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Forest Department

Soil Conditions of Degraded Natural Forest and Teak Plantations with Particular Reference to Ngalaik Reserved Forest, Pyinmana

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ငါးလိုက်ကြိုးဝိုင်းအတွင်း အဆင့်အတန်းလျော့ကျနေသော သဘာဝတောနှင့် ကျွန်းစိုက်ခင်းများ၏ မြေဆီလွှာအခြေအနေအားလေ့လာခြင်း

သီတာဆွေ ၊ သုတေသနလက်ထောက်–၂၊ သစ်တောသုတေသနဌာန၊ ရေဆင်း။
စောစီဒူး (အကြံပေးပုဂ္ဂိုလ်၊ သစ်တောတက္ကသိုလ်)
တင်တင်အုန်း (လက်ထောက်ညွှန်ကြားရေးမှူး၊ အငြိမ်းစား)

စာတမ်းအကျဉ်းချုပ်

အရှေ့တောင်အာရှရှိ အခြားနိုင်ငံများနည်းတူ မြန်မာနိုင်ငံတွင်လည်း အဆင့်အတန်းလျော့ကျနေသော သစ်တောများ အရှိန်အဟုန်ပြင်းစွာ တိုးပွားလျှက်ရှိပါသည်။ သစ်တောများအဆင့်အတန်းလျော့ကျခြင်းတွင် ပုံသဏ္ဍာန်နှင့် အချက်အလက်၊ အကြောင်းအရာများစွာရှိပါသည်။ ၁၉၈၀ မှ ၂၀၀၃ ခုနှစ်ကာလအတွင်း ငါးလိုက်သစ်တောကြိုးဝိုင်းရှိ မြေဆီလွှာ၏ ရူပနှင့်ဓါတုဂုဏ်သတ္တိများ ပြောင်းလဲသွားခြင်းကဲ့သို့ အဆင့်အတန်း လျော့ကျမှုအခြေနေကို လေ့လာထားပါသည်။ အဆင့်အတန်းလျော့ကျနေသောသစ်တော၊ သဘာဝတော နှင့် အသက်အရွယ်အစားသုံးမျိုး သတ်မှတ်ထားသည့် ကျွန်းစိုက်ခင်းများကြား မြေဆီလွှာ၏ ရုပ်နှင့် ဓါတ်ဂုဏ်သတ္တိ အခြေအနေ ပြောင်းလဲမှုကို နှိုင်းယှဉ်ထားပါသည်။ ၄င်းမြေအသုံးချမှုပုံစံများအကြား မြေဆီလွှာ၏အထက် ဖေါ်ပြပါ ဂုဏ်သတ္တိများ သိသာထင်ရှားစွာပြောင်းလဲကြောင်း တွေ့ရှိရပါသည်။ ကြိုးဝိုင်းအတွင်းရှိ သဘာဝတောများ အဆင့်အတန်းလျော့ကျမှုဖြစ်စဉ်ကြောင့် အပင်မှအသုံးပြုနိုင်သော ဖေါ့စဖေါရပ်၊ စုစုပေါင်း နိုက်ထရိုဂျင်၊နှင့် ပြောင်းလဲနိုင်သော ပိုတက်စီယမ်တို့သည် မူလအခြေအနေမှ ၇၃.၃၁%၊ ၄၇.၂၇% နှင့် ၅၃.၁၃% ခန့်အသီးသီး ကျဆင်းသွားပြီး မြေအချဉ်ဓါတ် တိုးလာကြောင်း တွေ့ရှိရပါသည်။ အခြေအနေအားလုံးအားခြုံငုံသုံးသပ်၍ ပြန်လည်ကုစားပေးနိုင်မည့် အကြံပြုချက်များ ကိုလည်း တင်ပြထားပါသည်။

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Abstract

Myanmar like other countries in Southeast Asia has degraded forest areas which are increasing at an alarming rate. Degradation has many factors and forms. The problems concerning degradation such as changes in soil physical and chemical properties occurred in Ngalaik reserved forest were studied for the period (1980-2003). Comparison was made among degraded forests, natural forest and three types of plantations (young, medium and old). It was found out that there were significant differences between them in all these parameters. Due to the forest degradation in the region, loss of available phosphorous (Ava. P) by 73.31% , total nitrogen (total N) by 47.27%, exchangeable potassium (exg-K) by 53.13%and increase in acidity were found out. Recommendations to remedy the overall situation were proposed.

Contents

1. Introduction

1.1 Statement of Forest Decline

The problem of increased degradation of forests in the tropics, including Myanmar, is of great concern. Deforestation and degradation of forest in many parts of the world cause the decreases of the availability of forest resources and services. Before the forest area in the developed countries are stabilized, but at present the rate of deforestation being continued in the developing countries. The estimated net annual change in forest area worldwide during the past decade (1990 - 2000) was - 9.4 million ha, and due to the increased degradation annual rate of 5.2 million ha; the total annual rate of forest area had changed to 14.6 million ha (FAO 2003).

Myanmar is a tropical country in continental Southeast Asia having a total land area of 676,553 km^2 of which about 43.3% is covered with closed forest, 7.5% with degraded forest, and 22.8% with forest under shifting cultivation in 1989. The forest area of Myanmar is 39,588,000 ha in 1990 and 34,419,000 ha in 2000. The annual change of forest area has increased by 517,000 ha and the annual rate is of 1.4% (FAO 2003). If the degradation of forest is accelerated at this rate, unless no remedial measure is taken, there will be a larger area of degraded forest in the future.

Myanmar, being an agriculture-based country, whose economy largely depends on agriculture and forest products, needs good lands for growing crops and better forests where the majority of the rural population depends for their livelihoods. Myanmar's forests are being degraded at a large scale by socio-economic factors such as over exploitation and illegal cutting. The demand for timber and fuelwood due to the increasing population, shifting cultivation and lack of community interest and co-operation are the major factors (Sein Maung Wint 1998).

The change of forest cover in Myanmar is due to shifting cultivation, illegal cutting of forest trees and encroachment for agriculture. The other causes of tropical forest degradation are the lack of funds for systematic development and management technology.

1.2 Objectives

The main objective of this study is to obtain the quantitative information on the soil conditions of degraded forest ecosystem of reserved forests and the specific objectives are;

1. to compare the soil conditions of the natural forest in 1988 with the existing physical and chemical status of soil in degraded forest, and teak plantations of three different age classes (i.e. young, middle and old ages)
2. to analyse the nutrient budget available and to detect the nature of problem soils of the degraded forest;
3. to assess changes in soil properties and the significance of those changes for forest productivity especially the range and variability of nutrient pools in plantation soils;
4. to characterize the nutrient dynamics in both natural and planted forest ecosystems and to establish nutrient budgets.

1.3 Problem statement

Many primary forests in the tropical regions of the world have been converted into degraded secondary forest and grasslands of species such as *Imperata cylindrica* (Ohta et al 2000). Once natural forest is disturbed, the original stocks of nutrients in soils can be exhausted severely. In 1992, 5 to 7 million hectares of arable land (0.3% to 0.5%) were lost every year through soil degradation (Lal and Steward 1992). Simultaneously, the tropical forest is converted to agriculture land and their soils are degraded rapidly.

Understanding the characteristics of soil properties of these degraded forest ecosystems is important not only to replenish these areas, but also to evaluate the effects of forest degradation on global environment. However, information on the soils of degraded ecosystem is very rare, especially in Myanmar. Lee and Choi (2001) gave an example that the degraded soils contain, generally, very thin or no layers of A and/or B-horizons. It had also been reported by Ohta (1988) and Dela Cruz (1986) that in Philippines soils under the degraded forest are severely eroded and acidic, low in organic matter and lacking in key elements, particularly N, P and Mg. However, Ohta et al. (2000) indicated in their findings that ecosystem degradation does not always accompany deterioration of soils with respect to certain soil characteristics.

2. Literature Review

Forest degradation is a kind of canopy gap forming process and/or retrogressive actions against plant succession process caused by natural disaster and human activities. A degraded forest delivers a reduced supply of goods and services from a given site and maintains only limited biological diversity. It has lost its structure, function, species composition and/or productivity normally associated with the natural forest type expected at that site. The term **forest degradation** refers to the reduction of the capacity of a forest to produce goods and services (ITTO 2002). **Degraded forest** are open and low forests, the productive of which has been reduced to outside influences, but could be restored if given sufficient protection and care (Kyaw Tint and Tun Hla 1991).

2.1 Causes and Effect of Deforestation and Forest Degradation

Deforestation and forest loss in Myanmar have also been published by the organizations such as Landsat Pathfinder, the Forest Department in Yangon, the United Nations Environment Program (UNEP) in Bangkok, and FAO in Rome.

Table 1. Average Annual Deforestation Rates and Forest Loss in Myanmar

Year	Deforestation Rate (%)	Forest Loss (sq km)	Data Source
1973-1985	0.69	3,234	Pathfinder*
1975-1989	0.71	2,139	FD*
1986-1993	1.84	5,706	UNEP*
1990-1995	1.38	3,874	FAO*
1990-2000	1.4	5,170	FAO**

Sources: * - Myint Hlaing (2004), ** - FAO (2003)

Onodera (1994) stated that degradation and deforestation are closely linked. Degradation of forest ecosystem is represented by a more gradual reduction of microbial activities in their biomass, productive capacity and biodiversity.

Forest degradation occurs in different forms and degree and may vary from country to country, region to region, depending on its stage of development and population density. The causes of forest degradation are also varied depending on climatic changes, pests and diseases and human activities: nonetheless human activities are the most destructive agents.

The great loss of forests and the degradation of the resources due to deforestation depend upon many kinds of factors, which affect land and water resources, the ecology and environment. Consequently, the impacts of forest degradation on the environment include ecological damage like soil degradation, decreases in species composition, impairment of water retention capacity of forest soil, the loss of biodiversity, climatic changes, an increase in atmospheric carbon and global warming. The other indirect impact accompanying is the retardation socio-economic development of rural and urban areas. So, it is very important to solve these problems, and to rehabilitate the degraded areas. Consequently, basic information and data pertaining to the conditions of vegetation cover and soil are eventually needed.

Ecologically, forest fires can cause enormous damage to the vegetation, fauna, soils and aquatic ecosystems. Reduction of vegetation cover and organic material both directly and indirectly influence soil characteristics and geomorphic processes due to the loss of soil aggregate stability. Additionally, they increase the probability of greater soil/land erosion, especially in open areas frequently subjected to high rainfall intensity (Sudarmadji 2001). The results of chemical changes that the soil undergoes after deforestation and the soil loss under different land use types were presented by Lee and Choi (2001) as shown in Tables 2 and 3 respectively.

Table 2. Effect of deforestation on soil chemical properties (kg/ha)

Chemical properties	**Total N**	**Ava. P_2O_5**	**Exchangeable**		
No. of deforestation			**K**	**Ca**	**Mg**
1st deforestation	5.80	17.59	4.37	6.30	6.50
2nd deforestation	4.59	1.09	3.86	6.01	5.80
3rd deforestation	4.5	0.88	3.96	5.23	4.00

Source: Lee and Choi (2001)

Table 3. Soil loss by cover vegetation

Land Use Type	**Denuded land**	**Mature Forest**	**Young Forest**	**Glass Land**
Slope (degree)	30	28	32	28
Soil loss (ton/ha)	177.3	1.6	9.3	0.3

Source: Lee and Choi (2001)

At more subsistence levels, deforestation causes severe hardships at social descriptions for forest dwelling and forest-dependent people. Another serious negative impact of deforestation and degradation is the loss of wildlife habitat. It is dangerous that the loss of one key species in an ecosystem will lead to the extinction of other species. Many countries in Asia and the Pacific have lost 70% -90% of their original wildlife habitat, and the populations of many species are dwindling (FAO 1998).

Reduction of tropical forest affects the ecosystems in various ways which include site degradation, reduced forest water supply, soil loss and greenhouse gas emission (Kobayashi et al 2001). According to experts, the burning and/or decomposition of tropical biomass in 1980 has contributed up to 10-30% of the total global CO_2 emissions of 6.6+/- 1.5 billion metric tons (Udarbe 1994). This immense quantity of CO_2 together with other industrial pollutants has caused an increase in the concentration of natural trace gases contributing to the greenhouse effect, which affected the exchange of heat radiation in the atmosphere, hence causing global warming. Many researchers argued that tropical deforestation is liable to change the hydrological cycle of the atmosphere and cause a drop in precipitation rate. The reduced tree cover influences the amount of water evaporation from the earth's surface which in turn causes an increase in temperature due to the increase of solar radiation reaching the ground. Its effect on the regional climate is associated with reduced rainfall, higher temperature close to ground level, and reduced cloud cover. This will affect the tree growth and the functions of the forests. At the present rate of deforestation and degradation of the tropical forests, Baumgardner (1978) (cited in Kobayashi et al. 2001) estimated that some 550 billion metric tons of CO_2 would be released into the atmosphere by the end of the century. As an example, Kobayashi et al (2001) observed changes in the microclimate of a logged-over tropical forest in Brunei, caused by the increase in the amount of sunlight reaching the forest floor, fluctuation in the air temperature, and soil damage such as compaction and reduced porosity.

2.2 Effect of Plantation Establishment

Chacko (1995) and Chundamanni (1998) revealed that site deterioration under teak was generally observed as decline of site quality with age. Deforestation and change in land use for establishing plantation forests can lead to compaction, erosion and depletion of soil organic matter, and thus degradation of soil physical and nutritional properties. In this case, Bell (1973) reported that under teak plantation rate of soil erosion is 2.5 times higher than under natural forest. Lal (1997) also showed that sediment concentration was very high during the first year after removal of native forest, and decreased subsequently as the vegetation cover re-established. In comparison with conversion to arable land use, however, establishment of forest plantation is likely to cause less erosion.

As monoculture teak plantations cannot utilize and maintain soil layers as in natural mixed forests, research results show that site quality in teak plantations declines with age. Under teak plantations, with the long period of rotations, the teak trees will have used up almost all of the soil nutrients in various forms, which deteriorates physical and chemical properties of soil (Chako 1995). The replacement of natural forest with plantation crops viz. Padauk (*Pterocarpus dalbergiodes*), Rubber (*Hevea brasiliensis*), Teak (*Tectona grandis*) and Red Oil Palm (*Elaeis guinensis*) has led to a rapid deterioration in soil properties (Mongia and Bandyapadhyay 1994).

The soil condition of teak plantations, after a long rotation, will become very much degraded, as the teak trees will have used up almost all the soil nutrients in their various stages of development (Jose and Koshy 1972) whereas Singh, et al. (1985) stated that teak is not a short rotation species and can efficiently fight the leaching of bases which surely deserves greater emphasis for the preservation of soil ecosystem. Due to the various problems that cropped up in the process of establishing teak plantations, some countries began to question the benefit of teak plantation establishment and some have discontinued teak as a promising species for plantation establishment (White 1991). Some have shortened the rotation of teak plantations down to 30, 25 or 15 years, so as to make their investments more remunerative and also to lesson the extent of soil erosion and site degradation due to teak plantation establishment (Keh 1995; Chacko 1995).

2.3 Ecosystem of Natural Forest and Plantation

The complexity of species and ecosystem in the natural forests play a vital role on the conservation of biodiversity, habitats for wildlife and the environment. The plantations are ecologically very different from the natural stands. Evans (1992) demonstrated the difference between the ecosystems of natural stand and plantation; the species in the natural stand are growing at interdependent relationship, called symbiosis, and if once the natural system was disturbed, the rehabilitation of natural ecosystem will take many years. Most natural forests consist of many tree species, whereas plantation consists of a few species, often only one or two.

3. Study Area

3.1 General Information of the Study Area

Ngalaik reserved forest, Pyinmana Township, Yamethin District, Mandalay Division, which is a part of the East *Bago Yomas*, has been once a very rich forest of Moist Upper Mixed Deciduous Forests with valuable commercial species like teak, pyinkado and padauk.

An inventory operation was carried out last 20 years with a collection of soil in some compartment in the resource for nutrient analysis. Situation at present remains with the completion of timber harvesting by the Myanmar Timber Enterprise, private timber traders and with other illegal logging which destroy a large area of the ecosystems. Moreover, light ground fire and encroachment for cultivation have also destroyed much of the ecosystems. These disturbances of the natural vegetation in this region lead to the destruction of balanced nutrient cycling and result in the degradation of these soils. Therefore, it is deemed necessary to evaluate such forest to be of a representative of the reserve whereby; the remedial information would be available for future conservation to avoid more degradation.

3.2 Location

The study site was located in Ngalaik forest reserve in Yamethin forest district where some degraded stands are found. According to GIS/RS information (1990), the original forests of this area were closed and high forest stands dominated by many economically valuable timber species and the forest types formally were Moist and Dry Upper Mixed Deciduous forests. The study area lies between approximately 19˚ 56' N and 95˚ 56' E at an elevation of 178-197 m a.s.l. approximately. The ridge belongs to the *Bago Yomas* and the Ngalaik stream flows along part of the river and water can be found until the end of December. The general information of the study area is shown in the following Table 4. Appendix 1 shows the conditions of the study areas. Some compartments of the reserved forest exist in Pyinmana Township, some in Takkone Township and some in Lewai Township. Kywe Shin, Moeswe and Laewin villages are situated near the compartments where the sample plots were allocated. Some villagers are rice cultivators and some earn for their livelihoods by making charcoal. Most of the villagers work for the Myanmar Forest Department, some are *taungya* cutters. A lot of abandoned *taungya* fields were found in and around the reserved forest.

Table 4. General information of the Study sites

Experimental Site	Year Planted	Area (ha)	Location	Altitude	Compartment no./Reserve	Remarks
YP	1998	4.047	19° 56.215'N 95° 54.823'E	658	8, Ngalaik	Near Laewin village
MP	1985	40.468	19° 51.978'N 96°00.882'E	596	78, Ngalaik	Near Kyweshin village
OP	1963	14.973	19° 51.413'N 95° 56.285'E	602	59, Taung-nyo	Near Kyweshin village
DF	-	-	19° 56.401'N 95° 56.562'E	592	9, Ngalaik	Near Yon-gyi village

where, YP = young-aged teak plantation OP = old-aged teak plantation
MP = mid-aged teak plantation DF = Degraded Forest

3.3 Ecological Factors of the Study Site

3.3.1 Climate, Geology and Topography

As the study area is located in and near Pyinmana township, the climatic conditions in the study area are assumed to be the same as in Pyinmana. Since all of the sites were found within a relatively short distance, there may not be much difference as to the definite long-time weathering in climatic and geological term. Figure 1 depicts monthly precipitation and means monthly maximum and minimum temperatures (1993-2003) at the Pyinmana weather station which is about 27 miles away from the study area.

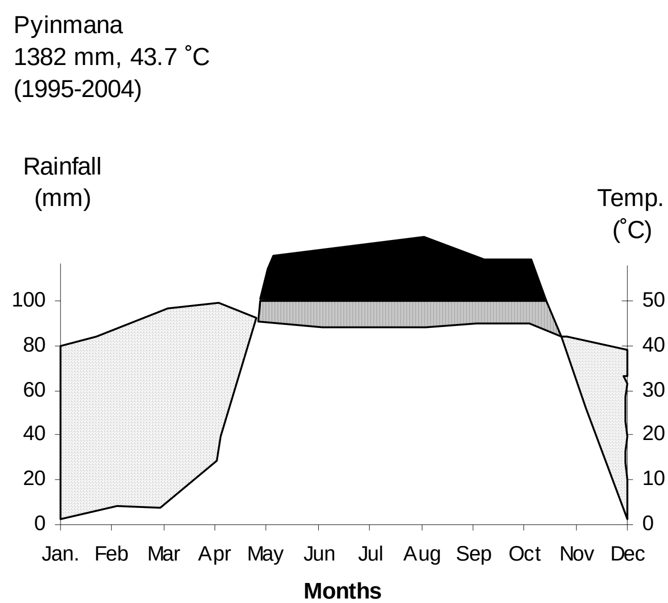


Figure 1. Monthly precipitation and temperatures measured at Pyinmana Weather Station (1993-2003)

The study area received an annual mean precipitation of 1500 mm and mean monthly relative humidity is 75.8%. The mean annual temperature is 26.7 ˚C with the maximum of 30.18 ˚C in April and the minimum of 22.5 ˚C in January (Table 5).

Table 5. The climatic data (monthly means) of Pyinmana Township

Month	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**
Temperature (˚C)	22.5	25.0	27.9	30.2	29.7	28.1
Rainfall (mm)	0.092	6.489	5.496	27.524	188.353	230.332

Month	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec**
Temperature (˚C)	27.8	27.5	28.0	28.3	25.8	23.1
Rainfall (mm)	244.140	270.695	184.981	168.933	53.825	1.570

Source: The Meteorological Station, Pyinma

According to Bender's classification (1983), the study area falls within the back-arc basin, and is characterized by thick Mio-Pliocene sediments. It belongs to the *Bago Yomas* Anticlinorium's. The study area corresponds to upper Miocene to Pliocene and it is also termed as Ayeyarwady formation (Kyi Khin 1996).

The Ngalaik reserved forest belongs to the *Bago Yomas* and is situated on its Eastern side of the northern part of the range. Although most parts of the areas are on undulating topography with some flat areas near streams, there are some hilly regions on the watershed area of the Ngalaik stream. The study sites are located on the flat plain (i.e., slope is not more than 5%, exception for the vegetation survey, on which its gradient is more than 35%).

3.3.2 Soil

The soils to the west of Yemethin, in which the study area is located, is of buff to yellowish color, medium to thick bedded, coarse to gritty, poorly consolidated sandstone (Kyi Khin 1996). The soils under this reserve are mostly yellow brown mountain forest soils of tropical monsoon forests and belong to the Xanthic Ferrasol. The soils, Ferrasol in the FAO scheme and Oxisol in Soil Taxanomy, are tropical soils, with an oxic B horizon and such a horizon is at least 30 cm thick, has > 15% clay, diffuse horizon boundaries, no weatherable minerals and a CEC of clay < 16 me per 100 g (Buringh 1979).

The soil conditions of the reserve forest, which had already been analysed since 1980, were shown in Appendix (I). As a result, it can be stated that these soils were favorable for plant growth at that time such as low soil bulk densities, neutral soil reaction, relatively high organic matter content and medium of total soil N, available P and K content. Almost all tree species which are typical of Moist Deciduous forests in Myanmar are grown in Ngalaik Reserve forest. These trees are mostly deciduous and shed leaves in the dry season which lasts for about 5 months. Semi-evergreen forests, moist upper mixed deciduous forest, Dry Upper mixed deciduous forest and dry forest also exists in the reserved forest.

3.3.3 Vegetation

The most frequent economically important species growing in this reserve were Teak (*Tectona grandis*), Pyinkado (*Xylia dolabriformis*) and Padauk (*Pterocarpus macrocarpus*), and Thitmagyi (*Albizzia ordoratissiama*) and other important species are Binga (*Mitragyna rotundifolia*),Yinma (*Chuksasia valutina*), Leza (*Lagerstromia roundifolia*), Thadi (*Protinum serrata*), Thapye (*Eugenia spp*.), Yon (*Anogeissus acuminata*), Panga (*Terminalia chebula*), Nabe (*Lonnea grandis*), Yemane (*Gmelina arborea*), Taukkyan (*Terminalia tomentosa*), Pyaukseik (*Holopteria integrifolia*), Thande (*Stereuspermum porsenatum*) and Thanthat (*Albizzia lusida*). Tawngetpyaw (*Musa itinerans*) plants were abundantly growing in degraded stands near the stream.

There are 62 tree species belonging to 29 families of diameter at breast height (DBH) greater than 10 cm in 0.69 ha plot. Among these *Holorrhena antidysenterica* (Lettok-gyi), *Tectona grandis* (Teak), and *Chukrasia valutina* (Yinma) were frequently found in the study area. The basal area was 11.54 m^2ha^{-1} and the total number of tree was 587 in the 0.69 ha study plot.

Figure 2 (a) Degraded Forest

Figure 2 (b) Young-aged teak plantation

Figure 2 (c) Mid-aged teak plantation

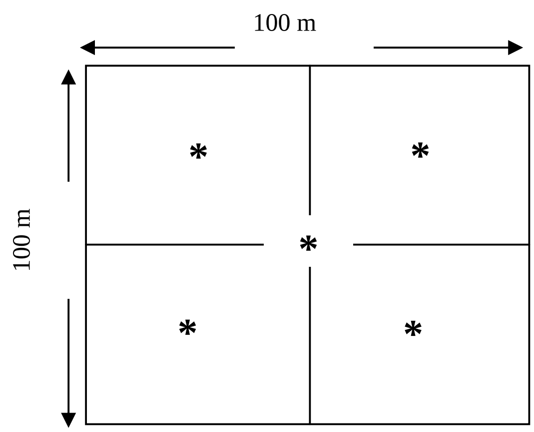
Figure 2 (d) old-aged teak plantation

4. Materials and Methods

4.1 Data Collection

4.1.1 Sampling Design

Subjective Sampling method was used appropriate to the spatial variation in soil properties. Square shape sample plots were used. Size of each sample plot is 100 m x 100 m and 10,000 m^2 (1 ha) and 5 plots for each forest land whereas 4 plots for young-age teak plantation due to the limited its size (i.e. 10 ac) were selected. 5 sampling points as shown in the figure were selected in each plot. For analysis, samples were reduced to one for each horizon per plot by mixing in equal amounts.
The soil sampling design for teak plantations and degraded forest is given in Figure 3.



*****- soil sampling points
Figure 3. Sampling Design

4.1.2 Survey on Nutrient Stores

The soil samples used for the determination of soil nutrient stores in this study were obtained from five depths (i.e. 0-10, 20-30,40-50,60-70 and 80-100 cm) to a maximum soil depth of 100 cm. Soil pedons were also exposed in the study site where it can be assumed as the representative areas and their morphological characteristics were studied. After scratching the layer, samples for physical and chemical analysis were also taken from genetic horizons as delineated by the morphology in the soil profiles. These collected samples were processed and analyzed at the Forest soil Lab, Natural Resources Division, Forest Research Institute (FRI), Yezin.

4.2 Analytical Methods

All these soil samples were air dried and passed through a 2 mm sieve prior to the analyses of soil physiochemical properties.

4.2.1 Physical Properties

From every forestland type, 4 core samples (100 cc) each were collected from the surface layer (0-5 cm) to determine soil densities (i.e. bulk density, particle density). Soil color was determined by reference to a Munsell Soil Color book and to know the vertical distribution of the soil hardness, a cone penetrometer equipped with a metal cone on top and a weight to push and make the cone penetrating depth by an attached scale was better used. It was fall the 2 kg of weight at each horizon, and records the penetrating depth by an attached scale. Based on the reading, penetrating resistance can be estimated. Haregawa type cone penetrometer (Daito, Green, H-60) was conveniently used.

4.2.2 Physico-chemical Properties

The analysis of the soil samples collected at the depth of 0-10 cm, 20-30 cm, 40-50 cm, 60-70 cm and 80-100 cm at all study sites in the Ngalaik reserve was performed for the evaluation of soil fertility. Thus, soil samples were air-dried and crushed to pass through a 2-mm sieve. Due to the limited time and finance, organic matter as loss-on-ignition (L.O.I), soil pH (H_2O), Texture, total N%, available P% and extractable K% were analyzed.

Soil Texture: Particle size distribution was carried out by mechanical analysis by using the pipette method.

Soil Organic Matter (SOM): SOM was detected by using Loss-on-ignition (L.O.I) method. The principle of which method is simple; the OM in a weighted quantity of soil is destroyed completely by heat, the sample reweighed and the loss in weight represents the organic matter.

Total Nitrogen in soil: Total Nitrogen levels were settled by Kjedahl's method by using Kjedahl digestion and distillation unit.

Available Phosphorous Content in Soil: Available phosphorous levels were resolved with double-acid extracting solution and molybdenum blue complex method by using Spectrophotometer Hach 2000.

Extractable Potassium Content in Soil: Potassium was assessed with double-acid extracting solution by using GBC, Atomic Absorption Spectrophotometer.

Bulk Density in soil

A metal cylinder was inserted into the soil by carefully beating it so as not to disturb the physical condition of the soil, until it is fully filled with soil. Then the soil around the cylinder was removed without disturbing the cylinder. The lower end of the cylinder was closed with a thin plate to make sure that there was no loss of soil from inside the cylinder. The metal cylinder was then taken out and the soil sample was transferred into a clean and dry container.

The container was closed tightly to avoid contamination in weighing. Then the container was weighed and the weight was recorded. The volume of the metal cylinder was calculated by using the following equation.

$$V = \pi r^2 h$$

where, V = volume of the cylinder
r = radius of the inside of the cylinder,
h = height of the cylinder

The bulk density of the soil was calculated by using the following equation.

$$Bulk\ density\ of\ the\ soil\ (BD) = \frac{Weight\ of\ soil}{Voloume\ of\ soil}\ g/cm^3$$

Total Porosity

Total porosity (%) was calculated by the formula,

$$Total\,porosity(PD) = 100 - \frac{(BD \times 100)}{PD} \quad g/cm^3$$

Where, BD = Bulk Density (g/cc)
PD = Particle Density (g/cc)

The particle density was determined in the laboratory for each soil bulk sample and the respective total porosity was calculated with the corresponding bulk density.

4.3 Data Analysis

After the laboratory analysis, the soil conditions found out were compared with previous soil conditions which had already been investigated 23 years ago. The data were entered into Excel worksheets as the basic format for analysis, thereafter, transformed into other formats according to the software used. The common software used in the analysis were STATISTICA for WINDOWS, MICROSOFT EXCEL 2000.

5. Results and Discussions

5.1 Soil Conditions at Present Situation

The following results are obtained concerning the condition of soil at present situation in the study.

5.1.1 Soil Morphological Characteristics

The physico-chemical properties of the soil collected from every horizon of degraded forest and Teak plantations was analysed and found out and given in the following tables (Tables 6 and 7). These described the soil morphological and physical properties of the pedons from each forest type.

Table 6. Soil Morphological characteristics found in the pedons under different forest lands.

Site	Horizon	Depth (cm)	Soil color	Texture[a]	Roots/ Gravel	Boundary[b]
YP	A_1	0-10	2.5 Y 5/4	SL	Common/none	aw
	A_2	10-30	2.5 Y 5/3	SL	A few/none	s
	AB	30-50	2.5 Y 6/4	SL	A few / none	b
	B_1	50-70	2.5 Y 5/4	SL	A few / none	ci
	B_2	70~	2.5 Y 4/3	SL	None / none	
MP	A_2	0-10	10 YR 6/9	LS	Common / few	aw
	B_1	10-40	10 YR 5/4	SL	Common / few	aw
	B_2	40	10 YR 5/6		Common / few	
OP	A_2	0-5	10 YR 5/3	S	Common / none	cb
	AB	5-25	10 YR 4/2	LS	Common / none	ci
	B_1	25-55	10 YR 5/4	SL	Common / none	cb
	B_2	55~	10 YR 6/6	SL	Common / none	
DF	A_2	0-20	10 YR 3/2	LS	Common / none	aw
	AB	20-40	10 YR 5/4	LS	Common / none	bw
	B_1	40-60	10 YR 4/4	SL	Common / none	bw
	B_2	60~	10 YR 5/4	SCL	Common / none	

a) S: Sand; SL: Sandy Loam; SCL: Sandy Clay Loam
b) aw: abrupt wavy; cw: clear wavy; bw: broken wavy; b: broken; s: smooth;
ci: clear irregular ; cb: clear broken

At all study sites, the "O" layer was absent owing to the frequent fire, which usually occurs from January to May before shower. At the MP and OP sites, Thatch grasses (*Impreta cylindrica*) were densely grown and the root mat (<10 cm) was well developed at these sites. Although all of the sites showed a very sandy texture in the surface "A" horizon, the most

significant difference among sites was the color and thickness of "A" horizon. In the pedon of OP, surface "A" horizon was only 5 cm in thickness with dull yellowish brown (by revised Standard Soil Color Chart) and brown (by Munsell Soil Color Chart) color of 10YR5/3. On the other hand, in the other pedons, the thicknesses of "A" horizon were 27-30 cm, 8-10 cm and 15-20 cm for YP, MP and NF, respectively. Among them the pedon in the YP which was situated at the foot of the hill, was more thick horizon than the others. The surface horizons had various colors of yellowish brown (2.5 Y 5/4 for YP), dull yellow orange (10 YR 6/9 for MP), dull yellowish brown (10YR 5/3 for OP) and brownish black (10YR 3/2 for NF). The difference in color and thickness of surface horizon might be brought about by the relative accumulation of organic materials in this reserve.

Table 7. Soil Physical Properties of each pedon under Degraded forest (DF) and Teak Plantations with three-aged classes

Soil Properties		**DF**	**YP**	**MP**	**OP**
A- horizon thickness (cm)	**Range**	35~40	10~30	8~10	4~5
Hardness (mm)	**Mean**	31 ± 2.04	22 ± 2.06	26 ± 3.41	17 ± 3.72
Bulk Density (g cm^{-3})	**Mean**	1.20 ± 0.06	1.40 ± 0.03	1.36 ± 0.07	1.34 ± 0.06
Total Porosity (%)	**Mean**	50 ± 2.53	41 ± 6.13	43 ± 5.05	25 ± 0.65
Sand (%)	**Mean**	79	60	85	80
Silt (%)	**Mean**	10	9	12	15
Clay (%)	**Mean**	7	26	4	4
B- horizon thickness	**Range**	60~100	70~100	35~100	55~100
Hardness (mm)	**Mean**	28 ± 1.50	25 ± 1.23	28 ± 2.65	25 ± 2.03
Sand (%)	**Mean**	57	56	65	74
Silt (%)	**Mean**	24	25	16	11
Clay (%)	**Mean**	18	15	19	10

DF and teak plantations were compared in terms of five factors for soil genesis, i.e., parent materials, topography, biology, time and climate. Biologically, there are clear differences reflecting the amount of OM accumulation. Since all of the sites were located within a relatively short distance, there may not be a definite difference in climate and geological time for long-term weathering. Sand content was higher than 65% for all soils, indicating that the parent materials were mainly consisted of sandstone. Soil profile assessment was made not only by digging 1 m deep profile vertical pit, but also checking the exposed soil profile made during road constructions (road cut) and at the head of gully erosion. As a result, there would not be seen parent materials even until 35 m deep at all sites. Topographically, all plots were located on the gentle slope facing northeast with mean inclination of 4 degrees.

Unfortunately hardness cannot be compared, as hardness has not been measured in the pedon under the NF. As the soil hardness could reflect the presence of clayey materials in lower layers of a pedon, the increasing soil hardness with depth might be attributed to increasing clay content with depth (Table 7). Based on these results, however, it can be concluded that soil hardness does not seem to be a limiting factor for plant growth. It was also confirmed by the presence of roots up to the depth of 100 cm.

5.2 Changes of Soil Properties

5.2.1 Soil Physical Properties

Soil Texture

In all the study sites sandy loam soil texture was found from 0 to 50 cm depth (Table 8).

Table 8. Particle size distribution of soils for the four sites

Soil Particle	Depth (cm)	NF	YP	MP	OP
% Clay	0-10	12	11	6	10
	20-30	16	14	16	13
	40-50	18	19	20	15
	60-70	21	21	20	20
	80-90	21	19	20	24
% Silt	0-10	19	18	10	11
	20-30	21	21	16	12
	40-50	24	23	13	11
	60-70	29	25	15	12
	80-90	29	30	13	13
% Sand	0-10	68	70	83	79
	20-30	60	64	68	76
	40-50	57	54	65	74
	60-70	50	57	62	68
	80-90	49	60	66	64
Textural classes	0-50	**SL**	**SL**	**SL**	**SL**

In spite of the texture, the particle size distribution in the surface soils was changed: i.e., percent sand was gradually decreased and clay percent was increased with forest degradation and ages of teak plantation. This is also a little decreased in the percentage of sand and clay distribution with depth in each study site. The soils in the study areas are sandy soils, which might influence the nutrient stock, since clay particles play an important role in retaining nutrients.

Bulk Density

With the exception of soil texture, soil physical properties (such as bulk density, porosity, infiltration, and strength) are dynamic characteristics and are easily altered by the climate and human intervention (Lal 1997). In an undisturbed forest, these transient properties would attain a steady state level and the densities of these soils are generally low in the surface horizon.

Table 9. Bulk density under NF, DF and Teak Plantations

Sites	Ranks	Means
NF	1	1.18 a
DF	2	1.20 a
YP	5	1.40 b
MP	4	1.36 b
OP	3	1.34 b

Means followed by a common letter are not significantly different at the 5% level by DMRT.

As shown in Table 9, the bulk density of the natural stand at the surface layer was increased after the forest degradation, although there was no statistically significant difference between them.

However, bulk densities were consistently higher under teak plantations than under NF but no consistent effect was observed amongst the pure teak plantations with different ages by mean values of 1.4 g per cc (Figure 5).

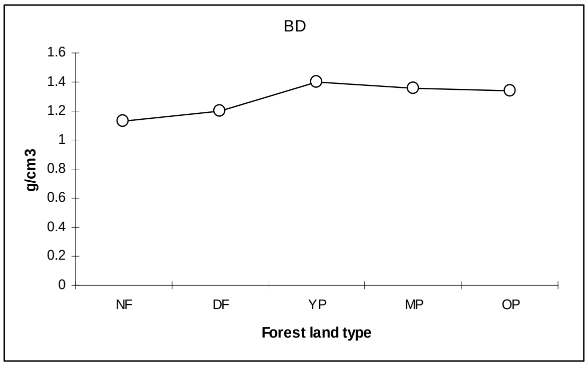


Figure 5. Bulk density (BD) of surface soil (0-10 cm) by types of forest land

As shown in Figure 5, the BD of the natural stand at the surface layer increased after 20 years and after the teak plantation establishment from 1.2 g per cc to 1.3 g per cc in DF and 1.4 g per cc in teak plantations. It can also be seen that no significant differences were observed amongst different ages of teak plantation. This is consistent with Mc Fee and Stone (1965) statement (in Buringh, 1979); soil BD was not influenced by the age of stand.

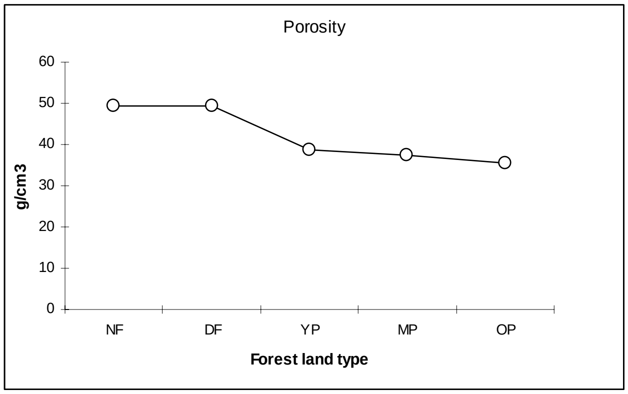


Figure 6. Porosity of surface soil (0-10 cm) by types of forest land

Although the total porosity percent was the same between NF and DF, this content was decreased with the ages of plantation (Figure 6). Favorable soil physical properties are due to high soil fauna activity and the lack of human interference in the delicate soil-vegetation if the rate of decline in soil physical and nutritional properties is very rapid and drastic. The low BD of soil supporting NF may be due to high activity of soil fauna. The leaf litter prevents the compacting effect of the raindrop impact on soil, and the high activity of termites, ants, earthworms and other soil animals keep the soil highly porous, with a predominance of macro pores and a loose and friable consistency (Lal 1997).

When the natural forest was disturbed by harvesting of timber, fire during the dry period, fuelwood gathering and clearing for certain purposes, i.e. in this case, plantation establishment, the soils become compact and subsequently BD increased. These increases were also due to the deterioration of soil structure by those activities which lead to the loss of litter layer and soil fauna.

5.2.2 Soil Physico-chemical Properties

The comparison of chemical properties between the NF and DF and also between NF and plantations of different ages were made and the results are given in Table 10.

Table 10. Soil Chemical properties at surface horizon in natural forest (NF), Degraded forest (DF), Young-aged (YP), Middle-aged (MP) and Old-aged (OP)Teak Plantations.

Soil Properties	NF Mean ± S_x	DF Mean ± S_x	YP Mean ± S_x	MP Mean ± S_x	OP Mean ± S_x
pH	6.56 ± 0.21 (20)	6.39 ± 0.45 (20)	5.93 ± 0.40 (25)	5.37 ± 0.24 (25)	5.27 ± 0.31 (25)
OM (%)	4.99 ± 2.59 (20)	2.95 ± 0.45 (20)	3.02 ± 0.23 (25)	2.36 ± 0.40 (25)	1.86 ± 0.73 (25)
Total N (ppm)	961 ±271.8 (20)	915 ± 157.26 (20)	783 ± 125.33 (25)	647 ± 184.78 (25)	570 ± 18.85 (25)
Ava. P (ppm)	11.75 ±3.00 (20)	6.5 ± 1.66 (20)	8.35 ± 1.13 (25)	1.67 ± 0.65 (25)	1.49 ± 0.28 (25)
Exc. K (ppm)	4320 ± 1187 (20)	76 ± 29.41 (20)	110 ± 10.01 (25)	99 ± 22.89 (25)	76 ± 17.71 (25)

Soil Reaction (pH)

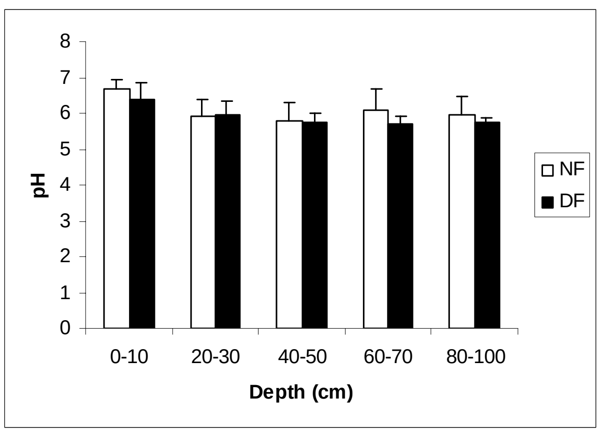


Figure 7. Changes in soil pH under natural forest and degraded forest

The highest maximum, minimum and the mean pH values such as 7.00, 6.36, 6.65 respectively were found in natural forest, and with slight decrease to 6.96, 5.90 and 6.39 in degraded forest.

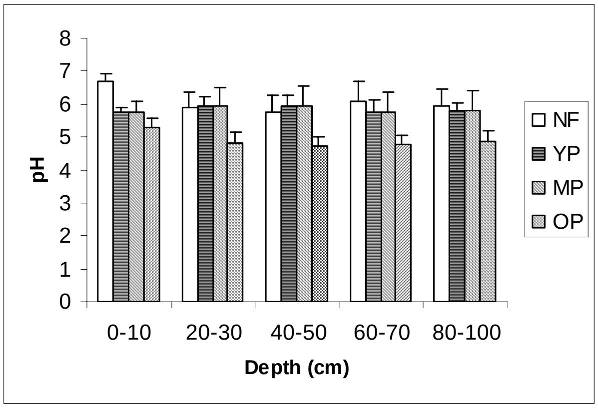


Figure 8. Changes in soil pH of surface soils in different vegetation types

The maximum pH values under YP, MP and OP were 6.61, 5.57 and 5.75 and the minimum values were 5.66, 5.06 and 4.97, respectively. The mean values of pH were 5.93, 5.37 and 5.27 under YP, MP and OP.

Figures7 and 8 depict the changes in soil pH according to different forest lands at the surface and subsurface horizons. Soil pH of surface soil (0-10 cm) decreased from NF to YP, MP and OP and showed significant difference amongst them. The increased in soil pH was found in subsurface soil of YP and it decreased with ages of teak plantation. The decreased in soil pH with depths was also observed in each land type. Although the pH (H_2O) value was slightly higher in the (10-20 cm) layer of NF than the DF, no significant decreased in soil pH was observed between them and the pH content at the surface layer was higher than that of overall soil layers in DF ecosystems. However, it slightly increased from the 40-50 cm layer to 60-70 cm layer.

Organic Matter

The higher soil OM content of 8.76 was found in the natural forest and OM decreased to 3.5% when it was degraded (Appendix II). The minimum and the mean values for the NF were 2.86%, 6.56% respectively. For the degraded forest the values were 2.43% for minimum OM content and 2.95% was the average.

The soil organic matter content under the NF significantly declined after forest degradation. There were no statistically significant differences of soil OM content amongst depths in each forestland type (Figures 9 and 10) and the highest content, however, was found in the upper layers of all types of forestland.

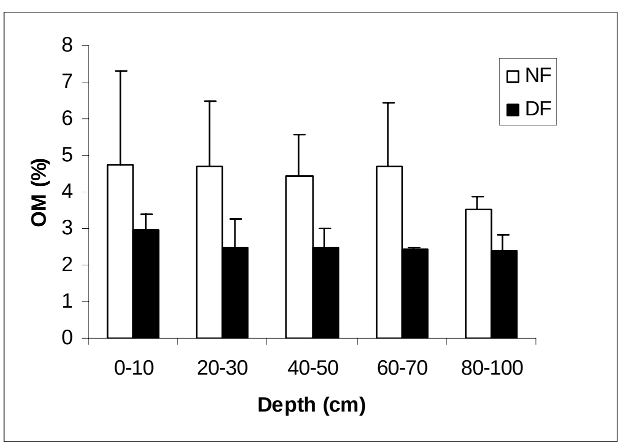


Figure 9. Changes of SOM content of soils under natural and degraded forest

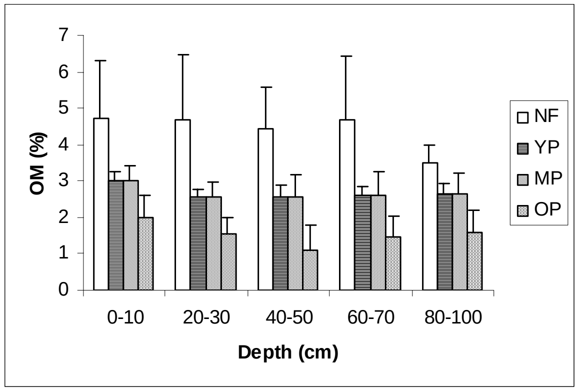


Figure 10. Changes of soil OM content in different vegetation type

In the YP, MP and OP, the maximum soil OM was 3.4%, 2.9% and 2.8%, respectively. The minimum values were 2.85%, 2.02% and 1.38% in YP, MP and OP respectively.

Although the OM content between NF and YP was not so different, according to the results, but the content declined significantly after 20 years teak plantation establishment and it decreased continuously with ages.

The high OM in NF may be the effect of ground cover vegetation and high soil moisture content. The teak seems unable to maintain the original level of surface OM and it is significant that it was always less than that recorded in a teak bearing forest area (Hase and Foelster 1983).

When the vegetation is removed, OM is no longer added to the upper layer of the soil, minerals are leached and fertility is quickly lost. Therefore, the large decrease in soil organic matter levels among the study sites indicates that the original A-horizon has been removed which is one of the characteristics of degraded forest ecosystem as stated by Lee and Choi (2001).

Total Nitrogen

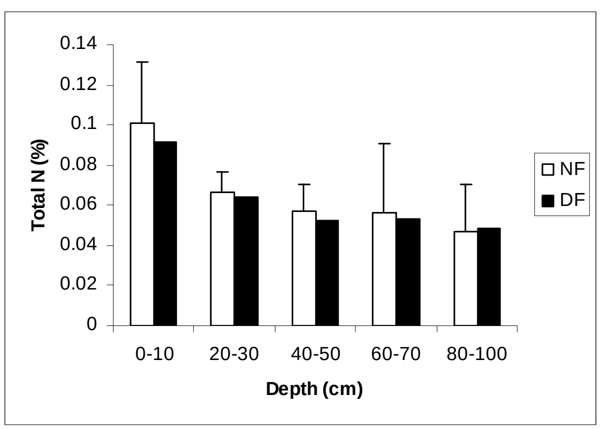


Figure 11. Changes in total N content under natural and degraded forest

Total N was high in NF with a maximum of 1316 ppm, a minimum of 574 ppm and an average of 981 ppm. This nitrogen content of NF was also decreased after 20 years of forest degradation, although no statistically significant different was observed between NF and DF as well as amongst horizons of each stand (Table 10).

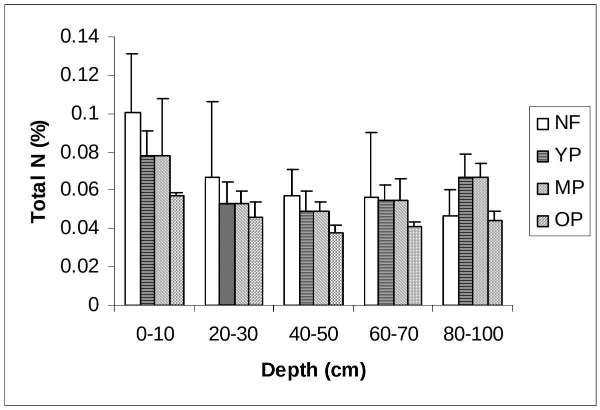


Figure 12. Changes in total N content of surface soils in different vegetation type

YP and MP followed with the mean of 783 ppm and 647 ppm and OP was lowest with an average of 570 ppm (Table 10). Total N content of NF at the surface layer showed slightly higher than the other forest lands and on the other hand, this content decreased with age of teak plantation (Figure 12).

The high total N content was usually found at the surface layers under all forestland types with exception in OP where there was no significant different of the N content amongst depths.

In the 40-year-old stand, the progress of nitrogen transfer from the soil to the biomass and its accumulation in the surface litter layer through absorption and litter production by trees might lead to the low total N in the mineral soil. The low of total N content in the OP might also be partially attributed to the lower clay content of soils since clay content also influences the total N.

Low Levels of Total N in surface soils under the degraded forest (especially in 0-20 cm) are one of the important factors of degraded ecosystems. Total N levels were lower in the degraded ecosystems compared with the primary forest. This might suggest a higher consumption of N by plant uptake and/or leaching loss in forms of inorganic nitrogen in the surface soils of the degraded ecosystems, which are possibly less efficient at conserving nutrients than in those of the natural forests.

One possible explanation for this is that nitrogenous organic compounds were altered qualitatively in the processes of biomass burning and/or repeated biochemical transformation of soil organic matter under harsher conditions of the soil surface of degraded ecosystems, and the nitrogen become incorporated into stable organic substances which are more resistant to decomposition. Scott found that nitrogen storage in the soil decreased with the progress of succession.

Available Phosphorous (Ava. P)

It was found that the NF had the highest maximum available P (11.75 ppm) compared to that of DF (Table 10). The minimum and average available P in NF was 6.7 ppm and 8.35 ppm. The maximum, minimum and average available P values under DF were 39.3 ppm, 12.7 ppm and 30 ppm, respectively.

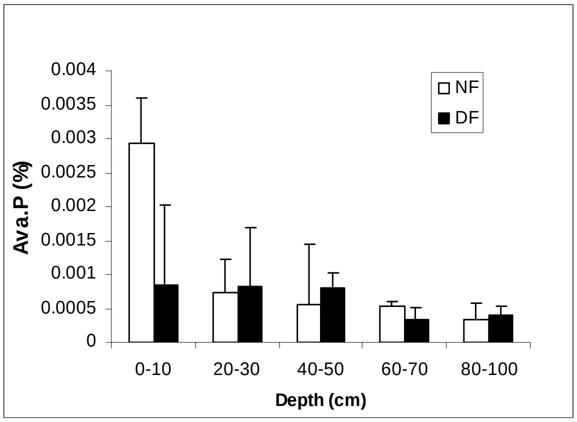


Figure 13**.** Changes in available Phosphorous (P) content under natural and degraded forest

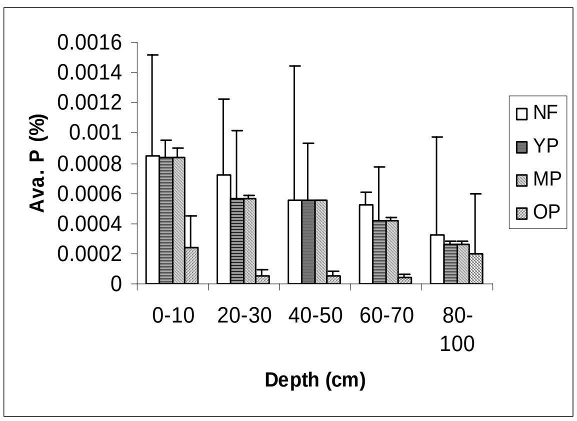


Figure 14. Changes in available P of surface soils in different vegetation types

The available P content in the surface soil of NF was higher than the DF, although there was no statistically significant in the difference. However, there is no difference in available P in the sub-surface layer for NF and DF (Figure 13)

The maximum available P contents of YP, MP, and OP were 19 ppm, MP 2.65 ppm and OP 1.78 ppm and however, the minimum contents were only round about 1 ppm. Average available P in YP was the highest 6.5 ppm followed by MP (1.67 ppm) and OP (1.49 ppm) respectively. Available P was also lower in teak plantations compared with the primary forests for all horizons.

Figure 14 also depicts the changes in content of available P. Available P of surface soil increased and reached its highest level under the teak plantation 6 years after establishment and vis-à-vis in subsurface layer. Although no significant difference in available P content of both surface and sub soil was observed between YP and MP, this content significantly lower in teak plantation of 40 years old.

As generally accepted, phosphorus is supplied only through the decomposition of the organic matter derived from vegetation and phosphate anion is very difficult to leach out chemically from the pedon.

Apparently lower levels of available P of surface horizon than in the natural stand were also one of the outstanding features of the surface soils in degraded ecosystems (Figure 13). This distinct deterioration in available P may be related with a possible decline in mycorrhizal activity in disturbed forest ecosystems, which are known to solubilize less soluble P compounds.

Consequently, it can be stated that depleted levels of nitrogen content and phosphorous availability are the outstanding characterizing features in soils of the degraded areas studied. Similar patterns were reported in the East Kalimantan, Indonesia (Ohata et al 2000) that it is a common phenomenon in the humid and monsoon tropics that forest degradation results in the depletion of available N and available P particularly in surface. It can be increased as the vegetation recovered, possibly in association with soil faunal development, particularly the mycorrhiza population, which plays a vital role in solubilizing insoluble phosphate.

Potassium

Exchangeable K was also high in NF with a maximum of 9909 ppm, a minimum of 132 ppm and an average of 4320 ppm. However, it decreased in DF with a maximum, minimum and an average of 119 ppm, 56 ppm and 76 ppm, respectively.

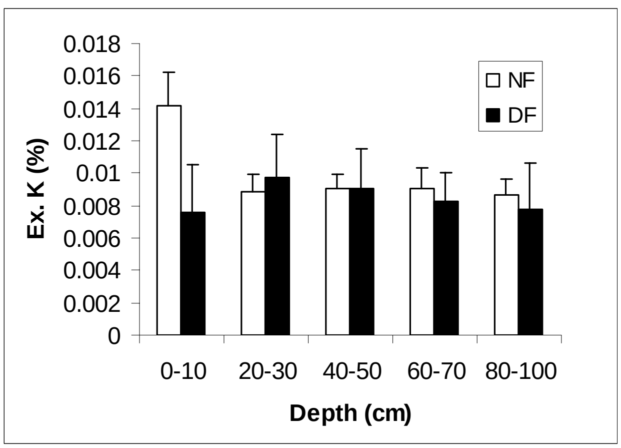


Figure 15. Changes in Exchangeable K under natural forest and degraded forest

The maximum extractable K contents at the surface layers of YP, MP, and OP were 122 ppm, 123 ppm and 97 ppm and the minimum contents were 98 ppm, 65 ppm and 57 ppm and average available P in YP was 109 ppm followed by MP (99 ppm) and OP (76 ppm) respectively. Available P was also lower in teak plantations compared with the primary forests for all horizons.

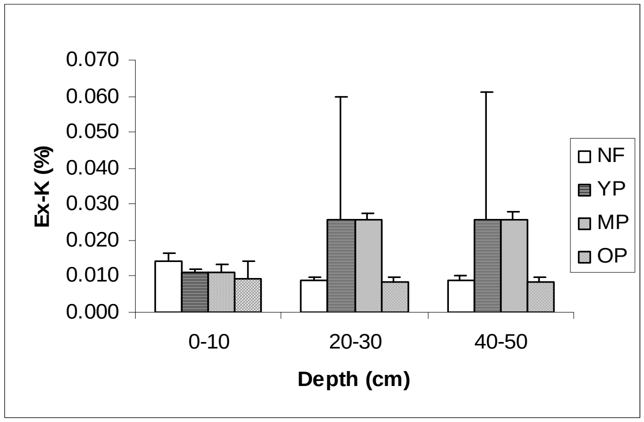


Figure 16. Changes in Exchangeable K content of surface soils in different vegetation types

Although the exchangeable K content was decreased with increasing depths under the NF, it was accumulated in the sub surface layers (i.e. 20-30 cm) under the DF and plantations. It can be concluded that the exchangeable K was decreased through the leaching losses and it was accumulated in the lower layer (Figures 15 and 16).

The cation stocks in soil increase greatly after forest burning and decreased in qunantity during the cultivation period due to leaching and plant uptake. After abandonment, cations are translocated from the soil to the regenerated biomass and accumulate in the biomass and litter (Morisada et al 2000). In Gran Pajonal, Peru, Scott (1978) (cited in Morisada et al 2000) showed that the stock of cations (Ca, Mg and K) in the vegetation, which included above and below ground biomass, tended to increase with vegetation succession, but the amount actually stored in the soil declined.

Although the content of K (base) was high but a slight acidic conditions was detected in both the NF and DF as mentioned below. This result is not consistent with Ohata's finding (2000); many of the Ah and E horizons of the degraded ecosystems were significantly higher in exchangeable Ca, Mg and K levels, and in each respective saturation percentage than those of the natural forests. The burning of primary vegetation is accompanied with a large input of ash to the soil surface, and drastically raises the concentration of exchangeable base cations and the pH of the topsoil. The increased base status will be gradually deteriorated though leaching and the wash-off of ash during the course of successive destructive land use episodes accompanied with repeated burning. However, the raised status will be maintained for a period during the earlier stages of degradation and this raised base level of the surface soils in the study area is presumed to be the result of the relatively short period (10-20 years) of the degradation history of the area (Ohata et al 2000). It can be assumed in this study that at one time there was ash affect on this degraded ecosystem. And the base status might be gradually deteriorated through leaching and the wash-off of the ash.

6. Recommendaitions and Conclusions

6.1 Recommendations

Based on the results obtained from the study, the following recommendations are made.

It is recommended to abstain from disturbing the natural forest vegetation especially in the studied area where the rate of decline of soil's physical, and nutritional properties were found to be very rapid and drastic. Further survey should be made to confirm the degradation process.

More conservative and restorative care should be given to the degraded forests. Priority must be given to the forestation for these areas.
Natural Regeneration be used, rather than Artificial Regeneration by clearing the land for establishing plantations. Methods like: Enrichment Planting, Line Planting, Gap Planting, Compensatory Planting, etc. are recommended.
Mixed Species Planting method should be used instead of monocultural planting if possible, using fertilizers in degraded soil.

Effective protection must be given to natural forests and plantation areas from forest fire and destructive elements including man. Forest fire in the dry period followed by heavy rain in the rainy season is one of the main causes of depletion of forest cover and erosion of soil in the forests. Measures such as ground cover crops planting and erosion control should be applied.

Forest degradation could result in severe damage to our forest ecology and climate, and if it is not checked in time it will lead to serious socioeconomic problems and further extinction of species. We should now act to protect whatever remaining forests before it is too late and redouble our efforts in reforestation and afforestation. There is a need for coordinated planning in the forest sector and management levels, and a comprehensive forest management system which can strike a balance between economic, ecological and social needs.

6.2 Conclusions

In order to understand the soil changes as a result of forest degradation and reforestation (plantation establishment with teak), it can be summarized as follows;

As a result of the soil analysis from various aspects, such as soil bulk density, soil morphological, physical and chemical properties, current land use in the Ngalaik reserve was greatly affected by the strength of the impacts given to the forest.

The bulk density of the natural stand at the surface layer was increased after the forest degradation and plantation establishment, although there was no statistically significant difference between natural forests and degraded stands and among the plantations.
The soils at present condition have a high bulk density, low to medium organic matter and were acidic. These conditions indicate that the soils were degraded. Sanchez et al (1994) reported physical and chemical degradation of forest land involves soil compaction, sheet and gully erosion, significantly increased soil acidity and decreased available nutrients.

Although the exchangeable K stock level in the surface and sub surface soils in the degraded forest was significantly lower than the natural forest area, a little change in soil pH was found. These findings demonstrate clearly that the status of exchangeable base cations, K, in the soils under the degraded forest ecosystem was not improved. It may be assumed that when taking account of the amounts of the element in terms of total biomass, the levels of the element existing within the whole ecosystem must be significantly higher in the degraded forest ecosystem compared with the natural forest. Ohata et al (2000) mentioned that the degradation of forest ecosystems and subsequent conversion to grassland or secondary forest causes soil deterioration is not always true and the pattern of deterioration in base status may differ depending on the degradation history.

In this study, it can be emphasized that the surface and sub surface soil under degraded ecosystems were distinctly deteriorated with respect to the status of the primary nutrients (N, P and K). Increased stabilization of organic matter and a decreased population of mycorrihizal fungi may be associated with the qualitative deterioration of N and P in the soils of the degraded forest. This deterioration in N and P is suspended to be a common phenomenon caused by forest degradation in the humid and monsoon tropics as recorded in other tropical areas (Ohata et al 2000). In order to attain successful future land utilization these elements in available forms will have to be replenished, depending on the N and P requirements of trees species to be grown.

The changes in soil chemistry that occurred after teak plantation establishment (decreases in pH, total N, available P, etc.) were consistent with other reports. Also stock levels of N, P and K decreased remarkably in the order of natural forest > degraded forest > teak plantations with ages.

Tropical forests support complex ecological chains while playing an essential and salutary role in the earth's climate and atmosphere. They can return as much as 75 percent of the moisture they receive to the atmosphere. Thus they have a profound effect on rainfall. Yet these vast natural forests, surrounded by poor populations, were rapidly diminished as they were being converted into plantations to meet market demands. Thus raising short-term and quick growing species in place of multi-layer mixed forests has serious ecological implications. All information about nutrient cycling, tree nutrition and soil chemistry has some meaning in terms of productivity.

Statement about the degradation of forest area studied can only be partly made due to the lack of thorough or complete informations on biological, chemicala nd physical conditions. So also is for nutrient reserves availability for long-term forest productivity and reforestation in the area. It can be concluded that the loss of protective cover, decomposition and loss of organc matters and top soil erosion are the main factors that initiated the degradation of the area.

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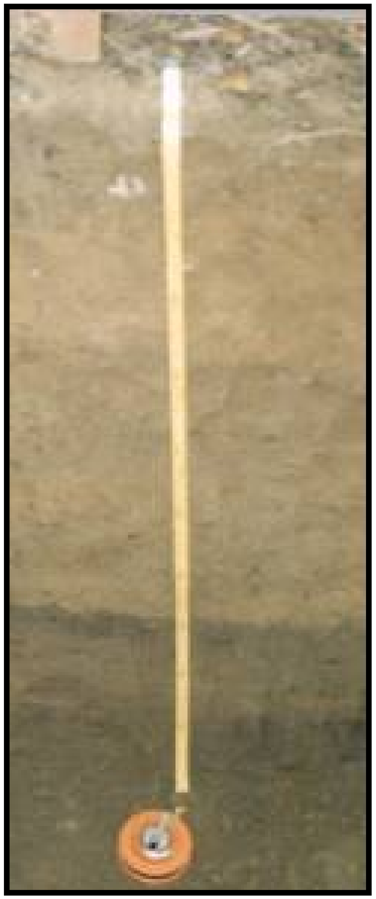
Degraded Forest



Young-aged teak plantation

Mid-aged teak plantation

Old-aged teak plantation

Figure (4) Soil profiles under degraded forest, young-aged teak plantation, mid-aged teak plantation and old-aged teak plantation

12

APPENDIX I (a)

Some physical and chemical properties of natural forest (NF)

Plot No.	Depth (cm)	pH	OM%	Total N%	Ava.P%	Exa.K %	Partical size distribution Sand %	Silt %	Clay %	Textural classes
1	0-10	7.00	4.32	0.0994	0.00010	0.01790	73	4	19	Sandy Clay Loam
	20-30	5.10	4.90	0.0938	0.00010	0.01020	70	5	24	Sandy Clay Loam
	40-50	5.20	4.00	0.0812	0.00030	0.00910	65	6	27	Sandy Clay Loam
	60-70	5.20	3.90	0.063	0.00030	0.00830	35	6	60	Clay
	80-100	5.10	3.90	0.0658	0.00050	0.00790	60	5	32	Sandy Clay
2	0-10	6.60	2.85	0.0574	0.00030	0.01320	78	8	14	Sandy Clay Loam
	20-30	6.10	2.37	0.0756	0.00070	0.01180	76	6	16	Sandy Clay Loam
	40-50	6.30	2.86	0.0602	0.00210	0.00970	77	6	14	Sandy Clay Loam
	60-70	6.40	2.08	0.1218	0.00010	0.00560	88	4	10	Sandy Loam
	80-100	6.20	3.26	0.1036	0.00040	0.00960	73	8	18	Sandy Clay Loam
3	0-10	6.80	8.76	0.1316	0.00060	0.01610	34	8	56	Clay
	20-30	5.30	6.78	0.098	0.00080	0.01240	37	10	53	Clay
	40-50	5.30	5.40	0.0868	0.00050	0.00750	40	13	47	Clay
	60-70	5.10	6.40	0.0826	0.00020	0.00640	44	10	45	Clay
	80-100	5.30	4.00	0.0784	0.00030	0.00750	47	12	41	Clay
4	0-10	6.50	4.03	0.0924	0.00160	0.01740	51	16	31	Clay
	20-30	5.10	4.54	0.0868	0.00130	0.01030	58	13	26	Clay Loam
	40-50	5.20	3.28	0.063	0.00020	0.00860	58	13	27	Clay Loam
	60-70	5.50	4.06	0.0406	0.00020	0.00790	63	9	26	Sandy Clay
	80-100	5.20	3.48	0.0476	0.00090	0.00890	64	10	26	Sandy Clay

APPENDIX I (b)

Some physical and chemical properties of degraded forest (DF)

Plot No.	Depth (cm)	pH	OM%	Total N%	Ava.P%	Exa.K %	Partical size distribution			Textural classes
							Sand %	Silt %	Clay %	
1	0-10	5.90	3.08	0.0909	0.00039	0.00646	53	27	21	Sandy Clay Loam
	20-30	5.46	3.51	0.0712	0.00014	0.01216	37	28	33	Clay Loam
	40-50	5.38	2.88	0.0564	0.00026	0.01140	34	30	33	Clay Loam
	60-70	5.64	2.43	0.0801	0.00011	0.00698	29	38	36	Clay Loam
	80-100	5.80	2.66	0.0506	0.00058	0.00549	28	31	37	Clay Loam
2	0-10	6.20	2.43	0.0743	0.00127	0.00566	76	14	8	Sandy Loam
	20-30	5.95	1.86	0.0658	0.00039	0.00966	69	16	11	Sandy Loam
	40-50	5.89	2.22	0.0618	0.00186	0.00606	64	23	12	Sandy Loam
	60-70	5.46	2.30	0.0609	0.00023	0.07110	62	22	14	Sandy Loam
	80-100	5.59	1.79	0.0515	0.00029	0.00642	66	19	15	Sandy Loam
3	0-10	6.49	2.81	0.0228	0.00353	0.00620	79	11	10	Sandy Loam
	20-30	6.23	1.89	0.0461	0.00100	0.00605	74	15	7	Loamy Sand
	40-50	5.96	1.89	0.0564	0.00059	0.00827	71	15	11	Sandy Loam
	60-70	5.89	2.48	0.0542	0.00036	0.00805	63	20	16	Sandy Loam
	80-100	5.90	2.70	0.0537	0.00036	0.01697	66	22	12	Sandy Loam
4	0-10	6.96	3.50	0.1281	0.00493	0.01195	64	25	9	Sandy Loam
	20-30	6.27	2.69	0.0725	0.00199	0.01096	59	24	13	Sandy Loam
	40-50	5.91	2.92	0.0336	0.00109	0.01064	60	27	15	Sandy Loam
	60-70	5.90	2.45	0.0183	0.00066	0.01085	46	36	18	Loamy Sand
	80-100	5.71	2.42	0.0367	0.00038	0.01204	37	42	20	Loamy Sand

APPENDIX I (c)

Some physical and chemical properties of young-aged teak plantation (YP)

Plot No.	Depth (cm)	pH	OM%	Total N%	Ava.P%	Exa.K %	Particle size distribution			Textural classes
							Sand %	Silt %	Clay %	
1	0-10	5.66	2.98	0.0907	0.00092	0.0098	69	16	11	Sandy Loam
	20-30	6.06	2.62	0.0510	0.00037	0.0077	65	25	10	Sandy Loam
	40-50	6.29	2.26	0.0358	0.00048	0.0065	38	41	19	Loam
	60-70	6.10	2.82	0.0627	0.00029		55	29	19	Loam
	80-100	6.08	2.54	0.0846	0.00027		52	26	17	Sandy Loam
2	0-10	5.92	3.35	0.0857	0.00087	0.0122	67	25	12	Sandy Loam
	20-30	6.28	2.78	0.0694	0.00029	0.0089	49	29	19	Loam
	40-50	6.17	2.72	0.0577	0.00026	0.0094	46	15	21	Sandy Clay Loam
	60-70	6.02	2.68	0.0599	0.00022		49	32	20	Loam
	80-100	5.91	3.01	0.0661	0.00027		63	15	20	Sandy Clay Loam
3	0-10	5.79	2.85	0.0627	0.00089	0.0107	75	11	11	Sandy Loam
	20-30	5.74	2.23	0.0437	0.00038	0.0083	68	15	16	Sandy Loam
	40-50	5.61	2.35	0.0470	0.00038	0.0071	67	16	16	Sandy Loam
	60-70	5.44	2.25	0.0510	0.00023		67	17	17	Sandy Loam
	80-100	5.55	2.35	0.0577	0.00024		71	15	17	Sandy Loam
4	0-10	5.66	2.88	0.0739	0.00067	0.0112	68	20	11	Sandy Loam
	20-30	5.76	2.56	0.0479	0.00124	0.077	75	13	11	Sandy Loam
	40-50	5.62	2.96	0.0560	0.00110	0.079	63	18	20	Sandy Loam
	60-70	5.51	2.60	0.0457	0.00095		57	22	26	Sandy Loam
	80-100	5.64	2.64	0.0573	0.00028		55	22	22	Sandy Loam

APPENDIX I (d)

Some physical and chemical properties of Mid-aged teak plantation (MP)

Plot No.	Depth (cm)	pH	OM%	Total N%	Ava.P%	Exa.K %	Particle size distribution			Textural classes
							Sand %	Silt %	Clay %	
1	0-10	5.57	2.02	0.06830	0.000124	0.0094	83	11	8	Loamy Sand
	20-30	5.28	1.51	0.04700	0.000027	0.0107	68	17	18	Sandy Loam
	40-50	5.38	1.16	0.03800	0.000032	0.0129	71	11	17	Sandy Loam
	60-70	5.33	1.51	0.03970	0.000036		74	7	18	Sandy Loam
	80-100	5.44	1.49	0.03470	0.000045		65	11	20	Sandy Loam
2	0-10	5.56	2.14	0.08330	0.000186	0.0123	83	9	7	Loamy Sand
	20-30	5.63	1.48	0.04570	0.000051	0.0089	73	15	9	Sandy Loam
	40-50	5.65	1.28	0.03860	0.000030	0.0086	73	10	14	Sandy Loam
	60-70	5.62	1.14	0.03690	0.000047		68	14	17	Sandy Loam
	80-100	5.61	1.59	0.04360	0.000041		65	17	22	Sandy Clay Loam
3	0-10	5.06	2.68	0.05150	0.000096	0.0095	81	17	4	Loamy Sand
	20-30	4.61	1.62	0.05710	0.000048	0.0080	62	24	15	Sandy Loam
	40-50	4.50	2.00	0.04700	0.000027	0.0091	55	25	20	Sandy Clay Loam
	60-70	4.59	2.43	0.04420	0.000032		57	26	11	Sandy Loam
	80-100	4.86	2.35	0.03470	0.000020		75	14	10	Sandy Loam
4	0-10	5.30	2.90	0.08019	0.000163	0.0117	82	9	7	Loamy Sand
	20-30	4.37	2.43	0.05645	0.000044	0.0056	68	12	20	Sandy Clay Loam
	40-50	4.10	2.42	0.04390	0.000027	0.0060	56	12	30	Sandy Clay Loam
	60-70	4.20	2.19	0.03890	0.000016		47	19	31	Sandy Clay Loam
	80-100	4.26	2.15	0.05197	0.000008		58	11	27	Sandy Clay Loam
5	0-10	4.79	2.07	0.01030	0.000265	0.0065	87	5	6	Sand
	20-30	4.51	1.40	0.06048	0.000029	0.0078	70	10	19	Sandy Loam
	40-50	5.14	1.03	0.04838	0.000032	0.0075	71	9	20	Sandy Clay Loam
	60-70	4.54	0.91	0.02912	0.000015		63	10	24	Sandy Clay Loam
	80-100	4.38	0.91	0.04301	0.000005		66	11	21	Sandy Clay Loam

APPENDIX I(e)

Some physical and chemical properties of old-aged teak plantation (OP)

Plot No.	Depth (cm)	pH	OM%	Total N%	Ava.P%	Exa.K %	Partical size distribution			Textural classes
							Sand %	Silt %	Clay %	
1	0-10	5.37	2.76	0.0554	0.000178	0.0066	80	9	7	Loamy Sand
	20-30	5.05	2.00	0.0380	0.000057	0.0078	78	10	13	Sandy Loam
	40-50	4.48	1.64	0.0330	0.000066	0.0091	76	7	17	Sandy Loam
	60-70	4.52	1.61	0.0414	0.000043		73	9	19	Sandy Loam
	80-100	4.49	1.88	0.0369	0.000027		68	11	22	Sandy Clay Loam
2	0-10	5.05	2.53	0.5540	0.000110	0.0068	75	13	16	Sandy Loam
	20-30	4.58	2.06	0.0520	0.000040	0.0074	79	14	7	Sandy Loam
	40-50	4.57	1.78	0.0375	0.000027	0.0068	72	11	16	Sandy Loam
	60-70	4.57	2.28	0.0386	0.000027		68	10	22	Sandy Clay Loam
	80-100	5.11	2.43	0.0481	0.000024		64	10	23	Sandy Clay Loam
3	0-10	5.21	1.38	0.0571	0.000013	0.0113	81	10	11	Sandy Loam
	20-30	5.22	1.30	0.0414	0.000028	0.0101	72	11	18	Sandy Loam
	40-50	5.19	1.13	0.0425	0.000029	0.0091	73	12	17	Sandy Loam
	60-70	5.14	1.06	0.0436	0.000025		64	13	23	Sandy Clay Loam
	80-100	5.25	1.14	0.0488	0.000036		59	17	27	Sandy Clay Loam
4	0-10	5.75	1.18	0.0600	0.000610	0.0167	80	13	8	Loamy Sand
	20-30	4.74	1.13	0.0399	0.000038	0.0099	75	13	10	Sandy Loam
	40-50	4.78	0.83	0.0345	0.000027	0.0067	76	12	12	Sandy Loam
	60-70	4.86	0.71	0.0417	0.000016		71	11	17	Sandy Loam
	80-100	4.72	0.96	0.0439	0.000008		68	13	20	Sandy Clay Loam
5	0-10	4.97	1.46	0.0573	0.000160	0.0057	78	12	10	Sandy Loam
	20-30	4.56	1.18	0.0565	0.000113	0.0077	74	12	15	Sandy Loam
	40-50	4.64	0.80	0.0417	0.000099	0.0101	71	12	15	Sandy Loam
	60-70	4.82	1.61	0.0417	0.000080		63	17	20	Sandy Clay Loam
	80-100	4.79	1.61	0.0448	0.000090		59	14	27	Sandy Clay Loam