8 per cent. The highest value is shown by the second horizon of profile 24 (120 year old teak plantation) and the lowest value by the first horizon of profile 8 (1 year old teak

plantation). As in the case of SiO_2 and Al_2O_3, the variation in the Fe_2O_3 content of clay from the different profiles is irregular and is not found influenced by the age of the plantation. The second layers of the profiles 22, 23 and 24 of the 120 year old teak plantations contain higher amounts of Fe_2O_3 (17.1 to 18.8 per cent) as compared to other profiles.

(4) Molecular ratios. The SiO_2/Al_2O_3, SiO_2/Fe_2O_3 and SiO_2/R_2O_3 molecular ratios of the clay do not show any significant difference with the age of the teak plantation (Tables XXV to XXX). The SiO_2/Al_2O_3 ratio varies from 1.10 to 2.44 in all the soils studied. The lowest ratio is noticed in the second layer of profile 24 (120 year old teak plantation) and the highest value in the first layer of profile 7 (1 year old teak plantation). The second horizon of profiles 22 and 23 also have very low SiO_2/Al_2O_3 ratio for the clay, viz., 1.24 and 1.22 respectively. The SiO_2/Fe_2O_3 ratio ranges from 3.63 to 9.08 and of SiO_2/R_2O_3 varies from 0.84 to 1.87. For both the ratios the highest value is obtained in the first layer of profile 8 (1 year old plantation) and the lowest value is given by the second horizon of profile 24 (120 year old teak plantation).

DISCUSSION

DISCUSSION

The results of the present investigation reveal that remarkable changes in the morphological, physical and chemical properties of forest soils take place as a result of clear-felling of forests and maintaining a pure teak plantation. However, in all the profiles studied there is a close resemblence in certain soil characteristics which is obviously due to the similarity in the conditions under which these soils originally developed.

The presence of unweathered pieces of gneiss and granite in the lower horizons of the various profiles leads to the assumption that these rocks form the main type of parent material of the soils under study. The morphological features of these soils indicate that all of them are basically lateritic in nature. Though typical laterite beds are not obtained in all the cases, the presence of red and yellow mottlings and the occurrence of iron concretions and patches of kaolin clay are indicative for the lateritic nature of these soils. Further evidence to their lateritic character is obtained from the low silica:alumina and silica: sesquioxide ratios (1.10 to 2.44 and 0.84 to 1.87) of the clay fractions separated from them. Some of them have a silica:alumina ratio of more than 2.0 and therefore, according to the definition of Martin and Doyne (1927, 1930), these soils may be considered as nonlateritic. However, Raychaudhuri and Sulaiman (1940) have pointed out that the silica:alumina ratio of the clay fraction of most of the Indian laterites are higher than 2 and hence a strict application of this definition is not valid for Indian laterites.

The variation in the content of silica, iron oxide and alumina of the soils is not found to be correlated to the nature of the vegetation and there is very little justification for the hypothesis that sesquioxides tend to accumulate under the influence of a teak vegetation (Davis, 1940). Furthermore, the chemical character of the clay fraction from the various soils under examination does not show any regular variation with the age of the teak plantation which indicates that the chemical constitution of the clay is not altered to any marked extent by the removal of natural forests and the planting of teak. This observation also reveals that laterisation, which is the predominant soil forming process in the tropics, is not appreciably accelerated by these silvicultural operations.

The high proportion of the sesquioxides both in the soil and in the clay fraction of profile 22, 23 and 24 (120 year old teak plantations) is obviously due to the typical laterite beds noticed in them at a very shallow depth. However, the occurrence of laterite beds in these profiles is not to be attributed to the influence of vegetation, for in the profile from the 120 year old preservation plot such beds are not found to be present. Moreover the silica:sesquioxide ratios of the clay fractions of the soils from the preservation plot are similar to that of the natural forests.

The morphological features of the soils studied show that in the natural forests the soil structure is usually of the crumb type in the surface layer. But this type of soil structure is found no more in existence in any of the teak plantations. The variation in the single value constants of the soil with age of the plantation also indicates that the physical conditions of the soil have been markedly altered as a result of deforestation and subsequent planting of teak. The surface soils of the various teak plantations exhibit remarkably higher values for apparent density and absolute specific gravity and relatively lower values for pore space, water holding capacity and percentage volume expansion than those of the natural forests. This variation in the physical constants can be attributed to the differences in the organic matter content of the surface soils of the various profiles. Further, the exposure of the surface soil by the removal of the forest cover and the subsequent compaction of the soil by mechanical disturbances during silvicultural operations might have caused this variation in the single value constants. Trimble and Tripp (1949) and Colthary (1960) observed similar changes in the physical properties of soil consequent on clear-felling. The apparent density of the surface soil steadily increases as the plantation becomes older until the 15th year and thereafter it slightly decreases, presumably due to the increase in the addition of organic matter by the growing teak trees. It is remarkable that the single value constants of the soil from the teak preservation plot (120 years old teak plantation) show a very close similarity to that of the soils from the natural forests. The 120 year old teak trees in this plantation have developed a dense canopy of foliage, as a result of which the site now resembles a natural forest with a high content of organic matter in the surface horizon. The soil from the teak failure area exhibits the highest value for apparent density and specific gravity and the lowest value for volume expansion which can be attributed to the presence of very hard laterite beds with a high content of iron and alumina in this profile and also to a lower content of organic matter due to the lack of a dense vegetational cover. Perhaps, the exposure of the soil in this area consequent on clear-felling of natural forests and planting of teak might have resulted in the hardening of the soft laterite originally present at a very shallow depth and hence the failure of the teak trees due to lack of root penetration.

The clay content of the soil from the natural forests and the 120 year old teak preservation plot is highest in the second horizon (10 to 30 cm.). But in the profiles from the various teak plantations the maximum value for clay is observed at a depth of 30 to 90 cm. This shows that the clay has been translocated to the subsoil in the teak plantations at a more rapid rate than in the natural forests and the preservation plot. Such a rapid eluviation of the clay can only be attributed to the excessive mechanical disturbances to the soil caused by deforestation and planting of teak.

The results indicate that the variation in the loss on ignition of the soils is closely correlated to the variation in the organic carbon content of the soils. The highest values for both carbon and nitrogen are obtained in the surface horizons of the natural forests and the preservation plot. The organic carbon and nitrogen contents of the soil decrease with the age of the teak plantation up to 30 years and thereafter these tend to increase in the 60 and 120 year old teak plantations. This is obviously because of the fact that the removal of the forest stand increases air movement and facilitates the oxidation of soil organic matter. By the time a period of 15 years has elapsed, practically the whole of the oxidisable organic matter which had accumulated under forest conditions might have been oxidised away. When the plantation reaches the age of 30 years the addition of organic matter by the teak trees becomes pronounced, as a result of which, the organic carbon and nitrogen contents of the soil are gradually built up. Muller (1887), Ehrenburg (1922), and Trimble and Tripp (1949) have also observed rapid oxidation of organic matter by the removal of the forest cover. The very low content of organic carbon and nitrogen in the soils from the teak failure area can be attributed to the scarce vegetation present in this area. The relatively higher percentage of nitrogen in the lower horizons of the profiles from the 1 year old teak plantation indicates that the decomposition of organic matter and the mineralisation and leaching of nitrogen have taken place at an increased rate immediately after clear-felling of the forests. This is possible because the thinning of natural forests meant for clearing generally starts 1 or 2 years before actual clear-felling begins.

The carbon:nitrogen ratio of the soils varies from 3.8 to 12.7. The surface soils of the natural forests and the preservation plot are characterized by a relatively higher ratio which can only be attributed to the higher amounts of undecomposed organic matter present in them. The low carbon:nitrogen ratios observed in the lower horizons may probably be due to the high infiltration of nitrogen into these layers. Russel (1961) attributes such a fall in carbon:nitrogen ratio to the inclusion of ammonium ions held by the clay in a form in which they can be displaced only by treatment with a strong acid. The normal carbon:nitrogen ratio observed in the top soils of the various teak plantations indicates that the process of decomposition of organic matter is quite rapid in these plantations.

The pH values of the soils show that the surface soils of the natural forests and the preservation plot are slightly more acidic than the surface soils of the various teak plantations. The higher acidity noticed may presumably be due to the accumulation of organic matter in these soils which may give rise to organic acids during their decomposition. This finding is in conformity with the observation of Requier (1953) who found that the removal of forests increased the pH of the soil by checking the subsequent accumulation of organic matter. Fuller (1955) attributed this change in pH to the removal of soluble salts by leaching.

The surface layers of the profiles from the natural forests and the preservation plot give higher values for P_2O_5 which is obviously due to the higher amounts of organic matter undergoing decomposition resulting in the mineralisation of this element. Under the influence of the teak vegetation, this nutrient generally tends to accumulate in the second horizon. It is noted that in all the teak plantations the clay content is also higher in this horizon (30 to 90 cm.). Goel and Agarwal (1960) found that soils which contain a higher amount of clay and silt retained more phosphorus than soils poor in these fractions. It is possible that the phosphorus released by mineralisation in the surface layers is held up in the subsoils containing an accumulation of clay.

In all the profiles under study the maximum amount of potassium is found in the second horizon.

The high mobility of potassium ions helps easy leaching of this element from the surface horizons and its accumulation in the lower layers. The surface soils of the natural forests and the preservation plot contain a slightly higher percentage of K_2O compared to the surface soils of the teak plantations. But when the distribution of K_2O in the lower horizons is considered, it is found that the teak plantations are richer in this plant food element. This accumulation of K_2O in the lower horizons is very marked in the case of the profiles from the 1 year old teak plantation and it becomes less pronounced by the time the plantations reach the age of 30 years. The accelerated mineralisation of potassium by the decomposition of the organic matter as well as the burning of the tree stumps subsequent to clear-felling of natural forests results in an accumulation of this element in the lower horizons of the 1 year old teak plantation. However, appreciable amounts of potassium are easily lost by percolation and drainage and consequently in the soils from the 15 and 30 years old teak plantations the accumulation of this element becomes less pronounced. This finding is in agreement with the observation of Chaly and Koshy (1967) who found that the soils denuded for 5 years contained substantially higher amounts of potassium compared to the natural forests.

The amount of both calcium and magnesium is highest in the surface soils and it decreases with depth in most of the profiles which can be ascribed to the accumulation of these elements in the top soil through leaf fall. The soils of the natural forests and the preservation plot contain relatively higher amounts of these constituents which can be attributed to the larger amounts of litter added into these soils. As regards the influence of the teak vegetation on these elements, it is noted that the CaO and MgO contents of the soil are lowest in the 1 year old teak plantation and these tend to increase with the age of the plantation. During the prolonged process of thinning and clear-felling of the forests the bases liberated from the decomposing organic matter get quickly and preferentially leached down the profile, and as a result very low values are recorded for them in the soils from the 1 year old teak plantation. As the teak trees grow older the addition of fresh litter by the leaf fall produces a slight increase in the magnesium and calcium contents of the soils.

Davis (1940) has expressed the view that the denudation of forests followed by the planting of teak results either in the formation of laterite or the exposure of the laterite beds originally present as a result of the erosion of the top soil. The evidence of the present investigation lends support to the view held by Laurie and Griffith (1942) and Griffith and Gupta (1947) that the process occurring after clear-felling and planting is not the chemical transformation of rock or soil material into laterite, but only the hardening of the laterites or lateritic soils originally present.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

A study has been made of the forest soils of the Nilambur Division, Kerala State, to determine the extent to which the morphological, physical and chemical characteristics of the soils are affected by deforestation followed by the maintenance of a pure teak plantation. Profile sites were selected to represent 6 types of vegetation, viz.,natural forests and teak plantations of age 1, 15, 30, 60, and 120 years. Four profile pits of depth 180 cm. were dug in each of the above areas. The profiles from the 120 year old teak plantations represent a teak preservation plot of this age, a teak failure area where teak was planted 120 years ago, and two plots of second rotation teak crop. The results of the investigation lead to the following findings:

(1) All the soils under study are basically lateritic in nature. The variations in the content of silica, iron oxide and alumina of the soils are not found to be correlated with the age of the teak plantation. The chemical character of the clay fractions from the various soils under examination indicates that the constitution of the clay is not altered to any marked extent by the removal of natural forests and by maintaining a pure teak plantation. These

observations reveal that the process of laterization is not appreciably accelerated by silvicultural operations.

(2) The variation in the single value constants of the soils with age of the plantation indicates that the physical condition of the soils has been markedly altered as a result of deforestation and planting of teak. The surface soils of various teak plantations exhibit remarkably higher values for apparent density and absolute specific gravity and relatively lower values for pore space, water holding capacity and percentage volume expansion. But this difference is well pronounced only up to a period of 30 years after planting. The single value constants of soils of the 120 year old teak preservation plot are comparable to that of the natural forests. However, considerable compaction of soil is noticed in the second rotation plots.

(3) The mechanical analysis of the soils reveals that the clay has been translocated to lower layers, consequent on clear-felling of trees and planting of teak.

(4) As a result of deforestation, there has been a rapid decrease in the organic carbon and nitrogen contents of the soils up to a period of 15 years.

Thereafter these constituents tend to increase in the 30, 60, and 120 year old teak plantations. Profiles from the 1 year old teak plantation contain considerably higher amounts of nitrogen in the lower horizons. The surface soils of the natural forests and the 120 year old teak preservation plot exhibit higher values for C/N ratio. In all the profiles the C/N ratio decreases with depth.

(5) The surface soils of the natural forests and the preservation plot are slightly more acidic than those of the various teak plantations.

(6) Relatively higher amounts of P_2O_5 are obtained in the surface layers of the natural forests and the preservation plot. As regards the influence of the teak vegetation the general tendency of this element is to accumulate in the second horizons (30 to 60 cm.).

(7) In all the profiles under study the maximum amount of K_2O is found in the second layers. The surface soils of the natural forests and the preservation plot contain slightly higher amounts of K_2O than those of the various teak plantations. But when the distribution of this element in the lower layers is considered it is found that the teak plantations are richer in this constituent. This

accumulation of K_2O in the lower horizons is very marked in the case of the profiles from the 1 year old teak plantation and it becomes less pronounced by the time the plantation reaches the age of 30 years.

(8) Calcium and magnesium contents are highest in the surface soils and these elements decrease with depth in most of the profiles. Soils from the natural forests and the preservation plot contain relatively higher amounts of these nutrients. Clear-felling of trees results in appreciable loss of these elements from the soil, but with the maintenance of teak vegetation for periods of 15 - 120 years the status of these elements in the soil is gradually restored.

The results of the investigation lead to the conclusion that clear-felling and planting of teak do not accelerate the process of laterization but may cause a temporary impoverishment of the soil and a hardening of the lateritic material originally present.

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