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Forest Department

Seasonal Soil Moisture Variations

at Pyinmana, Meiktila & Nyaung -Oo Sites

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ပျဉ်းမနား၊ မိတ္ထီလာနှင့်ညောင်ဦးဒေသများတွင် ရာသီအလိုက် မြေအစိုဓါတ် ပြောင်းလဲခြင်း

ဆွေဆွေထွန်း (သုတေသနလက်ထောက် - ၂)၊ သစ်တောသုတေသနဌာန
အောင်ကြင် (အကြံပေးပုဂ္ဂိုလ်၊ သစ်တောတက္ကသိုလ်)
တင်တင်အုန်း (လက်ထောက်ညွှန်ကြားရေးမှူး၊ အငြိမ်းစား)၊ သစ်တောသုတေသနဌာန

စာတမ်းအကျဉ်းချုပ်

မြန်မာ့ သစ်တောဌာနသည် သစ်တော စိုက်ခင်းများကို အရှိန်အဟုန်မြင့်စွာ ကျယ်ကျယ်ပြန့်ပြန့် တည်ထောင်လျက်ရှိပါသည်။ ဤသို့လုပ်ဆောင်ရာတွင် စိုက်ခင်းတည်ထောင်ချိန်၏ ကနဦးအခြေအနေ တွင် အပင်များကြီးထွားနှုန်း နှင့် ရှင်သန်နှုန်းသည် အလွန်အရေးကြီးပါသည်။ အောင်မြင်သော စိုက်ခင်း တည်ထောင်ရန် နှင့် စီမံအုပ်ချုပ်ရန်အတွက် သတင်းအချက်အလက်အချို့ကို အထောက်အကူ ပြုနိုင်ရန် မြေဆီလွှာအမျိုးမျိုး ၀–၁၀စင်တီမီတာ၊၂၀–၃၀စင်တီမီတာ၊ ၄၀–၅၀စင်တီမီတာ၊ ၆၀–၇၀စင်တီမီတာ၊ ၈၀–၉၀ စင်တီမီတာ တို့ ၌ ရာသီအလိုက်မြေအစိုဓါတ်အခြေအနေကို လေ့လာခဲ့ပါသည်။ မြေအစိုဓါတ် လေ့လာခြင်းကို ပျဉ်းမနားမြို့နယ် ၊ ကိုင်းကြီးဝိုင်း အကွက်အမှတ် ၁၀၊ မိတ္ထီလာ မြို့နယ်၊ ဖလန်ကျင်းကြီးဝိုင်း အကွက်အမှတ် (၅) နှင့် ညောင်ဦးမြို့နယ်၊ ကျောက်ကူအဆိုပြု ကာကွယ်တော ရှိ ကျောက်ကူစိုက်ခင်းတို့၌ ဆောင်ရွက်ခဲ့ပါသည်။ ဤဒေသများရှိ မြေအခြေအနေသည် သဲဆန် နုံး မြေ နှင့် နုံးဆန်သဲမြေများဖြစ်ပါသည်။ မိုးရာသီ နှင့် ခြောက်သွေ့ရာသီများတွင် နှစ်လ လျှင် တစ်ကြိမ် ဒေသတစ်ခုစီ၌ မြေစုဆောင်း၍ မြေဆီလွှာ၏ ရေရရှိနိုင်မှုအခြေအနေကိုနှိုင်းယှဉ်လေ့လာခဲ့ပါသည်။ ရာသီဥတုနှင့် လတ္တီတွဒ် တို့ကွဲပြားချက်ပေါ်တွင် အခြေခံ၍ နေရာရွေးချယ်ထားခြင်းကြောင့် မြေအစိုဓါတ်များသည် ဒေသ တစ်ခုနှင့် တစ်ခု ကွဲပြားနေသည်ကို တွေ့ရှိခဲ့ပါသည်။ မြေဆီလွှာအမျိုးမျိုးရှိ မြေအစိုဓါတ်များသည် ရာသီတစ်ခုမှ တစ်ခု ကွာခြားပြီး ၄င်းဇရိယာများရှိ မိုရှာသွန်းမှုနှင့် တိုက်ရိုက် ဆက်စပ် နေပါသည်။

Seasonal Soil Moisture Variations at Pyinmana, Meiktila & Nyaung -Oo Sites

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Abstract

Myanmar Forest Department has been establishing plantations extensively. In this process, the survival and growth of plants in the early stage of plantation establishment are very important. To provide some information for the successful establishment and management of plantations, seasonal soil moisture conditions at different soil layers (0-10 cm, 20-30 cm, 40-50 cm, 60-70 cm and80-90 cm) were examined. Soil moisture studies were conducted in Compartment No. (10) of Kaing Reserved Forest, Pyinmana Township, Compartment No. (5) of Palangyin Reserved Forest, Meiktila Township and Kyauk-ku plantation of Kyauk-ku Protected Public Forest, Nyaung-Oo Township. The soils in these areas are sandy loam and loamy sand type. The data were collected once every two months, during the wet and dry seasons and then compared with the available water range of each site. Since the chosen sites were based on the climatological and latitudinal different basis, the moisture contents in these areas were found to be different from each other. Soil moisture contents in different soil layers vary from one season to another and are strongly correlated with rainfall in all study areas.

Contents

1. Introduction

The forestry sector is coming under mounting pressure from having to support not only a greater number of people but people with more demanding and polluting life style. Already many countries especially in the developing world are experiencing rapid and massive forest destruction. In this respect Myanmar is not an exception. To check deforestation and its consequences and for the continuous supply of multiplicity of goods and services provided by forests, Myanmar Forestry sector is taking the following measures;

- Sustainable management of natural forest ecosystem.
- Establishment of various types of man-made forests/plantations
- Rehabilitation of degraded forests and afforestation in dry areas in Central Myanmar.
- Establishment of community forestry, agroforestry and forestry enterprises.

Soil moisture status is one of the most important factors influencing the growth of plant in natural habitat. The water received on the soil surface is immediately affected by the surface properties of the soil and the total water, which infiltrates the soil is not absorbed by the soil. The moisture regime of the soil profile, after the distribution of water according to hydraulic gradient, regulates the soil moisture supply to the roots (Jha and Rathore, 1981).

In this study, soil moisture is investigated in three different sites. One of the selected three sites is situated in natural teak bearing forest area and the other two are in central dry zone greening project area. So the soil moisture regime may be expected to change in three similar soils depending upon the site and climate. It is therefore important to know the soil moisture status of the soil and the changes taking place with time. Knowledge of soil moisture plays a central role in decision-making process of site and species selection of forest plantations especially in dry zone areas.

2. Objectives

1. To study seasonal soil moisture variations in Special Teak Plantation Program Areas and Dry Zone Greening Areas.
2. To evaluate the available water range of the sites.
3. To provide some information related to soil moisture for the establishment of plantation.

3. Literature Review

Soil moisture regime is a very important physiographic feature. This term has been found to be better suited to describe moisture availability to tree than the more familiar term "drainage". Soil moisture regime is controlled by a number of field factors including soil texture and structure, depth of soil over a compacted layer and depth of a gley horizon (i.e top of fluctuating water table), slope steepness and position on the slope (Burger, 1983).

For selecting sites of regeneration of native or exotic species, soil moisture appears to be the most important consideration. Soils that are supplied with minerals are completely unproductive without water but impoverished sand may support reasonably productive forest if supplied with adequate soil moisture (Pritchett, 1979). Under even the same environmental condition, different species require widely different demands on soil moisture.

A study of soil moisture is necessary, if it is to be ensured that plantations do not die off from moisture deficiencies after growing for some time, because of the increasing demand for growing trees (Muhammad, 1957). Soil moisture is the principle source of water for plant and plays an importance role in much soil process. It acts as a solvent and carrier of nutrients, leaching agents, reactant, plasticizing and in addition functions as a nutrient itself, and promote innumerable physical, chemical and biological activities of soil (Lyon et al., 1952).

Soil moisture regimes greatly affect the rate of root elongation during the growing season. Water deficits in the spring but some water stress causing slowing and cessation of expanding root tissue rarely affect root growth. It is often critical to survival for the capacity of transplants to resume root elongation rapidly (Pritchett, 1979). If soil moisture is deficient, the movement of nutrient ions towards the root in the mass flow of water decreases, and even diffusion is prevented by increasingly more tortuous pathways around gas-filled pores. Consequently, in infertile soil, nutrient deficiency may become more important than the reduced water availability for rapidly growing plants (Daubenmire, 1947).

Soil moisture starts to have an effect upon plant. Even before germination since the seeds of many plants must make contact with moist soil within a few days after maturation or perish. Plant resistance to certain insects is apparently reduced under stress condition carried by soil moisture deficiencies. Sometimes moisture stress induces flower initiation in certain plant but good soil conditions are required for best flower produces (Daubenmire, 1947).

Soil moisture is equally of importance in its role in the radial growth of trees. It effects the size of the annual ring, the proportion of earlywood and laterwood and wood specific gravity. Tree obtains moisture from water table or the capillary fringe within reach of their roots. The water table may be above the soil surface during wet seasons and fall to a certain depth during dry seasons. These fluctuations are due to variation in precipitation, transpiration, evaporation and temperature. Factor affecting soil moisture and hence tree growths are soil quality and depth, soil texture, availability of nutrients, exposure and competition among tree for the moisture (Pritchett, 1979).

The available water range in different soil varies widely (Kramer, 1969). The total content of a soil does not give a true picture of the volume of water available to plants. A clay soil retains higher amount of water than a sandy soil at both field capacity and wilting point, but the amount of water available water from these soils proportional to the actual water content. However, the volume of water available is greater in heavier than in lighter soils. The volume of available soil water increases with the fineness of soil particles up to silt loam, but it declines with further fineness of particles. Abrol and Bhumbla (1968) stated that the available soil water is a function of the content and the availability is the maximum when the silt fraction of the soil constitutes more then 50% of the total silt plus clay fractions.

Silt loam holds about 45% moisture (water mass as a percentage of equivalent soil dry mass) at Field capacity and about 10% moisture at –2MPa, for a water holding capacity of 35% of the soil's dry mass water than silt loams, but they hold it more tightly. The clay holds about 65% water at field capacity and 35% at –2 MPa, for a water holding capacity of 30% of the dry mass. At 35% moisture, roots obtain water easily from the silt loam (-2.0MPa) (Fisher & Binkely, 2000). The moisture content of soil between field capacity condition and permanent wilting point is widely accepted as plant available water, the total storage capacity for available water can be determined by subtracting the wilting percentage from the field capacity (Thorne and Peterson, 1954). The different amount is generally marked as 100% available moisture, and the percent of available moisture depletion can be used as an indicator for irrigation purpose. The amount of available moisture for the plants varies with soil type and ranges from 10-25% by volume of water (Kyi Myint, 1991).

4. Materials and Methods

4.1. Materials

4.1.1 Study areas

Three different locations were selected as study areas, namely Pyinmana, Meiktila and Nyaung-Oo. Maps showing the location of the study areas are Figures 1, 2 and 3.

4.1.1.1 Pyinmana township

Pyinmana is located in the edge of the Bago Yomas. The experiment was carried out in Compartment No.10 of Kaing Reserved Forest (approximately 19° 19' N and 95° 56'E). The total area is 500 acres, in which Teak (*Tectona grandis*) is planted.

The topography is flat and the area is well drained and generally flows from east to west. The slope % is 2-5 and its altitude is about 300-m a.s.l.

The geological formation of the study site belongs to the Back-Arc-Basin. The study area Pyinmana is characterized by thick Mio Pliocene sediments (Curray et al., 1979). The area belongs to the Pegu Yoma Anticlinorium, which is also filled by thick tertiary marine sediment (Bender, 1983). The soils are mostly yellow brown forest soil of tropical monsoon forests (Rozanov, 1961) and belong to the group of Xanthic ferrasol (Kyi Khin 1991).

The soils to the west of Yamethin, in which the study area located is of buff to yellowish color, medium to thick bedded, coarse to gritty, poorly consolidated sandstone (Kyi Khin 1991).

Figure 1 Location Map of Study Area in Kaing Reserved Forest (Compartment No.10), Pyinmana Township

Figure 2 Location Map of Study Area in Palangyin Reserved Forest (Compartment No.5), Meiktila Township

Figure 3 Location Map of Study Area in Kyauk-ku Protected Public Forest (Kyauk-ku plantation), Nyaung-Oo Township

The climate of the study site is greatly influenced by the monsoon season. The rainy season is from May to October with the ample rainfall arriving from the Bay of Bengal. From the end of October to April, the air current changes its direction and flows from the Northeast towards Southwest, causing the dry season. Climatic data (monthly means) and DE MARTONNE'S aridity index of Pyinmana Township are shown in Table 1.

Table 1. The climatic data (monthly means) and DE MARTONNE'S aridity index of Pyinmana Township

Month	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May.**	**Jun.**	
Temperature(°C)	22.48	24.96	27.82	29.98	29.62	28.04	
Rainfall (mm)	0.79	7.14	6.05	26.87	197.56	246.96	
DeMartonne's Aridity Index	0.29	2.45	1.92	8.07	59.84	77.9	
Month	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	Year
Temperature(°C)	27.64	27.42	27.97	28.4	25.82	23.5	26.97
Rainfall (mm)	239.42	271.22	192.51	173.96	56.00	1.73	1420
De Martonne's Aridity Index	76.33	86.98	60.84	54.36	18.76	0.62	37.36

***Source:* The Meteorological Station, Pyinmana.**

According to the climatic data for the period of 1993 to 2002, the number of rainy days was found to be around 60. Some critical climatic data (1993 - 2002) for Pyinmana Township are as follows:

Absolute maximum temperature:	40.7 ºC	(March 2001)
Absolute minimum temperature:	12.1	(January, 1997)
Highest maximum rainfall:	1634 mm	(1996)
Lowest minimum rainfall:	873 mm	(1998)
Average maximum rainfall :	August	(389.1 mm).
Average minimum rainfall :	February	(10.01 mm)

The climatogram of Pyinmana is shown in Figure 4 with monthly average temperature and rainfall.

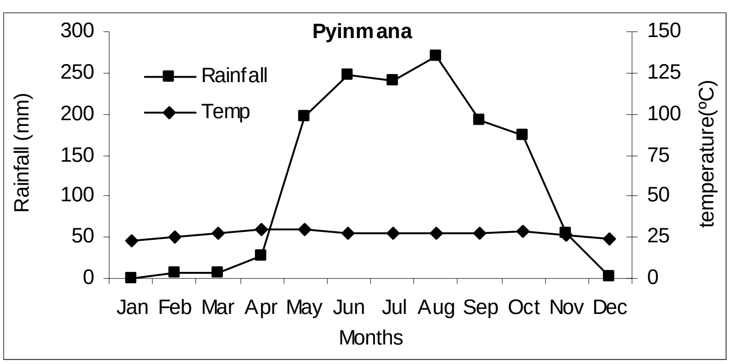

Figure 4. Climatogram of Pyinmana (1993-2002)

4.1.1.2 Meiktila township

The study area Meiktila is located in the middle of Myanmar. The experimental plot was located in Compartment 5, Palangyin Reserved Forest. It is situated at 20° 25' N and 95° 50' E. The study area has 264 acres in which Thit-Seint (*Terminalia belerica*) is planted.

Meiktila has mostly flat plain with slope gradient 2-3 % at 214-m a.s.l and the area is well drained and normally flows from southeast to northwest.

The geology of Meiktila consists of the lower Miocene sediments. There are intercalated calca- silicates (Bender, 1983).

Soil type is yellowish brown dry forest soil, belonging to the group of cambisol (Bender, 1983). Parent materials are apparently derived “in situ“from sandstone.

The study site is in the central dry zone, which is influenced by tropical savanna climate with a pronounced dry period between the monsoon rains. Rains commence in mid-May, almost stop from July to mid August and then resume intermittently from mid August to mid-September. Strong winds are common towards the end of summer and prior to the monsoon.

Climatic data (monthly means) and DE MARTONNE’S aridity index of Meiktila Township are shown in Table 2.

Table 2. The climatic data (monthly means) and DE MARTONNE’S aridity index of Meiktila Township

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	
Temperature(°C)	22.1	25.09	31.93	28.8	30.57	29.0	
Rainfall (mm)	0.1	0.81	6.83	25.5	153.29	106.4	
De Martonne’s Aridity Index	0.4	0.28	1.95	7.89	40.57	32.6	
Month	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**year**
Temperature(°C)	28.87	28.37	28.64	28.28	25.48	22.92	27.5
Rainfall (mm)	71.5	148.84	140.11	137.47	34.34	0.41	826
De Martonne’s Aridity Index	22.07	46.55	43.51	43.1	11.61	0.14	20.9

Source: **The Meteorological Station, Meiktila**

According to the climatic data of 1993-2000, the number of rainy days was found to be around 30. The aridity indices of Meiktila exhibits a pronounced dry season of 8 months from November to April, June and July. The following data are valid for the period from 1993-2002, based on the data of the Meteorological Station Meiktila.

Absolute maximum temperature:	40.7°C	(April 1997)
Absolute minimum temperature:	13 °C	(January 1997)
Highest maximum rainfall:	1056.9 mm	(2000)
Lowest minimum rainfall:	522.4 mm	(1994)
Average maximum rainfall:	May	(108.89 mm)
Average minimum rainfall:	January	(0.1mm)

The climatogram of Meiktila is shown in Figure 5 with monthly average temperature and rainfall.

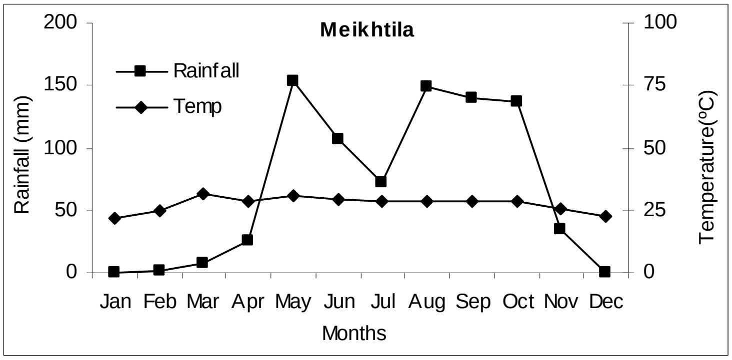

Figure 5. Climatogram of Meiktila (1993-2002)

4.1.1.3 Nyaung-Oo township

In Nyaung-Oo, the experiment was carried out in Kyauk-ku protected public forest (21° 12' N and 94° 55' E) which is the driest part of the dry zone. The study area covers 200 acres, in which Tama (*Azadrichata indica*) species are planted.

The study area is mostly flat-lands though undulating in some places. The highest elevation is 353-m a.s.l. The area is well drained and generally flows from north to south. The geology of Nyaung-Oo is Oligiocence and Miocene sediments. Normally it consists of a pebble bearing gravel at the base above which fluviatile and finally colian sands. Wornbones possibly from the Early Paleolithic are characteristic. The base section is often strongly solidified into an ironstone hardpan (Bender, 1983).

Soil is reddish brown dry forest soil of tropical dry savannas forests (Bender, 1983), belonging to the group of catena of luvisol on slopes vertisol in depression. The climate of the study area is almost the same to that of Meiktila. Climatic data (monthly means) and DE MARTONNE'S aridity index of Nyaung-Oo Township are shown in Table 3.

Table 3. The climatic data (monthly means) and DE MARTONNE'S aridity index of Nyaung-Oo Township

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	
Temperature(°C)	22.75	22.75	32.52	32.91	31.81	31.81	
Rainfall (mm)	0.18	3.81	7.11	8.64	90.42	54.1	
De Martonne's Aridity Index	13.96	1.3	2.01	1.15	25.95	15.53	
Month	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Temperature(°C)	31.13	31.13	30.88	29.3	26.72	23.09	28.09
Rainfall (mm)	30.23	82.3	118.36	86.87	32.51	0.76	410.93
De Martonne's Aridity Index	11.65	24.01	46	35.58	14.6	0.27	16.00

Source: **The Meteorological Station, Nyaung-Oo**

According to the climatic data of 1993-2002, the number of rainy days was found to be around 30. The aridity indices of Nyaung-Oo exhibits a pronounced dry season of 8 months from November to April and June and July. The following data are valid for the period from 1993-2002, based on the data of the Meteorological Station Nyaung-Oo.

Absolute maximum temperature:	42.84ºC	(May 2001)
Absolute minimum temperature:	11.58ºC	(January 2001)
Highest maximum rainfall:	700 mm	(1996)
Lowest minimum rainfall:	365 mm	(2001)
Average maximum rainfall:	September	(118.36mm)
Average minimum rainfall:	January	(0.18 mm)

The climatogram of Nyaung-Oo is shown in Figure 6 with monthly average temperature and rainfall.

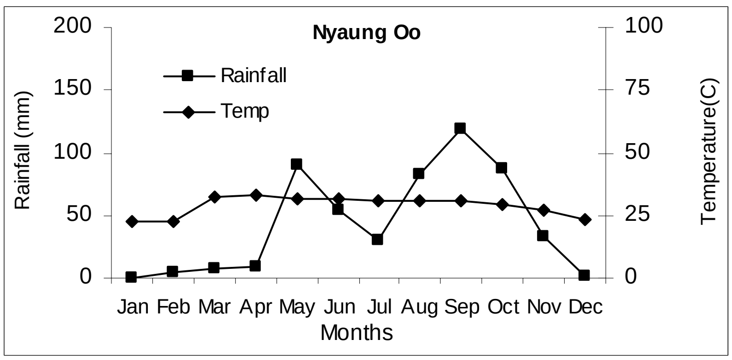

Figure 6. Climatogram of Nyaung-Oo (1993-2002)

4.2 Methods

4.2.1 Experimental design

The experiment was conducted at three different sites (Pyinmana, Meiktila and Nyaung-Oo), using factorial experiment with Randomized Complete Block Design (RCBD) and three replications.

4.2.2 Sampling method

Systematic sampling method was used in collecting soil sample. Three plots of size 100m x 100 m were constructed in the selected compartment in each study area. Five sites were systematically located in each plot by the following way.

The first site is the center of the plot. To set the other four points, the plot is divided into four equal subplots of size 50m x 50m. The centers of these subplots are the four sites for soil samples collection. In each study area, thus, there were 15 sites in total. Lay out of the sample plot is shown in Figure 7.

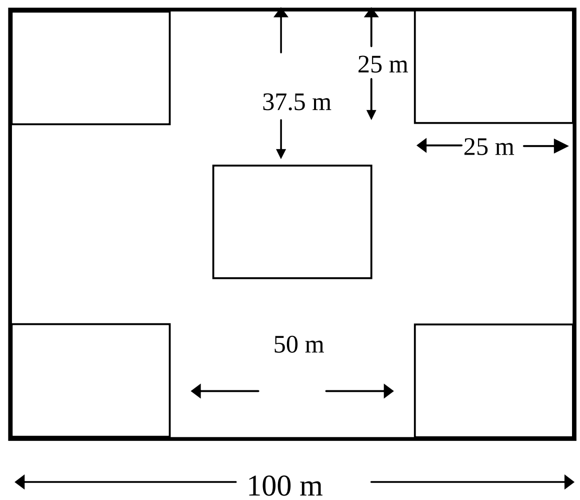

Fig 7. Lay out of sample plot

4.2.3 Data collection

Soil moisture measurings were made from 2003 June through 2004 April. Soil samples were collected once every two months. At each site, soil samples were taken at five different soil depths, namely (0-10cm), (20-30cm), (40-50cm), (60-70cm) and (80-90cm). Soil samples collection and soil profiles studied at all sites were also done in June 2003.

4.2.4 Field study

4.2.4.1 Soil moisture

Soil from each study site was collected at the depth of 0-10 cm, 20-30 cm, 40-50 cm, 60-70 cm and 80-90 cm by using auger. Each soil was transported to the soil laboratory in the sealed tin to minimize moisture evaporation.

4.2.4.2 Bulk density

Three samples of surface soil were collected from each three study sites. The collection of soil sample for bulk density was done by using steel bulk density corer (2.5 x 2.5 x 5 cm). The corer was driven into the ground with minimum disturbance using a hammer and wooden block. The core was dug out from the ground using a trowel and the surplus soil was trimmed at the ends of the corer by means of a sharp knife. The soil core was extracted into a labeled plastic bag and returned to the laboratory.

4.2.4.3 Soil properties

Three predetermined places in Pyinmana, Meiktila and Nyaung-Oo sites were selected by composite sampling. Soil samples were collected from different depths of horizon such as 0-10 cm 20-30 cm, 40-50 cm, 60-70 cm and 80-90 cm successively.

4.2.5 Laboratory analysis

4.2.5.1 Soil moisture

The gravimetric method for determining soil moisture is rather than time consuming, but it can be more accurate than determinations made in the field. Accuracy depends to a large extent on care in taking and handling samples.

(1) The initial wet weight of each soil sample was weighed and recorded as wet soil (Initial weight).

(2) Then the soil samples were oven dried at 105°C to obtain the constant weight and the oven-dried samples were weighed and recorded as dry soil.

(3) The moisture content of each sample at the net dry weight conditions was calculated by using the following equation.

$$MC\,(\%) = \frac{I.wt - O.D\,wt}{O.D\,wt} \times 100$$

MC = moisture content of the soil sample

I.wt = initial weight of sample

O.D wt = Oven dry weight of the sample.

4.2.5.2 Bulk density

The soil bulk cores were weighed immediately after being returned from the field, oven dried at 105° C for 24 hours and the oven dried weight determined. The bulk density is expressed in grams per cubic centimeter of the soil.

4.2.5.3 Total porosity (%)

Total porosity was calculated by using the formula,

$$\text{Total porosity (\%)} = 1 - \frac{B.D \times 100}{P.D}$$

Where B.D = Bulk density

P.D = Particle density

3.2.5.4 Physical and chemical properties of soil

Soil samples were air-dried and sieved through a 2mm sieve and the physical and chemical properties were analysed by the chemists.

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

Organic matter was detected by using the weight loss ignition method.

Soil reaction (pH) was determined by using Corning pH meter 12 equipped with calmol glass electrode on distilled water suspension (1:2.5).

Total nitrogen was settled by Micro Kjedahal digestion and distillation units.

Available phosphorus levels were resolved with double acid extracting solution and molybdenum blue complex method by using Hach DR/2000 spectrophotometer.

Extractable potassium was assessed with double-acid extracting solution by using Atomic Absorption Spectrophotometer

5. Results and Discussions

5.1 Results

5.1.1 Climatic Condition

Monthly rainfall, relative humidity and maximum and minimum temperature for the study areas from May 2003 to April 2004 are presented in Appendix 1.

5.1.1.1 Rainfall

Monthly rainfall ranged between 99 and 414 mm and the annual rainfall for Pyinmana was 1137 mm. In Meiktila, rainfall varied from 3.81 to 150 mm and the annual rainfall was 497 mm. For Nyaung-Oo, the annual rainfall was 530 mm with the minimum below 50 mm and the maximum around 170 mm.

5.1.1.2 Rainy days

Study areas Pyinmana, Meiktila and Nyaung-Oo had 49, 36 and 31 rainy days in the year, respectively.

5.1.2 Soil Condition

Some physical and chemical properties of study area were shown in Appendix 2. Soil profile descriptions for 3 different sites were presented in Appendix 3 and soil profiles and site conditions were shown in plates (1a, 1b, 2a, 2b, 3a, and 3b).

5.1.2.1 Pyinmana site

In Pyinmana, the soils from the experimental site were generally found to be loamy sand and sandy loam soil with slightly acid reaction (pH 4.82-5.98). Granular structure and deep soil depth condition were found in this area. The average value of bulk density of the undisturbed surface soils was 1.33 ranging from 1.2 to 1.4. Total porosity of surface soil varied from 30% to 41% in Pyinmana. Total nitrogen, available phosphorous and organic matter were found to be low for normal plant growth. Extractable potassium was generally normal in this area.

Plate 1 - a Soil Profile in Kaing Reserved Forest, Compartment No 10. Pyinmana Township

Plate 1 - b Special Teak Plantation (1998) in Kaing Reserved Forest, Compartment No 10. Pyinmana Township

Plate 2 – a Soil Profile in Palangyin Reserved Forest, Compartment No.5 Meiktila Township

Plate 2 – b Thit Seint Plantation (2002-2003) in Palangyin Reserved Forest, Compartment No.5 Meiktila Township

Plate 3 – a Soil Profile in Kyauk–ku Protected Public Forest, Kyauk-ku

Plate 3 – b Plantation Tama Plantation (2002–2003) in Kyauk–ku Protected Public Forest, Kyauk-ku Plantation

5.1.2.2 Meiktila site

Dominant textural class of sandy loam and loamy sand type with very alkaline reaction (pH 8.33- 9.01) were found in Meiktila site. Granular structure and shallow soil depth condition were observed. The average value of bulk density of the undisturbed surface soils was 1.54 ranging from 1.41 to 1.68. Total porosity of surface soil was ranging from 22% to 29%. Total nitrogen and available phosphorous were recorded as low level and organic matter was found to be low to medium level. Potassium concentration levels were medium in Meiktila.

5.1.2.3 Nyaung – Oo site

The major soil texture under study area was sandy loam and loamy sand type. Slightly alkaline reaction was observed in Nyaung-Oo. Soil structure and soil depth conditions of the study area were almost the same to Meiktila. The average pH value of soils was varied from 6.02 to 8.51. The bulk density of the undisturbed surface soils was ranging from 1.41to 1.51 respectively. Total porosity of surface soil varied from 18% to31% in Nyaung-Oo. Total nitrogen and organic matter were fairly contained in this soil but available phosphorous was recorded to be insufficient for the normal plant growth. Extractable potassium contents were subjected as medium level in this area.

5.1.3 Seasonal Soil Moisture Variations of Different Soil Layers in Study Areas

The results of seasonal soil moisture variations in the study areas were analyzed by using Data plus and IRRISTAT Statistical Software program and means were compared to using Duncan's Multiple Range Test (DMRT). Each of study sites for seasonal soil moisture variations on different soil layers are described in the following.

5.1.3.1 Pyinmana site

The analysis of variance of Pyinmana was shown in Appendix 4-a. According to the ANOVA Table, all months, all depths and interaction effects between months and depths were highly significantly different at 1% level. The mean of monthly soil moisture condition at different soil layer is shown in Table 4. The results of the experiment are found as follows:

Table4. Mean comparison of moisture content for different months in Pyinmana

	Month (M)						
Depth(D)	**Jun**	**Aug**	**Oct**	**Dec**	**Feb**	**April**	**D-Mean**
S=Pyinmana							
0-10	12.9883 b	17.2235 a	8.8206 d	4.897 d	3.1973 d	6.5073 a	8.9390
20-30	12.8387 b	15.7888 a	11.3223 c	5.6173 cd	4.2358 cd	4.5863 c	9.0649
40-50	13.9888 ab	16.4962 a	13.1075 b	6.4298 c	5.1628 b	5.3233 bc	10.0847
60-70	15.4635 a	17.1939 a	15.3703 a	8.4140 b	6.0167 ab	6.5154 ab	11.5956
80-90	15.7057 a	17.4520 a	16.3247 a	9.97775 a	6.6215 a	7.0273 a	12.1848
M-Mean	**10.7268**	**14.197**	**16.8309**	**12.9891**	**7.0671**	**5.0468**	**10.3538**

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

In June, mean comparison between all soil layers of moisture condition showed that 60-70 cm and 80-90 cm layers were significantly the highest and followed by 40-50 cm, 0-10 cm and 20-30 cm.

In August, the highest moisture content was obtained by 80-90 cm layer. But the moisture content has no statistically significant difference among the layers.

In October, it can be observed that 60-70 cm and 80-90 cm layers gave the highest moisture content and 0-10 cm layer has the lowest moisture content.

In December, 80-90 cm layer was significantly different from 0-10 cm layer which was the lowest moisture content.

In February 0-10 cm layer that has the lowest values was significantly different from all soil layers. 80-90 cm layer has the highest value of soil moisture content.

In April, 0-10 cm and 80-90 cm layers have the highest moisture content and gave the same result. The lowest moisture content was found in 20-30 cm layer.

The moisture content in different soil layers (0-10 cm, 20-30 cm, 40-50 cm, 60-70 cm and 80-90 cm) at different months (June, August, October, December, February and April) is shown in Table 5.

Table 5. Mean comparison of moisture content for different levels of soil in Pyinmana

	Depth(D)					
Month (M)	**0-10**	**20-30**	**40-50**	**60-70**	**80-90**	**M-Mean**
Jun	12.9883 b	12.8387 b	13.9888 b	15.4635 a	15.7057 a	14.1970
Aug	17.2235 b	15.7888 a	16.4962 a	17.1939 a	17.4520 a	16.8309
Oct	8.8206 c	11.3223 b	13.1075 b	15.3703 a	16.3247 a	12.9891
Dec	4.8971 e	5.6173 c	6.4298 c	8.4140 b	9.9775 b	7.0672
Feb	3.1973 f	4.2358 d	5.1628 d	6.0167 c	6.6215 c	5.0468
April	6.5073 d	4.5863 d	5.3233 d	6.5154 c	7.0273 c	5.9919
D-Mean	10.7268	10.8778	12.1017	13.7948	14.6217	12.4246

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

In 0-10 cm, August showed the highest moisture 17.22% and followed by June 12.99%, October 8.82%, April 6.51% and December 4.9% and February 3.2%.

In 20-30 soil layer, the maximum moisture content was retained in August 15.79 % and June and October showed the same effect (12.84% and 11.32%) and followed by April 4.59 % and February 4.24%.

In 40-50 cm layer, soil moisture content showed the highest in the month of August 15.79% and the lowest in February 4.2%.

In 60-70 cm layer, June, August and October have the highest moisture content and followed by December 8.41 %, April 6.52 % and February 6.02%.

In 80-90 cm, February has the lowest moisture content 6.63 % and June, August and October showed the highest moisture and gave the same effect.

5.1.3.2 Meiktila site

The analysis of variance of moisture for Meiktila site is shown in Appendix 4-b. F test indicated that a significantly different at 1% level.

Monthly soil moisture conditions at different soil layers (See Table 6) are found as follows: -

Table 6. Mean comparison of moisture content for different months in Meiktila

	Month(M)						
Depth (D)	**Jun**	**Aug**	**Oct**	**Dec**	**Feb**	**April**	**D-Mean**
S= Meiktila							
0-10	4.2557 b	7.2207 a	9.9663 b	4.4500 c	2.9112 c	2.1255 b	5.1549
20-30	5.8544 a	6.5073 ab	12.4729 a	6.4751 b	4.9943 b	4.1976 a	6.7503
40-50	5.3869 ab	5.6408 ab	11.9146 ab	7.3463 ab	5.7727 ab	5.0100 a	6.8452
60-70	6.3957 a	6.0053 b	11.7343 ab	7.8858 ab	6.4331 ab	4.6888 a	7.1905
80-90	6.7552 a	6.6891 ab	10.1547 b	8.3283 a	6.8429 a	4.7235 a	7.2489
M-Mean	**5.7298**	**8.3283a**	**11.2486**	**6.8971**	**5.3908**	**4.1491**	**6.6380**

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

In June, 0-10 cm layer was the lowest moisture content. 20-30 cm, 60-70 cm and 80-90 cm layers were not significantly different at 5% level by DMRT.

In August, 0-10 cm layer gave the highest moisture content. 20-30 cm and 80-90 cm layers showed the same moisture effect and followed by 40-50 cm and 60-70 cm layers.

In October, 0-10 cm layer was the lowest moisture content and followed by 80-90 cm. 20-30 cm layer significantly showed the highest moisture.

In December and February, 80-90 cm layer has the highest moisture content. 40-50 cm and 60-70 cm layers gave the same moisture content and followed by 20-30 cm and 0-10 cm layers.

In April, the layers from 20-30 cm to 80-90 cm were not significantly different at 5% level by DMRT. 0-10 cm layer has the lowest moisture content.

The mean moisture content in different soil layers (0-10cm, 20-30cm, 40-50cm, 60-70cm and 80-90 cm) at different months is shown in Table 7.

Table 7 . Mean comparison of moisture content for different levels of soil in Meiktila

	Depth(D)					
Month (M)	**0-10**	**20-30**	**40-50**	**60-70**	**80-90**	**M-Mean**
Jun	4.2557 c	5.8544 bc	5.3869 c	6.3957 bc	6.7553 b	5.7296
Aug	7.2207 b	6.5073 b	5.6408 bc	6.0053 c	6.6891 b	6.4126
Oct	9.9663 a	12.4729 a	11.9146 a	11.7343 a	10.1547 a	11.2485
Dec	4.0500 c	6.4751 b	7.3463 a	7.8887 b	8.3283 b	6.8177
Feb	2.9117 cd	4.9943 bc	5.7727 bc	6.4331 bc	6.8442 b	5.3921
April	2.1255 d	4.1976 c	5.0100 c	4.6888 c	4.7235 b	4.1491
D-Mean	**6.1859**	**8.1003**	**8.21422**	**8.6286**	**8.6987**	**7.9655**

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

To know which layer showed significant seasonal variation within layers, monthly means of moisture content of each layer were compared for significant differences.

According to DMRT in 0-10 cm, October has the highest moisture content 9.96% and followed by June 4.26 %, December 4.05%, April 2.13%.

In 20-30 cm layer, the highest moisture content 12.47% was found in October, where April was significantly the lowest.

In 40-50 cm layer, October has the highest moisture % and followed by December. However, there was no significant difference among the months of February, August, June and April.

Mean comparison between all months in 60-70 cm, October was found to have the best moisture content 11.73% and followed by December 7.89%, June 6.4%, February 6.43%, August 6.01% and April 4.72%.

In 80-90 cm layer, the maximum moisture content of 10.15% was observed in October and the minimum 4.72% in April.

5.1.3.3 Nyaung- Oo site

The analysis of variance of Nyaung Oo site was shown in Appendix 4-c. ANOVA Table showed that there was significantly different at 1% level.

The mean of moisture content of all of months of different soil layers was compared for significant difference test as shown in Table 8.

Table 8. Mean comparison of moisture content for different months in Nyaung-Oo

	Month(M)						
Depth(D)	**Jun**	**Aug**	**Oct**	**Dec**	**Feb**	**April**	**D-Mean**
S= Nyaung-Oo							
0-10	2.1071 b	3.2961 a	6.3061 a	1.6676 b	1.7589 b	0.9496 b	2.6809
20-30	3.4009 b	4.2629 a	7.5647 a	3.4481 a	3.7531 a	2.7667 a	4.1694
40-50	4.4131 a	4.3579 a	7.4313 a	4.1213 a	3.8773 a	3.4433 a	4.6074
60-70	3.9571 a	3.5682 a	7.0585 a	3.8314 a	3.6459 a	3.1980 a	4.2099
80-90	3.9440 a	3.6712 a	6.9300 a	3.7610 a	3.6144 a	3.1111 a	4.1720
M-Mean	**3.5644**	**3.83113**	**7.0781**	**3.3659**	**3.2939**	**2.6937**	**3.9679**

In a column under each S, means followed by a common letter are not significantly different at the 5% level by DMRT.

In June, December, February and April, 0-10 cm layer was found to have the lowest moisture content. The layers from 20-30 cm to 80-90 cm layers were not significantly different at 5% level by DMRT.

In August and October, 40-50 cm layer showed the highest moisture content but the moisture content has no statistically significant difference among other soil layers.

The average moisture content of each layer was tested for significant difference to investigate the significant variance at the months of June, August, October, December, February and April and the results were given in Table 9.

Table 9. Mean comparison of moisture content for different levels of soil in Nyaung-Oo

	Depth(D)					
Month (M)	**0-10**	**20-30**	**40-50**	**60-70**	**80-90**	**M-Mean**
Jun	2.1071 c	3.4009 bc	4.4131 b	3.9571 b	3.9440 b	3.5644
Aug	3.2961 b	4.2629 b	4.3579b	3.5682 b	3.6712 b	3.8312
Oct	6.3061 a	7.5647 a	7.4313 a	7.0585 a	6.9300 a	7.0581
Dec	1.6676 c	3.4481 bc	4.1213 b	3.8314 b	3.7610 b	3.3659
Feb	1.7589 c	3.5731 bc	3.8773 b	3.6459 b	3.6144 b	3.2939
April	0.9496 d	2.7667 c	3.4433 b	3.1980 b	3.1111 b	2.6938
D-Mean	**3.2171**	**5.0033**	**5.5288**	**5.0518**	**5.0063**	**4.7615**

In a column under each S, means followed by a common letter are not significantly different at 5% level by DMRT.

In 0-10 cm layer, October was significantly different from April, which has the lowest moisture content.

In 20-30 cm layer, the highest moisture content 7.56% was found in October where April was significantly the lowest.

In 40-50 cm, 60-70 cm and 80-90 cm layers, October has the highest moisture content. However, there was no significant difference among other months.

5.1.4 Comparison of Monthly Soil Moisture Variations in Pyinmana, Meiktila and Nyaung-Oo Sites

The analysis of variance for all study areas was shown in Appendix 5.

The mean comparison of monthly soil moisture conditions for all three sites is shown in Table 10.

In June and August, Pyinmana showed the highest moisture in all soil layers and followed by Meiktila and Nyaung Oo.

In October, Nyaung Oo has the lowest moisture content in all soil layers than Pyinmana and Meiktila. The moisture content in Pyinmana and Meiktila have no statistically significant difference in 0-10 cm, 20-30 cm and 40-50 layers.

In December, Pyinmana and Meiktila showed the highest moisture content in soil layers, except 80-90 cm layer.

0-10 cm, 60-70 cm and 80-90 cm layers in Pyinmana and Meiktila have no statistically significant difference in February. However, these sites were higher than Nyaung- Oo.

In April, 0-10 cm, 60-70 cm and 80-90 cm layers in Pyinmana were significantly different from Nyaung Oo. Pyinmana has the highest moisture content and Nyaung- Oo, the lowest.

20-30 cm and 40-50 cm layers in Pyinmana and Meiktila showed the higher moisture content than Nyaung-Oo in April. But there was no significant difference in this month.

Table 10.Mean comparison of moisture content for different sites

SITE(S)	Jun	Aug	Oct	Dec	Feb	April	Month(M) S-MEAN
D=0-10							
Pyinmana	12.9883 a	17.2235 a	8.8206 a	4.8971 a	3.1973 a	6.5073 a	8.9390
Meiktila	4.2557 b	7.2207 b	9.9663 a	4.4500 a	2.9112 a	2.1255 b	5.1549
NyaungOo	2.1071 c	0.2961 c	6.3061 b	1.6676 b	1.75889 b	0.9496 c	2.6809
D=20-30							
Pyinmana	12.8387 a	15.7888 a	11.3223 a	5.6173 a	4.2358 ab	4.5863 a	9.0649
Meiktila	5.8544 b	6.5073 b	12.4729 a	6.4751 a	4.9943 a	4.1976 a	6.7503
NyaungOo	3.4009 c	4.2629 c	7.5647 b	3.4481 b	3.5731 b	2.7667 b	4.1694
D=40-50							
Pyinmana	13.9888 a	16.4962 a	13.1075 a	6.4298 a	5.1628 ab	5.3233 a	10.0847
Meiktila	5.3869 b	5.6408 b	11.9146 a	7.3463 a	5.7727 a	5.0100 a	6.8452
NyaungOo	4.4131 b	4.3579 b	7.4313 b	4.1213 b	3.8773 b	3.4333 b	4.6074
D=60-70							
Pyinmana	15.4635 a	17.1939 a	15.3703 a	8.4140 a	6.0167 a	6.5154 a	11.4956
Meiktila	6.3957 b	6.0053 b	11.73343 b	7.8858 a	6.4331 a	4.6888 b	7.1905
NyaungOo	3.9751 c	3.5682 c	7.0585 a	3.8314 b	3.6459 b	3.1980 c	4.2099
D=80-90							
Pyinmana	15.7057 a	17.4520 a	16.3247 a	9.9775 a	6.6215 a	7.0273 a	12.1848
Meiktila	6.7552 b	6.6891 b	10.1547 b	8.3283 b	6.8429 a	4.7235 b	7.2489
NyaungOo	3.9440 b	3.6712 b	6.9300 c	3.7610 c	3.6144 b	3.1111 c	4.1720
M-Mean	**7.8303**	**9.022249**	**10.4319**	**5.7767**	**4.5772**	**4.2783**	**6.9866**

In a column under each D, means followed by a common letter are not significantly different at the 5% level by DMRT.

5. 2 Discussions

The physical properties of the soil and the rainfall of the locality largely influence the moisture holding capacity or the moisture content of a soil.

5.2.1 Rainfall- Soil Moisture Relationship

The relationship between rainfall and soil moisture content in Pyinmana, Meiktila and Nyaung-Oo is shown in Figure 8.

Seasonal soil moisture contents in all areas were positively correlated with rainfall. (R^2 =.75 for Pyinmana, R^2 =.71 for Meiktila and R^2 =.86 for Nyaung-Oo)

In Pyinmana, the highest moisture content was observed in August although the rainfall was less in this month. It may be due to continuous shower without long break before sample collection (35 rainy days with 695 mm rainfall through May to July. See Appendix 1) and better moisture holding capacity of soil than other two sites.

In Meiktila and Nyaung-Oo, when the rainfall was high, the amount of moisture content was also high.

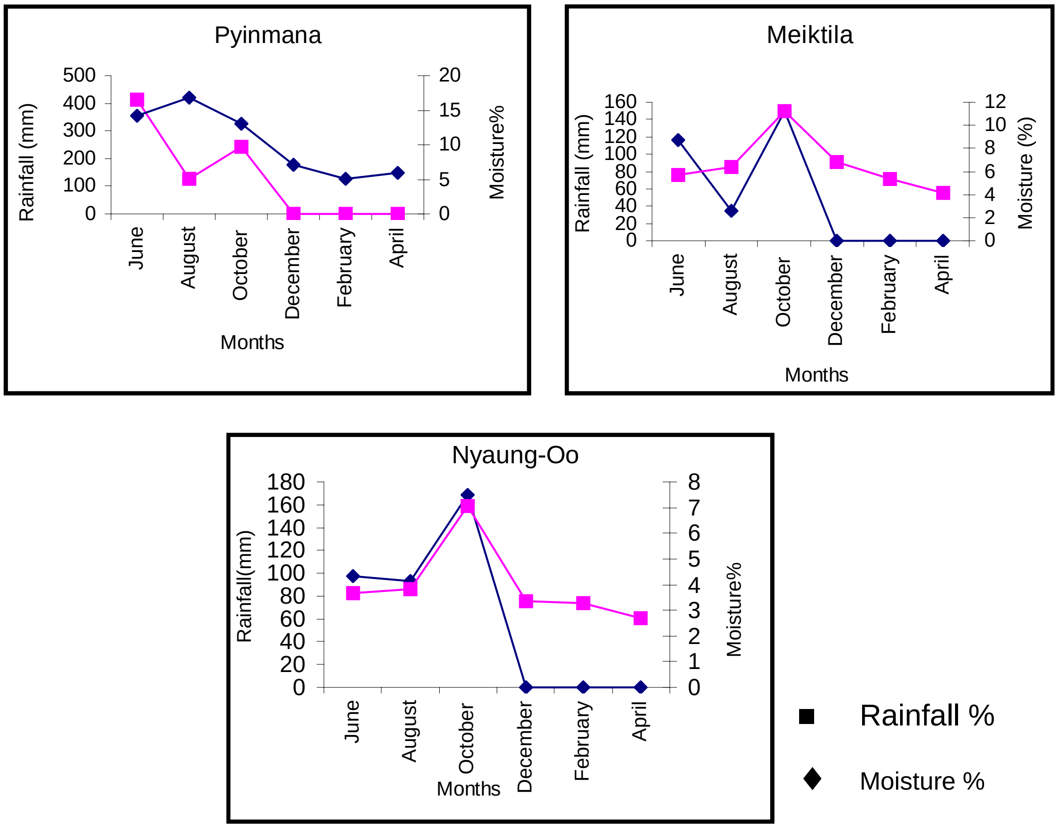

Fig 8. Rainfall-soil moisture relationship in study areas of Pyinmana, Meiktila and Nyaung-Oo

5.2.2 Seasonal soil moisture Variations in the Study Sites

Seasonal soil moisture variations in different soil depths in Pyinmana, Meiktila and Nyaung-Oo were found out as follows from soil sample tests at different soil depths in the month of June, August, October, December, February and April.

5.2.2.1 Seasonal Soil moisture variations in Pyinmana

Seasonal soil moisture variations in different soil depths in Pyinmana were shown in Figure 9.

Seasonal soil moisture conditions in Pyinmana were found to decrease from the upper layers and then slightly increase towards the lower layers.

The least moisture content was found in the upper layer during the study period. The amount of moisture tends to decrease as the soil depth move upward as the water content of surface layer was depleted by evaporation and absorption of plant cover.

Mostly 80-90cm layer was highly significant in moisture content among different layers in each observed month, respectively. It seems that soil layer with greater silt and clay percentage encourages more water adsorption at that particular layer than at any other soil layers. Moisture content in every layer in April was more than found in February. It may be due to the light shower in April.

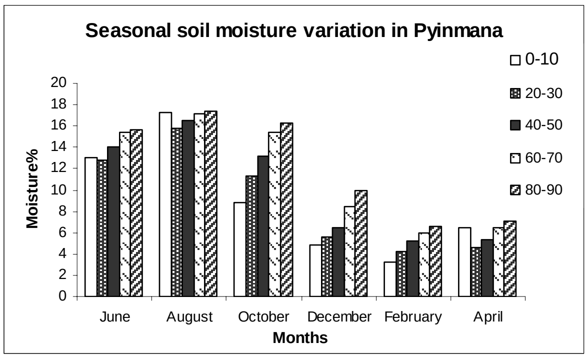

Fig 9. Seasonal soil moisture variations in Pyinmana

5.2.2.2 Seasonal soil moisture variations in Meiktilia

Seasonal soil moisture variations in different soil depths in Meiktila were shown in Figure 10.

20-30 cm layer in Meiktila has the highest moisture content than the lower layers in the highest rainfall month in October. Perhaps this is due to the temporary saturation which occurred as a result of too frequent or too heavy rainfall combined with poor internal drainage.

Moisture distribution in all soil layers were found to fluctuate in the rainy season. But at the end of dry season in April, 40-50 cm layer was found to become slightly increased in its moisture content than the other soil layers. Perhaps this is due to the accumulation of finer particles forming the clay plate in this layer.

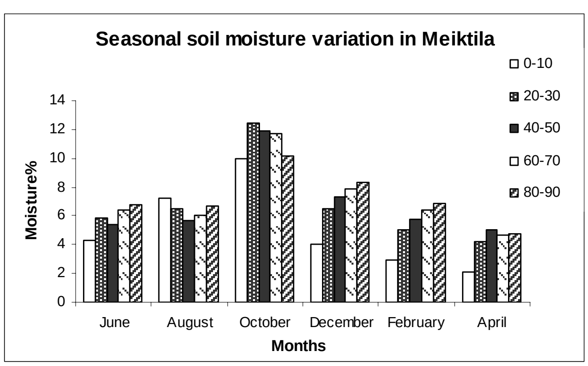

Fig 10. Seasonal soil moisture variations in Meiktila

5.2.2.3 Seasonal soil moisture variations in Nyaung Oo

Seasonal soil moisture variations at different soil depths in Nyaung Oo were shown in Figure 11.

0-10cm layer showed the minimum moisture content in all months. The amount of moisture moved upward as the water content of surface layer was depleted by evaporation and absorption of plant cover.

20-30cm to 80-90cm layers were no statistically significant difference through the study period.

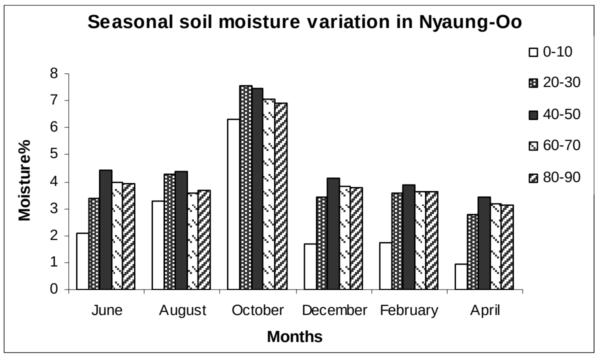

Fig 11. Seasonal soil moisture variations in Nyaung –Oo

5.2.2.4 Comparison of monthly soil moisture conditions in sites

The percent of moisture from all areas differ significantly for all sites (See Figure 12). Since the chosen sites were based on the climatological and latitudinal different basis, therefore there would be differences in frequency and duration of rainfall and potential evaportranspiration rate.

In the dry season, results indicated that the moisture content in the upper layers was not significantly different in Pyinmana and Meiktila because of the sandy soil as well as the higher potentialevaporation rate.Nyaung-Oo had the lowest moisture content than the other two sites. It may be due to coarse sandy soil which has low water holding capacity.

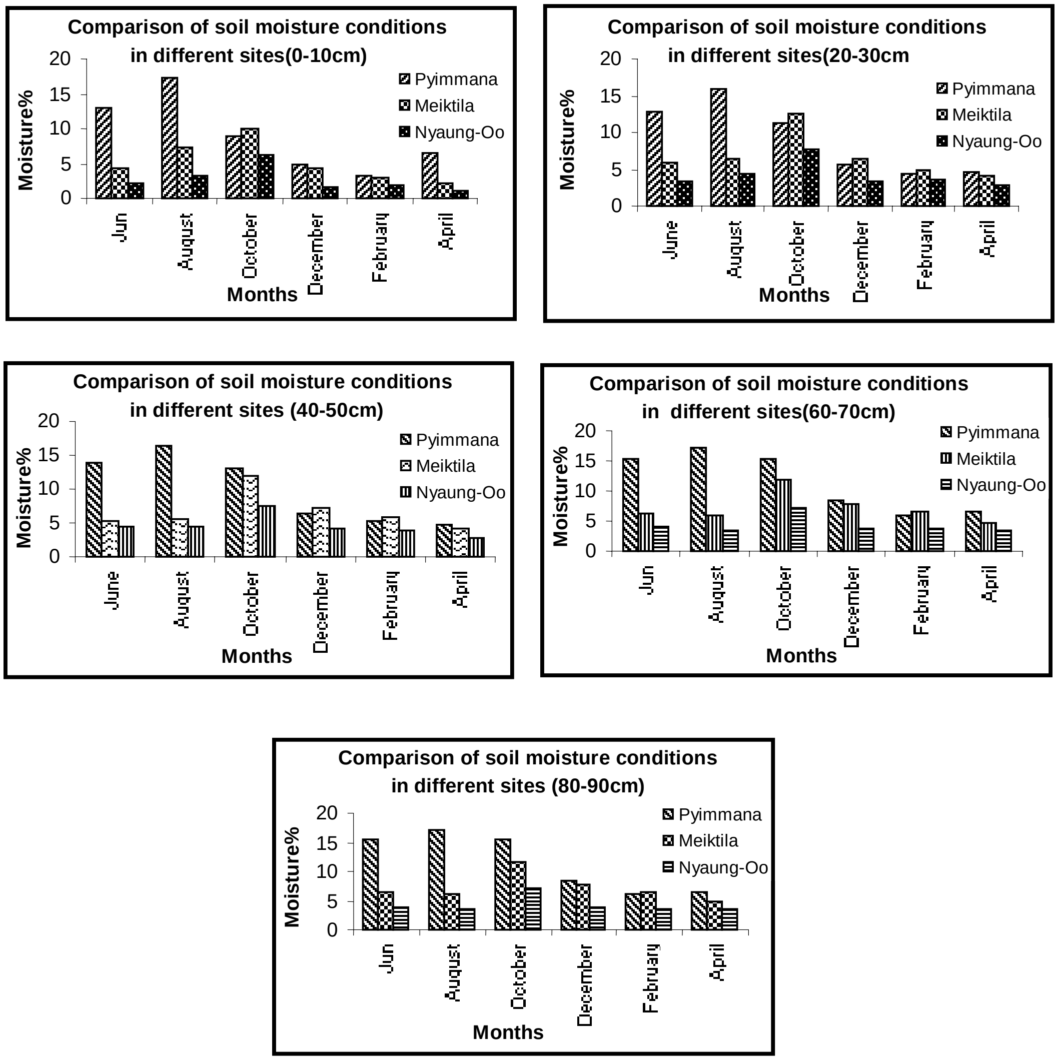

Fig 12. Comparison of monthly soil moisture conditions in different sites

5.2.3 Effect of Available Water at Rooting Zone and the Survival Rate

5.2.3.1 Pyinmana site

Rooting zone and the survival rate of Pyinmana site are found as follows:-

5.2.3.1.1 Rooting zone

Champion & Seth (1968) stated that the root of natural seedling was mostly confined to the first 30-40cm of the soil at the end of the first growing season. In Teak, healthy seedling produced a stout tap root which might attain a length 30cm or more during the first season and 54-81cm or more by the end of the second season (Troup,1921).

During the rainy season in Pyinmana, the upper and the lower layers were held in saturation with at field capacity. So Pyinmana still has sufficient soil moisture for the growth of the plant at the time of planting. When the rainfall had ceased, they dried out rapidly and reached a deficit moisture condition to a greater depth (60-70cm) during the dry season (Feb-April). But the moisture content in 80-90cm layer was in the available state. The seedlings can utilize this moisture but it is very demanding for the seedlings to reach this layer.

5.2.3.1.2 Survival rate

Planting has been carried out since August, 1998. There was 872-mm annual rainfall. The survival result of the first year showed good survival (89%) and the average height was 1.56' in 8 month after planting. Site selection for Teak plantations is found to be suitable in terms of soil type. More than 85% of 124 plantations were established on sandy loam soil. If survival percent of first year planted seedling are reviewed in 27 young plantations, all exceeded 80%. This means that Teak plants are well matched with their sites (Kyaw Htun & Chit Hlaing, 2001). For this present study, the rainfall and the moisture condition in different layers were found to be good enough for the survival of the plantation.

5.2.3.2 Meiktila site

Rooting zone and the survival rate of Meiktila site are found as follows:-

5.2.3.2.1 Rooting zone

In Meiktila, moisture content in each layer was found to be below the available range except in October.

Plant with expanded root system continued to grow with water available from the extended region of the root zone, while plants with restricted root system experience water stress in the same field under the same condition of the limited water supply (Majumdar, 2002). In this condition, present moisture status was not sufficient enough for the development of root at the time of planting.

5.2.3.2.2 Survival rate

In Meiktila, some of Thit-seint (Terminalia belerica) seedling included in the experiment died during the dry season, although fertilizer was applied at 1-1/2 month after planting.

Moreover, the species was badly attacked by shoot borer causing the shoot and top branches to break down. This result is in height increment to be rather erratic. This area has lower rainfall and less rainy day than Pyinmana and also has high temperature during the rainy season.

This species was found in the deciduous forests throughout the greater part of India and Myanmar but not in arid temperature region. In its natural habitat, the absolute maximum shade temperature varied from 97º to 115ºF (Troup, 1921). Thus the result of survival % in this area may be very low (<50%) due to the above stated factors. The influence of soil characteristic of the location tested towards the performance of the species was not observed. So Thit-seint (*Terminalia belerica*) was found to be not suitable to plant on such soil type and climatic condition.

5.2.3.3 Nyaung-Oo site

Rooting zone and the survival rate of Nyaung-Oo site are found as follows:-

5.2.3.3.1 Rooting zone

Costin et.al (1974), (quoted in FAO,1985) suggested that in regions with the mean annual rainfall of around 100mm, the limiting point of the moisture content to establish plantation of drought resistant tree was about 2 to 3%, if it was distributed at least up to 1.2-1.5 m in depth. This will provide about 136to 168mm of moisture which should adequately meet the requirements of young plants with relatively low transpiration surface.

In Nyaung-Oo, the moisture content in different soil layers was between 2 and 4% except in October, where the soil condition was sandy soil which contains more gravel %. The rainfall was greater than 100mm. The soil moisture was found to be near wilting percentage, so that shortage of moisture may result in restricted availability to plant and decline in growth and yield.

5.2.3.3.2 Survival rate

The species planted in Nyaung-Oo was Tama (*Azadrichata indica*). It was found that the first year survival was 42.86% and the average height was 1.6' for the 1999 plantation.

For the present study, first year survival was 80% and the average height was 4 feet. Survival percent of the species and height growth could be further increased if regular soil working, weeding and watering is done during the dry periods. So the species seemed to do reasonably well with soil working and watering.

6. Conclusions and Recommendations

6.1 Conclusions

Physical characteristic of soil, seasonal soil moisture variations, effect of available water at rooting zone and survival rate of three different study areas are described in the previous chapters. It can be concluded that

(1) Soil moisture in different soil layers vary from one season to another and is positively correlated to rainfall in all study areas.

(2) The quantity of soil moisture is probably related to the quantity and distribution rainfall, soil bulk density, total porosity, aeration porosity and potential evapotranspiration rate.

(3) During the raining season in Pyinmana, soil moisture content in all soil layers are held in the field capacity and was sufficient for the growth of plant at the time of planting. Although soil moisture status reached the lower condition between 0-45 cm in dry season of first year, plant root can pass through soil layers at that region so that good survival rate can be obtained. Consequently, plantation can therefore be established successfully in Pyinmana.

(4) In Meiktila and Nyaung-Oo the moisture content in different soil layers were near wilting percentage except in October. Present moisture status of these areas was not getting enough moisture for the survival of the plant. To collect more runoff water in planting pits, new water correction techniques should be applied before the time of planting. The addition of organic matter like mulch to cover the soil will be greatly required at the time of planting so as to increase the water retention in soils by holding up more moisture in crop root zone and allowing less passes through the sub-soil layers. It also greatly reduces the rate of water evaporation into the atmosphere. After the seedlings are planted out, soil working is necessary for quick rooting. Before the end of the rains, a second soil working is again repeated for retention of run-off water collected through the rainy months.

(5) As there is much difference in the available water in these study sites, the growth and the survival rate of the same species can vary.

6.2 Recommendations

(1) Moisture content and water requirement of various species should be found out and the choice of species should be made on the basis of their water requirement and on the availability of water from the soil.

(2) Where the availability of soil moisture does not cover the water requirements of the species, the possibility of increasing the water holding capacity of soil by simple measure such as soil working, irrigation practice and the application of organic manure etc. to alter the texture of soil should be considered. Soil moisture studies can indicate the intensity and extent of these operations.

(3) In areas, where soil moisture reached below the wilting percentage and none of the above measure are likely to improve the soil moisture status of the soil, drought resistance species which possess the capacity to use less water due to certain morphological character like thick cuticle, small evaporating surfaces and the stomata regulation of transpiration should be used.

(4) Watering with different moisture level and fertilization are necessary to get the interaction between moisture and the fertilizer on the growth of plantation in dry zone areas.

Appendix 1

Climatic data of study areas

Month	Rainfall (mm)						Relative Humidity (%)			Maximum Temperature			Minimum Temperature		
	P		M		N										
	Rainy days	Intensity	Rainy days	intensity	Rain y days	Intensity	P	M	N	P	M	N	P	M	N
May	19	181.00	9	120.14	8	156.72	77.32	74.00	51.70	35.20	35.40	38.61	24.70	24.80	28.74
June	6	414.27	4	116.33	7	97.79	81.19	79.00	65.45	28.04	32.10	34.00	22.83	24.40	27.00
July	10	99.31	5	47.75	2	42.93	80.41	63.00	64.51	31.37	34.30	36.29	22.62	25.00	28.70
Aug.	6	127.00	9	34.04	6	92.96	82.09	66.00	70.12	29.97	33.60	35.61	22.56	24.60	27.93
Sep.	8	72.90	9	144.78	8	130.05	81.58	76.00	76.60	31.71	33.60	35.60	21.79	24.60	27.43
Oct.	8	242.57	9	150.11	8	168.66	79.10	78.00	62.32	29.16	33.10	34.93	22.40	24.10	25.93
Nov.		-	2	3.81		-	75.78	74.00	75.56	31.22	32.60	33.30	19.42	18.10	19.20
Dec.		-		-		-	74.75	75.00	78.51	32.01	30.55	30.61	17.49	17.20	15.83
Jan.		-		-		-	74.14.	68.00	71.85	31.56	30.95	29.96	13.04	14.40	13.48
Feb.		-		-		-	72.74	55.00	72.30	33.62	33.50	34.34	12.21	16.00	16.17
March		-		-		-	68.82	54.00	33.40	37.81	38.10	39.51	18.20	22.54	24.22
April		0.88		2.03		-	71.1	56.00	33.00	38.10	38.10	41.40	24.30	24.30	28.53

P= Pyinmana   N= Nyaung-Oo   M= Meiktila

Physical and Chemical Properties of soil in Kaing Reserved Forest, Compartment No.10, Pyinmana Township

Particular	Depth	B.D	Porosity %	P^H	Total N %	Ava P %	Ext. K%	O.M%	Texture Sand %	Texture Silt %	Texture Clay %	Remarks
Block I	0-10	1.410	30.07	5.03	0.0650	0.000151	0.00608	1.96	81	11	5	Loamy- sand
	20-30			4.82	0.0345	0.000082	0.00936	1.07	77	12	10	Sandy-loam
	40-50			4.90	0.0278	0.000067	0.01179	0.91	75	8	13	Sandy- loam
	60-70			4.97	0.0358	0.000057	0.00620	1.19	70	10	20	Sandy Clay Loam
	80-90			5.14	0.0305	0.000080	0.01770	1.20	63	14	19	Sandy Loam
Block II	0-10	1.374	34.54	5.19	0.0551	0.000181	0.00760	1.87	83	9	3	Sand
	20-30			4.95	0.0269	0.000072	0.00639	0.94	77	14	6	Loamy-Sand
	40-50			5.01	0.022	0.000104	0.02118	0.83	76	12	8	Loamy-Sand
	60-70			5.10	0.0291	0.000059	0.00802	0.88	62	15	17	Sandy-Loam
	80-90			5.17	0.0202	0.000056	0.02001	0.73	64	17	17	Sandy-Loam
Block III	0-10	1.200	41.20	5.98	0.0515	0.000063	0.00778	1.68	86	7	3	Sand
	20-30			5.38	0.0354	0.000322	0.01890	0.18	85	8	6	Loamy-Sand
	40-50			5.27	0.0228	0.000092	0.00728	1.09	75	19	8	Sandy-Loam
	60-70			5.14	0.0309	0.000067	0.01120	1.08	74	8	15	Sandy-Loam
	80-90			4.96	0.0309	0.000028	0.00716	1.05	74	10	16	Sandy-Loam
Profile	A_1			5.19	0.0663	0.000172	0.00474	1.81	83	9	6	Loamy-Sand
	B_1			4.95	0.0327	0.000067	0.01598	0.63	84	9	4	Sand
	B_2			5.03	0.0332	0.000043	0.00580	0.87	73	10	14	Sandy-Loam

Appendix 2-a

Appendix 2-b

Physical and Chemical Properties of soil in Palangyin Reserved Forest, Compartment No.5, Meiktila Township

Particular	Depth	B.D	Porosity %	P^H	Total N %	Ava P %	Ext.K%	O.M %	Texture			Remarks
									Sand %	Silt %	Clay %	
Block I	0-10	1.41	28.96	8.33	0.081	0.000702	0.02046	1.67	82	10	8	Loamy-Sand
	20-30			8.40	0.0493	0.000356	0.00560	1.26	78	11	7	Loamy-Sand
	40-50			8.66	0.0336	nil	0.01572	0.70	91	4	5	Sand
	60-70			8.86	0.0381	nil	0.02250	1.11	80	7	11	Loamy-Sand
	80-90			8.86	0.0381	nil	0.02344	0.92	86	7	4	Sand
Block II	0-10	1.68	22.28	8.83	0.0564	0.000625	0.01598	1.71	78	8	13	Loamy-Sand
	20-30			8.56	0.030	0.000026	0.02594	1.41	82	9	8	Loamy-Sand
	40-50			8.81	0.0278	0.000029	0.01122	0.86	77	10	9	Loamy-Sand
	60-70			9.01	0.0408	0.000030	0.01020	0.68	88	5	6	Sand
	80-90			9.09	0.0318	0.000006	0.00648	0.83	77	12	8	Loamy-Sand
Block III	0-10	1.54	26.20	8.93	0.0668	0.000005	0.00962	2.09	83	8	8	Loamy-Sand
	20-30			8.55	0.0586	0.000018	0.00572	1.79	75	14	8	Loamy-Sand
	40-50			8.61	0.0385	0.000020	0.01330	1.53	87	6	8	Loamy-Sand
	60-70			8.86	0.052	0.000020	0.00758	1.92	81	8	13	Sandy- Loam
	80-90			8.76	0.0587	0.000032	0.02210	2.43	65	14	20	Sandy- Clay -Loam
Profile	B			8.97	0.0623	0.000028	0.00868	2.17	83	9	10	Sandy- Loam
	B_1			8.83	0.0148	0.000035	0.01638	0.97	94	3	7	Sand
	B_2			8.65	.0435	.000032	_	2.07	67	19	14	Sandy Loam
	B_3			8.94	.03	.000055	_	1.27	82	7	14	Sandy Loam

Appendix 2-c

Physical and Chemical Properties of soil in Kyauk-ku Protected Public Forest, Kyauk-ku Plantation, Nyaung- Oo Township

Particular	Depth	B.D	Porosity %	P^H	Total N %	Ava P %	Ext. K%	O.M%	Texture			Remarks
									Sand %	Silt %	Clay %	
Block I	0-10	1.57	18	6.99	0.0412	0.001720	0.00674	1.49	81	5	9	Loamy-Sand
	20-30			6.93	0.0412	0.001620	0.01406	1.40	81	4	17	Sandy- Loam
	40-50			6.55	0.0578	0.001750	0.00632	1.13	80	8	14	Sandy- Loam
	60-70			7.94	0.0314	0.002696	0.00940	1.17	85	8	9	Loamy- Sand
	80-90			8.57	0.0296	0.002540	0.02086	1.08	82	6	11	Loamy- Sand
Block II	0-10	1.57	18	6.02	0.0426	0.000178	0.00998	1.15	83	7	8	Loamy- Sand
	20-30			6.28	0.0233	0.000058	0.00736	1.23	80	4	15	Sandy- Loam
	40-50			6.30	0.0305	0.000042	0.01186	1.20	80	7	13	Sandy- Loam
	60-70			6.44	0.0296	0.000029	0.00804	0.93	82	6	10	Loamy- Sand
	80-90			6.51	0.0318	0.000032	0.01256	0.87	82	6	11	Loamy- Sand
Block III	0-10	1.4	31.1	6.86	0.0435	0.000336	0.00742	1.28	92	6	5	Sand
	20-30			6.82	0.0363	0.000122	0.00988	1.15	80	7	9	Loamy- Sand
	40-50			7.26	0.0296	0.000136	0.00678	0.76	80	8	12	Loamy- Sand
	60-70			8.51	0.0336	nil	0.01778	0.89	84	6	9	Loamy- Sand
	80-90			8.36	0.0222	nil	0.00852	0.59	88	6	7	Loamy- Sand
Profile	B			6.65	0.0420	0.002510	0.01660	0.66	84	4	9	Loamy -Sand
	B_1			6.86	0.0372	0.000222	0.00970	0.71	82	3	13	Loamy- Sand
	B_2			7.51	0.0323	0.000464	0.01690	0.58	85	3	10	Loamy- Sand
	B_3			8.51	0.0224	0.000012	0.01472	0.72	80	6	12	Loamy- Sand

Appendix 3-a

Soil profile description for Pyinmana site

Soil Type	-	Yellow brown Forest Soil
Date of examination	-	15 -June -2003
Location	-	Kaing Reserved Forest, Compartment N0.10. About 2 miles from Pyinmana - Moswe road (16 miles from Pyinmana)
Land form	-	Flat
Slope	-	Flat
Aspect	-	East
Elevation	-	300 a.s.l
Drainage	-	Well drained
Forest Type	-	Dry Upper Mixed Deciduous
Parent material	-	Apparently derived "insitu" from sand stone
Land use	-	Reserved Forest, Denuded area
Profile	-	
A_1 (0-20 cm)	-	Brownish black (7.5 YR 2/2) moist and dark olive brown (2.5 Y 3/3) dry, loamy sand, fine granular structure, firm when moist and, hard when dry, sticky, some roots and sharp boundary to
B_1 (20-60 cm)	-	Dark brown(7.5 YR 3/4) moist and brightly yellowish brown (2.5 YR 6/6) dry, sand, fine granular structure hard when dry, firm when moist, sticky, diffuse boundary to
B_2 (60-100cm)	-	Bright brown(7.5 YR 3/4) moist and dull orange (2.5 YR 6/4) dry, sandy loam, fine granular structure, hard when dry, firm when moist, sticky, diffuse boundary to

Appendix 3-b

Soil profile description for Meiktila site

Soil Type	-	Yellow Brown Dry Forest Soil.
Date of examination	-	25 - June - 2003
Location	-	Palangyin Reserved Forest, Compartment No.5. About 1 mile from Meiktila- Kyaukpadaung road (8 miles from Meiktila).
Land form	-	Flat
Slope	-	2 – 3 %
Aspect	-	Northwest
Elevation	-	214 m a.s.l
Drainage	-	Well drained
Forest Type	-	Dry Diospyros Forest
Parent material	-	Apparently derived "insitu" from sand stone
Land use	-	Reserved Forest, Denuded area
Profile		
B (0-28 cm)	-	Olive brown (2.5 Y 4/4) moist and yellowish brown (2.5 Y 5/4) dry, sandy loam, weakly developed medium granular structure, firm when moist, hard when dry some grass roots and diffuse boundary to.
B_1 (28-32 cm)	-	Yellowish brown (2.5 Y 5/4) moist and bright yellowish brown (2.5 Y 6/6) dry, sand, weakly developed medium granular structure, firm when moist, hard when dry some grass roots and diffuse boundary to
B_2 (32-60 cm)	-	Yellowish brown (2.5 Y 5/4) moist and olive brown (2.5 Y 4/4) dry, sandy loam, some roots mostly fibrous, few mottling, trace of hard pan between 42-60cm within the horizon
B_3 (60 –90 cm)	-	Yellowish brown (2.5 Y 5/4) moist and olive brown (2.5 Y 4/4) dry, sandy loam, weakly developed medium granular structure.

Appendix 3-c

Soil profile description for Nyaung -Oo site

Soil Type	-	Reddish Brown Dry Forest Soil
Date of examination	-	30 - June - 2003
Location	-	Kyauk - ku Protected Public Forest, Kyauk - Ku Plantation. About 1 mile from Nyaung Oo - Myingyan Road (3½ miles from Nyaung Oo)
Land form	-	Flat
Slope	-	2-4%
Aspect	-	East
Elevation	-	353 m a. s. l
Drainage	-	Well drained
Forest Type	-	Southern Cutch Thorn Forest
Parent material	-	Apparently derived “insitu” from sand stone
Land use	-	Protected Public Forest, Denuded area
Profile		
B (0-20 cm)	-	Brown (7.5 YR 4/6) moist and brown (7.5 YR 4/6) dry, loamy sand, weakly developed medium granular structure, loose when moist or dry, very gravelly.
B_1 (20-40 cm)	-	Dull reddish brown (5 YR 4/4) moist and brown (7.5 YR 4/6) dry, loamy sand, weakly developed medium granular structure, loose when moist or dry, very gravelly.
B_2 (40-80 cm)	-	Brown (7.5 YR 4/4) moist and brown (7.5 YR 4/4) dry, loamy sand, weakly developed medium granular structure, loose when moist or dry, very gravelly
B_3 (80-90 cm)	-	Olive brown (2.5 Y 4/4) moist and brown (10 YR 4/6) dry, loamy sand, weakly developed medium granular structure, loose when moist or dry, very gravelly.

Analysis of variance for moisture at Pyinmana site

SV	DF	SS	MS	F
REPLICATION	14	1583	113	9.96 **
TREATMENT	29	10254	354	93.66 **
MONTH(M)	5	9127	1825	483.54 **
DEPTH(D)	4	755	189	49.97 **
MxD	20	372	19	4.93 **
ERROR	406	1533	4	
TOTAL	449	13370		

cv =18.88 % ** = significant at 1% level

Analysis of variance for moisture at Meiktila site

SV	DF	SS	MS	F
REPLICATION	14	617.05	44.08	98.22**
TREATMENT	29	2797.22	96.46	17.98**
MONTH(M)	5	2243.52	448.70	83.64**
DEPTH(D)	4	282.19	70.55	13.15**
MxD	20	271.51	13.58	2.53**
ERROR	406	2178.20	5.37	
TOTAL	449	5592.47		

cv=35% ** =significant at 1% level

Analysis of variance for moisture at Nyaung-Oo site

SV	DF	SS	MS	F
REPLICATION	14	152.5286	10.8949	15.87**
TREATMENT	29	1143.0820	39.4167	57.43 **
MONTH(M)	5	906.3641	181.2728	264.12**
DEPTH(D)	4	196.5608	49.1402	71.60**
MxD	20	40.1583	2.0079	2.93**
ERROR	406	278.6470	0.6863	
TOTAL	449	1574.2588		

cv=20.9% ** =significant at 1% level

Appendix 5

Analysis of variance of moisture at all sites

SV	DF	SS	MS	F
REPLICATION	14	1199.2055	85.6575	17.93**
TREATMENT	89	26757.2314	300.6343	62.93**
DEPTH(D)	4	1398.1568	349.5319	73.17**
MONTH(M)	5	8616.0084	1723.2017	360.72**
SITE (S)	2	10769.8356	5384.9178	1127.23**
DXM	20	448.4659	22.4233	4.69**
DXS	8	361.4267	45.1783	9.46**
MXS	10	4655.1270	465.5127	97.45**
DXMXS	40	508.2136	12.7053	2.66**
ERROR	1246	5952.2733		
TOTAL	1349	33908.7104		

** =significant at 1% level

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