THE BEARING CAPACITY OF THE SOILS OF AHERO IRRIGATED RICE FIELDS UNDER THE EXPOSURE TO LAND PREPARATION TRAFFIC

BY

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DECLARATION

I hereby, declare that this thesis is my original work and it has not been presented for a degree in any other university.

.... 2/4/93....
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This thesis has been submitted for examination with our approval as the university supervisors.

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.... 20/4/93
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DEDICATION

Dedicated to:

my parents Josphat M'Marete and Esther M'Marete

with gratitude

and to

my wife, Dr. Mary N. M'Marete and

daughter Rebecca K. M'Marete

for their understanding,

encouragement, patience

and love, during the

preparation of

this work.

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LIST OF ABBREVIATIONS

AIRS	-	Ahero Irrigation Research Station
APS	-	Ahero Pilot Scheme
ANOVA	-	Analysis of Variance
BD	-	Bulk density
BIS	-	Bunyala Irrigation Scheme
CI	-	Cone index
MRT	-	Multiple Range Test
DOP	-	Drying Out Process
GOK	-	Government of Kenya
JICA	-	Japanese International Cooperation Agency
LPL	-	Lower Plastic Limit
LR	-	Long rains
MC	-	Moisture Content
MISS	-	Mwea Irrigation Settlement Scheme
MOA	-	Ministry of Agriculture
NIB	-	National Irrigation Board
PR	-	Penetration resistance
RMC	-	Residual Moisture Content
SBC	-	Soil bearing capacity
SP	-	Soil Porosity
SMC	-	Soil moisture content
SR	-	Short rains
TARC	-	Tropical Agricultural Research Centre
TARDA	-	Tana and Athi River Development Authority
T&M	-	Thornthwaite and Mather model
WKPS	-	West Kano Pilot Scheme

LIST OF SYMBOLS

ac	-	acre (= 4047 m^2)
cm	-	centimeter
C_n	-	Wheel numeric
ha	-	hectares = (10,000 m^2)
hr(s)	-	hour(s)
m	-	metre
mm	-	millimeter
N	-	Newton
Pa	-	Pascal
kPa	-	kilo Pascal
MPa	-	Mega Pascal
lb	-	pound
in	-	inch
g	-	gram
kg	-	kilogram
ln	-	natural logarithm
No.	-	number
max	-	maximum
min	-	minimum
Eq.	-	equation
pF	-	logarithm of the suction pressure in cm
i.e.	-	that is
e.g	-	for example
etc	-	et cetera

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ABSTRACT

Investigations for the causes of immobility of tractors during land preparation and the possibility of re-introducing the Double Cropping System (DCS) of rice production at the Ahero Pilot Scheme (APS) were carried out between December 1990 and May 1991. The area of study is used for irrigation of rice and is mainly covered by heavy clay soils with a clay content of more than 60%.

The parameters that were monitored during the study were meteorological factors, soil moisture content (SMC) and penetration resistance (PR) - as an indicator of the soil bearing capacity measured. Meteorological parameters were monitored on daily basis while SMC and PR were monitored on average once or twice a week. The study was conducted in three blocks of the scheme that had shown persistent mobility problems over a long period. In each block, the experiment was replicated four times. Sampling was carried out at the drain, middle and feeder sides of each plot (replicate) and under ashes or straw heaps. Sampling was also carried out in the field nurseries. At each location the sampling depths were 0-5, 15, 30, 45 and 60 cm. Simulation equations for predicting SMC and PR were developed with the help of the data collected and the soil drying model of Thornthwaite and Mather.

Through the simulation equations, it was found that with the given climatic conditions and the rice varieties grown at APS, DCS of rice production is impossible as the soils do not attain adequate strength by the time of land preparation. The major causes of mobility problems were attributed to be the management of land preparation and of straw after harvesting rice and lack of a hardpan. The effect of ashes or straw cover reduced PR by about 3.6 times as compared with the no-cover situation.

1. INTRODUCTION

Most of Kenya's rice is grown in four national irrigation schemes managed by the National Irrigation Board (NIB). Now there are upcoming upland and small-scale irrigation schemes especially in the Coast, Western and Nyanza Provinces. The large-scale irrigation schemes include:

- Mwea Irrigation Settlement Scheme (MISS);
- Ahero Pilot (Irrigation) Scheme (APS);
- West Kano Pilot (Irrigation) Scheme (WKPS) and
- Bunyala Irrigation Scheme (BIS).

Njokah (1985) reports that the four schemes account for 90% of the marketed rice in Kenya.

All the schemes with an exception of MISS (which is situated in central Kenya) are located in western Kenya (see Fig. 1.1). At the establishment stage, the three Western Kenya Schemes practiced double cropping system (DCS) of paddy rice production (growing of two rice crops in a year). However, due to problems associated with land preparation activities, (mainly the bogging down of tractors) the schemes switched to single cropping system (SCS) of rice production (growing of one rice crop in a year). Even after switching to SCS, bogging down of tractors is commonly reported but at lower degree and therefore there was need to find out the causes and remedies to this problem.

The BIS and WKPS were started in 1969 and 1976 respectively. During the short rains (SR) season of the 1979/80 year BIS switched to the SCS. This is the practice to date. In 1984, WKPS too switched to the SCS leaving APS the only one practicing the double cropping of rice. However, in the SR of 1988/89 year, APS also switched to the SCS. Wandahwa (1988) who carried out a study at APS in which he compared some soil physical properties under SCS, DCS and no cropping, associated the problem of bogging down of tractors with decline in the soil bearing capacity.

The APS was started in 1969 and after three years of operation of the project, bogging down of tractors was reported as a problem. By 1972, a comparison of MISS and APS shows that the tractor and rotovator output in land preparation for APS was 1.6 acres/day while MISS enjoyed 3.6 acres/day. The cost of rotavation at APS was Ksh 35.30 when

Fig. 1.1 Locations of the Large Scale National Rice Irrigation Schemes

at MISS it was Ksh 22.40 per acre (AIRS, 1972). A bogging down survey in 1972 showed that 27% of the plots at APS experienced this problem and in 12%, of the plots, problems were severe. These problems forced the scheme to switch to SCS. However, this has not solved the problem completely and therefore more exhaustive investigations should be devoted to this problem so that rice production can be boosted to meet the demand.

The National Food Policy (GOK, 1986) emphasizes self-sufficiency in food production and since rice is becoming a major source of carbohydrates in the Kenyan society (see Table 2.1), an increase in production of this cereal will help in achieving the food policy goal. However, this is hampered by the problems outlined above as far as rice production is concerned. Whenever tractors bog down, time is wasted pulling them out of the mud and due to the pulling of tractors, they often break down. The end result is loss of time and hence a prolonged rotavation period, lower cropping intensity, production and increased maintenance costs which contribute to making the scheme function uneconomically.

One of the measures of achieving self-sufficiency in food is to introduce the DCS of rice production in the irrigation schemes where soils and climate allow. This is because good land for cultivation is scarce but rice production can be increased through DCS without increasing land under irrigated rice. Therefore, the main task in this study is to find out whether with the given climatic conditions (rainfall/evaporation) of the Ahero area and its montmorillonitic soils, it is possible to get a period between two crops which is long enough to allow the soils to dry and attain the required strength in order for the tractors not to bog down. It has been shown that at the APS, prolonged drying of the soil after drainage for harvesting reduces the mobility problem during land preparation for the following crop (AIRS, 1974b; 1979; 1980; Lenselink, 1980a). The causes and remedies of immobility in the APS are also addressed to in this study.

1.1 Objectives of study

The overall objective of this study is to tackle the problems associated with the Double Cropping System of rice production at the APS of which the major one has been the bogging down of tractors during land preparation. The cause of the problem has been associated with a decline of the soil bearing capacity in the scheme. The specific objectives are:

a) to investigate how the soil moisture content (SMC) changes with depth and time during the fallow period (i.e. to monitor the soil drying process) under various treatments;
b) to develop through simulation, a soil drying curve for APS that can be used to predict SMC;
c) to describe how the soil bearing capacity (SBC) through penetration resistance (PR) changes with respect to time, soil depth and SMC under various treatments;
d) to develop a relationship between SMC and PR for predicting PR when SMC is known;
e) to determine whether double cropping is possible by considering the results of the first four objectives and analyzing the historical rainfall data.

2. LITERATURE REVIEW

2.1 General Background of Rice Production and Consumption in Kenya

Rice is one of the world's three most important food crops of which 90% is grown in Asia (Foth 1984). In the past, rice was the staple food for communities living along the coastal areas of Kenya and was used as a ceremonial meal in the countryside. However, this has now changed and rice has become common in the diet of most Kenyans especially those living in urban areas. Although 90% of marketed rice (see Section 1.1) is grown in the four national irrigation projects, small scale irrigation projects especially in the Coast, Nyanza and Western province are being promoted. The areas under rice and mean annual yields from the main schemes are given on Table 2.1.

Table 2.1 Rice Irrigation Schemes and Their Output

Irrigation Schemes		Planted Area		Paddy Production	
		(ha)	(%)	(ton)	(%)
Mwea	(MISS)	5,860	77.5	27,011	78.7
Ahero	(APS)	1,070	14.2	3,700	10.8
West Kano	(WKPS)	420	5.5	2,330	6.8
Bunyala	(BIS)	210	2.8	1,257	3.7
Total		7,560	100.0	34,271	100.0

Source: Japanese International Corporation Agency (JICA), 1988.

In Kenya, an average of 41,000 tonnes of rice is produced including production from the small scale farmers according to FAO Production Yearbook, 1985-1987. Even with this rice that is produced in Kenya, the supply cannot meet the demand for rice. More rice has to be imported. The average amount of rice imported to Kenya annually is about 23,892 tons (FAO, 1985-1987). Part of the scarce foreign exchange the country has is used in importing rice which could be produced locally and hence save the government that money for use elsewhere.

Rice consumption in the country has been rising as the population increases. Bearing in mind that Kenya has one of the highest rates (3.34%) of population growth in the world

(GOK, 1991), it means more rice has to be grown to feed the increasing number of people in the country. In 1981, consumption stood at 31,000 tons and by 1987, it had risen to 127,000 tons (JICA, 1988; GOK, 1989). This represents a per capita consumption of 2.0 and 6.3 Kg for 1981 and 1987 respectively (Ndiritu, 1989). By projection, using a per capita consumption of 6.3 kg, a deficit of 130,000 tons is expected by the year 2000. Rice production, consumption and excess or deficits are shown on Table 2.2.

Table 2.2 The Trend of Rice Production, Consumption and Deficit or Excess in Kenya

(Unit: 1,000 tonnes)

Year	1970	1975	1980	1985	1990	2000
Population ($*10^6$)	10.9	13.1	15.3	21.0	23.5	34.8
Rice Production	27.0	43.0	43.0	37.0	39.0	62.0
Rice Consumption	20.0	25.0	31.0	82.0	143.0	192.0
Excess or Deficit	7.0	18.0	12.0	-45.0	-104.0	-130.0

Source: Ndiritu, (1989).

From Table 2.2, it is evident that as the population has increased since 1985, the country has experienced rising deficits in rice production. As such, it is very necessary to do something to improve the situation. This study will be concerned with one of the problems affecting rice production (see Section 2.1.5) and which if overcome, it would be possible to reduce the amount of rice that is imported to cover the deficits.

In order to meet the demand for rice taking into consideration the rate at which the Kenyan population is growing, several steps need to be taken which include:

a) Improvement of irrigation efficiency, management efficiency and agricultural productivity in all the existing schemes;
b) Increasing the area under irrigated rice;
c) Growing more rainfed rice;
d) Introduction of double-cropping system of rice production in all the schemes where possible;
e) Combining several or all the above four measures.

In order to produce sufficient rice to meet the country's demand and perhaps for export, an appropriate combination of the first four measures is required. These measures are briefly discussed below.

2.1.1 Agricultural Productivity in Kenyan Rice Irrigation Schemes

The need to improve irrigation and management efficiencies and agricultural productivity cannot be over-emphasized if at all the various rice producing projects will operate economically. At the moment only MISS and BIS are operating economically. Agricultural productivity to a great extent depends on the irrigation and management efficiencies. In the Kenyan irrigation schemes both irrigation and management efficiencies are low. For dependable agricultural systems, sustainability of the systems is a must.

Due to lack of funds, canals at the APS stay for a long time unattended. As a result, the banks collapse leading to spillage of water even in fallow fields. This in turn increases the cost of running the pumps since more water has to be pumped to reach the required destination. Eventually, low returns are realized. The greatest damage to the walls of the canals is caused by livestock as the farmers are allowed to graze freely in the fallow fields.

2.1.2 Proposed Rice Schemes and Improvement of the Existing Ones

Njokah (1985) states that large-scale schemes have been proposed in the Kano Plains in Western Kenya (40,000 ha) and at the Tana River Delta at the East Coast. This is a step in the right direction provided thorough feasibility studies are carried out before implementation of such projects. It has been found that lack of proper or thorough investigations can lead to project failure as far as large scale irrigation projects are concerned.

Feasibility studies on rice irrigation in the Kano Plains have already been completed through the help of JICA, (JICA, 1989). JICA is also rehabilitating the Mwea Irrigation Settlement Scheme (MISS) and carrying out tests on the possibility of a DCS by introducing short duration rice varieties (JICA, 1988). At the same time JICA together with the Government of Kenya are studying the possibility of expanding the MISS. Tana and Athi River Development Authority (TARDA) is just about to start the construction of phase one (2,000 ha) of the Tana Delta Irrigation Project (M'Arimi, 1990). The whole project is estimated to have a net area of 12,000 ha which will be purely commercial as opposed to the tenant types at MISS, APS, WKPS and BIS (M'Arimi, 1990).

2.1.3 Rainfed Rice in Kenya

Rainfed rice is mainly grown within the costal and the Lake Victoria Basin areas of Kenya. At the Coast, rice is mainly grown in the valley bottoms of Kilifi, Kwale, Mombasa and Lamu Districts (MACP, 1982). Rainfed rice in Western Province is grown in the swampy areas of the districts of Busia, Bungoma, and Mumias Division of Kakamega District (MAWP, 1988). Most of the rainfed rice in the Western Province is grown in Busia. The potential for rainfed rice in the whole province is estimated at 18,400 ha (MAWP, 1989). In Nyanza Province, rainfed rice is grown in Kisumu, Siaya and South Nyanza Districts. The potential in South Nyanza District alone is estimated to be 2,400 ha (MASND, 1984). The Lake Basin Development Authority (LBDA) together with the Ministry of Agriculture (MOA) are implementing projects geared towards promoting rainfed rice in South Nyanza and Busia Districts.

The trend of rainfed rice production in some areas of Kenya over several years is shown on Table 2.3. Figures from the table show that rainfed rice is being promoted as indicated by increases in hectarage and production. Njokah (1985) points out that the government is promoting rainfed rice as well as small-scale rice growing projects.

2.1.4 Double and Single Cropping Systems of Paddy Rice Production

The DCS of rice production is the practice of growing two crops of rice in a year. This practice was discarded at the APS and all Western Kenya Schemes due to the following problems:

- a) immobility of tractors during land preparation which would result to:
  - i) increase in rotavation costs due to frequent breaking down of tractors
  - ii) prolonged land preparation period and;
  - iii) reduced cropping intensity
- b) increased incidence of pests and diseases.

Table 2.3 The Trend of Rainfed Rice in Kenya

Province	Coast		Nyanza		Western	
District	Kilifi		S. Nyanza		All Dist.	
Year	Area (ha)	Prod. (ton)	Area (ha)	Prod. (ton)	Area (ha)	Prod. (ton)
1981	1030	1030	355	578	516	464
1982	1343	1343	520	1757	1651	1680
1983	1774	1774	694	2410	1622	1662
1984	2703	5406	663	2191	1325	1456
1985	2267	5668	115	345	1090	1420
1986	2650	5300	*	*	1335	1750
1987	*	*	*	*	2454	3696
1988	*	*	350	656	1340	1800
1989	3115	6230	300	563	960	1405
1990	2152	4304	*	*	1435	2385

Source: MOA Provincial and Districts' Annual Reports (1981-1990).
* - Data not available

Palutikof (1976) states that it was a mistake to introduce the DCS at the APS. Palutikof (1976) associates the problem of immobility at APS with the DCS of rice production. Njoka (1985) argues that the DCS of rice production contributes to the spread of pests and diseases which destroy rice. When the problem of trafficability at the APS arose, the cropping intensity was lowered to 1.6 crops per year (Ten Have 1979). Ten Have (1979) suggested to lower the cropping intensity at the APS to 1.2 per year because even the 1.6 cropping intensity per year was realized with great difficulties.

The rice varieties grown at the APS take about 150 days (five months) to mature. This means that with two rice crops in a cropping calendar, there are about 65 days (two months) left to be split between the two crops and hence the fallow period is only about 32 days (one month). Since rainfall can interfere with some farm operations like harvesting and land preparation, these operations at the APS are carried out during the months of low rainfall i.e. December to March during the first crop and July to September during the second crop. At APS, land preparation activities are staggered over a period of two and three months in case of double and single cropping respectively.

In the case of SCS, the fallow period is usually about six months. Therefore the soils have ample time to dry and regain strength but still immobility is commonly reported (AIRS, 1990). With SCS, land preparation is staggered for three months. Under SCS at APS, land preparation is carried out between May and August.

When the SCS of rice production was introduced at BIS, the production costs were reduced and the yields were improved significantly.

Although the disadvantages of DCS seem to be more than its advantages, DCS has one major advantage over SCS. One of the ways to increase agricultural productivity (in rice production without cultivating more land) is to introduce double cropping in the projects where it is possible. After introducing the SCS at BIS, the yields are usually higher than one crop during the DCS but lower than with two crops combined (Lenselink, 1980a; 1983). However production costs during SCS are significantly reduced. For the advantage of DCS over SCS to be realized, the problems associated with the DCS of rice production have to be solved. The major problem being the bogging down of tractors during land preparation. This study will therefore try to find out the causes and remedies of immobility at the APS.

2.1.5 The Nature of the Problem and Previous Studies

In the BIS, due to mobility problems, the output fell from 0.79 ha per tractor per day in 1975 to 0.24 ha per tractor per day in 1978 while the cost of land preparation rose from Ksh 100 in 1973 to more than Ksh 1,000 per ha in 1978 and also the farmers' earnings went down from Ksh 5,115 for their 1.6 ha in 1975 to Ksh 2,267 in 1978 (Lenselink, 1980a). From the figures above, it can be seen that the problem of bogging down is acute and needs serious attention. Some work has been carried out in this regard as outlined further in this section.

For the DCS of rice production to be re-introduced at APS, the causes and remedies of the bogging down of tractors have to be determined. Wandahwa, (1988) carried out a study at the APS in which he compared soil compaction and bulk density, shear strength, consistency and organic matter under single cropping, double cropping and no cropping. He concluded that the soils at the APS have a high propensity for structure recovery and suitable for double cropping of rice. The question then is why experience the problem of trafficability if the soils are said to be suitable for double cropping of rice? Wandahwa (1988) suspected that there was a decline in the SBC and hence the problem of trafficability. This study therefore is to investigate whether this is so and therefore determine whether it is possible to have more than one rice crop in a year.

When mobility during land preparations became an acute problem at the APS, a survey on bogging down of tractors was carried out by the Ahero Irrigation Research Station (AIRS) in order to determine the causes and find some remedies. Several factors that were thought to contribute to bogging down were considered and tested. The factors that were investigated include:

a) "boma sites" (locations of homesteads);
b) cut and fill sites in the different fields;
c) former low spots and average slopping parts;
d) position of big trees before construction of the scheme;
e) bad levelling of fields;
f) period of flooding before rotavation and period between drainage for harvesting (the fallow period) and flooding and
g) depth of firm layer (mud depth).

Of these factors, only mud depth was found to have a correlation with bogging down (AIRS, 1972). After this survey, several recommendations were suggested some of which were:

a) a close check on bogging down compared with the SMC of the upper layer to determine if there is any relationship between them;
b) monitoring the drying out process of the soil in a selected number of fields and
c) repeating the bogging down survey over the season that followed.

Although the first two recommendations were not implemented, the last one was, and over several seasons.

During the SR 1973 and the long rains (LR) 1979 seasons, it was noticed that the number of cases in which severe bogging down occurred during the rotavation was considerably reduced and this was attributed to the dry weather during the rotavation season in 1973 and due to the preceding dry season in the case of 1979 (AIRS, 1973 and

1979). At the time of rehabilitation of APS in 1979/80, it was found that in Block N which was prone to bogging down, improvement of in-field drainage and prolonged drying (a season had been skipped) almost eliminated the bogging down problems (AIRS, 1980). When the BIS was switching to single cropping system, the LR 1979 cropping season was skipped and during the following season, bogging down was almost absent in 71% of the scheme. From the foregoing it can be concluded that sufficient drying of the fields can reduce the bogging down problem. The question is, how much time should be given to the fields after harvesting for it to dry enough and to avoid bogging down while at the same time not leaving a field fallow for more than four months. Solving this question will determine whether DCS of rice production at the APS is possible or not.

2.1.6 Location, Climatic Conditions and Soils of APS

The APS is situated in the Kano Plains (in the lake Victoria region), about 24 km from Kisumu town along the Kisumu - Kericho Road. Geographically it is located on latitude 00°09'S and longitude 34°56'E and at an altitude of 1160 m above mean sea level.

The area has two rain seasons, Long Rains (LR) season from March to May and Short Rains (SR) season from October to December. According to the meteorological station in the scheme, the area receives an average rainfall of 98.1 mm per month. During the LR season, April receives the highest amount of rainfall (200.2 mm) while during the SR season, November receives the highest (103.2 mm). Temperatures do not vary much between months. The monthly mean temperature ranges from 29.9 °C (max.) to 14.7°C (min). Relative humidity varies from 64% to 75% with a monthly mean of 69%. The monthly mean pan evaporation stands at 5.8 mm/day. Table 2.4 shows the monthly means of the meteorological parameters at the APS for the period 1962-1990.

Soils found in the APS are montmorillonitic type with 60% clay content (Wandahwa, 1988). These vertisols (heavy clay commonly known as black cotton soils) are found in all the NIB rice irrigation schemes. In APS, the soils are very deep, with high natural fertility. They are favourable for irrigation of rice due to their low deep percolation rates but difficult to cultivate for an upland crop. This is because black cotton soils are difficult to till when dry and they are very sticky when wet. Moreover, after harvesting rice and the soil surface has dried, these soils form a thin self mulching layer of about

Table 2.4 Average Meteorological Data at the APS (1962-1990)

Month	Rain Fall (mm)	Evaporation (mm/d)	Temperature Max (°C)	Temperature Min (°C)	Relat. Humid. (%)	Solar Rad. (Lang)	Sun Shine (hrs)	Wind Speed (kph)
Jan.	78.4	6.7	30.8	14.1	65	603	8.5	5.29
Feb.	87.4	6.9	31.2	14.5	66	639	8.4	5.52
Mar.	136.4	6.9	31.2	15.1	68	605	7.9	5.25
Apr.	200.2	5.8	29.4	16.0	74	577	7.2	4.62
May.	132.0	5.3	28.8	15.6	74	569	7.3	4.04
Jun.	78.3	5.0	28.6	14.5	75	543	7.3	3.99
Jul.	71.8	4.9	28.7	14.1	75	525	7.5	3.98
Aug.	76.6	5.3	29.2	14.1	72	539	7.0	4.30
Sep.	68.4	5.7	30.1	13.9	66	572	7.2	4.66
Oct.	72.5	6.1	30.8	15.2	64	532	7.5	4.54
Nov.	103.2	5.4	30.0	14.7	66	566	7.1	4.44
Dec.	71.4	6.0	30.3	14.3	66	592	8.2	4.65
MEAN	98.1	5.8	29.9	14.7	69	572	7.6	4.61

2.0 cm and as a result, the soil profile takes long to dry. This in-turn increases the turnaround time from rice harvesting to seed-planting of an upland crop if the latter was to follow rice in a crop rotation series as has been tried in some schemes.

2.1.7 Irrigation of Rice and the Related Activities at the APS

A cropping season at APS begins with land preparation. With the single cropping system of rice production, land preparation begins in May and continues up to November. One or two days before rotavation begins, the fields are submerged with water to a depth of about 70 mm. This is done to soften the soil so that little energy is required to break up the clods (see Sections 2.2 and 2.3). After puddling and levelling of the fields, a water depth of 50 mm remains on the soil surface but in order to reduce the incidence of weeds, this water depth is raised to about 175 mm.

Immediately after land preparation is over, for each block, farmers are issued with seeds for planting in the nurseries. Transplanting is done 21 days later but the seedlings can take as long as four weeks in the nurseries. During transplanting, the fields are drained and any weeds removed. The first irrigation is applied a week after transplanting once the seedlings have established themselves in the soil. A water depth is maintained and increased as the crop increases in height.

Drainage for harvesting is done two to three weeks before harvesting although trials at AIRS have shown that up to five weeks, yields are not significantly affected (AIRS, 1982; 1983; 1984; 1985). Drainage for harvesting is done to enable the rice crop to ripen uniformly and to create comfortable conditions for harvesting to take place. Harvesting is done manually. After harvesting, the fields are left fallow for about one month on average before the next rotavation in the case of the double cropping system and about six months in the case of the single cropping system. The period of concern for the purposes of this study is the one between drainage for harvesting and land preparation. This is the drying or fallow period and the soil strength before land preparation depends on what happens within this time. Some of the management aspects during this period that were thought to influence land preparation negatively are:

a) *Management of Straw*

After harvesting rice, straw is left to sun dry arranged in five or six heaps of about 10-15 m diameter and about 15 m apart. On drying, the straw is burnt although not all of it burns. The burning is said to reduce the incidence and spread of diseases by pests. However, Wandahwa (1989) found that burning of straw at APS lowers organic carbon in the soil which in turn affects the soil's plastic limit and hence increase the turnaround time from harvest to seed-planting of an upland crop. Straw cover has been found to reduce the soil drying rate considerably (Kamp, et al. 1982).

b) Organisation of Land Preparation Activities at APS

When AIRS begun a survey on the bogging down of tractors at APS, it was found that after several seasons of investigations, although bogging down was persistent in some blocks than in others the problem shifted from one block to another (AIRS, 1974). As the practice is at APS, land preparation does not begin in the block that was rotavated first the previous season. Instead, the beginning of land preparation rotates from block to block. The NIB changed to such a system after the farmers complained that the yields of the farmers' whose blocks were rotavated last were always low. In some cases the last blocks to be harvested were the first ones to be rotavated during the following season and this explains why the problem of bogging down was shifting between blocks. It means that there was very little time for the last blocks to be harvested to dry enough to attain the required strength for no bogging.

c) *In-field Drainage*

Although there has been an effort to improve the in-field drainage in the scheme, sometimes the drainage channels cut in the poorly drained fields are left unattended to and therefore water tends to remain on the field for a long time even after harvesting or after rains. Lenselink (1980a) showed that improved in-field drainage improved trafficability a great deal.

2.2 Puddling and its Effect on Soil Physical Properties

Lowland rice is mostly grown in small fields or paddies that have been levelled and enclosed (bunded) with a ridge to retain water. The paddy fields are flooded and puddled before rice transplanting and a unique physical soil environment is created. Puddling can be defined as tillage of water saturated (flooded) soil when water is standing on the field. Puddling renders soil impervious.

Flooding of dry soil causes water to enter pore spaces of soil aggregates and to compress the air in the pores resulting in small explosion that break the aggregates apart (AIRS, 1972; Foth, 1984; Sharma and De Datta, 1985). The stability of soil aggregates is greatly reduced and the aggregates that remain are easily crushed. Aggregates that are already weakened and broken down are worked into a uniform mud, which is essentially a two phase system of solids and liquids. Puddling mainly takes place within the top 30 cm but some researchers say it is in the range of 10-25 cm (Moormann and Van Breemen, 1978).

When soils are puddled, their bulk density decreases, large pores and capillary porosity are eliminated. In medium textured soils, stratification of soils occurs whereby sand settles first followed by silt and finally a thin surface layer high in clay content which introduces low infiltration. Changes in bulk density of a soil affect soil properties like permeability, available water, air capacity and trafficability (Archer and Smith 1972). Their observations agree with those of Moormann and Von Breemen (1978) and Sur et al. (1981). Soil permeability is usually reduced during puddling at the depth of 30 cm from the soil surface where a hard pan forms. This is so because soil aggregates break down and pores are clogged with microbial wastes. This is a desirable phenomenon in paddy rice production because the amount of water needed to produce rice is reduced significantly. Therefore a low hydraulic conductivity of soil is of great importance in maintaining standing water on the paddy during the crop growing season. However, with the black cotton soils of the NIB schemes, this is not so due to the low permeability of the soils.

The other advantage of hard pans is that they help in making lowland rice fields accessible to man, animals and machinery (Foth, 1984; Prihar et al. 1985; Sakai et al. 1987). Mechanized cultivation is most successful where the underlying clay is firm, thus supporting machinery and preventing bogging down (Grist, 1975; Sakai et al. 1987). Removal of the pans in some intermediate textured soils makes them soft and muddy, thus limiting tractor use (Prihar et al. 1987). According to Moormann and Van Breemen (1978), pans, depending on soil type, climate, hydrology, and puddling frequency can take from 3 to 200 years to form. With high swelling clays, the pressure (or hard) pans formed during initial land preparation period break up due to the drying and cracking of the soils as is the case with vertisols. This seriously affects trafficability or mobility in rice fields. Gill (1968) defines trafficability as the ease with which terrain may be transversed. One of the disadvantages of pan development is that they inhibit deep crop rooting (Greenland, 1985).

Dudal (1966) pointed out that in considering the kind of implement and the type of power to be used for mechanized cultivation, a knowledge of the soil properties such as moisture content, consistency, stoniness and density is important. The reason is that some of the above properties seriously affect soil strength. In simple terms, soil strength is the capacity of the soil to withstand deformation. Gill (1968) defines soil strength as the ability or capacity of a particular soil in a particular condition to resist or endure an applied force. During puddling, soils undergo two types of deformations - normal stress which is associated with compression and tangential stress which causes shear (Sharma and De Datta 1985). In the case of standing water and water logged areas, soil strength is usually inadequate and therefore land preparation must be carried out with low pressure machinery, by animals or manually (Greenland, 1985). Greenland also noted that draining of soils or seasonal drying may increase soil strength. Soil strength is the main factor to be investigated at APS in order to determine when the soils attain enough of it for land preparation.

Wandahwa (1988) found that double cropping lowers soil strength at a depth of 15 to 30 cm. He suspected this to be the cause of tractor "sinking". He also found that single cropping recorded high soil shear strength which he attributed to the associated longer drying periods.

2.3 Effect of Soil Moisture Content on Land Preparation

The purpose of tillage on clay soils is to break up the large soil aggregates (or clods that develop after the drying of the clay soils) and to re-arrange them in a loose packing. This process requires an application of a certain amount of mechanical energy which depends on the friction and cohesion forces between the implements used and the soil aggregates and between the aggregates themselves. The friction and cohesion forces depend heavily on the moisture content of the soil (Koenigs, 1961). Cohesion and friction forces between soil aggregates themselves is lowest at moisture content levels below the lower plastic limit and highest at sticky point moisture content.

In wetland rice cultivation, the soil moisture content is a very crucial factor as far as land preparation is concerned. Kisu (1978) points out that tillage is influenced by the soil moisture content and therefore tillage operations should be carried out within an appropriate soil moisture range because soil consistency changes widely with moisture content.

According to Craig, (1984) soil consistency is the physical state of fine-grained soil at a particular moisture content (defined as the ratio of the mass of water in the soil to the mass of solid particles) but Foth, (1984) defines it as the resistance of the soil to deformation or rapture. Soil consistency therefore includes such properties as resistance to compression and shear, friability, plasticity and stickiness. However, field observations show that consistency of soils varies with texture, organic matter, amount and nature of the colloidal material, structure and moisture content (Baver, 1956). Therefore consistency is important to tillage and traffic considerations.

Laboratory tests of workability of APS soils, (AIRS,1972) indicate that the moisture content that corresponds to:

- lower plastic limit = 42%;
- sticky point = 44%;
- saturation point = 127%.

The lower plastic limit (LPL) is the mass wetness at which the soil stiffens from plastic to a semi-solid and friable state. It represents the minimum moisture percentage at which the soil can be puddled (Baver, 1983). The inter-aggregate cohesion and the friction is lowest at MC below the LPL and highest at sticky point MC. The latter represents that moisture content at which the soil no longer sticks to foreign objects. The cohesion and friction forces decrease between the sticky point and the saturation point.

On the basis of the tests mentioned above, it was recommended (AIRS, 1972) that the soil moisture content should be below 41% and above 127% for dry and wet rotavation respectively. This ensures maximum results with minimum energy. Before flooding for wet rotavation, the SMC should be 20%. The reason for this recommendation is given below.

As explained in Section 2.2, when water enters a dry soil, it forces the air in the pore spaces out with an explosion and hence clods break up. However this is true if the cohesion forces of the soil aggregates are smaller than the force of the pressurized air and in this case the moisture content level is below the shrinkage point (which is the MC at which the soil changes from a semi-rigid to a rigid solid with no additional change in specific volume as the drying process proceeds). At the shrinkage point for APS soils, the suction pressure is between 5 and 6 pF which corresponds to 20-22% moisture content, (AIRS, 1972). After the explosions, the soil loses structure and the aggregates are dispersed, hence requiring only a small amount of energy for rotavation. It was on the basis of the foregoing that it was recommended that the moisture content before flooding for wet rotavation should be 20%.

Lando (1989) conducted an experiment with clay soil in North Lampung, Indonesia, to determine the effect of soil moisture content on power requirements and found out that draft resistance differed significantly with soil moisture content levels and ploughing depths. Lando (1989) concluded that ploughing depth contributes to high draft resistance and that soil draft resistance is linearly proportionate to power requirements. Raghavan and Mckyes (1979), stated that tractive force is reduced by increases in SMC.

In the same place, Lando (1990) carried out another experiment (with similar treatments as the experiment above) to determine the effect of soil moisture content on tractor wheel slip and found out that the latter varied significantly with the soil moisture content and ploughing depth. These experiments confirm the views of other researchers concerning the effect of moisture content on tillage.

2.4 Soil Bearing Capacity and Trafficability

Soil bearing capacity (or soil strength) has a significant effect on terrain trafficability. The measurement and characterization of the mechanical properties of the terrain in relation to vehicle mobility are very complex and no universally accepted method has been established (Wong 1989). The two main types of measuring techniques available for field use include:

a) The bevameter technique and

b) The cone penetrometer technique.

The bevameter technique was developed on the basis that terrain properties pertaining to vehicle mobility can best be measured under loading conditions similar to those exerted by an off-road vehicle on the terrain surface (i.e normal and shear forces). The cone penetrometer was developed mainly for military use to tell whether terrain trafficability and vehicle mobility was possible or not. "Cone index" (CI) is a parameter given by the penetrometer which represents the soil bearing capacity or resistance to penetration into terrain per unit cone base area.

The performance of a tractor can be related to soil strength in terms of rating cone index (Rush, 1968). Wong (1989) observes that CI which also represents the combined shear and compressive characteristics of the terrain, has been used as a basis for predicting off-road vehicle performance in fine grained soils (clay soils). He also notes that where the terrain moisture content, bulk density, shear strength and structural state may vary significantly with depth, the interpretation of the cone penetrometer data becomes very difficult. This is because the relative proportions of the shear, compressive and tensile strengths reflected by the cone index vary with moisture content. Wells and Treesuwan (1978), express the same opinion by saying that CI is one of the soil strength parameters which exhibit discernible dependency relationship with various levels of SMC. However, as the SMC increases the CI becomes increasingly insensitive to changes in the shear or compressive strengths. Wismer and Luth (1974) reported that the CI - SMC relationship revealed that for a constant compactive effort, a maximum CI is produced at a specific SMC.

Although Wong (1989) indicates that the interpretation of cone indices may be difficult at times, other authors (e.g. Wismer and Luth, 1974; Kisu, 1978; Ayers and Perumpral, 1982; Müller et al. 1990) say that trafficability can be predicted with the knowledge of the CI. Kisu, (1978) argues that there are fairly clear relationships between machine performance and soil constants and the prediction of machine performance is possible for any soil type and moisture content. Müller et al. (1990) concurs with Kisu (1978). Müller (1990) contends that assessment of trafficability and workability of heavy soils on the basis of consistency and penetrometer data is a practicable way of quickly obtaining data for decision concerning the use of agricultural machinery. Hayes and Ligon (1981) also state that a relationship between CI and soil properties does appear possible if adequate data is collected. Therefore, if a relationship between CI and soil properties (like SMC) that influence trafficability can be obtained, the latter can be predicted.

Researchers such as Ezaki et al. (1976) and Anyoji and Tharavaj (1987) have reported that sinking of tractors is highly correlated with soil bearing capacity or strength within a depth of 25-30 cm below the soil surface. According to Scheltema (1974), tractor trafficability depends on tractor weight per unit area as well as the soil strength. In the Muda Irrigation Project, Malaysia, Ezaki et al., (1976) report that after the introduction of a double cropping system, the area that permitted the use of four-wheel tractors was reduced from 99% before the double cropping to 77% in the off season and 31% in the main season of the double cropping. They found out that the main problem was due to the decline in soil bearing capacity as a result of double cropping. After conducting an experiment to determine how the soil moisture content affects the soil bearing capacity, they came to a conclusion that soil hardness is dependent on the extent to which the soil dries (as expressed by decreased soil moisture content). It means that by allowing the soil to dry enough, one can achieve the soil hardness required for trafficability of tractors.

Soil, unlike water, has no uniform properties and its bearing capacity as well as load-sinkage relationship can not be expressed in simple form (Bekker, 1960). Bekker (1960) continues to say that a load which is safe in one soil, or soil condition may not be safe in another and the same ground pressure applied to different forms of tracks and wheels will produce different sinkage. The latter should remain smaller than the clearance of the vehicle if immobilization is to be avoided. Different authors have come up with different values of safe bearing capacities. Those discussed below pertain to paddy rice fields or clayey soils in which rice is mainly grown.

Johnson (1972) points out that fundamental factors to describe vehicle mobility (trafficability) in wet soils have not been established. Prihar et al. (1985) also observes that little is known about the stability of aggregates of lowland rice soils puddling of such soils and its long term effects on soil structure is not well documented. However through experience, according to Johnson (1972), it has been noticed that with standard tractors with cage wheels, immobility seldom occurs when the cone penetrometer index (CI) exceeds 70 lb/in^2 (482.6 kPa or 5.0 kg/cm^2) at 30 cm depth while bogging is likely to occur when it is less than 35 lb/in^2 (241.3 kPa or 2.5 kg/cm^2). He further observes that these two values were used in extensive field surveys in the Philippines and it was found that with the SCS, 85% of the fields had a CI of 5.0 kg/cm^2 at a depth of less than 30 cm but with a DCS, 55% of the fields had a CI of 5.0 kg/cm^2 at less than 30 cm depth. Müller et al. (1990), state that the upper topsoil is trafficable if the resistance exceeds 300 kPa.

2.5 The Theory of Traction and Compaction

Yong et al. (1984) distinguishes three causes of immobilization of a vehicle as:

a) Physical impediments derived from the mechanical characteristics and properties of the terrain (i.e. properties that lead to sinkage or slip);
b) Physical impediments due to obstacle geometric characteristics and
c) Terrain roughness.

In paddy fields during harvesting or land preparation operations, the last two of the above listed causes of immobilization do not play a great role and therefore immobilization is caused by the first one. Therefore, this section will deal mainly with soil compaction as it contributes to the bearing capacity which in turn affects traction.

2.5.1 Traction Theory

Once the ground is strong enough to sufficiently support the weight of a vehicle, the latter will move across a terrain if it has adequate power. Two major reaction forces come into play - the vertical and horizontal forces known as "flotation", "traction" and motion resistance. Yong, et al. (1984), defines flotation as the ability of a vehicle to travel without excessive sinkage and traction as the ability of the vehicle tractive element (wheel or track) to generate enough forces to overcome all types of vehicle resisting forces. According to Yong et al. (1984), the primary purpose of a vehicle tractive element is to provide sufficient flotation and traction required for moving a vehicle between two points.

A moving track or tyre tread loaded with a vertical force W - weight of vehicle develops a force H produced by shearing strength of soil called the gross tractive effort or soil thrust (see Fig. 2.1(a)). If the ground is plastic (wet clay), the spaces between the spuds or tread are filled with soil within the area A of spuds or tread in contact with the ground. This is due to the cohesive forces which bind the soil particles. In the setting above, the tractive force H remains constant and does not depend on the value of W (see Fig. 2.1(b)). The force required to shear the area A is proportional to the stickiness of the soil mass and the size of surface. Therefore:

$$H = A * c \qquad \ldots(2.1)$$

Where

c = the coefficient of cohesion.

For a frictional soil like sand, the force H is not constant, it increases proportionally to the load W in accordance with Coulomb's law of friction (see Fig. 2.1(c)). Therefore;

$$H = W * \tan\phi \qquad \ldots(2.2)$$

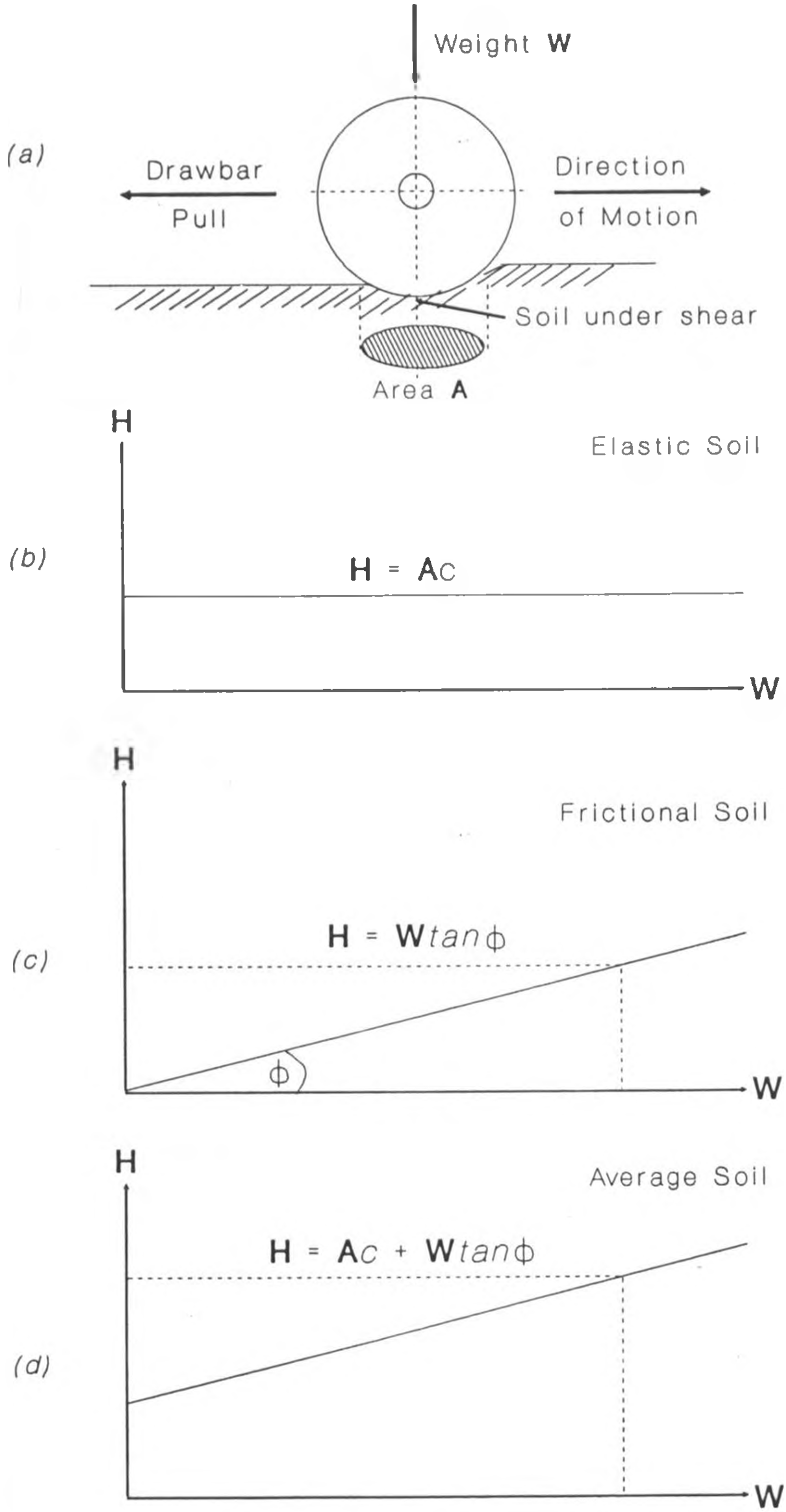


Fig. 2.1 Soil Shear (Bekker 1960)

Where,

ϕ = the angle of internal friction

Most soils possess both properties ie they are neither purely plastic nor purely frictional. Thus adding equations 2.1 and 2.2 we get Fig. 2.1(d) represented by equation 2.3.

$$H = A * c + W * \tan\phi \qquad ...(2.3)$$

This fundamental relationship between soil thrust or gross tractive effort *H* of the vehicle, its weight *W*, the size of the ground contact area *A* and soil constants *c* and ϕ was introduced by Micklthwait (Bekker, 1960).

The ability of a vehicle to cross a terrain with or without negligible sinkage is determined by the bearing capacity of soil, which in turn is defined by its friction - ϕ, cohesion - *c* and density - τ. The smaller dimension *b* of the loading area is an important factor (Bekker 1960). The values of *c* and ϕ for some depth intervals at the APS area have been determined by Wandahwa (1988), see Fig. 2.2.

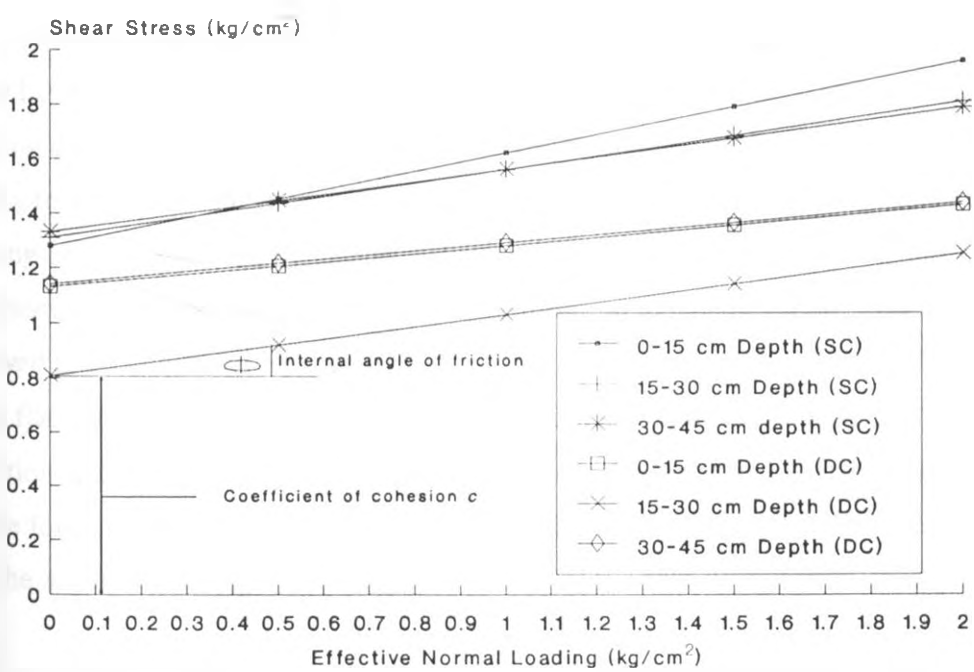


Fig. 2.2 Shear Stress for Singleand Double Cropping at Various Depths (Wandahwa, 1988).

The traction mechanism is dependent on two things:

a) the tractive element type and

b) ground support type.

a) The tractive elements

The tractive element could either be a track or a wheel. Mechanized operations in rice fields are normally carried out with wheeled vehicles. The tractive characteristics of a tire depend on the type and condition of the soil, the soil physical parameters and tyre loading (Wulfsohn, 1986). Although experimental evidence indicates that the soil has a greater influence on the traction capabilities than the tyre design features (Taylor et al. 1967), it has also been shown that within a given soil type and condition, tire design has a significant effect on the tractive performance (Taylor, 1973; 1974).

Several types of tyre designs were tried at the APS when the problem of immobility became acute. Some of those tried include: cage wheels; double tyres; and Rice Lug tyres (Schut, 1978). No positive results were achieved with these tyre trials. Powerful and light machines were also tried. Among the machines tried were John Deere, Same tractors, power tillers from the Philippines and light tractors from India. John Deere was found to have a better output in comparison with the others (Kuria and Lenselink, 1978).

It is not clear why the cage wheels and the dual tyres did not show positive results and they have done so in other places like the Philippines. Perhaps the inflation pressure used during the testing had something to do with the results obtained. Low inflation pressure and a tread pattern which provides soil-cutting action are preferable in the soft clay soils, (Yong et al., 1980). Salokhe et al. (1989) states that out of the many traction aids tried to improve mobility of the off-road vehicles during wetland cultivation, cage wheels have proved to be one of the best for such working environment. The author continues to say that flat-lugged cage wheels are a popular development in wet rice fields due to their high traction and flotation. Concerning the dual tyres, Taylor et al. (1986) reports that they were found to reduce subsoil pressures significantly when compared to larger single tyres of the same load rating.

b) Type of ground support

Immobilization of a vehicle may result from lack of ground support (leading to sinkage immobilization) or lack of strength in the terrain to provide the means of development of thrust (leading to slip immobilization). Flotation provides the support bearing capability of a vehicle while thrust provides the driving force. The ground support in rice fields is mainly of soft cohesive soils (clay soils) which Yong et al. (1985) describe as a severe condition for tractive performance.

Development of hard-pans in rice fields due to soil compaction has great effect on the bearing capability of the support ground (see Section 2.2). Therefore the next section will look at compaction in relation to mobility in rice fields.

2.5.2 Soil Compaction Relating to Bearing Capacity as a Physical Process Which Affects Traction

Soil compaction can be defined as an increase in its dry density and the closer packing of particles or reduction in porosity (McKyes 1985). In paddy fields, compaction can be caused by human, animal or machine traffic. The major concern in this section is compaction due to machine traffic since compaction due to animals and human traffic at the APS is negligible. Land preparation at the APS is carried out with tractors and rotavators. However, in the nurseries land preparation is carried out with the help of animal draft.

The degree of compaction mainly depends on the soil type, normal pressure, the number of repeated passes by a machine and moisture content (Raghavan et al. 1977a; b; c; d). As far as soil type is concerned, some soils like clay are easy to compact than others, e.g. sand. There is a close relationship between density changes and normal pressure. Vanden Berg (1966) showed that density changes are proportional to the logarithm of normal pressure. The number of repeated passes has a similar effect as the contact pressure of a tyre. Raghavan et al. (1977a; b) showed that soil dry density is proportional to the logarithm of MC and the number of repeated passes of a tyre. Maximum density under a given load is attained at an optimum SMC. At a given load, dry density of a soil increases with increase in SMC up to a certain MC after which any further increase in MC reduces the dry density. Land preparation at the APS is carried out when the soil is saturated and therefore, very little compaction is expected at such SMC.

Although some researchers (e.g. Raghavan et al. 1977b c; d) have reported that slip increases compaction, this does not seem to happen at the APS. This is attributed to the saturated conditions of the soil during land preparation. It is reported that before the sinking of tractors at the APS, the tyres normally spin for some time without any forward movement (AIRS, 1972). Slip is a primary physical process in rolling motion on soft soils. It reduces the distance over which the pull does work and contributes greatly to sinkage of machines. Leflaive (1966) states that sinkage is difficult to determine; a part of it is due to slip while the remaining portion corresponds to bearing capacity.

Field tests on sandy and clay soils showed that when slip exceeds 25-35%, less compaction takes place especially on the topsoil, (Raghavan et al. 1977c). The authors observed that with a high level of slip, the tyres excavate a good amount of soil and throw it to the sides. The above observations may explain why Wandahwa (1988) found that at the depth 15-30 cm the soil strength was lower at the APS under double cropping than with single and no cropping.

2.6 The Drying Out Process of Soil After Drainage for Harvesting

The drying out process (DOP) of the soil in irrigated rice fields takes place during the fallow period plus the two to three weeks before harvesting. During this time the soils are supposed to recuperate but unfortunately, this does not happen always depending on the weather conditions during the farrow perlod.

In general, the major factors that determine the rate of the DOP of soils are:

a) type of soil;
b) topographical conditions of the field;
c) vegetation cover and
d) climatic factors mainly rainfall and evaporation.

The main climatic parameters that influence the DOP include rainfall and the rate of evaporation. The latter is mainly dictated by parameters such as air temperatures, humidity, sunshine hours, solar radiation and wind speed. Below is a brief discussion of the main factors that influence the DOP.

2.6.1 Soil Type

Soils differ greatly in their physical as well as their chemical properties. Due to the different soils' properties, their ability to retain or yield water also differ greatly. Soils with high infiltration rates dry faster than soils with low infiltration rates. This is because the former retain less moisture content in their profiles. Soils with a high ground water level (GWL) take longer to dry than soils low or without GWL.

Clayey soils have a tendency to form a thin layer (1-2 cm thick) on the soil surface when the soil has dried considerably. The dry surface layer has a self-mulching effect on the soil and hence the DOP is greatly reduced. However, some clay soils crack when dry and this increases the rate of the DOP.

2.6.2 Vegetation Cover

Vegetation cover, depending on the density provide a shading effect on the soil and therefore evaporation rate is reduced significantly. Thus a bare soil surface dries faster than one covered with vegetation even if soil loses moisture through both evaporation from soil surface and transpiration from plants (evapotranspiration). Campbell (1985) states that even in a field covered with vegetation cover, evaporation is still 10% of evapotranspiration. According to Shaw (1983), evaporation from a vegetated surface is a function of available energy, the net radiation, the temperatures of surface and air, the saturation deficit, the wind speed and the soil moisture.

Instead of leaving a field fallow for a long time after harvesting rice, a dry-footed crop that would make use of the residual moisture could be grown. However tillage of flooded rice fields after puddling has been known to result in hard medium to large clods particularly in fine textured soils. Moreover, the residual moisture may not be enough for the crop to grow up to maturity, thus, making it necessary to irrigate the crop till it matures. As a result, soils may not have enough time to rejuvenate and attain the required strength for land preparation to be carried out without experiencing the problem of bogging down of tractors.

Due to difficulties outlined above, it makes it hard for an upland crop to follow rice in a rotation cycle. Nevertheless it has been found that cereals and pulse crops (maize, wheat, sunflower, sorghum, cotton, green-grams, soya beans, cow peas, groundnuts, pigeon peas, chickpeas, mung-beans, black-grams, mustard), and vegetables (tomatoes, potatoes, chilis, onions, watermelons), can be rotated with rice on residual moisture and or with a little irrigation (Prihar et al., 1985; Patil, 1984; Patil et al., 1980; Prakash and Tandon, 1985; Katre et al., 1986; Uttaray et al., 1988; Babu et al., 1988; Mazumdar et al., 1989; Umapathy et al., 1989; Angadi et al., 1991). Trials at the APS with maize, green grams, and sorghum showed that green grams were suitable as an alternative dry land crop after rice (AIRS, 1982 and AIRS, 1983).

2.6.3 Topographical Conditions

Topography also plays a major role in the DOP especially in rice fields. It has been noticed that where the fields are not level, water tends to collect in the low spots and these spots dry out slowly. Although the bogging down survey carried out by AIRS, did not show any correlation between low spots and bogging down, it was however noted that in some cases the low spots could not be ruled out as not to have contributed to bogging down (AIRS, 1972).

2.6.4 Effect of Rainfall

When rain falls during the drying out time, depending on the intensity and duration, the soils may even become wet to the point of saturation. Therefore if rain falls frequently, the rate of the DOP of the soils is reduced and hence soils do not attain the required strength for good mobility at the time of land preparation.

2.6.5 Evaporation and Transpiration

Moisture leaves the soil profile and reaches the atmosphere through evaporation, transpiration or through the combined effect of the two processes. The rates of these two processes are influenced by the soil properties and environmental conditions. After drainage for harvesting the DOP of the soil take place through the combined effects of direct evaporation from the soil surface and transpiration from the unharvested rice. When rice is harvested, the DOP continues through evaporation only - at APS no other crops follow rice. Farmers keep on grazing in the fallow fields and therefore the few weeds that grow are consumed by livestock. As such there is very little vegetation cover during the fallow period and therefore evaporation continues to be the major factor contributing to the drying of the soil.

The evaporation process from a bare soil surface can be divided into three stages (Hillel, 1977; Baver et al., 1983; Campbell, 1985; White, 1987; Wild, 1988), viz:

a) constant rate;

b) falling rate and

c) vapour diffusion

The three stages are shown in Fig. 2.3.

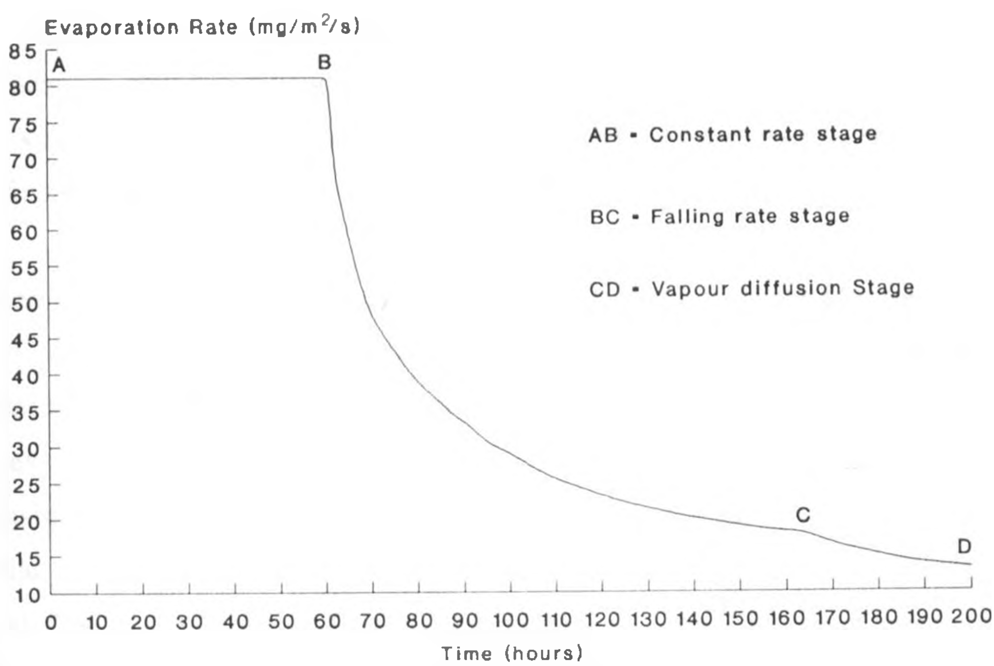


Fig. 2.3 Evaporation Rate for a Bare Soil Surface (Campbell, 1985).

a) The Constant Rate Stage

A constant rate of evaporation is controlled by evaporative demand. This constant rate of evaporation persists so long as the soil can supply water to the surface fast enough to keep it moist. The constant rate of evaporation of the soil can approximate that of evaporation from an open water surface depending on the albedo of the soil (White, 1987).

b) The Falling Rate Stage

During the falling rate stage, evaporation rate is controlled by the soil physical properties like the soil profile's transmission of water to the evaporation zone. Once the soil has dried enough and the water reaching the soil surface is less than the evaporative demand, the soil surface dries and the rate of evaporation falls sharply. At this stage, Wild (1988) states that instead of water vapour being produced at the soil surface, and diffusing immediately into the air to be readily removed by the air currents, it is produced below the soil surface and most diffuse through soil pore space under small concentration gradient before it reaches the atmosphere. After this, the evaporation rate continues to decrease as the depth of the dry layer increases.

c) The Vapour Diffusion Stage

Some authors have argued that this stage may not be determined due the small difference between it and the falling rate stage. The vapour diffusion stage during which evaporation continues at a very slow and relatively constant rate is controlled by the diffusion of the dried surface zone.

When the soil has dried for a day or two, the upward movement of water depends on SMC and it is usually very slow (Hanks, 1985). He also observes that in the absence of water table, very little soil water below 20-30 cm will ever flow to the surface and be lost by evaporation. In an experiment carried out at Rothamsted in Britain after a prolonged drought, no water moved up from below 45 cm and only 6 cm moved from below 22 cm (Wild, 1988). This compares well with Hanks' (1985) observation. In the tropics, the depth from which a bare soil loses water depends on several factors of which one is the amount of soil cracking. This is because water vapour diffuses faster from the surface of even deep cracks into the atmosphere than the equivalent depth of soil (Wild, 1988). Thus, the loss is greater from deep-cracking montmorillonitic clays than kaolinitic soils.

2.7 Methods of Estimating Soil Drying Rates

Several authors have developed various methods of estimating the soil drying rates. Some of these methods are:

a) Yoshida;

b) Bolton and Zandstra;

c) Thornthwaite and Mather.

2.7.1 Yoshida's Method

According to Yoshida (IRRI, 1985; McMahon, 1985) soil drying for rice fields in Tropical Asia may be represented by:

$$E = 0.0105 * S \qquad \ldots(2.4)$$

where,

E = cumulative potential evaporation (mm);

S = cumulative incident solar radiation (cal/cm^2).

This method was developed for an area with calm prevailing wind conditions and McMahon et al., (1985) noted that this is the reason why there is a close relationship between the measured values and the results using this expression. The above expression is an equation for a straight line and referring to the three stages of evaporation process from a bare soil, linearity comes only at the first stage which is very short indeed. For that matter, this method cannot be suitable for this study since the drying period under consideration is long (about five months).

2.7.2 The Method of Bolton and Zandstra

Bolton and Zandstra (1981) developed an expression for estimating the drying rate (for a clay soil in Iloilo, Philippines) the relationship of which involves actual evaporation, maximum evapotranspiration and prevailing SMC as given below:

$$Y = 0.0086 * X - 0.5 \text{ (mm)} \qquad \ldots(2.5)$$

where;

Y = the ratio of actual evaporation to maximum evapotranspiration;

X = prevailing soil moisture (mm).

The method yields good results and it could be used in this kind of study. However, since changes in SMC in this study will be monitored over a period of time (the fallow period), this method therefore will not be used due to the time element lacking in it. The next method (the Thornthwaite and Mather model) is preferred as it estimates SMC over a period of time.

2.7.3 The Method of Thornthwaite and Mather

As given by Van der Molen (1984), Thornthwaite and Mather's expression involve the actual amount of SMC remaining in the soil, maximum SMC at saturation, potential evaporation and time from the start of the DOP of the soil. The equation gives valid results provided no rewetting occurs during the DOP by evaporation. The expression is given by:

$$MC_a = MC_s * \exp^{-(ET * t / MC_S)} \qquad \ldots (2.6)$$

where,

MC_a = actual amount of moisture remaining in the soil (mm);

MC_s = maximum moisture in the soil for evaporation at saturation (mm);

ET = potential evaporation (mm/day);

t = time since the start of drying (day).

The model of Thornthwaite and Mather gives a good estimate of SMC from the time the DOP begins provided there is no rewetting of soil. Therefore it will be used in this study to develop a soil drying curve for soils at the APS.

3. RESEARCH METHODOLOGY AND MATERIALS

3.1 Site Selection for the Experiment

To be able to meet the objectives of this study as given in Section 1.2, three major parameters had to be monitored during the fallow period. These included:

a) monitoring the DOP of the soil in a selected number of fields;

b) monitoring the soil strength and the SMC of the upper layer of the fields to determine if there is any relation with bogging down and

c) monitoring the meteorological parameters during the fallow period.

In addition, frequency analyses of the dry weather days from the daily historical rainfall records for the months which fall within the fallow period and which have the highest amount of rainfall was carried out.

Site selection therefore was based on the ease of obtaining the required data and the elimination of extraneous factors like rainfall variations within the scheme. Soil variation within the scheme could be neglected because the soils did not vary significantly from place to place (see Annex 1).

The scheme is divided into thirteen blocks and the blocks are divided into tenant holdings which are in turn subdivided into four fields of an acre each. Due to the size of the scheme, it was not possible (within the short period available) to carry out the study in all the blocks in the scheme or in all the tenant holdings in a given block. It was therefore decided to carry out the study in a few selected blocks and tenant holdings.

Block selection was based on the bogging down survey obtained from the AIRS Technical Reports (AIRS, 1972; 1973; 1974; 1979; 1980;). The blocks selected had recorded a persistent high degree of bogging down. These included blocks A, B, D, F, G, and N. Out of these blocks with a high degree of bogging down, Blocks A, D and N were selected as representative blocks for the study. A map of the scheme showing the selected blocks is given in Annex 2. The selection criteria for the three blocks was based on the distance from the four rainfall stations in the scheme. The three blocks were selected because, of the blocks with a high degree of bogging down, they were located near three rainfall stations in the scheme. This was necessary in order to eliminate rainfall variation within the scheme.

Table 3.1 shows the area affected in the selected blocks in acres and percentages according to three categories of bogging down. According to AIRS (AIRS, 1972), the three categories were defined as follows:

Table 3.1 Degree of Bogging Down For Selected Blocks

	Degree of Bogging Down						
	Severe		Moderate		No Bogging		Total Bogging
	Affected Area		Affected Area		Affected Area		
Block	(Acres)	(%)	(Acres)	(%)	(Acres)	(%)	(%)
N	71	30	19	8	147	62	38
A	31	14	59	26	188	60	40
D	21	9	19	9	180	82	18

Source: AIRS Report on Bogging Down, (AIRS, 1972).

a) No bogging down - a tractor does not bog at all within a given field;
b) Moderate bogging down - a tractor bogs down once or twice in each field;
c) Severe bogging down - a tractor bogs down more than two times in each field.

After choosing the blocks, the problem was then how to choose a number of tenant holdings which were representative of those blocks which persistently recorded high degree of bogging down. Since the bogging down survey carried out by the AIRS (AIRS, 1972; 1973; 1974; 1979; 1980;) did not indicate which tenant holdings were seriously affected, it was decided to choose the tenant holdings from the selected blocks at random. A tenant holding in all the selected blocks was adopted as the smallest unit in which to carry out the study and the four fields (plots) in a tenant holding were taken as replicates. The tenant holdings chosen from each block are shown below:

a) Block N - tenant holding No. 407;
b) Block A - tenant holding No. 041;
c) Block D - tenant holding No. 157.

As it would be difficult to rotavate the whole scheme in a few days due to water, machinery, personnel, land size and other constraints, land preparation is normally staggered over a period of 60 and 90 days in the case of double and single cropping respectively. As a result, drainage for harvesting and harvesting are also spread over the same period. This implies that different blocks and tenant holdings in a block can be drained on different days. Therefore during the experiment, the three tenant holdings were all drained at different dates and sampling also begun at different dates as shown in Table 3.2. In each tenant holding, all the four fields (replicates) were drained on the same day.

Table 3.2 Dates for drainage, first and last days of sampling

Unit of Time: Days

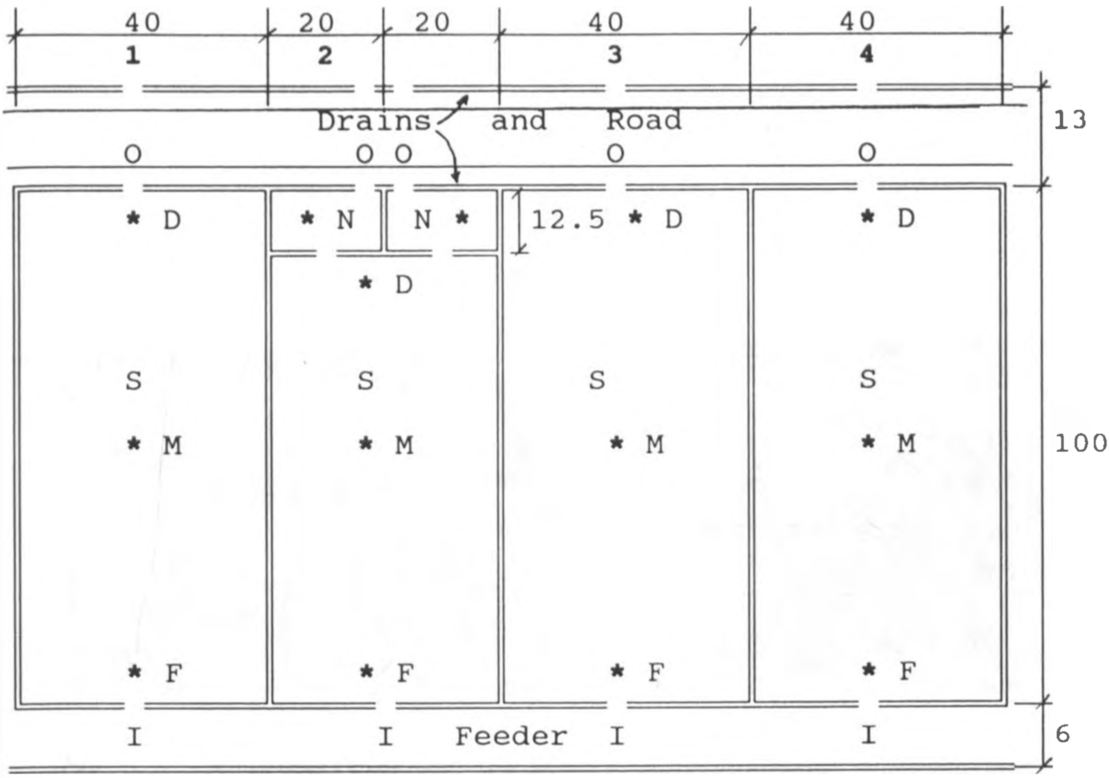
Block/ Holding	Date of Drainage	First Date of Sampling	Time From Drainage	Last Date of Sampling	Drying Time
N/407	12/11/90	20/12/90	38	06/05/91	175
D/157	24/11/90	19/12/90	25	18/05/91	175
A/041	02/05/91	10/05/91	08	28/05/91	26

The commencement of sampling on different dates was due to the limited number of soil samples the drying oven at the APS laboratory could accommodate. At the same time, sampling on fields drained at different dates would give an idea as to what extent the soil dried before land preparation begins under the present practices.

3.2 Experimental Design and Layout

In the APS, tenant holdings are of 1.6 ha (4 acres) in area with length and width of 160 m and 100 m respectively. A holding is divided into four equal fields with a length of 100 m and a width of 40 m. The second of four fields has a nursery of 500 m². Fig. 3.1 shows the layout of a tenant holding and the sampling positions.

A systematic method of sampling in the fields was preferred to random sampling due to the effect of field slope, management of straw after harvesting and the effect of drains and feeders. For this matter, three sampling positions (treatments D, M, and F) i.e. drain side, middle of field, and feeder side respectively were used. Sampling was done



Legend

* - Sampling position
D - Drain side
M - Middle of field
F - Feeder side
N - Field nursery
S - Straw or ash heap

I - Inlet
O - Outlet
1,2,3,4 - Field (Plot) number
═══════ - Bunds or boundaries
All measurements in metres

Fig. 3.1 Experimental Layout.

at the centre of the shorter dimension of a field. The reason for taking samples at three positions only in each field was dictated by the number of soil samples the oven at the APS soil laboratory could carry at a time. At the same time, if there was an influence to the drying rate of soil by field slope, it could only be detected by a minimum of three points along the slope.

The cultural practice at APS after harvesting rice is to arrange the straw in four to six heaps in each field and later burn it (see Figures 3.2 and 3.3). After sampling two times, it was noticed that under such heaps of straw (or ash), the drying rate of the soil was very low in comparison with the rest of the field. Due to this observation and after inquiring from the workers and farmers as to whether the spots under straw or ash

Fig. 3.2 A Farmers Plot Showing Straw Arranged in Heaps of Approximately 10-15 m Apart.

Fig. 3.3 A Farmers Plot Showing Straw Burnt After Drying.

contribute to bogging down (to which they were agreeable), sampling under the straw or ash (treatment S) was also carried out. Owing to lack of space in the oven for a large number of samples, only the third heap of straw or ash from the drain side of every field was sampled. The reason for selecting the third heaps of straw or ash was because they were situated approximately in the middle of every field and it was felt that they were representative of each field.

As some authors (Prihar et al. 1987; Wandahwa 1988) have indicated that hardpans, normally form at a depth of about 30 cm in rice fields and they can be destroyed by machinery during land preparation, it was decided to check whether this was the case for APS. This was done by comparing the soil strength in the field nurseries (treatment N) with that obtained from other sampling locations. Land preparation in field nurseries is done manually while in other parts it is done mechanically.

It has been shown that power requirements increase with increased ploughing depth and moisture content. Using MC of 10, 15, 20, 25 and 30% and ploughing depth of 10, 15, and 20 cm, Lando (1990) found that power requirements were highest (20 kW) at 30% MC and 20 cm ploughing depth and lowest (11.2 kW) at 20% MC and 10 cm ploughing depth. This means that land preparation operations should be limited to 20 to 25 cm depth. Authors like AIRS, 1972 and Hanks, 1985 have reported that soil drying by evaporation hardly exceeds 30 cm below the soil surface. Since hard pans also form at about 30 cm depth below the soil surface, it would have been adequate (in this study) to consider a sampling depth of up to 30 cm in view of the foregoing. However, a 60 cm sampling depth was chosen so that the drying trend below 30 cm could also be established. Therefore sampling was done at 15 cm depth intervals from the soil surface up to a 60 cm depth.

3.3 Parameters and Their Measurements

The major parameters that were monitored during the experiment included soil strength, soil moisture content and meteorological ones. Bulk density was also determined for the purpose of converting SMC by weight to SMC by volume. Conversion was necessary because SMC in Eq. 2.6 which is used in this study (see Sections 2.7.3 and 3.5) is on volume basis expressed in depth units. SMC by volume could not be determined directly due to lack of enough cores for undisturbed soil samples.

Except for the meteorological parameters which were monitored on daily basis, SMC and soil strength were monitored depending on the field and weather conditions. When the fields had just been drained or after a rain event, sampling was carried out after every three-four days until when the SMC would tend to remain constant between successive samplings. This meant that as the DOP progressed, there was little moisture leaving the soil profile through evaporation. Therefore under such circumstances it was not necessary to sample frequently and sampling was carried out on weekly basis on average and sometimes after about 10 days.

3.3.1 Determination of Bulk Density

According to Foth, (1984) bulk density (BD) is the weight per unit volume of oven dry soil. For the determination of bulk density, undisturbed soil samples were taken using rings of 100 cm^3 volume. At every sampling depth interval in a soil profile pit, six replicates were taken. For every replicate BD was calculated using Eq. 3.1 (Foth 1984). The Gravimetric method (described in Section 3.3.2) was used to arrive at the weight of oven dry soil. An average value of the six samples at every depth interval was adopted as the BD for that interval.

$$BD = \frac{\text{weight of oven dry soil}}{\text{volume of oven dry soil}} \qquad ...(3.1)$$

3.3.2 Determination of Soil Moisture Content

Soil moisture content (SMC) was determined in the soil laboratory at APS through the gravimetric method. This method was used because it is accurate in comparison with measurements obtained using tensiometers and neutron probes. Shaw (1983) states that the gravimetric method is reliable, accurate and that it is used to calibrate other techniques. In the gravimetric method of measuring SMC, a soil is sampled, put into a can, weighed in the sampled moist condition, oven dried at 105°-110°C till a constant weight is reached when it is weighed again. Although most soils take about 24 hrs to reach a constant weight, clay soils take longer (42 hrs for APS soils). According to Donahue, et al. (1983), SMC (in percentage on dry basis) is given by:

$$SMCW = \frac{(MSW) - (ODSW)}{(ODSW)} * 100 \qquad ...(3.2)$$

where:

SMCW = soil moisture content on an oven dry weight basis, (%);

MSW = moist soil weight, (g);

ODSW = oven-dry soil weight, (g).

Soil samples were weighed using an electronic balance with a precision of 0.01 g. A soil auger marked with masking tape at every 15 cm from the bottom up to 60 cm was used to obtain soil samples for determination of SMC on weight basis at various depths. SMC (on weight basis) determined above was converted to SMC by volume using Eq. 3.3.

$$SMCV = SMCW * BD / DW \qquad ...(3.3)$$

Where,

SMCV = soil moisture content on volume basis, (%);

BD = bulk density (g/cm^3);

DW = density of water (g/cm^3);

= 1 g/cm^3.

After this conversion, the SMC obtained on volume basis in percentage (%) was transformed to SMC by volume in depth (mm). For this operation, the various layer depths for each sampling point (0, 15, 30, 45 and 60 cm) were determined as demonstrated in Fig. 3.4.

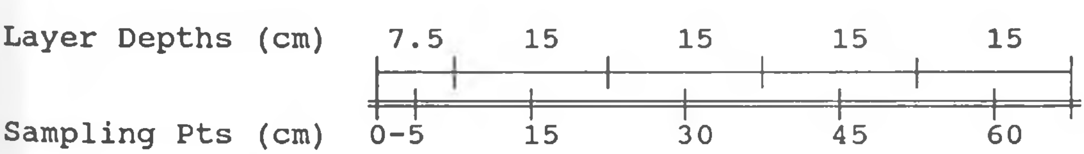


Fig. 3.4 Graphical representation of Layer Depths' Determination

The SMC on volume basis in mm, was calculated for each layer for every sampling day using the following relationship:

$$SMCD = SMCV * d * 0.1 \qquad ...(3.4)$$

Table 3.3 Conversion of Soil Moisture Content by Weight to Soil Moisture Content by Volume (Block D/157)

Depth (cm)			0-5		15		30		45		60	
BD (g/cm³)			0.92		0.99		1.01		1.04		1.09	
No.	Sampling Date	Drying Time (day)	SMCW (%)	SMCV (%)	SMCW (%)	SMCV (%)	SMCW (%)	SMCV (%)	SMCW (%)	SMCV (%)	SMCW (%)	SMCV (%)
1	19/12/90	25	69.2	63.5	72.6	72.1	51.9	52.6	50.0	52.1	42.5	46.5
2	22/12/90	28	59.4	54.5	64.7	64.3	51.2	51.9	47.7	49.7	44.9	49.1
3	26/12/90	32	34.0	31.2	54.6	54.2	50.0	50.7	48.5	50.5	45.2	49.4
4	31/12/90	37	25.5	23.4	62.3	61.9	52.9	53.6	48.6	50.6	45.1	49.3
5	11/01/91	48	76.3	70.0	76.1	75.6	56.9	57.7	53.7	55.9	51.0	55.8
6	21/01/91	58	18.9	17.4	62.0	61.5	56.1	56.8	54.4	56.6	48.9	53.4
7	28/01/91	65	51.7	47.4	61.8	61.4	54.9	55.6	50.6	52.7	48.6	53.2
8	04/02/91	72	18.3	16.8	54.1	53.8	51.3	52.0	47.9	49.9	45.5	49.8
9	11/02/91	79	23.0	21.1	47.0	46.6	47.8	48.4	45.1	47.0	43.5	47.6
10	18/02/91	86	18.2	16.7	42.9	42.6	41.2	41.7	42.6	44.3	40.5	44.3
11	25/02/91	93	19.7	18.1	37.5	37.3	39.7	40.3	40.5	42.2	39.7	43.4
12	01/03/91	97	21.6	19.8	32.6	32.4	34.2	34.7	33.0	34.3	32.3	35.3
13	06/03/91	102	17.2	15.8	33.3	33.1	35.9	36.4	37.6	39.2	37.4	40.9
14	14/03/91	110	50.2	46.1	40.6	40.3	42.5	43.1	41.7	43.4	41.2	45.0
15	18/03/91	114	14.4	13.2	30.9	30.7	33.8	34.3	35.8	37.3	35.6	38.9
16	25/03/91	121	39.7	36.5	26.7	26.5	27.9	28.3	27.5	28.6	27.6	30.2
17	01/04/91	128	46.7	42.9	34.3	34.1	34.1	34.6	35.7	37.2	34.4	37.6
18	07/04/91	134	52.9	48.5	44.1	43.8	45.2	45.8	43.4	45.2	41.1	44.9
19	12/04/91	139	42.7	39.2	46.9	46.6	46.7	47.3	43.6	45.4	42.1	46.1
20	18/04/91	145	28.1	25.8	40.0	39.8	41.8	42.3	42.4	44.1	41.4	45.3
21	22/04/91	149	34.3	31.5	41.0	40.7	44.5	45.1	45.3	47.2	43.5	47.5
22	26/04/91	153	18.3	16.8	38.4	38.1	40.3	40.8	40.5	42.1	38.8	42.5
23	30/04/91	157	18.9	17.4	36.8	36.5	40.5	41.1	41.7	43.4	40.1	43.8
24	04/05/91	161	34.7	31.9	37.4	37.1	39.3	39.9	40.3	42.0	40.1	43.9
25	08/05/91	165	21.9	20.1	38.5	38.2	40.3	40.8	39.7	41.3	39.5	43.2
26	12/05/91	169	50.9	46.8	37.2	36.9	40.6	41.1	40.9	42.6	40.9	44.7
27	18/05/91	175	26.7	24.6	36.3	36.0	38.1	38.6	39.6	41.2	38.5	42.1

Table 3.4 Soil Moisture Content By Volume for Block D/157 Expressed in Depth

Sampling Depth (cm)			0-5		15		30		45		60	
Layer Depth d (cm)			7.5		15.0		15.0		15.0		15.0	
No.	Sampling Date	Drying Time (day)	SMCV (%)	SMCD (mm)	SMCV (%)	SMCD (mm)	SMCV (%)	SMCD (mm)	SMCV (%)	SMCD (mm)	SMCV (%)	SMCD (mm)
1	19/12/90	25	63.5	47.7	72.1	108.1	52.6	78.9	52.1	78.1	46.5	69.7
2	22/12/90	28	54.5	40.9	64.3	96.4	51.9	77.9	49.7	74.5	49.1	73.7
3	26/12/90	32	31.2	23.4	54.2	81.3	50.7	76.0	50.5	75.7	49.4	74.2
4	31/12/90	37	23.4	17.6	61.9	92.9	53.6	80.4	50.6	76.0	49.3	73.9
5	11/01/91	48	70.0	52.5	75.6	113.3	57.7	86.5	55.9	83.8	55.8	83.7
6	21/01/91	58	17.4	13.0	61.5	92.3	56.8	85.2	56.6	85.0	53.4	80.1
7	28/01/91	65	47.4	35.6	61.4	92.1	55.6	83.5	52.7	79.0	53.2	79.7
8	04/02/91	72	16.8	12.6	53.8	80.7	52.0	77.9	49.9	74.8	49.8	74.7
9	11/02/91	79	21.1	15.8	46.6	70.0	48.4	72.6	47.0	70.5	47.6	71.4
10	18/02/91	86	16.7	12.5	42.6	63.9	41.7	62.6	44.3	66.5	44.3	66.5
11	25/02/91	93	18.1	13.6	37.3	55.9	40.3	60.4	42.2	63.3	43.4	65.1
12	01/03/91	97	19.8	14.9	32.4	48.6	34.7	52.0	34.3	51.5	35.3	53.0
13	06/03/91	102	15.8	11.9	33.1	49.6	36.4	54.7	39.2	58.7	40.9	61.3
14	14/03/91	110	46.1	34.6	40.3	60.5	43.1	64.6	43.4	65.1	45.0	67.5
15	18/03/91	114	13.2	9.9	30.7	46.1	34.3	51.5	37.3	55.9	38.9	58.4
16	25/03/91	121	36.5	27.4	26.5	39.8	28.3	42.5	28.6	42.9	30.2	45.3
17	01/04/91	128	42.9	32.2	34.1	51.2	34.6	51.9	37.2	55.7	37.6	56.5
18	07/04/91	134	48.5	36.4	43.8	65.8	45.8	68.7	45.2	67.8	44.9	67.4
19	12/04/91	139	39.2	29.4	46.6	69.8	47.3	71.0	45.4	68.1	46.1	69.1
20	18/04/91	145	25.8	19.4	39.8	59.7	42.3	63.5	44.1	66.2	45.3	67.9
21	22/04/91	149	31.5	23.6	40.7	61.1	45.1	67.6	47.2	70.8	47.5	71.3
22	26/04/91	153	16.8	12.6	38.1	57.2	40.8	61.3	42.1	63.2	42.5	63.7
23	30/04/91	157	17.4	13.0	36.5	54.8	41.1	61.6	43.4	65.1	43.8	65.7
24	04/05/91	161	31.9	23.9	37.1	55.7	39.9	59.8	42.0	63.0	43.9	65.8
25	08/05/91	165	20.1	15.1	38.2	57.4	40.8	61.2	41.3	62.0	43.2	64.8
26	12/05/91	169	46.8	35.1	36.9	55.4	41.1	61.7	42.6	63.9	44.7	67.0
27	18/05/91	175	24.6	18.4	36.0	54.0	38.6	57.9	41.2	61.9	42.1	63.2

where,

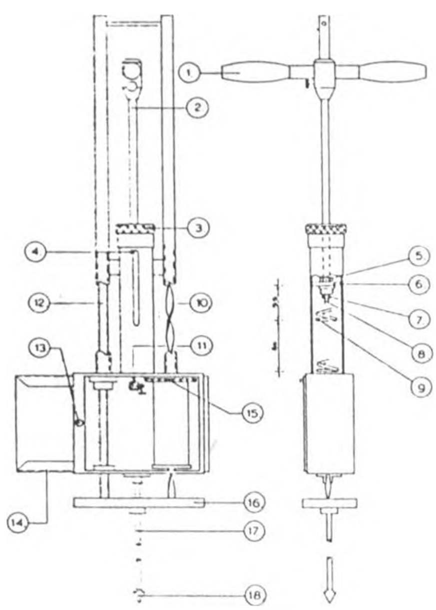
SMCD = soil moisture content by volume, (mm);

SMCV = soil moisture content by volume, (%);

d = layer depth (cm);

0.1 = units conversion coefficient.

The results are given in Annexes 5, 6 and 7 but a sample of these calculations is given in Tables 3.3 and 3.4 for the Drain-Middle-Feeder (DMF) treatment (see Section 3.4.2).



1 - Detachable handle
2 - Push rod
3 - Locking nut for spring casing
4 - Adjustable guide pin for pressure rod
5 - Locking nut
6 - Adjustable spring seat
7 - Locking nut
8 - Adjustable writing rod
9 - Spring
10 - Helical spindle
11 - Adjustable pen holder
12 - Square guide rod
13 - Magnetic door lock
14 - Chart slide groove
15 - One-direction drive cylinder
16 - Bottom plate
17 - Sounding rod
18 - Cone

Fig. 3.5 The Cone Penetrometer Used for Measuring Penetration Resistance.

3.3.3 Soil Bearing Capacity

Soil bearing capacity was determined by a measure of penetration resistance (PR) obtained by using a cone penetrometer. In this study, a self recording cone penetrometer (penetrograph) was used. Fig. 3.5 shows the apparatus used. Cones of various surface area (5.0 3.33, 2.0 and 1.0 cm^2) were used depending on the field soil conditions (very soft, soft, hard or very hard). The biggest and the smallest cones had a measuring range of 0 to 100 and 0 to 500 N/cm^2 respectively. The cones were pushed into the soil at an approximate speed of 2 cm per second. The depth of measurement in centimeters was indicated on the top of the recorder charts. PR in N/cm^2 and different scales for the type of cone used were also indicated on the charts. Values of PR from every sampling position were taken at 15 cm depth intervals from the soil surface up to a 60 cm depth.

It is worthy noting that the penetrometer was not calibrated and therefore the data obtained may not be absolutely without errors. However, since the instrument used was new (it had not been used before) and it had been maintained well in the store, it is believed that if there were any errors they would not affect the results significantly.

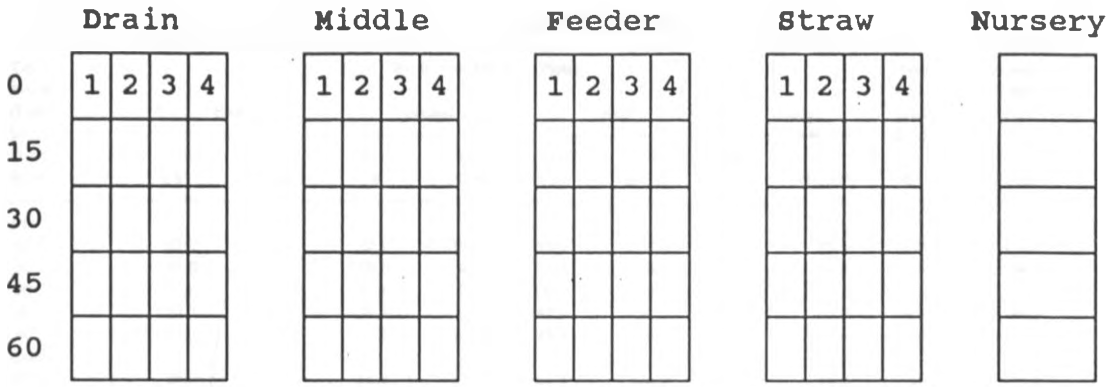
3.4 Processing of Field Data

3.4.1 Preliminary Findings

After a few days of sampling, a preliminary analysis of the collected data was carried out. This was necessary in order to determine whether it was possible to group some treatments together for ease of data management or whether to handle each treatment and replicate individually. To determine this, a statistical analysis was essential.

For this statistical analysis, the experiment was treated as a Factorial Block Design with four blocks (replicates) and two factors. Factor A was the sampling locations with four levels - D, M, F, and S and factor B was the sampling depths with five levels - 0, 15, 30, 45, and 60 cm. The N treatment was used as a control since it was not replicated due to the physical lay-out of a tenant holding (see Fig. 3.1). The replicates were the four fields (plots) of a tenant holding. Fig. 3.6 shows the blocking of the treatments.

Preliminary findings from blocks D and N for the first day of sampling under the ashes or straw heaps are presented in Tables 3.5 and 3.6. From Table 3.5, the average MC for the first layer and under the treatments D, M, and F (Block D) varied between 30.6 and 36.0% while under treatment S, MC was as high as 103.8%. For the first layer, MC



1, 2, 3, 4, represent the four replicates
0,15,30,45,60 represent the sampling depths in cm

Fig. 3.6 Schematic Representation of Treatment Blocking

from treatment N was higher (45.5%) compared with that of treatments D, M, and F. However, for the other layers, it was within the same range i.e. between 42.5 and 55.2%. Treatment S recorded a higher MC (48.5-63.4%) than the other layers.

The average PR in Block D for the first depth interval under D, M, and F varied between 120.8 and 122.3 N/cm² but it was much lower (6.5 N/cm²) under the S treatment. Treatment N recorded a low PR (71.0 N/cm²) in comparison with treatments D, M, and F. Just like with MC, PR from the other layers under treatments D, M, F and N fell within the same range - between 54.0 and 104.0 N/cm². This range was lower (20.8-83.5 N/cm²) under the S treatment. Almost a similar trend is observed in Block N (Table 3.6) for both MC and PR in all the treatments and replicates. Thus, grouping of treatments was found to be necessary but it had to justified statistically.

To determine whether it was necessary to combine (or group) some treatments together, an analysis of variance (ANOVA) was carried out. The aim was to find out if there was a significant difference in SMC and PR among the replicates, sampling locations and sampling depths. Data in Tables 3.7 and 3.8 (derived from Table 3.5) were used for the analysis.

The level of significance (α) was taken to be 5%. Statistical tables in Irwin and Freund (1985) were used. The resulting ANOVA tables are represented on Tables 3.9 and 3.10.

Table 3.5 SMC by Weight and PR Sampled on 26/12/90 in Block D/157

Treat-ments (Posit-ion and Depth in cm)	First SMC (%)	First PR (N/cm^2)	Second SMC (%)	Second PR (N/cm^2)	Third SMC (%)	Third PR (N/cm^2)	Fourth SMC (%)	Fourth PR (N/cm^2)	Aver. Soil Moist. Cont. (SMC) (%)	Average Penet. Resist. (PR) (N/cm^2)
Drain										
05	25.1	122.0	29.1	146.0	35.9	136.0	32.3	85.0	30.6	122.3
15	53.5	60.0	58.6	41.0	55.0	50.0	53.6	68.0	55.2	54.8
30	50.6	75.0	57.8	70.0	50.1	70.0	47.4	70.0	51.5	71.3
45	50.2	90.0	54.4	75.0	47.9	90.0	44.4	90.0	49.2	86.3
60	45.3	100.0	47.6	100.0	43.8	100.0	41.7	116.0	44.6	104.0
Centre										
05	28.2	157.0	34.2	126.0	34.6	134.0	44.8	66.0	35.5	120.8
15	51.7	61.0	61.4	46.0	55.6	50.0	48.7	59.0	54.4	54.0
30	45.0	70.0	52.4	72.0	47.2	71.0	49.5	70.0	48.5	70.8
45	44.8	92.0	50.9	80.0	49.6	85.0	50.3	87.0	48.9	86.0
60	41.5	105.0	47.0	95.0	45.5	90.0	49.4	90.0	45.9	95.0
Feeder										
05	38.9	136.0	46.0	68.0	33.5	132.0	25.5	148.0	36.0	121.0
15	54.0	59.0	57.4	46.0	59.6	58.0	45.7	60.0	54.2	55.8
30	49.1	71.0	54.5	62.0	49.8	77.0	46.1	66.0	49.9	69.0
45	44.4	97.0	50.0	86.0	49.5	96.0	45.3	98.0	47.3	94.3
60	43.0	100.0	46.3	98.0	46.5	101.0	45.0	104.0	45.2	100.8
Ashes/Straw										
05	122.0	3.0	95.8	8.0	98.8	10.0	98.7	5.0	103.8	6.5
15	47.4	25.0	60.6	15.0	50.5	35.0	95.0	8.0	63.4	20.8
30	54.4	50.0	49.4	35.0	84.1	35.0	57.2	45.0	61.3	41.3
45	53.7	56.0	50.7	50.0	49.5	65.0	49.4	80.0	50.8	62.8
60	56.8	95.0	47.7	65.0	44.1	65.0	45.5	109.0	48.5	83.5
Nursery								Overall for D,M,F		
05	-	-	45.5	71.0	-	-	-	-	34.0	121.3
15	-	-	53.9	64.0	-	-	-	-	54.6	54.8
30	-	-	48.0	71.0	-	-	-	-	50.0	70.3
45	-	-	46.0	80.0	-	-	-	-	48.5	88.8
60	-	-	42.0	98.0	-	-	-	-	45.2	99.9

Table 3.6 SMC by Weight and PR Sampled on 27/12/90 in Block N/407

Treat-ments (Posit-ion and Depth in cm)	First SMC (%)	First PR (N/cm^2)	Second SMC (%)	Second PR (N/cm^2)	Third SMC (%)	Third PR (N/cm^2)	Fourth SMC (%)	Fourth PR (N/cm^2)	Aver. Soil Moist. Cont. (SMC) (%)	Average Penet. Resist. (PR) (N/cm^2)
Drain										
05	21.4	184.0	18.6	220.0	24.6	194.0	25.6	188.0	22.6	196.5
15	64.7	58.0	52.2	113.0	54.1	81.0	44.5	115.0	53.9	91.8
30	46.8	98.0	69.9	59.0	58.6	73.0	44.3	85.0	54.9	78.8
45	49.3	92.0	53.4	63.0	44.4	90.0	44.4	80.0	47.9	81.3
60	46.7	98.0	53.2	102.0	45.7	110.0	46.3	80.0	48.0	97.5
Centre										
05	18.7	220.0	25.6	161.0	15.7	355.0	21.1	185.0	20.3	230.3
15	57.6	126.0	52.7	107.0	58.4	73.0	45.1	90.0	53.5	99.0
30	46.5	116.0	51.1	112.0	52.4	89.0	47.9	90.0	49.5	101.8
45	54.4	116.0	49.1	115.0	50.2	100.0	50.1	120.0	50.9	112.8
60	50.0	116.0	47.6	118.0	51.3	107.0	47.9	122.0	49.2	115.8
Feeder										
05	21.3	200.0	26.5	150.0	17.8	256.0	23.1	290.0	22.2	224.0
15	67.2	45.0	47.8	120.0	48.9	100.0	60.6	122.0	56.1	96.8
30	48.1	127.0	48.8	115.0	51.7	90.0	54.4	114.0	50.8	111.5
45	46.9	118.0	53.1	114.0	50.9	115.0	48.8	116.0	49.9	115.8
60	56.4	114.0	47.5	120.0	45.4	118.0	44.1	121.0	48.4	118.3
Ashes/Straw										
05	93.5	14.0	103.5	0.0	32.7	10.0	55.9	58.0	71.4	20.5
15	70.3	55.0	70.6	36.0	78.0	10.0	51.6	65.0	67.7	41.5
30	59.4	79.0	54.0	85.0	55.1	80.0	74.6	88.0	60.8	83.0
45	53.2	68.0	52.7	112.0	51.4	105.0	48.6	121.0	51.5	101.5
60	50.7	81.0	51.0	120.0	49.0	120.0	61.6	53.0	53.1	93.5
Nursery								Overall for D,M,F		
05	-	-	14.2	240.0	-	-	-	-	21.7	216.9
15	-	-	50.3	97.0	-	-	-	-	54.5	95.8
30	-	-	51.6	95.0	-	-	-	-	51.7	97.3
45	-	-	53.5	93.0	-	-	-	-	49.6	103.3
60	-	-	54.9	91.0	-	-	-	-	48.5	110.5

Table 3.7 Totals of SMC Over the Replicates for Each Location and Depth as Sampled on 26/12/90

Factor A (Sampling Location)	Factor B (Sampling Depth in cm) 0	15	30	45	60	Total SMC (mm)
D	122.4	220.7	205.9	196.9	178.5	924.3
M	141.8	217.4	194.1	195.6	183.4	932.3
F	143.9	216.7	199.5	189.2	180.8	930.1
S	415.3	253.5	245.1	203.3	194.1	1311.3
Total	823.4	908.3	844.6	785.0	736.7	4098.0

Table 3.8 Totals of PR Over the Replicates for Each Location and Depth as Sampled on 26/12/90

Factor A (Sampling Location)	Factor B (Sampling Depth in cm) 0	15	30	45	60	Total PR (N/cm^2)
D	489.0	219.0	285.0	345.0	416.0	1754.0
M	483.0	216.0	283.0	344.0	380.0	1706.0
F	484.0	223.0	276.0	377.0	403.0	1763.0
S	26.0	83.0	165.0	251.0	334.0	859.0
Total	1482.0	741.0	1009.0	1317.0	1533.0	6082.0

Table 3.9 ANOVA to Investigate the Effects on SMC of Replication, Sampling Locations and Depths

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F	$F_{0.05}$
Replication	3	74.5	24.8	0.4	2.77
Main Effects					
A	3	5485.3	1828.4	29.2	2.77
B	4	1036.0	259.0	4.1	2.54
Interaction	12	9905.7	825.5	13.2	1.93
Error	57	3571.5	62.7		
Total	79	20073.1	254.1		

Table 3.10 ANOVA to Investigate the Effects on PR of Replication, Sampling Locations and Depths

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F	$F_{0.05}$
Replication	3	1511.4	503.8	2.18	2.77
Main Effects					
A	3	29266.1	9755.4	42.25	2.77
B	4	28120.0	7030.0	30.45	2.54
Interaction	12	19530.9	1627.6	7.05	1.93
Error	57	13161.6	230.9		
Total	79	91590.0	1159.4		

From both Tables 3.9 and 3.10 for SMC and PR ANOVA respectively, it was found that there was no significant differences in the replicates since $F_R < F_{\alpha=0.05}$. Since F_A, F_B, and F_i exceeded their respective values of $F_{\alpha=0.05}$, it was concluded that there was a significant differences among sampling locations, sampling depths and their interactions for both SMC and PR.

A Duncan multiple-range test (MRT) was carried out to determine which sampling locations significantly differed. For the Duncan MRT, the mean of means of PR over the sampling locations were computed (using data from Table 3.5) and arranged in an ascending order (see Table 3.11).

Table 3.11 Means of PR Arranged in an Increasing Order

Number of Means	1	2	3	4	5
Sampling locations	S	N	M	D	F
Mean of Means	48.4	76.8	85.3	87.7	88.2

The standard error of mean was computed using the error mean square from (see Table 3.8): $s_x = \sqrt{(347.95/5)} = 8.34$. The values of r_p for $\alpha = 0.05$ and 16 df were used to calculate the least significant ranges and least significant sums of squares, (see Table 3.12).

Table 3.12 Least Significant Ranges and Least Significant Sums of Squares

Means *p*	2	3	4	5
r_p	3.00	3.14	3.23	3.30
$R_p = s_x * r_p$	25.03	26.19	26.94	27.53
$SS_p = \frac{1}{2}(R_p)^2$	313.25	342.96	362.88	378.95

Comparison of the means were carried out as follows:

F - S = 88.2 - 48.4 = 39.8 > R_5 = 27.53, hence, F and S are significantly different.

$F - N = 88.2 - 76.8 = 11.4 < R_4 = 26.94.$

Considering the group of four means containing the means of PR for F, D, M and N, their sum of squares is found to be:

$$SS_{FDMN} = 88.2^2 + 88.7^2 + 85.3^2 + 76.8^2 - (88.2 + 88.7 + 85.3 + 76.8)^2/ 4$$
$$= 83.86 < SS_4 = 362.88$$

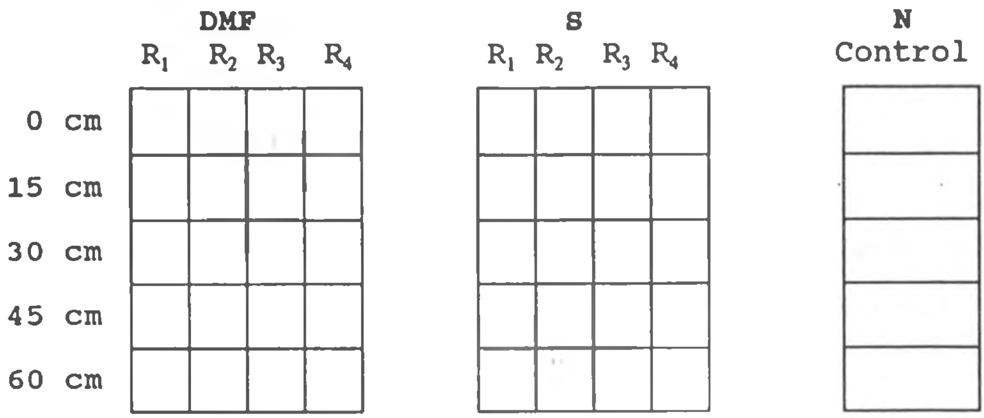
Therefore, there were no significant differences in the group FDMN (i.e. Feeder, Drain, Middle and Nursery). For any paired means of the F, D, M and N treatments, no significant difference was found to exist by comparing their sum of squares the SS_p.

A comparison of the treatments D, M, and N with treatment S showed that the sampling location S significantly differed with the others since their respective differences (i.e. D-S=39.3, M-S=36.3, N-S=28.4) were greater than their respective R_p (i.e. R_4=26.94, R_3=26.19 and R_2=25.03).

Due to the results of the ANOVA and the Duncan MRT, grouping of the data was found to be necessary so as to reduce the number of treatments during the final analysis and also to avoid analyzing data that may not be necessary. The question then was how to carry out the grouping and this is dealt with in the next Section.

3.4.2 Grouping of Treatments

For the analysis of the collected data, it was carefully and logically grouped into three categories. The three categories (treatments) were based on the mode of land preparation and the variation of data according to the sampling positions. Therefore it was decided that the nursery treatment would be analyzed individually due to the mode of land preparation. Owing to the differences between the data obtained under the S treatment and the other treatments (D, M, F), the treatments were grouped as two, S and DMF, where DMF was the combination of D, M and F. As such, this grouping yielded three treatments: S, N, and DMF. For each of these, the sampling depths (0-5, 15, 30, 45 and 60 cm) were considered. Fig. 3.7 shows the treatments after grouping.



DMF - Drain, Middle and Feeder treatments
S - Straw or Ash treatment
N - Nursery treatment
R_1, R_2, R_3, R_4 - Represent the four replicates

Fig. 3.7 Schematic Representation of Treatment Blocking After Grouping Treatments

After grouping of the data, means were first computed over the sampling positions and depth for each sampling day. Further averages were calculated over the sampling depth intervals. The results are shown in Annexes 5, 6 and 7.

3.5 Simulation of the Drying Out Process

3.5.1 The Basis of the Simulation Process

The study of a complex process like the drying out process (DOP) of soil leads to attempts to describe the process in such a way that the main determining factors can be evaluated easily. This means that the process has to be simplified and in so doing, certain properties, influences and relations are neglected or lumped together. As described in Section 2.6, there are many factors that influence the DOP. However, it can be simplified in order to come up with an expression that can describe the process fairly well. Given below are the assumptions made in arriving at the expressions that were used in this study:

a) On day zero (that is the day of drainage), the SMC is at the saturation point;
b) From among the meteorological factors that influence the DOP of the soil, only rainfall and evaporation play the most important role;
c) The SMC on any day during the fallow period depends upon the rainfall and

evaporation of that day and the SMC of the previous day;

d) Rainfall below 5.0 mm, is taken to be ineffective. This concept was used by Ezaki, et al., (1976).

The aim of this simulation was to help predict the SMC and PR during the fallow period when time from the date of drainage (day zero), rainfall and evaporation during the period are known. The actual SMC in the soil profile on day t from the date of drainage mainly depends on the SMC of the previous day (i.e. day $t-1$), rainfall (P_t) and evaporation (ET_t) on day t. Therefore in general:

$$SMC_t = f\{SMC_{(t-1)}, P_t, ET_t\} \qquad \ldots(3.5)$$

On the basis of the Thornthwaite and Mather (T&M) model (Eq. 2.6), a soil drying model (a modification of Eq. 2.6) for APS was developed. The modification process is presented in Section 3.5.2.

From the observed values of moisture content and penetration resistance, curves of PR vs. SMC were plotted. After verifying the trends of the curves, regression analysis was carried out to evolve a relationship between the two parameters. Penetration resistance mainly depends upon the SMC. Therefore:

$$PR = f(SMC) \qquad \ldots(3.6)$$

With the help of a relationship between SMC and PR, if the values of SMC are known, PR can be predicted. SMC values would be predicted using the modified equation of Thornthwaite and Mather. All what would be required is the knowledge of the duration (in days) of a "dry" weather interval within the fallow period.

3.5.2 Soil Drying Model for Ahero Pilot Scheme

To obtain a function of moisture content and time, the Thornthwaite and Mather equation was modified for the APS conditions using climatic data (for the longest continuous dry weather period) obtained from Block D. The model of Thornthwaite and Mather is given below:

$$MC_a \quad = \quad MC_s * \exp^{-(ET * t / MC_S)} \qquad ...(2.6)$$

where,

MC_a = actual amount of moisture remaining in the soil (mm);

MC_s = maximum moisture in the soil for evaporation at saturation (mm);

ET = potential evaporation (mm/day).

t = time since the start of drying (day).

From Eq. 2.6, it would appear as if MC would tend to zero if time *t* would tend to infinity (i.e. if *t* was in the order of hundreds of days). However, evaporation cannot deplete all the moisture content in the soil. There is a minimum (residual) MC that remains in the soil even after a prolonged drought (see Section 2.6.5). In this study, the residual moisture content (MC_r) was taken to be the minimum MC obtained through the gravimetric method during the experiment. Therefore, the actual moisture in the soil (MC_a) at any time can be viewed as a sum of two components namely:

i) the residual moisture content (MC_r) and

ii) part of the evaporable soil moisture that has not yet evaporated (MC_e).

Hence:

$$MC_a \quad = \quad MC_r + MC_e \qquad ...(3.7)$$

Since the relationship between MC and time for a soil drying by evaporation is curvilinear (see Section 2.6.5), and MC_r = Const. for given weather conditions, then the curvilinear nature must be due to the MC_e component. Therefore assuming that:

$$MC_e = SMC_s * \exp^{-(ET * t / SMC_s)} \qquad ...(3.8)$$

where,

SMC_s = soil moisture content at saturation less the residual moisture content.

= MC_s - MC_r

Then combining equations 3.7 and 3.8 gives:

$$MC_a \quad = \quad MC_r + SMC_s * \exp^{(-ET * t / SMC_s)} \qquad ...(3.9)$$

If *t* is equal to zero, the actual SMC in the considered layer becomes the sum of the MC_r and SMC_s i.e. the MC in the soil layer at saturation point. If *t* tends to infinity, the actual SMC tends to the MC_r i.e. the minimum MC the soil can dry to through evaporation. Graphically, MC_r becomes an asymptote.

Using Eq. 3.8, MC was calculated for Block D for the period 10/01/91 - 11/03/91. An exponential regression analysis was carried out to smoothen the curve obtained (see Fig. 4.10). The analysis yielded a constant *(a)* and a coefficient *(b)* for time *t*. Therefore, Eq. 3.8 in general could be written as:

$$MC_e \quad = \quad a * \exp^{(b * t)} \qquad \ldots(3.10)$$

Hence Eq. 3.9 becomes:

$$MC_a \quad = \quad MC_r + a * \exp^{(b * t)} \qquad \ldots(3.11)$$

Equation 3.11 represents the general form of the modified Thornthwaite and Mather soil drying model for APS. Using Eq. 3.11, and after determining the values of *a* and *b* and analyzing the rainfall data for Block D, the actual moisture content in the soil (MC_a) was estimated for the longest "relatively dry period". This period was between 10/01/91 and 11/03/91. A "dry spell" within the fallow period was selected because the Thornthwaite and Mather model is only valid if there is no rewetting of the soil. The calculated values of SMC were compared with the observed ones to make sure that the modified model gave values close to the observed ones. The modified equation was validated by calculating MC for a dry period for Block N and comparing the results with the observed values of MC for that period. The period chosen for Block N was between 30/01/91 and 11/03/91.

3.6 Analysis of Historical Rainfall Data

Since the soil condition at the time of land preparation is mainly determined by the preceding climatic conditions during the fallow period, one can make an inference concerning the possibility of practicing double cropping of rice through the analysis of rainfall data for the fallow period. The objective here is to find out the number and the frequency of continuous dry days during the critical months. The critical months are those with high rainfall amounts and in which the fallow period falls. If a high amount of rainfall is received during the fallow period, it interferes with the DOP of the soil and hence the land preparation activities.

The month with the highest amount of mean monthly rainfall out of the staggering period for land preparation (see Section 2.1.4) was selected from each cropping season for analysis. To do this, March and August were selected as the critical months. The historical rainfall data (1962-1991) recorded covered a period of 26 and 25 years for March and August respectively. In some years, no rainfall records were made. The cropping seasons, land preparation periods for double cropping of rice at APS and monthly rainfall distribution are given in Fig. 3.8.

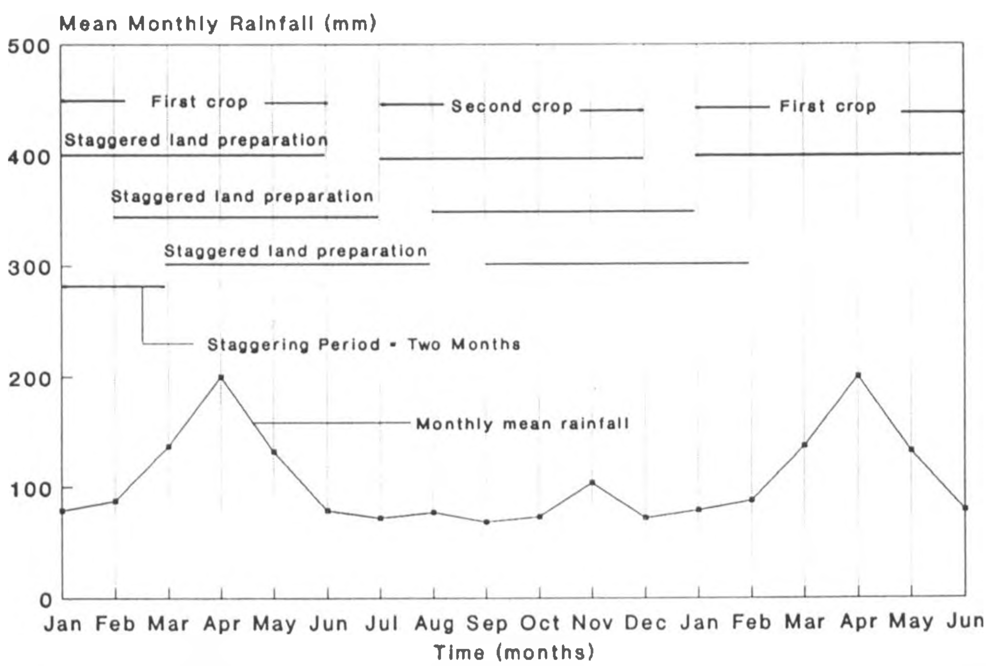


Fig. 3.8 Land Preparation CalendarShowing Staggering Period and Monthly Mean Rainfall.

Frequency curves were plotted from which one could tell the frequency a specific number of days (time t) a continuous dry weather could be expected. This was necessary in order to use the simulated drying curve (equation) which is valid provided there is no rewetting of soil (or rainfall is less than 5.0 mm). Having determined time t from the frequency curves, the extent to which the soil dries (or penetration resistance) before land preparation was predicted using the relationships derived from the simulation process.

4. RESULTS AND DISCUSSION

4.1 Results of Bulk Density Determination

The bulk density determined for APS ranged between 0.92 for upper soil layer and 1.09 g/cm^3 for the 60 cm depth. Taking the considered soil profile, the average bulk density was found to be 1.01 g/cm^3. However, the average BD for the layer 0-30 cm (which is of major concern in this study) was found to be 0.97 g/cm^3. According to Foth (1984), the bulk density of clay soils varies from 1.0 to 1.3 g/cm^3. The results of BD determination for the various layers and replicates is shown in Table 4.1 but the data for determining the BD is shown in Annex 4.

Table 4.1 Results of Bulk density determination

Replication	Sampling Points (cm) 0 BD (g/cm^3)	15 BD (g/cm^3)	30 BD (g/cm^3)	45 BD (g/cm^3)	60 BD (g/cm^3)
1.	0.83	0.99	0.96	1.00	1.08
2.	0.96	0.93	1.03	1.01	1.11
3.	0.88	1.01	1.03	1.06	1.04
4.	0.96	1.03	1.04	1.10	1.13
5.	0.99	0.99	1.01	1.02	1.10
6.	0.89	1.01	1.01	1.06	1.10
Mean	0.92	0.99	1.01	1.04	1.09

4.2 Soil Moisture Content as Monitored During the Fallow Period

From the date of drainage for harvesting, and in the absence of rainfall, SMC in the profile decreases with time. The soil surface dries faster. Re-wetting (by rainfall) increases the amount of SMC in the profile. If there is a considerable long dry spell, the soil dries to a certain degree leaving some residual moisture in the soil profile. For the period between December 1990 and May 1991, the observed trends of SMC in Blocks D, N, and A under various treatments with respect to rainfall and time in the soil layers 0-30 and 0-60 cm depths are presented in Figures 4.1, 4.2 and 4.3.

It was observed that during the drying period, SMC did not at all times correspond

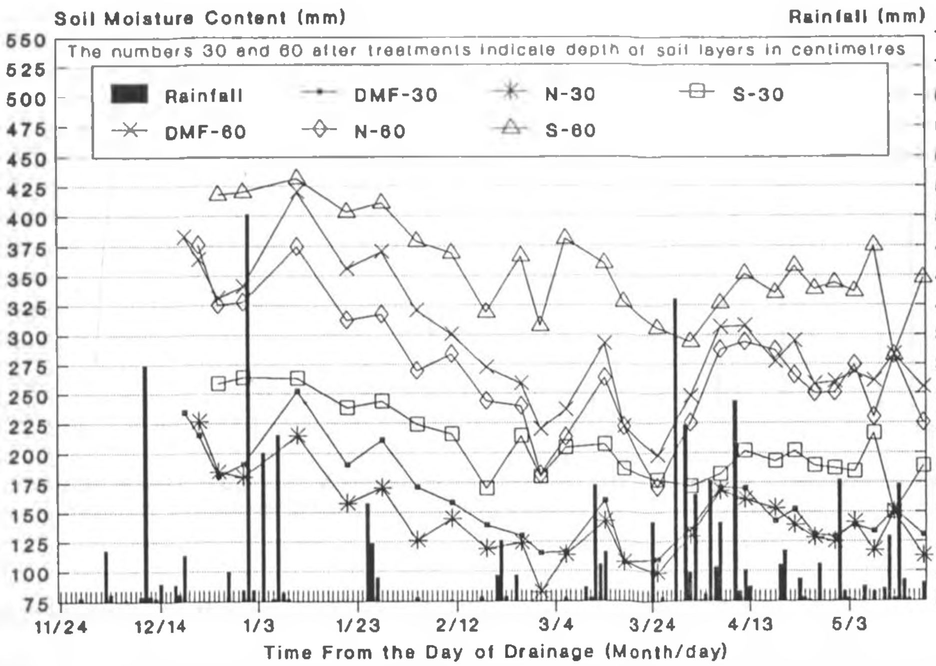


Fig. 4.1 Soil Moisture Content Variation With Time and Rainfall Under Drain-Middle-Feeder, Nursery and Straw Treatments - Block D

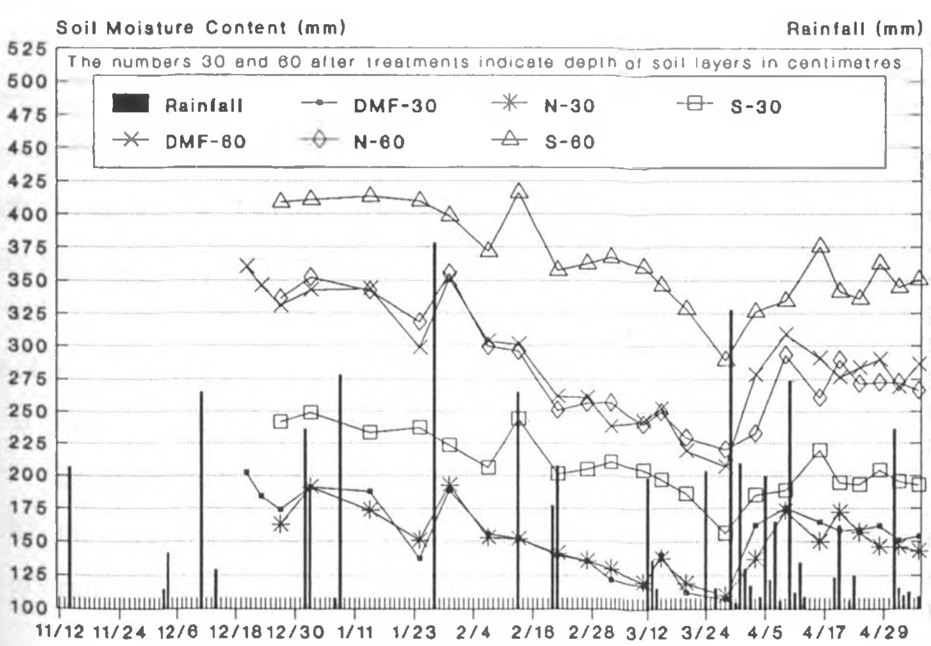


Fig. 4.2 Soil Moisture Content Variation With Time and Rainfall Under Drain-Middle-Feeder, Nursery, and Straw Treatments - Block N

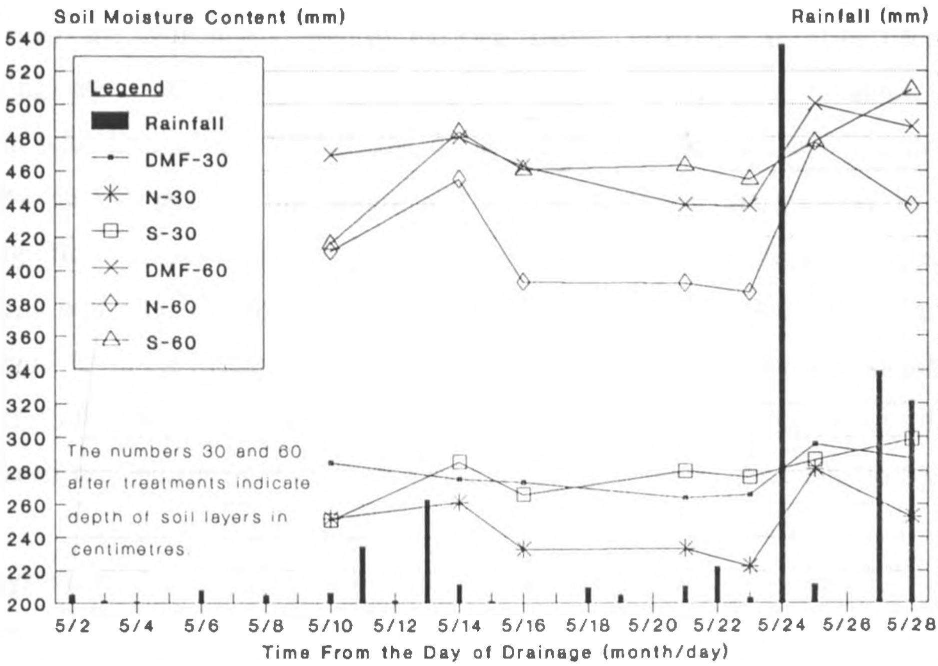


Fig. 4.3 Soil Moisture Content Variation With Time and Rainfall Under Drain-Middle-Feeder, Nursery, and Straw Treatments - Block A

proportionally to the amount of rainfall received as would have been expected. For instance from Fig. 4.1, total rainfall amounts received in the periods from 24/11/90 to 24/01/91 (an interval of 61 days) and from 24/03/91 to 13/04/91 (an interval of 20 days) were 158.4 and 163.4 mm respectively. Spread equally over the respective intervals, these rainfall amounts were equivalent to 2.6 mm/day and 8.2 mm/day. Therefore, the rainfall intensity in the second interval was 3.2 times more than the rainfall intensity in the first interval. However, the average SMC (of 365.5 mm) recorded in the first interval was 1.4 times more than the average SMC (of 264.7 mm) recorded in the second interval which received more rainfall than the first one. A similar trend is observed in Block N (see Fig. 4.2) in the periods from 20/12/90 to 26/1/91 and 28/3/91 to 11/4/91. From Fig. 4.3, during the initial stages of the DOP of the soil, the MC was comparable.

The above observations were attributed to three main factors:

a) time lapse between drainage for harvesting and sampling, i.e. the length of the drying period;
b) the degree (or stage) to which the soil had dried before a rain event;
c) rainfall intensity of each storm.

After drainage for harvesting (normally carried out two to three weeks before harvesting of rice), the DOP was slowed by the rice stubble. Kamp et al. (1982) found that the drying rate is affected by stubble height and other management variables. Therefore, even with little or no rainfall, the drying of the soil during the initial drying period (between drainage for harvesting and beginning of harvesting) may be said to be insignificant as demonstrated in Fig. 4.3. Even after three to four weeks after harvesting rice, it was very difficult to walk in the fields when sampling as the fields were still very soggy. In all the blocks, SMC initially remained almost constant with slight increments after a rain event. However, a time reached after several (40-60) days of drying when isolated rain storms of even 20-40 mm did not significantly contribute to SMC.

A systematic drop in SMC under all the treatments was observed after 8/1/91 and 28/1/91 in Fig. 4.1 and 4.2 respectively. It was noticed that this drop in SMC coincided with the time when cracks begun to develop on the soil surface in the respective blocks. After this stage of drying (i.e. when cracks had formed), it was observed that rainfall had almost no significant influence on the DOP of the soil. This is demonstrated in Fig. 4.1 during the period from 8/1/91 to 28/2/91 and in Fig. 4.2 in the period from 28/1/91 to 28/3/91.

After cracks had developed on the soil surface, a rain storm would seal all the cracks and saturate the top soil layer which in turn would permit very little moisture into the soil profile. Where an isolated rain event was involved and the subsequent one or two days were dry, cracks would quickly form again and the MC would drop significantly. However, in the case where rainfall was persistent for several days (e.g. between 24/3/91 and 13/4/91 in Fig. 4.1), the SMC increased but did not reach saturation point except in the top soil layer.

If rainfall intensity is greater than the infiltration rate of a soil, most of the rainfall becomes runoff. More rainfall turns into runoff especially when a soil has a low infiltration rate which is a characteristic property of clay soils. The soils at APS had a low infiltration rate of 0.01-2.66 cm/hr (Wandahwa 1988). As such, once rainfall intensity is greater than the above infiltration rate and the top layer of the soil has been saturated, very little water infiltrates into the profile. It was observed that immediately after heavy downpours (which is very common at APS), change in MC was mainly restricted to the top (0-15 cm depth) soil layer. However with time, a change would also be noticed in the other layers. Immediately after a long light shower, a significant change in SMC was observed in the soil layer 0-30 cm depth.

For comparison of SMC under the various treatments, means over the whole sampling periods for each block were computed. The results are presented in Table 4.2. From Table 4.2 and also from Figures 4.1, 4.2 and 4.3, SMC under treatment N in comparison with the other treatments always recorded a lower value with differences ranging from 6.0 to 86.6 mm depending on treatments and Blocks. SMC under treatment S showed a high value than the other except in Block A where the difference between treatments S and DMF was very small, 0.4-1.7 mm (see Table 4.2).

Table 4.2 Average SMC Over the Sampling Period and Differences Between Various Treatments

Treatment	Block D		Block N		Block A	
	SMC (mm)	Difference (mm)	SMC (mm)	Differ. (mm)	SMC (mm)	Differ. (mm)
			0-30 cm Depth Soil Layer			
S	204.6	S-N = 61.6	207.6	58.0	277.6	29.8
DMF	158.1	S-DMF = 46.5	155.6	52.0	278.0	0.4
N	143.0	DMF-N = 15.1	149.6	6.0	247.8	30.2
			0-60 cm Depth Soil Layer			
S	355.4	S-N = 86.6	364.2	84.1	466.3	45.0
DMF	292.5	S-DMF = 62.9	289.3	74.9	468.0	-1.7
N	268.8	DMF-N = 23.7	280.1	9.2	421.3	46.7

The difference in SMC under treatments N and DMF ranged between 6.0 and 30.2 mm, on average 17.1 mm in the soil layer 0-30 cm depth. In the soil layer 0-60 cm depth the difference ranged between 9.2 and 46.7 mm which on average was 26.5 mm. This means that the rate of the DOP in the nurseries was higher than in the other parts of the fields. The reason for these differences was attributed to the structural status of the soil under different treatments. Wandahwa (1988) found that the soils at APS in general have a high propensity for structural recovery after puddling, rice production under flooded conditions and drying. It was concluded that the rate of structural recovery in the field nurseries was higher than in other parts of the fields. Therefore, the use of machinery during land preparation does seem to have a negative effect on the DOP of the soil.

The highest SMC was always recorded under the S treatment except at the beginning of the DOP of the soil when straw or ash acted as protective cover from the rain and hence preventing the rain water from entering the soil profile (see Table 4.2 under Block A). However, as the DOP progressed, straw or ash hampered evaporation and therefore the rate of the DOP was lower in comparison with the other treatments. From Figures 4.1 and 4.2 as well as Table 4.2, the difference in SMC in Blocks D and N under the DMF and S treatment ranged between 46.5 and 52.0 mm in the soil layer 0-30 cm depth. In the soil layer 0-60 cm depth, the difference ranged between 62.9 and 74.9 mm. These figures show that straw or ash had a significant effect on the DOP of the soil.

A two way analysis of variance was carried out with data from Blocks D and N for the 0-30 cm soil depth to investigate whether the differences obtained from various treatments and Blocks were statistically significant or not. Block A was excluded in this analysis because of the unequal duration of sampling with the other Blocks. In the analysis, the differences were taken as treatments and Blocks D and N as blocks (see Table 4.3). A significance level of 0.05 was used in the analysis.

Table 4.3 Differences in SMC Among Treatments.

Differences	Block D	Block N	TOTAL
S-N	61.6	58.0	119.6
S-DMF	46.5	52.0	98.5
DMF-N	15.1	6.0	21.1
TOTAL	123.2	116.0	239.2

Since $F=49.5$ exceeded $F_{0.05}(2, 2\ df)=19.0$, it was concluded that the differences among treatments (DMF, N and S) were significant. There was no significant difference between Blocks D and N since $F=0.3$ did not exceed $F_{0.05}(1,2df)=18.5$ (see Table 4.4).

Table 4.4 ANOVA for SMC Differences Among Treatments and Blocks

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F	$F_{0.05}$
Difference	2.0	2689.7	1344.9	49.5	19.0
Blocks	1.0	8.6	8.6	0.3	18.5
Error	2.0	54.4	27.2		
Total	5.0	2752.7			

Straw cover (of 3360 kg/ha) as compared to no-cover situation was found to halve the rate of evaporation (Greb 1966). With no straw cover, Bond and Willis (1969 and 1970) found that initially the DOP of soil was characterized by a high constant rate of drying followed by a rapidly falling rate of drying. When a straw cover ranging from 6.7 to 9 t/ha was applied, they found that the initial drying rate of soil was 10 to 20% of the drying rate with no cover. However at APS, even without the straw cover, initially the DOP was found to be slow.

4.3 Penetration Resistance Monitored During the Fallow Period.

Measuring the penetration resistance (PR) under saturated conditions was found to be relatively inaccurate. It was observed that under wet conditions, even when a cone of a bigger base area was used, it was still less sensitive than when the soil was relatively dry. This observation agrees well with those of Wells (1978) and Wong (1989). It was found that during the initial stages of the DOP, re-wetting of the soil drastically reduced PR especially in the top soil layer (0-15 cm). After cracks had began to develop on the soil surface, although PR would still be drastically reduced by rainfall, the soil regained strength faster than during the initial stages of the DOP. This was attributed to the recovering of the soil structure once the soil had dried to a certain degree. The observed trends and PR variation with rainfall in the soil layers 0-30 and 0-60 cm depth over the fallow period are presented in Figures 4.4, 4.5, 4.6, 4.7 and 4.8.

Unlike SMC which did not change significantly with rainfall during isolated storms, PR changed drastically with rainfall as demonstrated in Figures 4.4 - 4.8. Even at the initial stages of the DOP, PR was observed to react sharply to changes in SMC due to rainfall

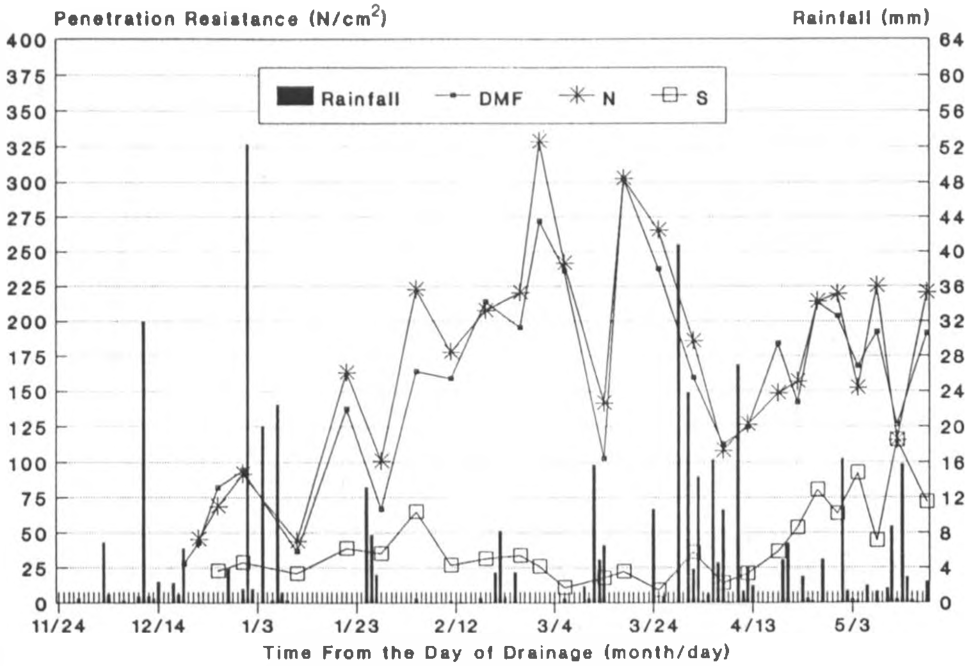


Fig. 4.4 Penetration Resistance Variation With Time and Rainfall Under Drain-Middle-Feeder, Nursery and Straw Treatments For the Layer 0-30 cm - Block D

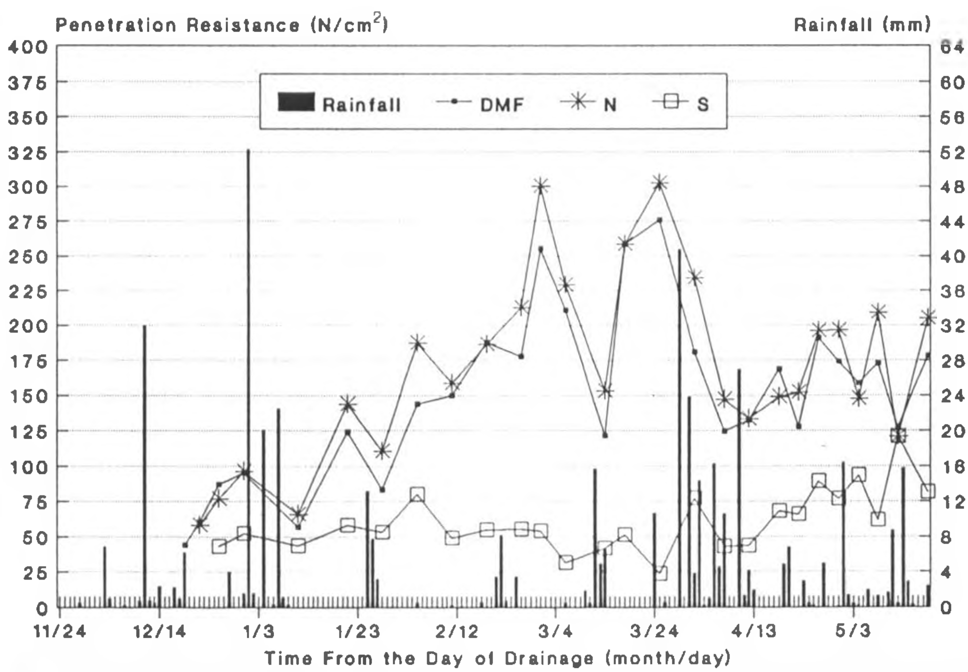


Fig. 4.5 Penetration Resistance Variation With Time and Rainfall Under Drain-Middle-Feeder, Nursery and Straw Treatments For the Layer 0-60 cm - Block D

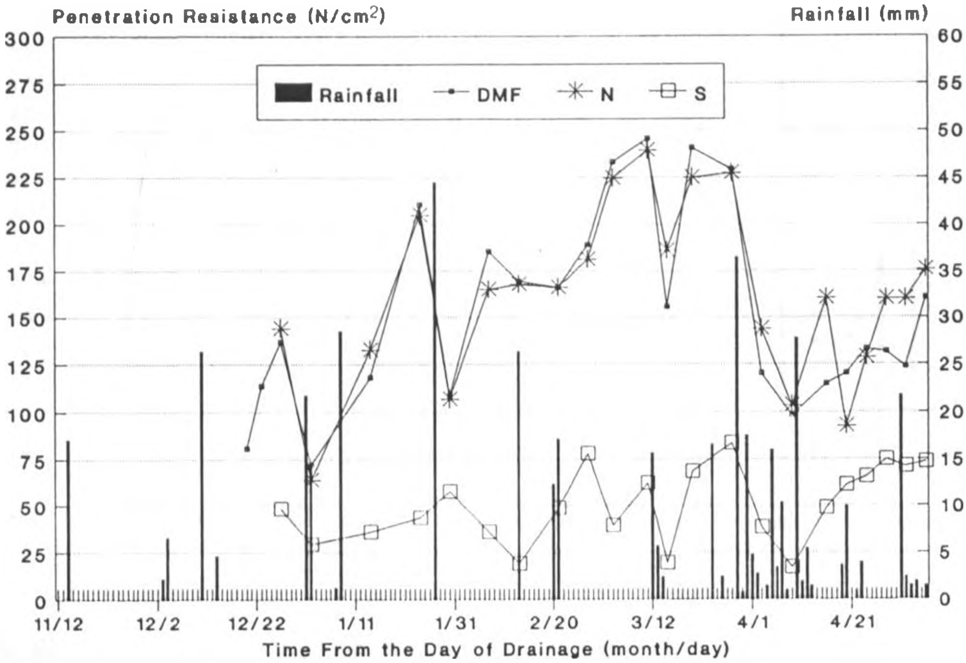


Fig. 4.6 Penetration Resistance Variation With Time and Rainfall Under Drain-Middle-Feeder, Nursery and Straw Treatment For the Layer 0-30 cm - Block N

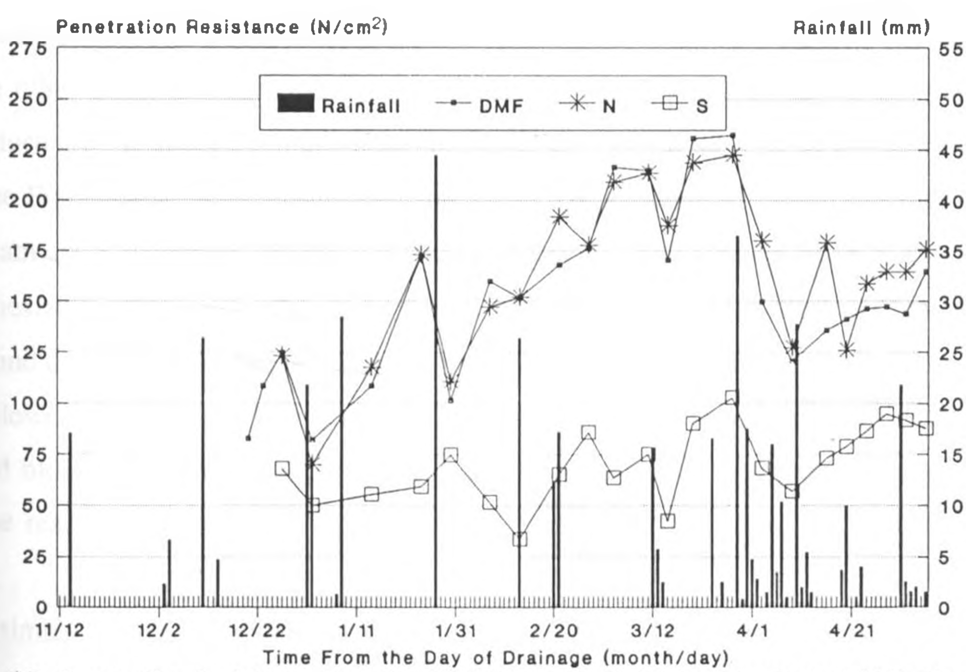


Fig. 4.7 Penetration Resistance Variation With Time and Rainfall Under Drain-Middle-Feeder, Nursery and Straw Treatment For the Layer 0-60 cm - Block N

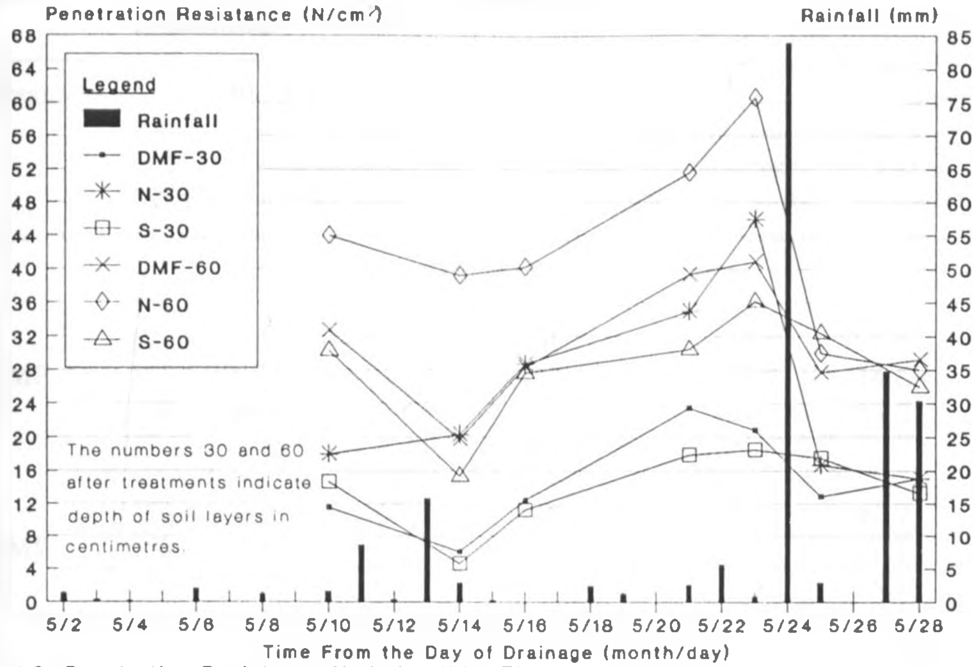


Fig. 4.8 Penetration Resistance Variation With Time and Rainfall Under Drain-Middle-Feeder, Nursery and Straw - Block A

(see Fig. 4.8). It was observed that the top soil layer 0-15 cm depth responded faster to changes in MC more than the other layers that were considered.

Under treatment S, PR at the initial stages of the DOP was in the same range with data obtained from treatments N and DMF. After several days of drying of the soil, PR under the other treatments (see Annexes 4, 5, and 6). It was also observed that rain did not reduce the PR under treatment S so drastically as it did in the case of the other treatments (see Figures 4.4 - 4.8). Therefore, there was less variation in PR with rainfall under the treatment S increased slightly but remained low as compared to the data obtained from ashes/straw than under the DMF or nursery. Comparing the three treatments, it was found that during the fallow period in all the blocks, the N treatment recorded higher PR, followed by DMF and finally the S treatment. Means were computed for each treatment and block and the differences between the means under each treatment were evaluated. The results are shown in Table 4.5.

A similar statistical analysis of variance as the one described in the previous Section was carried out with data obtained from Blocks D and N for the 0-30 cm depth to find out whether the differences in PR under the various treatments were significant.

Table 4.5 Average PR Over the Sampling Period and Differences Between Various Treatments

Treatment	Block D		Block N		Block A	
	PR (N/cm²)	Difference (N/cm²)	PR (N/cm²)	Differ. (N/cm²)	PR (N/cm²)	Differ. (N/cm²)
			0-30 cm Depth Soil Layer			
S	172.8	N-S = 132.0	161.7	110.7	25.7	11.7
DMF	155.1	N-DMF = 17.7	152.4	9.3	14.6	11.1
N	40.8	DMF-S = 114.3	51.0	101.4	14.0	0.6
			0-60 cm Depth Soil Layer			
S	170.4	N-S = 109.8	163.1	92.4	41.9	13.6
DMF	150.7	N-DMF = 19.7	152.0	11.1	31.1	10.8
N	60.8	DMF-S = 90.6	70.7	81.3	28.3	2.8

Table 4.6 Differences in PR Among Treatments

Treatments	Block D	Block N	TOTAL
N-S	132.0	110.7	242.7
N-DMF	17.7	9.3	27.0
DMF-S	114.3	101.4	215.7
TOTAL	264.0	221.4	485.4

Table 4.7 ANOVA for PR Differences Among Treatments and Blocks

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F	$F_{(0.05)}$
Differences	2.0	13810.5	6905.3	322.1	19.0
Blocks	1.0	302.5	302.5	14.1	18.5
Error	2.0	42.9	21.4		
TOTAL	5.0	14155.9			

The data used are presented in Table 4.6 while the results of the analysis are shown in Table 4.7. Highly significant differences in PR among treatments were found to exist since $F=322.1 >> F_{0.05}(2, 2\ df)=19.0$. Between Blocks, there was no significant differences in PR as demonstrated in Table 4.7.

Referring to Table 4.5, in Blocks D and N, highly significant differences in PR between treatments S and N (ranging between 92.4 and 132.0 N/cm²) and between S and DMF (in the range of 81.3 and 114.3 N/cm²) were observed. These significant differences were observed where the soil had a long time of about six months to dry as opposed to Block A where observations were carried out for only one month.

In comparison with treatments N and DMF, the effect of ash/straw cover on the PR was found to be multiplicative. In the soil layer 0-30 cm depth, ashes or straw reduced PR by a factor ranging between 3.0 and 4.2 (on average 3.6). However, the reduction factor in the soil layer 0-60 cm depth ranged between 2.1 and 2.8 (on average 2.4). The difference between the two soil layers was attributed to the fact that ash/straw cover affect PR more seriously in the soil layer 0-30 cm depth. Kamp et al. (1982) found that the rate of increase of soil CI without straw cover to be 23.2 kPa and with cover to be 8.7 kPa which is a reduction factor of 2.7. From Figures 4.4, 4.5, 4.6 and 4.7, there was no outright discernible relationship between PR and time for the two soil layers. Only where there was a long dry period was an orderly increase in PR observed. The relationship in this case was exponential.

In Section 2.1.4, it was shown that with DCS at APS, the fallow period is only one month. During one month of drying of the soil in the selected tenant holding in Block A, the average PR in the soil layer 0-30 cm depth under treatments S and DMF were 14.0 and 14.6 N/cm² respectively. These values were far much less than the reported safe SBC by various authors working in lowland rice fields as shown below.

Johnson (1972)	-	(70 Ib/in²) ≈ 50 N/cm²;
Ezaki et al. (1976)	-	30 to 40 N/cm²;
Kamp et al. (1982)	-	690 kPa or 69 N/cm²

Therefore, the PR attained (on average 14.3 N/cm² under treatments S and DMF in Block A) after one month of drying is inadequate in comparison with the required PR (about 50 N/cm²) for good trafficability. As such immobility would be inevitable if the fallow period would be one month as it was with the DCS at APS. Under these conditions, it would be impossible to practice the DCS.

4.4 Penetration Resistance Versus Soil Moisture Content.

During the DCS of rice production at APS, it was reported that the soil does not dry below 30 cm deep (AIRS, 1972). Ezaki, et al. (1976) observed that only in the soil layer 0-20 cm depth where there exists a close relationship between PR and tractor trafficability. Kamp et al. (1982) indicated that the depth 15-20 cm represents the critical depth of sinkage if vehicle mobility problems were to occur. With these considerations, more attention in this study will be given only to the soil layer 0-30 cm depth.

Several researchers have reported curvilinear relationships between soil moisture content and penetration resistance (Camp and Lund, 1968; Utomo and Dexter, 1981; Hussain et al. 1985; Perfect, et al. 1990). Utomo and Dexter, (1981) and Hussain, et al. (1985) found that there was a highly significant relationship between the resultant of expressing MC as a fraction of plastic limit, and the logarithm of PR.

The trends exhibited by plotting the observed values of PR against SMC for the soil layers 0-30 and 0-60 cm depth were exponential curves. This agrees well with the observations of the above mentioned authors. For the DMF and N treatments, exponential regression curves were fitted as shown in Figures 4.9 and 4.10. Since the PR vs. SMC curves were more or less the same for both Blocks D and N, only curves from Block D are presented below.

The average correlation coefficients (R) were 0.986 and 0.982 under treatments DMF and N respectively. Bearing in mind what has been reported by other authors, such high correlation factors cannot be attributed to chance. It means that there exists relationships between PR and SMC which are dependable and could be used to predict one parameter if the other was known.

Whereas there was a strong relationship between PR and MC under the DMF and N treatments, it was not so with the data obtained under the S treatment (see Fig. 4.11). No discernible relationship was noticed between PR and SMC from the S treatment. The great scatter in the observed points under treatment S was reflected by the low coefficient of correlation of 0.344 and the high standard deviation of 0.341 (see Fig. 4.11). This means that when the SMC is high, there is no correlation between penetration resistance

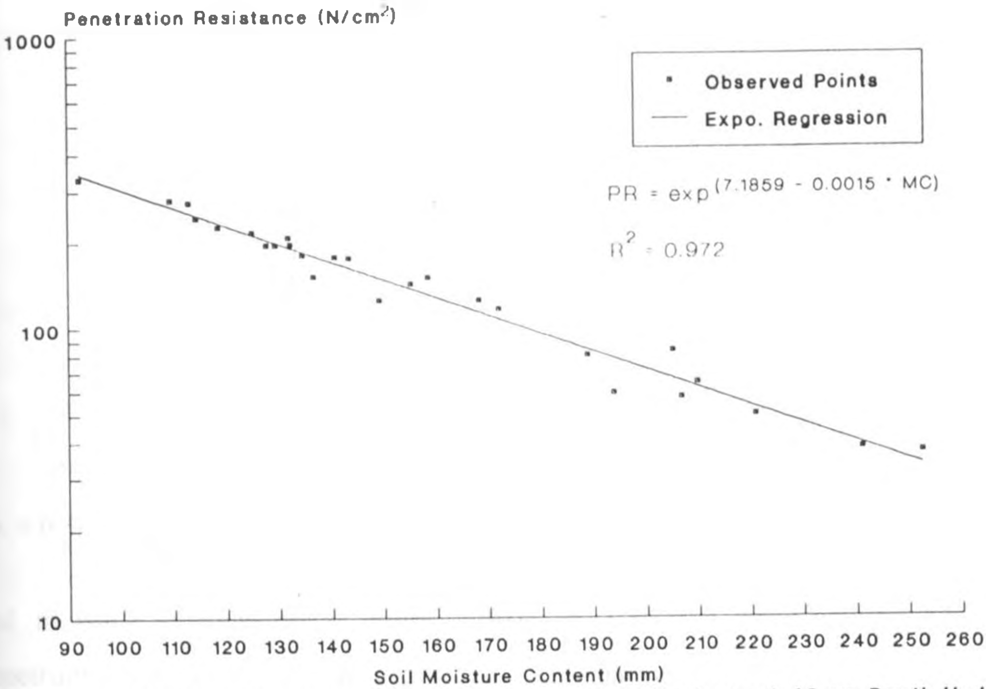


Fig. 4.9 Penetration Resistance vs. Soil Moisture Content in the Layer 0-30 cm Depth Under Drain-Middle-Feeder (DMF) Treatment - Block D

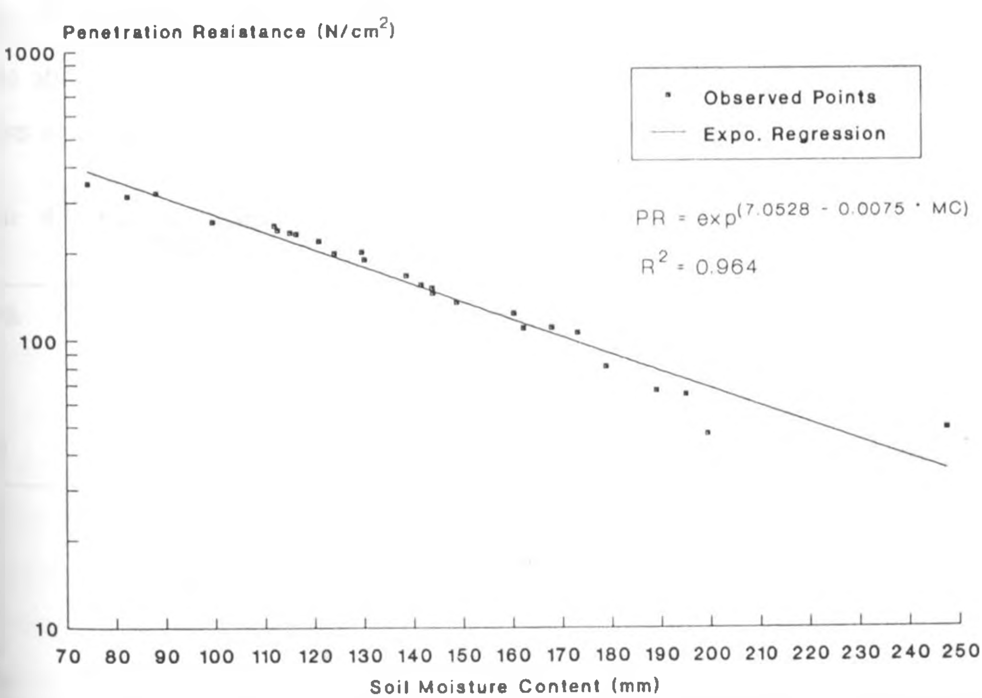


Fig. 4.10 Penetration Resistance vs. Soil Moisture Content in the Layer 0-30 cm Depth Under Nursery Treatment - Block D

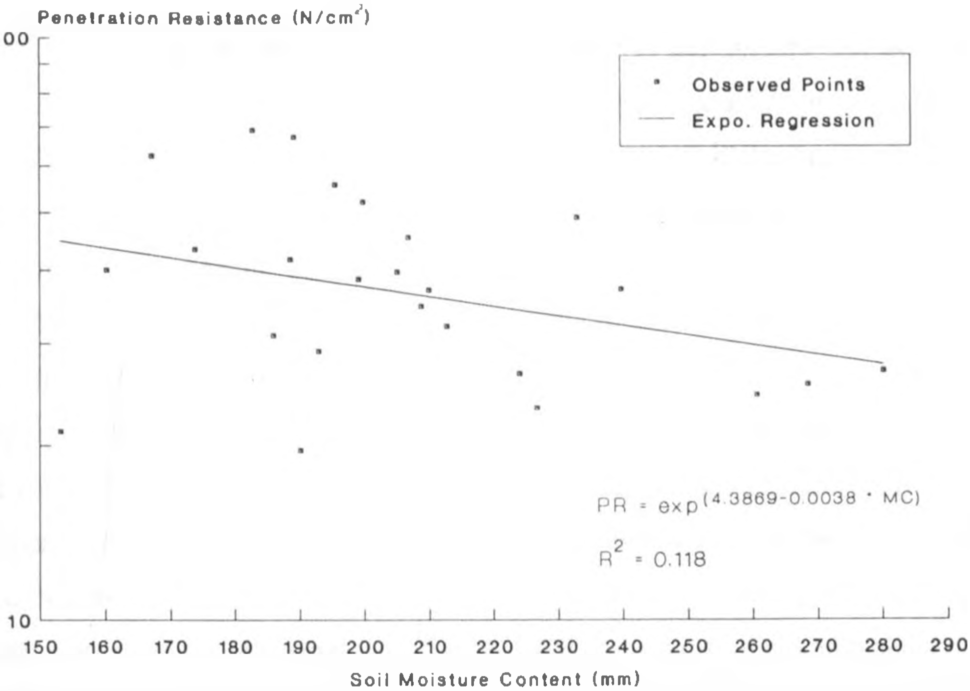


Fig. 4.11 Penetration Resistance vs. Soil Moisture Content in the Layer 0-30 cm Depth Under Straw/Ash (S) Treatment - Block D

and moisture content or as Wong (1989) puts it, the interpretation of the cone penetrometer data becomes very difficult. Comparing the five depth intervals, it was observed that PR increased with depth while MC decreased with depth. Since bulk density increased with depth (see Table 4.1), it was expected that PR would increase with depth also. However friction between the soil and the sounding rod of the penetrograph might also have contributed to the increased PR with depth. Some of the observations made above are summarized herebelow in form of a table (see Table 4.8). Table 4.8 shows a pooled mean of all the observed values of SMC and PR.

Table 4.8 Pooled Means of SMC and PR For the Various Sampling Depths, Soil Layers and Treatments

Depth	Treatments					
	DMF		N		S	
(cm)	SMC (%)	PR (N/cm²)	SMC (%)	PR (N/cm²)	SMC (%)	PR (N/cm²)
0-5	39.1	171.0	39.6	169.7	65.4	26.1
15	49.5	118.0	44.6	134.5	61.0	36.5
30	46.8	122.1	43.0	143.9	52.9	59.1
45	44.9	131.9	42.2	148.1	50.4	80.3
60	43.1	141.3	41.3	158.4	48.7	96.7
0-30	45.1	137.0	42.4	149.4	59.8	40.6
0-60	44.7	136.9	42.1	150.9	55.7	59.7

From Table 4.8, it can be seen that PR was highest in the nursery (on average 149.4 N/cm² for the soil layer 0-30 cm depth) and lowest under the ashes or straw (on average 40.6 N/cm²). There are several factors that could have contributed to the differences in the PR values with depth and treatments. These include bulk density (which could be an indicator of presence or absence of a hardpan), soil structure and shear strength. Wandahwa (1988) reported that double cropping of rice at APS lowers soil strength between 15 and 30 cm depth. Although by the time this survey was carried out double cropping of rice had been stopped, it can be seen that PR was lower in the second and third layers (i.e. 15 and 30 cm depths) as compared to the first and fourth layers. Under treatment DMF for instance the pooled means for the soil layer 15-30 cm depth was 120.0 N/cm² while that of the layers 0-5 and 45-60 cm depth were 171.0 and 136.6 N/cm² respectively. Bearing in mind that PR represents the combined shear and compressive characteristics of terrain (Wong 1989), then it can be concluded that even if double cropping of rice was stopped the soil at APS might not have recovered its shear strength as indicated by lower PR in the soil layer 15-30 cm depth in comparison with other soil layers. Low PR in soil layer 15-30 cm also implies that hardpans do not exit at APS. In Section 2.2 it was shown that hardpans form at a depth of 20-30 cm in rice fields.

The higher values of PR under treatment N in comparison with treatments DMF and S could be attributed to the mode of land preparation. In Chapter 3 it was mentioned that land preparation in the Nurseries is usually carried out manualy. Therefore it can be concluded that the soil structure in the nurseries has not been damaged as under the other treatments and hence the higher values of PR.

A pooled mean of the SMC and PR obtained from the S treatment for the layers between 0-30 cm gives a MC of 59.8% and a PR of 40.6 N/cm². In Section 2.3, literature has that the best results for wet rotavation are obtained when the SMC before flooding is between 20 and 22% on weight basis. Therefore, with a MC of 59.8%, a lot of energy would be required to puddle the soil during rotavation and hence encourage immobility. A PR of 40.6 N/cm² too is just within the critical range of poor trafficability and therefore there is high likelihood that areas under the ashes or straw have been contributing to the bogging down problems. Since the black cotton soils become very sticky when the SMC is between the sticky point and the LPL, the friction forces are very high and therefore values of PR obtained may be much higher than what they should have been. This means that the average value of PR under the ashes or straw may have been much less than the 40.6 N/cm^2.

Under the DMF and N treatments the SMC pooled mean were 45.1% and 42.4% respectively (see Table 4.8). Even though this was higher than the recommended SMC before flooding for wet rotavation, there were instances during the fallow period when the MC would drop to the range of 27% which is close to the recommended one of 20%. The drying model that will be developed in Section 4.5 will serve as a tool to predict when the right MC could be attained and therefore enable rotavation to be carried out at the right time.

4.5 Prediction of Trafficability

As it was shown in the previous section, there is a close relationship between penetration resistance and moisture content. The latter also depends on the time the soil dries provided there is no re-wetting within the drying period. Therefore by expressing penetration resistance as a function of moisture content, and moisture content as a function of time, two equations with three unknown parameters are obtained which can be solved as set of simultaneous equations if one of the variables could be determined independently. Since the objective is to find out how long it takes the soil to dry so as to enable land preparation operations to take place without bogging down, time could be determined independently (see Section 3.6) and then using the other two functions, test whether trafficability is possible or not. Due to the fact that trafficability during land preparation operations is mainly influenced by the top soil layer (0-30 cm depth), only this layer will be dealt with henceforth.

4.5.1 Prediction of Soil Moisture Content

In the processes of developing a general soil drying model for APS (Eq.3.11) on the basis of Thornthwaite and Mather equation in Section 3.5.2, three major equations were evolved and all together are listed below:

$$MC_e = SMC_s * \exp^{-(ET * t / SMC_s)} \qquad \ldots(3.8)$$

$$MC_a = MC_r + SMC_s * \exp^{(-ET * t / SMC_s)} \qquad ...(3.9)$$

$$MC_e = a * \exp^{(b * t)} \qquad ...(3.10)$$

$$MC_a = MC_r + a * \exp^{(b * t)} \qquad ...(3.11)$$

where,

MC_a = actual moisture content in the soil, (mm);

MC_e = part of the evaporable soil moisture that has not yet evaporated, (mm);

SMC_s = maximum moisture in the soil for evaporation at saturation, (mm);

MC_r = residual moisture content, (mm);

t = time since the start of drying, (days);

a, b = constants.

In order to determine constants *a* and *b*, the value of SMC_s had to be determined first. The minimum values of MC in Blocks D and N were found to be 107.4 and 107.0 mm respectively (see Annex 5 and 6). Therefore in this study, MC_r was taken to be 107.0 mm. The maximum value of MC recorded in Block D was 280.1 mm. Therefore, the maximum moisture for evaporation in the soil (layer 0-30 cm), was found to be:

$$SMC_s = 280.1 - 107 = 173.1 \text{ mm.}$$

The value of SMC_s was substituted in Eq. 3.8 and then MC_e calculated using the evaporation data for the period 10/01/91-11/03/91 for Block D. An exponential regression analysis was carried out using the values of MC_e and it was found that: a = 188.6 and b = -0.045. By substituting the values of *a* and *b* in Eq. 3.11, the resulting soil drying model for APS becomes:

$$MC_a = 107.0 + 188.6 * \exp^{(-0.045 * t)} \qquad ...(4.1)$$

Using Eq. 4.1, soil moisture content was estimated for Block D for a selected period for the soil layers 0-30 cm depth. The calculated values of MC were compared with the observed ones and these are presented in Table 4.9. Fig. 4.12 shows a graphical comparison of the observed and calculated MC values. From Fig. 4.12, it can be seen that Eq. 4.1 describes the DOP fairly well. The coefficient of correlation between the

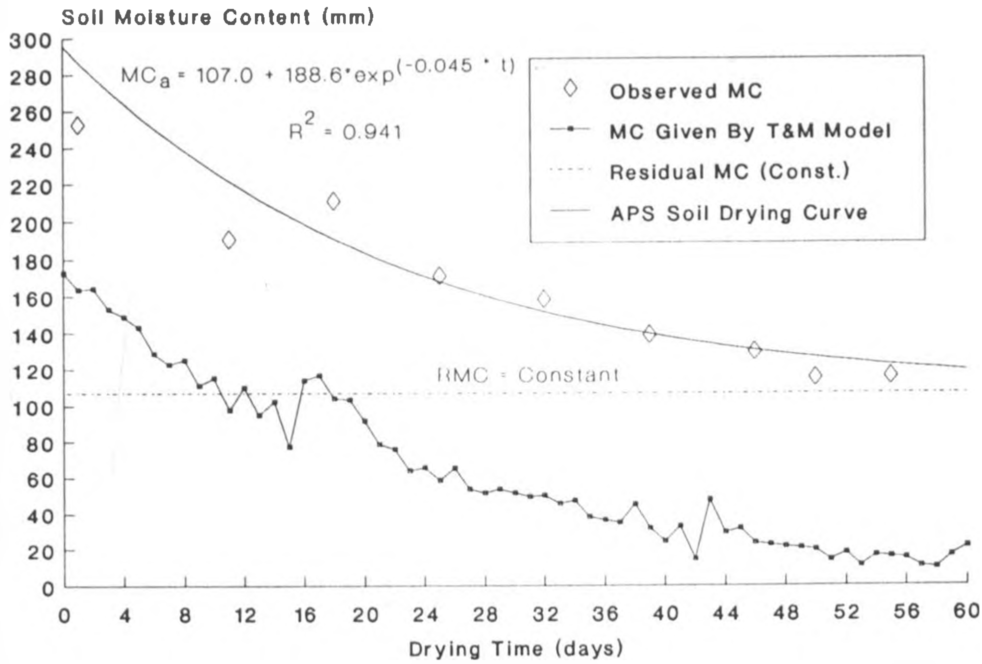


Fig. 4.12 Simulated Soil Drying Curve Showing RMC and SMC Obtained Using T&M Model.

observed and calculated values of MC was found to be 0.951.

The constant 188.6 represents the evaporable SMC or water which is required to saturate the soil during land preparation. The evaporable MC (or saturation requirement) is the difference between MC at saturation point and the residual moisture. The saturation requirement for Ahero from the observed moisture data for Block D was found to be 173.1 mm although a higher value of 188.6 mm was obtained through simulation. The difference was due to the time lag of 25 days between the date of drainage for harvesting (when MC was at saturation point) and the start of measurement of MC. Therefore the MC was not at saturation point which is approximately equal to 295.6 mm. Many researchers have reported different values for saturation requirements. Lenselink (1980a) recommended a saturation requirement of 175 mm for BIS. Chuaga (1980) and Van Gessel (1982) found that it required 153 and 155 mm respectively to saturate the soils at MISS. However, Githae and Ndiritu (1984) obtained a higher value of 168 mm for MISS. Bratamidjaja (1985), Deguchi (1975), Kung (1975), Nakagawa (1985) and Hasegawa, et al. (1985) report between 150 and 200 mm for saturation of clay rice growing soils in South East Asia and Sub-Saharan areas of Africa.

Table 4.9 Observed and Calculated Soil Moisture Content in the Depth 0-30 cm for a Selected Period for Block D

Date	Time of Drying (day)	Time From Date of Drainage (day)	Pan Evpo-ration (mm/day)	Sampling Depths 0-5 SMC (mm)	15 SMC (mm)	30 SMC (mm)	Observed Total MC In 0-30 cm Depth (mm)	Calculated SMC Using The Modified T&M Model (mm)
11/01	1	48	9.4	52.5	113.3	86.5	252.4	287.3
12/01	2	49	4.5					279.4
13/01	3	50	7.0					271.8
14/01	4	51	6.5					264.5
15/01	5	52	6.5					257.6
16/01	6	53	8.5					251.0
17/01	7	54	8.5					244.6
18/01	8	55	7.0					238.6
19/01	9	56	8.5					232.8
20/01	10	57	7.0					227.2
21/01	11	58	9.0	13.0	92.3	85.2	190.6	222.0
22/01	12	59	6.5					216.9
23/01	13	60	8.0					212.1
24/01	14	61	6.5					207.4
25/01	15	62	9.3					203.0
26/01	16	63	4.5					198.8
27/01	17	64	4.0					194.7
28/01	18	65	4.9	35.6	92.1	83.5	211.1	190.9
29/01	19	66	4.7					187.2
30/01	20	67	5.5					183.7
31/01	21	68	6.5					180.3
01/02	22	69	6.5					177.1
02/02	23	70	7.5					174.0
03/02	24	71	7.0					171.0
04/02	25	72	7.5	12.6	80.7	77.9	171.2	168.2
05/02	26	73	6.5					165.5
06/02	27	74	7.5					162.9
07/02	28	75	7.5					160.5
08/02	29	76	7.0					158.1
09/02	30	77	7.0					155.9
10/02	31	78	7.0					153.7
11/02	32	79	6.7	15.8	70.0	72.6	158.4	151.7
12/02	33	80	7.0					149.7
13/02	34	81	6.6					147.8
14/02	35	82	7.5					146.0
15/02	36	83	7.5					144.3
16/02	37	84	7.5					142.7
17/02	38	85	6.1					141.1
18/02	39	86	7.5	12.5	63.9	62.6	139.0	139.6
19/02	40	87	8.5					138.2
20/02	41	88	7.0					136.8
21/02	42	89	10.2					135.5
22/02	43	90	5.2					134.2
23/02	44	91	7.0					133.0
24/02	45	92	6.5					131.9
25/02	46	93	7.5	13.6	55.9	60.4	129.8	130.8
26/02	47	94	7.5					129.7
27/02	48	95	7.5					128.7
28/02	49	96	7.5					127.8
01/03	50	97	7.5	14.9	48.6	52.0	115.4	126.9
02/03	51	98	8.5					126.0
03/03	52	99	7.5					125.2
04/03	53	100	9.0					124.4
05/03	54	101	7.5					123.6
06/03	55	102	7.5	11.9	49.6	54.7	116.2	122.9
07/03	56	103	7.5					122.2
08/03	57	104	8.5					121.5
09/03	58	105	8.5					120.9
10/03	59	106	6.9					120.2
11/03	60	107	6.0					119.7

Eq. 4.1 is only valid when considering a DOP of the soil starting from the saturation point. If a drying period under consideration did not begin with MC at saturation point, then the evaporable moisture content has to be determined before Eq. 4.1 can be used. In this case the evaporable MC would be the difference between the initial moisture content (i.e. MC in the soil at the beginning of the drying period under consideration) and the MC_r. If the evaporable MC at time $t = 0$ is represented by SMC_0, then:

$$SMC_0 = SMC_{t=0} - MC_r \qquad \text{...(4.2)}$$

where,

$SMC_{t=0}$ = actual moisture content in the soil at the beginning of the drying period when $t = 0$

The modified model would then be:

$$SMC_a = 107.0 + SMC_0 * \exp^{(-0.045 * t)} \qquad \text{...(4.3)}$$

where,

SMC_0 = evaporable moisture in the soil at the beginning of a drying period under consideration, mm.

Finally, Eq. 4.3 was adopted as the soil drying model for APS and is valid even when the MC at the start of DOP was not at the saturation point. As such, the MC at time $t=0$ has to be measured. For validation of Eq.4.1, it was used to estimate MC for the longest "dry period" for Block N, and the obtained values were compared with the observed ones. The coefficient of correlation between the observed and the estimated values of MC was found to be 0.983 and therefore it was concluded that the model describes the DOP at APS well. Table 4.10 shows the values of the calculated MC and the observed ones and a graphical comparison is shown in Fig. 4.13.

Ndiritu, (1989) developed a soil drying model for MISS using a different approach and he arrived at an expression similar to the above one. However, the constants in his expression were different from the one above because he considered a soil depth of about 80 cm and certainly the soil and climatic conditions in Mwea are not the same as those of Ahero. In addition, Ndiritu (1989) lumped together the saturation requirement and the evaporable MC.

Table 4.10 Observed and Calculated SMC in the 0-30 cm Depth for a Selected Drying Period in Block N

Date	Time From Date of Drainage (day)	Drying Time (day)	Sampling Depths 0-5 SMC (mm)	15 SMC (mm)	30 SMC (mm)	Observed Total MC In 0-30 cm Depth (mm)	Calculated SMC Using Simulation Equation (mm)
30/01	79	0	22.8	83.2	82.7	188.6	188.6
31/01	80	1					185.0
01/02	81	2					181.6
02/02	82	3					178.3
03/02	83	4					175.2
04/02	84	5					172.2
05/02	85	6					169.3
06/02	86	7					166.5
07/02	87	8	14.1	71.0	71.0	156.1	163.9
08/02	88	9					161.4
09/02	89	10					159.0
10/02	90	11					156.7
11/02	91	12					154.5
12/02	92	13					152.5
13/02	93	14	15.3	67.2	70.2	152.7	150.5
14/02	94	15					148.5
15/02	95	16					146.7
16/02	96	17					145.0
17/02	97	18					143.3
18/02	98	19					141.7
19/02	99	20					140.2
20/02	100	21					138.7
21/02	101	22	25.0	57.7	57.1	139.8	137.3
22/02	102	23					136.0
23/02	103	24					134.7
24/02	104	25					133.5
25/02	105	26					132.3
26/02	106	27					131.2
27/02	107	28	15.1	60.3	60.2	135.5	130.1
28/02	108	29					129.1
01/03	109	30					128.1
02/03	110	31					127.2
03/03	111	32					126.3
04/03	112	33	12.3	53.7	55.4	121.4	125.5
05/03	113	34					124.7
06/03	114	35					123.9
07/03	115	36					123.1
08/03	116	37					122.4
09/03	117	38					121.8
10/03	118	39					121.1
11/03	119	40	11.2	50.9	55.5	117.7	120.5

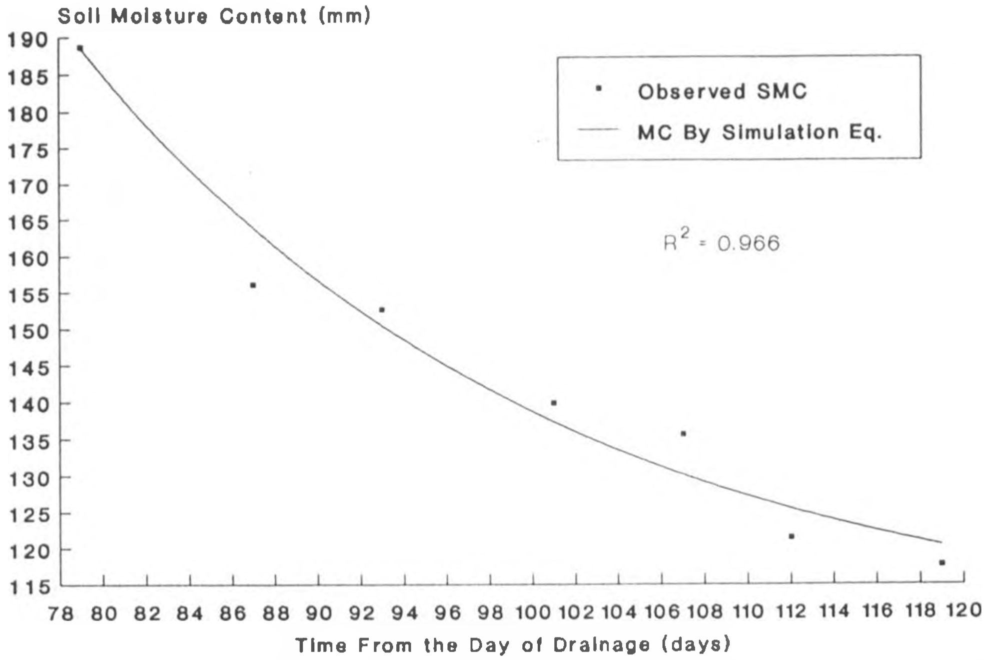


Fig. 4.13 Comparison of Observed and Calculated SMC Using the Simulation Equation.

4.5.2 Continuous Dry Weather Frequency Analysis

After determining the function of moisture content and time, the problem left is how the time parameter could be determined. Since the drying simulation equation is valid provided rainfall does not exceed 5.0 mm, the time parameter in question must be for the "dry period" (with rainfall $\leq$5.0 mm). Time was therefore calculated by analyzing the frequency of consecutive dry weather days within the critical months for land preparation operation (see Section 3.6). Probability distribution functions for the continuous dry weather days for the same months were determined. The results of this analysis for two critical months (March and August) for double cropping of rice at APS in graphical form is presented in Figures 4.14, 4.15, 4.16 and 4.17. Table 4.11 shows the determination of the probability functions for the two months.

The relationships between frequency F and time t for March and August are given by Eq. 4.4 and 4.5 respectively.

$$F_m = 11.8 * \exp^{(-0.266 * t)} \qquad \ldots(4.4)$$

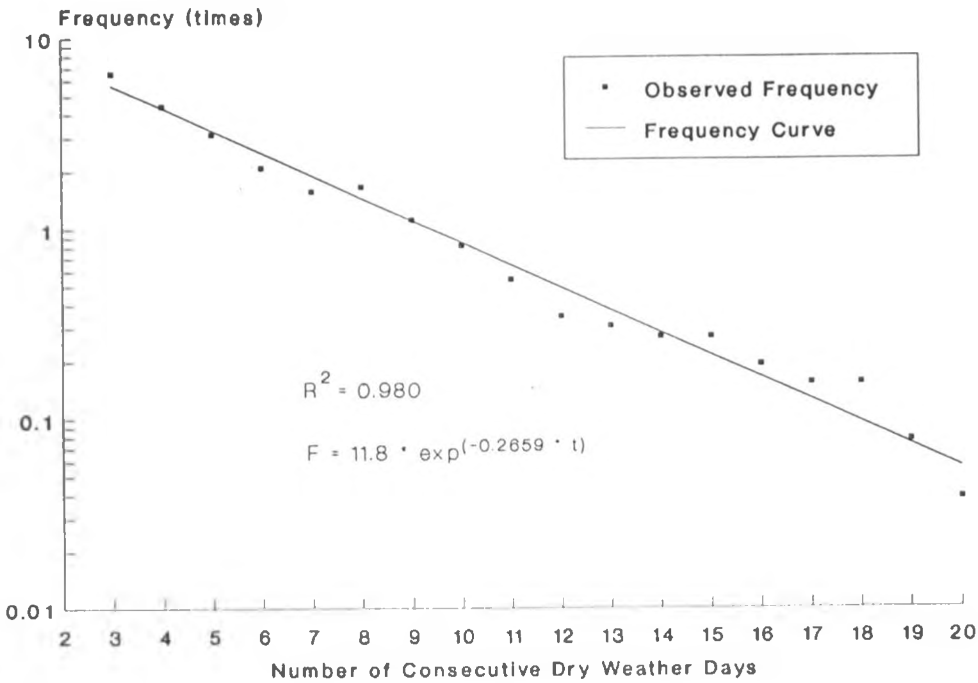


Fig. 4.14 Monthly Frequency of Continuous Dry Weather For March (1964-1991).

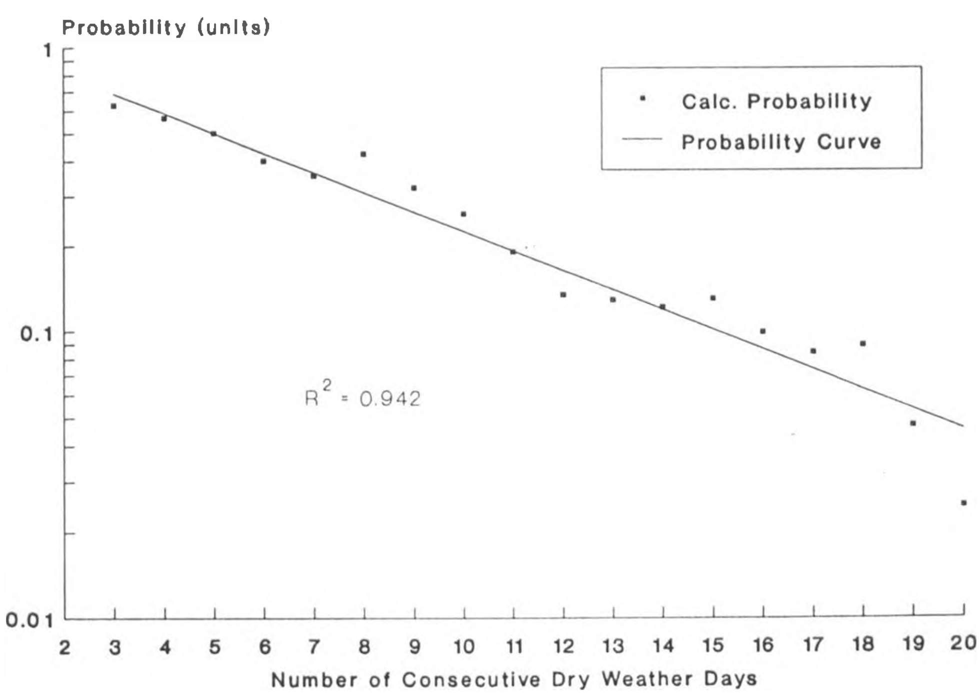


Fig. 4.15 Probability Distribution Curve For March.

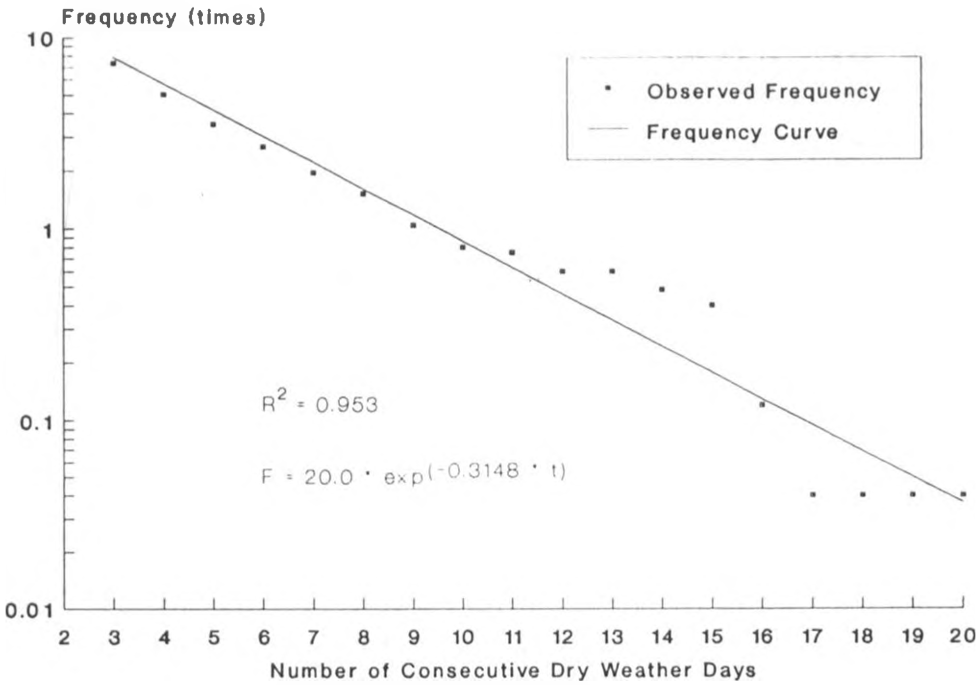


Fig. 4.16 Monthly Frequency of Continuous Dry Weather For August (1964-1990).

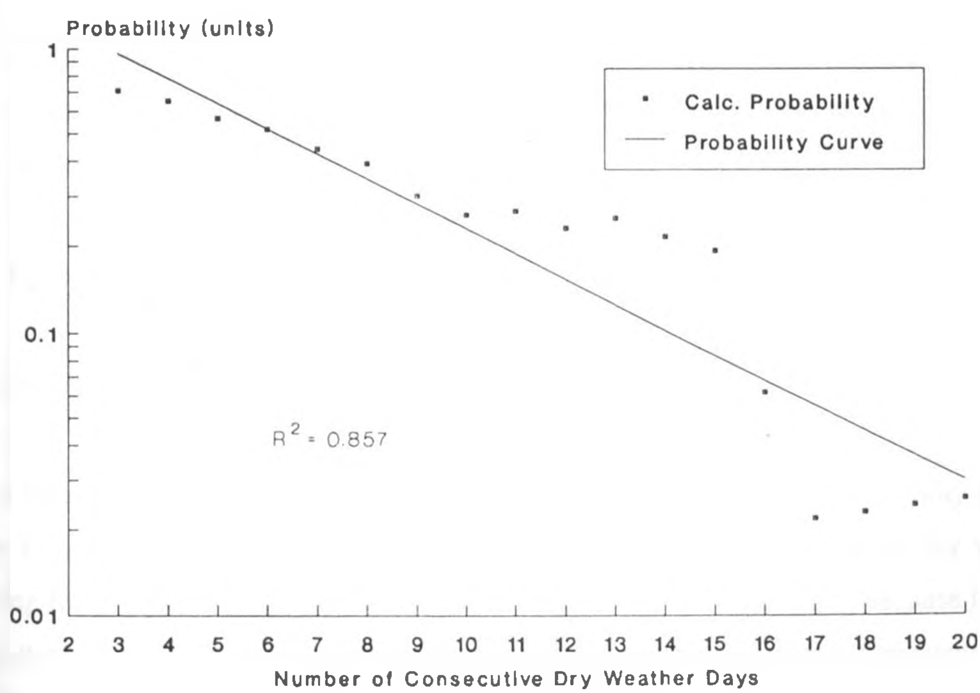


Fig. 4.17 Probability Distribution Curve For August.

Table 4.11 Determination of Probability For Continuous Dry Weather Days

Number of Dry Days	3	4	5	6	7	8	9	10	11
Maximum Times in a Month	10.00	7.50	6.00	5.00	4.29	3.75	3.33	3.00	2.73
Observed Times For March	6.50	4.38	3.12	2.08	1.58	1.65	1.12	0.81	0.54
Observed Times For August	7.32	5.04	3.52	2.68	1.96	1.52	1.04	0.80	0.75
Probability For March	0.65	0.58	0.52	0.42	0.37	0.44	0.34	0.27	0.20
Probability For August	0.73	0.67	0.59	0.54	0.46	0.41	0.31	0.27	0.28
Number of Dry Days	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Maximum Times in a Month	2.50	2.31	2.14	2.00	1.88	1.76	1.67	1.58	1.50
Observed Times For March	0.35	0.31	0.27	0.27	0.19	0.15	0.15	0.08	0.04
Observed Times For August	0.60	0.60	0.48	0.40	0.12	0.04	0.04	0.04	0.04
Probability For March	0.14	0.13	0.13	0.14	0.10	0.09	0.09	0.05	0.03
Probability For August	0.24	0.26	0.22	0.20	0.06	0.02	0.02	0.03	0.03

$$F_a = 20.0 * \exp^{(-0.315 * t)} \qquad \ldots(4.5)$$

where,

F_m = Frequency for continuous dry weather for March, (number of times);

F_a = Frequency for continuous dry weather for August, (number of times);

t = duration of a continuous dry weather period, (days).

To find out how long a continuous dry weather occurring, for example once in the month of March would last, one would just need to read from the frequency curve for March the time that corresponds to a frequency of one as indicated in Fig. 4.14. Alternatively, substituting $F=1$ in Eq. 4.4 would give the time that corresponds to a frequency of one. In this case the value of t would be approximately 9 days from Fig. 4.14 and from Eq. 4.4, t would be:

$$F_m = 1 = 11.8 * \exp^{(-0.266 * t)}$$

Hence: $t = 9.28 \approx 9$ days

This means that in the month of March, it would be expected with a probability of 25% (see Fig. 4.15), that at least once, there would be a period of continuous dry weather lasting for 9 days. A frequency of one was chosen in the above example because it would give the longest continuous dry weather corresponding to a non-fractional frequency. The probability is very low to rely on.

Assuming that the MC at the start of the DOP of the soil is at saturation point, it was found that the soil drying curve for APS can be represented by equation 4.1 and therefore, by substituting *time* t = 9 days in Eq. 4.1 gives:

$$MC_a = 170 + 188.6 * \exp^{(-0.045 * 9)} = 232.8 \text{ mm.}$$

Therefore even if the soil at the onset of these 9 consecutive dry (weather) days was at the point of saturation (295.6 mm), it would be expected to evaporate to a MC of 232.8 mm. On average this is a drying rate of 7.0 mm/day. The mean evaporation rate for March during the experiment was found to be 7.1 mm/day.

4.5.3 Prediction of Penetration Resistance and Trafficability

Several authors have indicated that prediction of trafficability can be done by knowing the soil physical parameters and others have indicated that a relationship between PR and soil properties is possible if adequate data is available (e.g. Raghavan and Mckyes, 1979; Hayes et al. 1981; Wells and Treesuwan, 1982). As reported by Wells and Treesuwan (1982), Collins suggested a relationship given below:

$$\ln(CI) = a_{ci} + b_{ci}\ln(MC) \qquad ...(4.6)$$

where:

a, b = constants

CI = Cone Index

MC = Moisture Content

However Collins could not define a_{ci} and b_{ci} in terms of commonly measured soil physical properties. Wismer and Luth (1974) also developed a model incorporating the CI, the dynamic load on tractor wheels and the dimensions of the tire as given below:

$$C_n = \frac{CI * b * d}{W} \qquad ...(4.7)$$

Where,

C_n = wheel numeric;

CI = Cone Index, (N/cm^2);

b = tire width, (m);

d = tire diameter (m) and

W = dynamic load on the wheels.

In this study, in order to predict whether trafficability is possible or not, a simple function of PR and SMC was developed so that after determining SMC from the soil drying model, penetration resistance could be evaluated. As was explained in Section 3.5.1, the relationship between PR and SMC was developed through regression analysis of the observed data for the soil layer 0-30 cm depth. In this calculation, all the observed data (from both Block D and N) for the soil layer 0-30 cm was lumped together. With PR, average values for the three layers were calculated for each sampling day while the total SMC was determined for the same. The results are shown in Fig. 4.18.

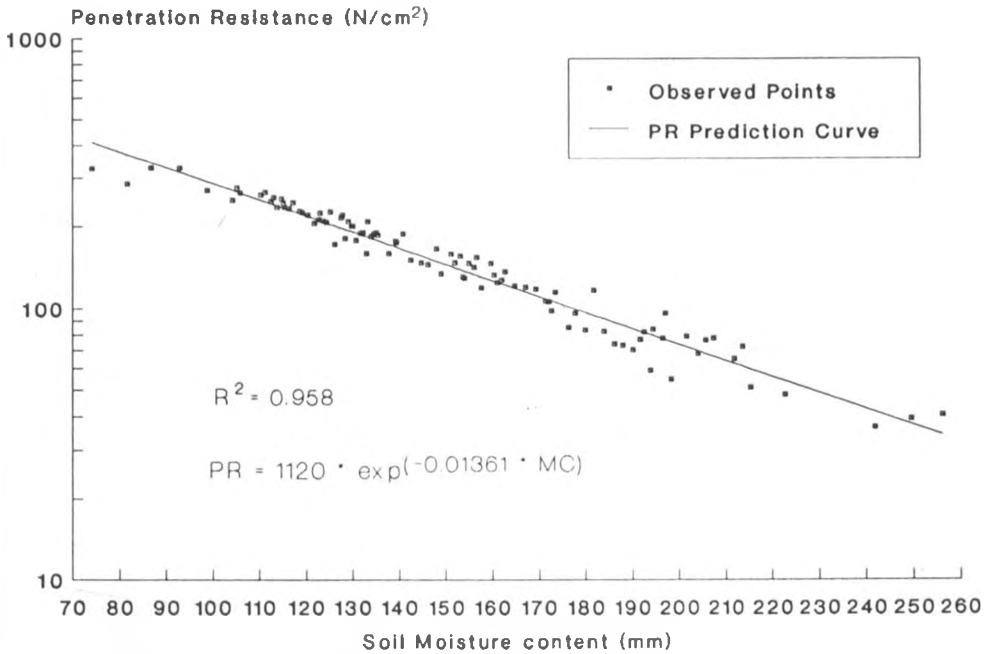


Fig. 4.18 Penetration Resistance (PR) Prediction curve.

The resulting equation from the regression analysis was found to be:

$$PR = 1120 * \exp^{(-0.0136 * MC)} \quad \ldots(4.8)$$

With a MC of 232.8 mm (see Section 4.5.2), the expected PR would be:

$$PR = 1120 * \exp^{(-0.0136 * 232.8)} \quad => \quad PR = 47.1 \text{ N/cm}^2$$

This means it is expected that at least once in the month of March, the soil should attain a PR of 47.1 N/cm². In Section 4.3, it was shown that the reported safe SBC is in the range of 50 N/cm². Therefore, it would require more than 9 consecutive dry days in the month of March for land preparation to take place without mobility problems. To find out exactly how many days of dry weather would be required for the soil to attain a PR of 50 N/cm² in the month of March, the safe PR would be substituted in Eq. 4.8 and then calculate the MC as follows:

$$50 = 1120 * \exp^{(-0.0136 * MC)}, \quad => \quad MC = 228.5 \text{ mm}$$

By substituting a MC of 228.5 mm in Eq. 4.1, the time required for the soil to attain a penetration resistance of 50 N/cm² is given by:

$$228.5 = 107 + 188.6 * \exp^{(-0.045 * t)} \quad => \quad t = 9.77 \approx 10 \text{ days.}$$

This implies that after 10 days of dry weather, it is expected that a PR of 50 N/cm² should be attained. Again referring to the month of March, ten days of dry weather are expected 0.8 times (see Fig. 4.14) which is very low to rely upon. Since in developing the soil drying equation, rainfall of up to 5.0 mm was neglected, the time it takes the soil to attain a PR of 50 N/cm² may be slightly longer than 10 days which further reduces the chances of ever attaining a PR of 50 N/cm² in the month of March. Therefore, with the varieties of rice that are grown at APS which take 150 days to mature leaving only one month fallow period in the case of two crops per year, DCS is impossible without bogging down of tractors during land preparation. This conclusion is contrary to what Wandahwa (1989) arrived at by investigating some soil physical properties like bulk density, relative compaction, shear strength and consistency.

The above conclusion is only based on attaining a PR of 50 N/cm². However, since CI is not the only indicator of the SBC, the above argument is not conclusive without incorporating C_n in such a study. It would be necessary to use C_n in future investigations and then finally make a decision on whether to discard the DCS completely or not.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Investigations of the causes of poor trafficability during land preparation and the possibility of re-introducing double cropping of rice at the Ahero Pilot Scheme (APS) were carried out between December 1990 and May 1991 using a measure of penetration resistance as an indicator of the soil bearing capacity. The study was carried out through five specific objectives and the major conclusions arrived at through those objectives are presented herebelow.

The soil drying process monitored through the changes in the soil moisture content with depth and time during the fallow period showed that:

a) During a dry period, changes in SMC with depth was found to depend on the evaporation rate and the length of the dry spell;
b) SMC was found to reduce exponentially with time during a dry period;
c) Between drainage for harvesting and 2-3 weeks after harvesting, the drying of the soil was not significant and therefore the DOP could be considered to begin 4-6 weeks after drainage for harvesting of rice. However, this period would be prolonged if rains persisted during the initial stages of the DOP;
d) After cracks had developed on the soil surface, rainfall had almost no significant effect on the DOP irrespective of its intensity and magnitude under treatments N and DMF;
e) The rate of the DOP of the soil was highest under treatment N and lowest under treatment S.

From the analysis of the rainfall, evaporation and SMC data, it was found that a soil drying curve for APS to predict SMC could be represented by the following equation:

$$MC_a = 107.0 + 188.6 * \exp^{(-0.045 * t)} \qquad ...(4.1)$$

where,

MC_a = actual moisture content in the soil, (mm);

107.0 = a constant representing the residual soil moisture;

188.6 = a constant representing evaporable moisture in the soil at the beginning of a drying period under consideration, (mm);

t = time of drying (days);

Soil bearing capacity monitored through changes in PR with respect to time, soil depth and SMC showed that:

a) During the initial stages of the drying process and when moderately high rainfall would persist for a long period, there was no discernible relationship between time and PR. During long dry spells, PR was found to increase exponentially with time and soil moisture;
b) The rate of increase of PR with depth was found to be parabolic with high PR in the layer 0-15 cm, low PR in the layer 15-30 cm and high PR in the layer 45-60 cm. Therefore existence of a hardpan at APS was not confirmed and this could be one of the factors contributing to the mobility problem.
c) A comparison of the PR with and without ash/straw cover showed that the cover reduced PR by 3.6 times in the layer 0-30 cm depth. Therefore, straw management was highly associated with the mobility problems;
d) A curve for predicting PR when SMC is known could be represented by the following relationship:

$$PR = 1120 * \exp^{(-0.0136 * MC)} \quad \ldots(4,8)$$

where,

PR = penetration resistance, N/cm²

MC = moisture content, mm.

e) From the above two equations, one month fallow period was found to be inadequate for land preparation to take place without the tractors bogging down. It was found that it requires at least 10 days of continuous dry weather to attain a PR of 50 N/cm² which was considered to be safe for trafficability. In the critical month of March the chances of getting 10 days of dry weather are slim. Therefore, with the rice varieties grown at APS, double cropping system of paddy rice production is impossible due to the short fallow period between crops. This is not conclusive without carrying out further investigations where the wheel numeric (C_n) is used as an indicator of SBC.

5.2 Recommendations

It is recommended that:

a) before completely abandoning DCS, some more work be carried out addressing the use of C_n as a measure of soil bearing capacity and an actual traction wheel and more reliable measuring equipment;

b) a survey of penetration resistance and soil moisture content be carried out over a longer period of time (several years) in order to ascertain the constants in the simulation equations developed in Section 4.5;

c) extensive investigations be carried out to establish the safe soil bearing capacity at the APS for the tractors and rotavators used in the scheme;

d) a thorough study be carried out incorporating (a), (b) and (c) but covering a larger area of the scheme than was covered in this study;

e) agronomical tests be carried out to obtain rice varieties that take a shorter period to mature so that the fallow period can be lengthened. Only then would Double Cropping System be economically practicable;

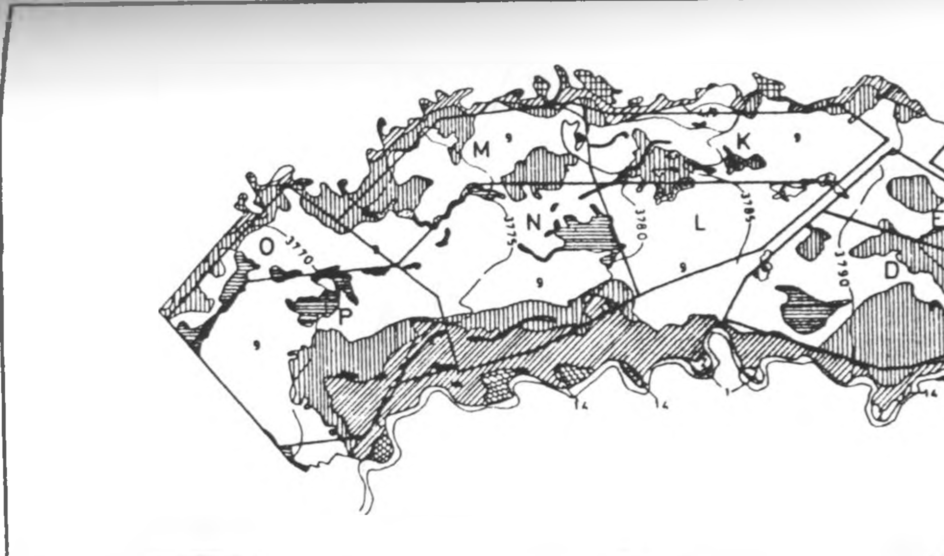
f) trials be carried out to ascertain the cropping intensity that could be practiced without any problems.

ANNEXES

ANNEX 1

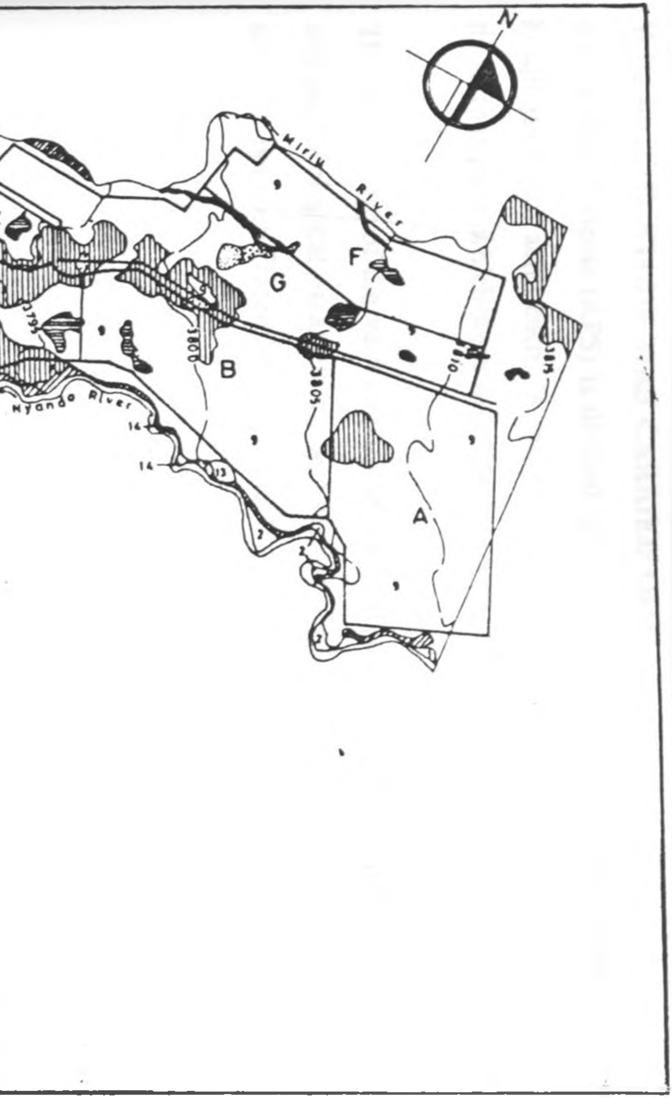
SOIL MAP OF THE AHERO PILOT SCHEME

Fig. A.1 shows the soil map compiled by the Survey of Kenya (S.o.K) in 1966 just before the implementation of the Ahero Pilot Scheme project. In Blocks A, D and N where the study was carried out, the predominant soil type was described as poorly drained dark grey heavy clays with slow or negligible permeability throughout. However, in Block D, a large portion was covered by a dark brown light clay overlying a dark grey medium or heavy clay of slow permeability and impeded drainage.



MAP SYMBOL	SOIL CHARACTERISTICS	PROVISIONAL IRRIGATION STATUS
1	Undifferentiated river bank levees of coarse sand to sandy loam.	TOPOGRAPHICALLY UNSUITABLE
2	In-filled meanders dark brown silty clays, sometimes overlying sandy clay loam	.. ..
3	In-filled meanders Dark brown light clays	FAIRLY SUITABLE
4	A minimum of 6" of recent dark brown light clay overlying a medium or heavy very dark grey clay	.. ..
4/9	Slightly undulating topography Higher lying areas are 4 Lower lying areas are 9	
5	As 4, recent alluvium including at least 3" of coarse sandy clay loam.	.. ..
6	Old levees Higher-lying dark brown coarse sandy clay, sometimes with accretions of fine gravels	.. ..
7	Old levees Higher-lying very dark brown fine sandy clay, silty clay or light clay overlying poorly drained medium clay	UNSUITABLE
8	Very dark brown light clay overlying very dark grey medium or heavy clay of slow permeability & impeded drainage	FAIRLY SUITABLE
9	Poorly drained very dark grey heavy clays with very slow or negligible permeability throughout	UNSUITABLE FOR CROPS OTHER THAN RICE
10	As 9 very poorly drained, receiving drainage in slight basin depressions.	.. ..
11	Old meanders Heavy clay or silty clay subject to seasonal floods	USE AS MAIN DRAINS OR LEVEL OFF
12	Old meanders and local ponds subject to permanent flooding	.. ..
13	Map unit 9 Underlain by impermeable mudstone between 3-10 feet.	UNSUITABLE
14	Lowest terrace eroded to river level by floods	..

Fig. A.1. The Soil Map of Ahero Pilot Scheme.


N
River
Nyando River
F
G
B
A
3800
3805
3810
3814
14
13

ANNEX 2

MAP OF THE AHERO PILOT SCHEME SHOWING THE SELECTED BLOCKS WHERE THE STUDY WAS CARRIED OUT

Ahero Pilot Scheme (APS) is divided into blocks which in turn are divided into tenant holdings of four acres each. A tenant holdings has four plots of an acre each. It was in these four plots which were taken as four replicates where the study was carried out.

The monitoring of the various parameters (soil moisture content, penetration resistance and meteorological parameters), was carried out in the shaded blocks (see Fig. A.2) of the APS between December 1990 and May 1991.

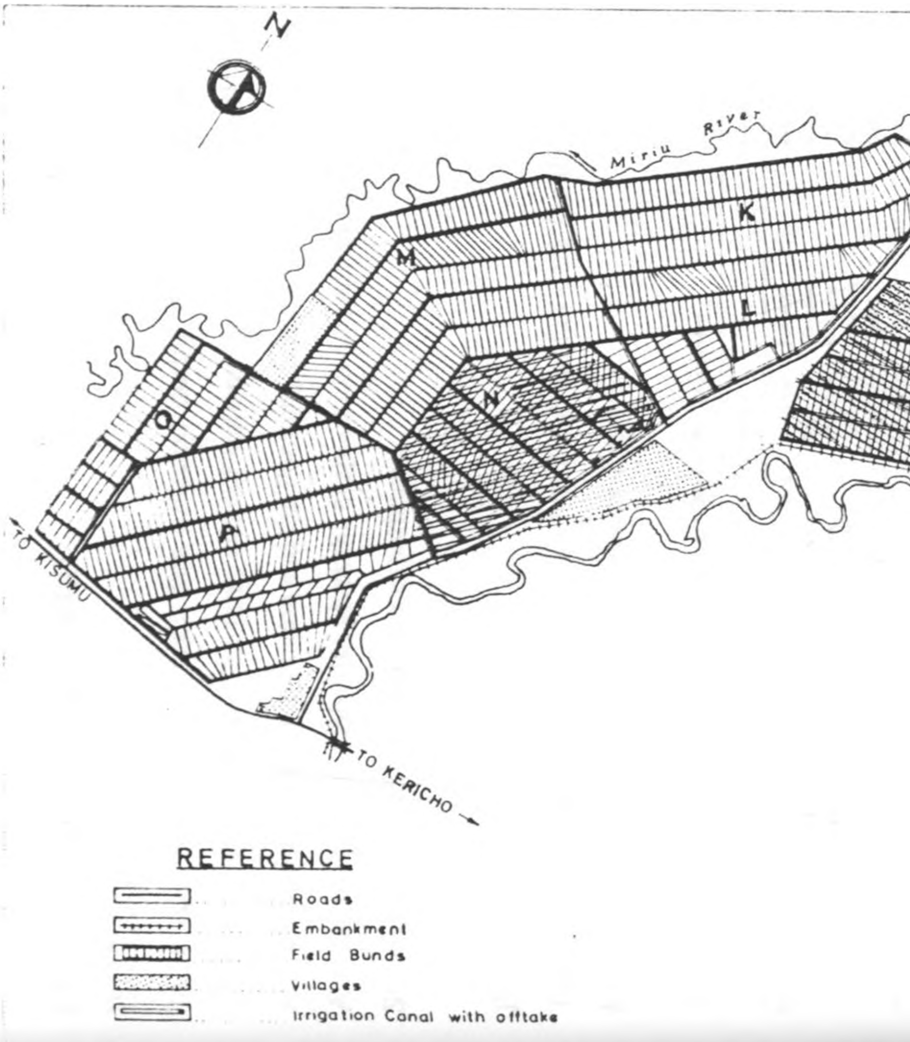
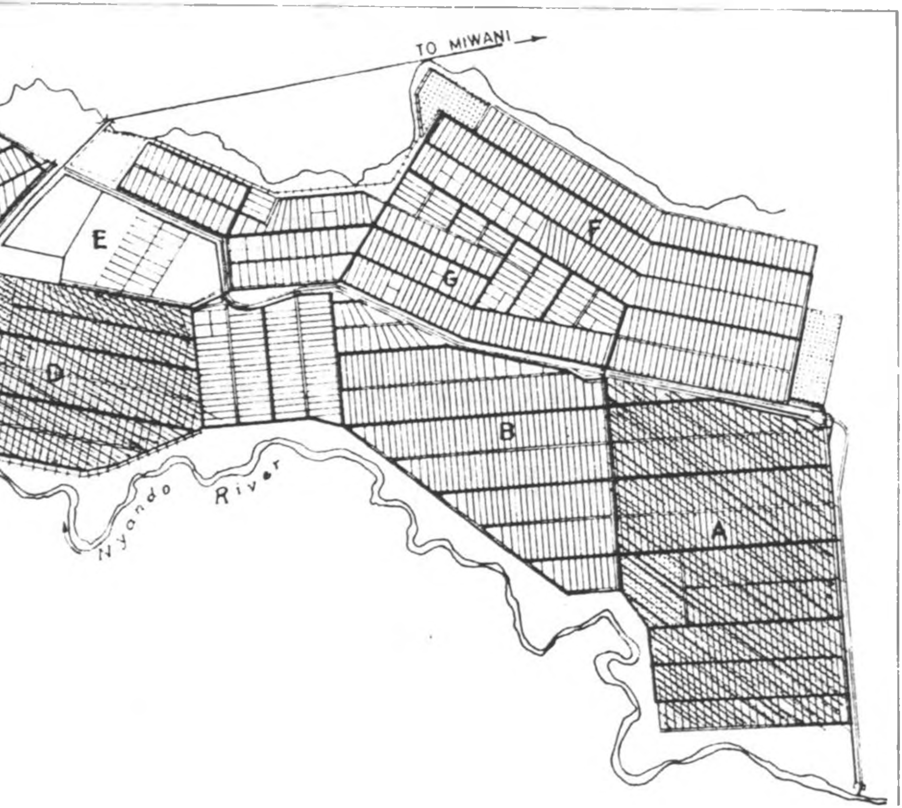


Fig. A.2. The Map of APS Showing the Selected Blocks Where


TO MIWANI
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ANNEX 3

CLIMATIC DATA FOR AHERO

PART ONE

Table A3.1 shows the rainfall data collected during the experiment at three rainfall stations situated at APS. The three rainfall stations located at Ahero Girls High School, Ahero Irrigation Research Station and the Pumping Station were close to Blocks N, D and A respectively. The table also gives the evaporation data monitored at the Meteorological Station at the scheme during the experiment.

PART TWO

Tables A3.2.1 and A3.2.2 shows the historical rainfall data for the critical months of March and August refered to in Chapters 2 and 3.

TABLE A3.1 Evaporation and Rainfall Data Observed During the Experiment

Block N			Block N			Block N			Block A		
Date	Evaporation (APS Met. Station) (mm/day)	Rainfall Measured at Ahero Girls Sch. (mm)	Date	Evaporation (APS Met. Station) (mm/day)	Rainfall Measured at Ahero Girls Sch. (mm)	Date	Evaporation (APS Met. Station) (mm/day)	Rainfall Measured at Ahero Girls Sch. (mm)	Date	Evaporation (APS Met. Station) (mm/day)	Rainfall Measured at Pump House (mm)
11/12	5.5	-	12/18	5.5	-	1/23	8.0	-	5/2	3.4	1.4
11/13	5.5	-	12/19	5.7	-	1/24	6.5	-	5/3	4.9	0.4
11/14	2.8	17.1	12/20	6.5	-	1/25	9.3	-	5/4	5.2	0.2
11/15	5.5	-	12/21	6.0	-	1/26	4.5	-	5/5	6.5	-
11/16	4.5	-	12/22	6.5	-	1/27	4.0	44.5	5/6	4.5	2.0
11/17	5.5	-	12/23	6.0	-	1/28	4.9	-	5/7	4.5	-
11/18	4.5	-	12/24	6.5	-	1/29	4.7	-	5/8	4.3	1.3
11/19	6.0	-	12/25	7.0	-	1/30	5.5	-	5/9	5.0	-
11/20	4.5	-	12/26	6.5	-	1/31	6.5	-	5/10	5.7	1.7
11/21	4.0	-	12/27	6.5	-	2/1	6.5	-	5/11	5.7	8.7
11/22	7.0	-	12/28	7.0	-	2/2	7.5	-	5/12	4.9	0.4
11/23	7.5	-	12/29	5.5	-	2/3	7.0	-	5/13	2.3	15.8
11/24	5.0	-	12/30	6.5	-	2/4	7.5	-	5/14	5.4	2.9
11/25	6.5	-	12/31	6.1	-	2/5	6.5	-	5/15	4.8	0.3
11/26	6.5	-	1/1	9.8	21.8	2/6	7.5	-	5/16	4.5	-
11/27	6.0	-	1/2	5.0	14.6	2/7	7.5	-	5/17	4.5	-
11/28	4.5	-	1/3	7.0	-	2/8	7.0	-	5/18	4.9	2.4
11/29	6.5	-	1/4	8.5	-	2/9	7.0	-	5/19	2.3	1.3
11/30	5.0	-	1/5	5.0	-	2/10	7.0	-	5/20	4.5	-
12/1	5.0	-	1/6	5.5	-	2/11	6.7	-	5/21	5.1	2.6
12/2	6.5	-	1/7	9.2	1.3	2/12	7.0	-	5/22	6.6	5.6
12/3	5.9	2.3	1/8	6.7	28.5	2/13	6.6	26.4	5/23	3.4	0.9
12/4	5.5	6.7	1/9	5.0	-	2/14	7.5	-	5/24	-	84.0
12/5	5.5	-	1/10	5.5	-	2/15	7.5	-	5/25	4.5	2.9
12/6	4.0	-	1/11	9.4	-	2/16	7.5	-	5/26	5.0	-
12/7	5.7	-	1/12	4.5	-	2/17	6.1	-	5/27	11.3	34.8
12/8	5.0	-	1/13	7.0	-	2/18	7.5	-	5/28	12.4	30.4
12/9	3.5	-	1/14	6.5	-	2/19	8.5	-			
12/10	10.7	-	1/15	6.5	-	2/20	7.0	12.4			
12/11	7.0	26.4	1/16	8.5	-	2/21	10.2	17.2			
12/12	2.8	-	1/17	8.5	-	2/22	5.2	-			
12/13	4.0	-	1/18	7.0	-	2/23	7.0	-			
12/14	4.9	4.7	1/19	8.5	-	2/24	6.5	-			
12/15	4.0	-	1/20	7.0	-	2/25	7.5	-			
12/16	4.5	-	1/21	9.0	-	2/26	7.5	-			
12/17	2.3	-	1/22	6.5	-	2/27	7.5	-			

TABLE A4.1 Continued

Block N			Block D			Block D			Block D		
Date	Evaporation (APS Met. Station) (mm/day)	Rainfall Measured at Ahero Girls Sch. (mm)	Date	Evaporation (APS Met. Station) (mm/day)	Rainfall Measured at AIRS (mm)	Date	Evaporation (APS Met. (mm/day)	Rainfall Measured at AIRS Station) (mm)	Date	Evaporation (APS Met. Station) (mm/day)	Rainfall Measured at AIRS (mm)
2/28	7.5	-	11/24	5.0	-	1/31	6.5	-	4/9	5.5	-
3/1	7.5	-	11/25	6.5	-	2/1	6.5	-	4/10	10.0	27.0
3/2	8.5	-	11/26	6.5	-	2/2	7.5	-	4/11	4.9	1.4
3/3	7.5	-	11/27	6.0	-	2/3	7.0	-	4/12	6.7	4.2
3/4	9.0	-	11/28	4.5	0.5	2/4	7.5	0.5	4/13	4.5	2.0
3/5	7.5	-	11/29	6.5	-	2/5	6.5	-	4/14	4.5	-
3/6	7.5	-	11/30	5.0	-	2/6	7.5	-	4/15	5.5	-
3/7	7.5	-	12/1	5.0	-	2/7	7.5	-	4/16	6.0	-
3/8	8.5	-	12/2	6.5	-	2/8	7.0	-	4/17	6.0	-
3/9	8.5	-	12/3	5.9	6.9	2/9	7.0	-	4/18	6.5	-
3/10	6.9	-	12/4	5.5	1.0	2/10	7.0	-	4/19	4.9	4.9
3/11	6.0	-	12/5	5.5	-	2/11	6.7	0.2	4/20	6.8	6.8
3/12	9.2	15.7	12/6	4.0	-	2/12	7.0	-	4/21	5.5	-
3/13	5.0	5.8	12/7	5.7	0.2	2/13	6.6	0.1	4/22	5.5	-
3/14	6.6	2.5	12/8	5.0	-	2/14	7.5	-	4/23	4.5	3.0
3/15	7.0	-	12/9	3.5	-	2/15	7.5	-	4/24	5.0	0.5
3/16	8.0	-	12/10	10.7	0.7	2/16	7.5	-	4/25	5.7	0.2
3/17	8.0	-	12/11	7.0	32.0	2/17	6.1	0.6	4/26	5.5	-
3/18	6.5	-	12/12	2.8	0.8	2/18	7.5	-	4/27	3.5	5.0
3/19	7.5	-	12/13	4.0	0.5	2/19	8.5	-	4/28	4.0	-
3/20	7.0	-	12/14	4.9	2.4	2/20	7.0	3.5	4/29	5.5	-
3/21	7.0	-	12/15	4.0	-	2/21	10.2	8.2	4/30	3.1	0.1
3/22	7.0	-	12/16	4.5	-	2/22	5.2	0.7	5/1	7.4	16.4
3/23	8.5	-	12/17	2.3	2.3	2/23	7.0	-	5/2	3.4	1.4
3/24	9.7	16.6	12/18	5.5	1.0	2/24	6.5	3.5	5/3	4.9	0.4
3/25	4.5	-	12/19	5.7	6.2	2/25	7.5	-	5/4	5.2	0.2
3/26	5.6	2.5	12/20	6.5	-	2/26	7.5	-	5/5	6.5	-
3/27	4.5	-	12/21	6.0	-	2/27	7.5	-	5/6	4.5	2.0
3/28	4.0	-	12/22	6.5	-	2/28	7.5	-	5/7	4.5	-
3/29	10.8	36.5	12/23	6.0	-	3/1	7.5	-	5/8	4.3	1.3
3/30	5.0	0.8	12/24	6.5	-	3/2	8.5	-	5/9	5.0	-
3/31	10.8	17.5	12/25	7.0	-	3/3	7.5	-	5/10	5.7	1.7
4/1	4.4	4.8	12/26	6.5	-	3/4	9.0	-	5/11	5.7	8.7
4/2	6.4	2.8	12/27	6.5	-	3/5	7.5	-	5/12	4.9	0.4
4/3	4.7	-	12/28	7.0	4.0	3/6	7.5	0.5	5/13	2.3	15.8
4/4	4.0	1.5	12/29	5.5	-	3/7	7.5	-	5/14	5.4	2.9
4/5	6.1	16.0	12/30	6.5	-	3/8	8.5	-	5/15	4.8	0.3
4/6	4.1	3.5	12/31	6.1	1.6	3/9	8.5	-	5/16	4.5	-
4/7	6.6	10.4	1/1	9.8	52.3	3/10	6.9	1.9	5/17	4.5	-
4/8	6.1	1.0	1/2	5.0	1.6	3/11	6.0	0.5	5/18	4.9	2.4
4/9	5.5	-	1/3	7.0	-	3/12	9.2	15.7			
4/10	10.0	27.8	1/4	8.5	20.1	3/13	5.0	5.0			
4/11	4.9	2.0	1/5	5.0	-	3/14	6.6	6.6			
4/12	6.7	5.5	1/6	5.5	0.3	3/15	7.0	-			
4/13	4.5	1.5	1/7	9.2	22.5	3/16	8.0	-			
4/14	4.5	-	1/8	6.7	1.2	3/17	8.0	-			
4/15	5.5	-	1/9	5.0	0.3	3/18	6.5	-			
4/16	6.0	-	1/10	5.5	-	3/19	7.5	-			
4/17	6.0	-	1/11	9.4	-	3/20	7.0	-			
4/18	6.5	-	1/12	4.5	-	3/21	7.0	-			
4/19	4.9	3.7	1/13	7.0	-	3/22	7.0	-			
4/20	6.8	10.0	1/14	6.5	-	3/23	8.5	-			
4/21	5.5	-	1/15	6.5	-	3/24	9.7	10.7			
4/22	5.5	1.0	1/16	8.5	-	3/25	4.5	-			
4/23	4.5	4.0	1/17	8.5	-	3/26	5.6	0.6			
4/24	5.0	-	1/18	7.0	-	3/27	4.5	-			
4/25	5.7	-	1/19	8.5	-	3/28	4.0	-			
4/26	5.5	-	1/20	7.0	-	3/29	10.8	40.8			
4/27	3.5	-	1/21	9.0	-	3/30	5.0	-			
4/28	4.0	-	1/22	6.5	-	3/31	10.8	23.8			
4/29	5.5	-	1/23	8.0	-	4/1	4.4	3.9			
4/30	3.1	-	1/24	6.5	-	4/2	6.4	14.4			
5/1	7.4	21.8	1/25	9.3	13.2	4/3	4.7	0.2			
5/2	3.4	2.5	1/26	4.5	7.8	4/4	4.0	1.0			
5/3	4.9	1.6	1/27	4.0	3.2	4/5	6.1	16.3			
5/4	5.2	2.0	1/28	4.9	-	4/6	4.1	4.6			
5/5	6.5	-	1/29	4.7	-	4/7	6.6	10.6			
5/6	4.5	1.5	1/30	5.5	-	4/8	6.1	0.1			

TABLE A3.2.1 HISTORICAL RAINFALL DATA FOR MARCH FROM STATION NO. 9034086 (AHERO PILOT SCHEME ALTITUDE = 1219 M.; LATITUDE = 00°08'S.; LONGITUDE = 34°56'E.)

Date	1964	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	3.8	3.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	3.6
2	40.4	0.0	4.8	0.0	0.9	0.0	2.8	0.0	24.1	0.0	0.0	3.3	0.0
3	2.0	7.4	3.0	0.0	1.2	0.0	0.0	0.0	0.0	12.8	0.0	9.4	0.8
4	0.0	3.8	5.1	0.0	0.0	0.0	1.0	0.0	0.0	18.0	0.0	0.0	0.0
5	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0	0.0	34.7	0.0	0.0	0.0
6	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.6
7	0.0	0.0	1.3	8.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	0.0
8	0.0	2.5	2.5	0.0	5.2	0.0	0.0	0.0	0.0	3.0	0.0	1.7	3.0
9	0.0	0.0	36.1	0.0	26.7	13.5	0.0	0.0	4.0	18.3	0.0	0.0	14.5
10	0.0	0.0	2.5	0.0	0.0	0.0	17.8	0.0	0.0	0.0	0.0	1.1	6.2
11	0.0	0.0	1.8	2.3	1.7	9.3	1.3	0.0	0.0	0.0	0.0	2.5	0.0
12	0.0	2.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	37.6
13	3.8	0.0	4.3	6.3	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0
14	15.2	9.7	24.1	0.0	0.0	0.0	10.1	0.0	0.0	7.7	0.0	0.0	6.3
15	4.8	0.0	0.0	41.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7
16	3.8	0.0	5.1	0.0	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	11.2	0.0	4.6	6.6
18	0.0	0.0	2.5	0.0	0.0	0.0	0.0	1.5	1.4	16.7	0.0	10.0	5.9
19	0.0	21.3	1.3	1.0	0.0	0.0	1.5	0.0	7.7	5.2	0.0	1.0	0.8
20	0.0	0.0	1.3	25.7	0.0	0.0	5.0	0.0	29.8	29.4	0.0	10.7	0.0
21	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	16.3	0.0
22	0.0	0.0	3.8	22.4	13.7	0.0	0.0	0.0	0.0	0.8	6.6	0.0	1.0
23	3.3	0.0	0.0	3.8	0.8	0.0	0.0	0.0	5.4	2.9	0.0	4.5	38.0
24	17.0	2.8	0.0	5.1	7.8	0.0	20.2	0.0	41.7	0.0	0.0	0.0	13.6
25	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	4.3	10.5
26	2.5	25.9	0.0	10.7	27.7	1.1	0.0	2.6	0.6	0.0	3.2	2.1	0.0.
27	0.0	0.0	0.0	0.0	38.3	0.0	0.0	0.0	0.8	0.0	9.5	0.0	0.5
28	0.0	2.5	0.0	0.0	10.4	0.0	0.0	0.0	2.7	0.0	21.2	0.7	37.7
29	0.0	6.6	0.0	0.0	1.8	0.0	0.0	0.0	5.0	0.0	0.0	0.0	9.1
30	0.0	3.6	0.0	0.0	0.0	6.7	0.0	0.0	84.5	1.4	0.0	40.0	0.3
31	33.8	2.8	0.0	12.7	14.6	3.4	0.0	0.0	6.1	15.9	0.0	0.0	0.0

TABLE A3.2.1 Continued

Date	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
1	0.0	16.2	0.0	0.0	0.0	5.2	0.0	0.2	0.0	0.0	0.0	1.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0
3	0.0	13.7	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.9	0.0	0.0	0.0
4	0.0	1.4	0.0	0.0	14.9	0.0	0.0	8.8	0.0	13.0	0.0	4.9	0.0
5	0.0	1.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	15.0	0.0	1.5	0.0
6	0.0	0.0	37.8	1.2	0.0	0.0	0.0	12.5	2.3	3.8	4.1	0.0	0.5
7	0.0	0.0	0.0	0.0	0.0	0.0	1.0	19.7	3.2	0.0	0.0	0.0	0.0
8	0.0	9.6	4.1	7.5	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0
9	0.0	0.0	22.0	0.3	0.0	0.0	0.0	12.0	32.0	0.0	5.8	0.0	0.0
10	0.0	0.0	0.2	0.0	0.0	0.0	0.0	4.9	3.7	3.6	0.0	5.5	1.9
11	16.4	4.7	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
12	13.3	3.9	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	15.7
13	33.1	4.5	0.6	0.6	1.0	12.3	0.0	0.0	0.0	0.0	9.8	2.4	5.0
14	11.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	18.0	6.6
15	17.4	0.0	0.0	0.6	18.8	23.2	0.0	0.0	70.0	14.8	0.0	35.3	0.0
16	4.1	0.0	2.6	0.0	1.2	0.0	0.0	11.3	1.0	0.0	0.0	15.0	0.0
17	38.0	0.0	17.0	0.0	0.0	0.0	0.0	0.6	0.8	6.5	0.0	0.0	0.0
18	0.0	0.0	9.0	0.0	0.0	0.0	4.0	0.6	26.2	0.0	20.5	0.0	0.0
19	17.7	0.0	38.0	0.0	0.0	0.0	4.8	0.0	0.4	0.6	6.9	0.0	0.0
20	0.0	0.0	4.5	2.5	0.0	0.0	6.1	48.2	0.0	9.0	0.0	0.0	0.0
21	0.0	0.0	0.0	46.2	0.0	0.0	6.9	14.4	0.0	19.8	33.0	0.0	0.0
22	0.0	0.0	0.2	0.0	0.0	0.0	54.3	0.0	0.0	0.0	21.2	1.0	0.0
23	0.0	0.0	9.4	0.0	0.0	0.0	27.0	0.0	0.0	7.9	0.6	1.0	0.0
24	0.0	0.0	38.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90.0	0.0	10.7
25	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.2	0.0	0.5	0.0	0.0
26	0.0	0.0	6.2	0.0	3.7	0.0	16.0	0.0	0.2	48.0	1.5	0.0	0.6
27	0.0	24.5	19.0	0.0	0.0	9.0	13.4	0.0	0.0	7.5	160.0	0.0	0.0
28	28.0	0.0	0.7	1.4	0.0	4.5	0.0	0.0	0.0	0.0	39.3	0.0	0.0
29	4.5	1.5	0.0	0.0	0.0	0.0	9.7	0.0	0.5	0.0	6.7	23.5	40.8
30	0.0	15.4	10.6	0.4	0.0	0.0	25.8	14.1	1.8	0.0	50.1	27.2	0.0
31	41.1	0.0	0.0	0.0	0.0	0.0	6.5	0.6	0.0	0.0	0.3	3.0	23.8

TABLE A3.2.2 HISTORICAL RAINFALL DATA FOR AUGUST FROM STATION NO. 9034086 (AHERO PILOT SCHEME: ALTITUDE = 1219 M.; LATITUDE = 00°08'S; LONGITUDE = 34°56'E)

DATE	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
1	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.2	1.6	0.0	0.0	0.0
2	8.6	2.5	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0
3	3.3	3.8	0.0	0.0	5.1	0.0	3.6	0.0	0.0	0.0	2.6	0.0	13.3	0.0
4	0.0	1.3	0.0	0.0	1.5	0.0	0.0	7.8	0.0	0.0	1.4	0.0	0.0	0.0
5	0.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
6	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.3	0.0
7	0.0	1.8	0.0	0.0	0.5	1.8	0.0	5.8	2.9	0.0	4.0	0.0	0.0	31.3
8	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.2	0.0	2.0	0.0	4.8
9	0.0	3.6	0.0	0.0	2.0	1.3	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
10	0.8	1.3	0.0	0.0	13.7	0.0	0.0	1.5	0.0	3.6	49.0	0.0	5.8	0.0
11	6.3	0.0	0.0	0.0	0.0	4.1	0.0	7.1	0.8	0.0	0.0	0.0	0.0	0.0
12	7.1	0.0	0.0	0.0	2.8	0.0	0.8	0.0	16.0	3.3	0.9	0.0	0.0	15.2
13	0.0	0.0	0.0	0.0	0.0	0.0	2.8	1.3	0.0	0.2	0.0	0.0	1.2	0.0
14	6.1	0.0	0.0	0.0	1.0	0.0	2.5	8.8	0.0	0.0	0.0	14.2	0.0	0.0
15	23.9	1.3	0.0	0.0	0.0	0.5	1.5	3.4	0.0	0.0	1.8	0.0	7.6	0.0
16	0.0	7.6	0.0	0.0	0.0	0.5	1.8	0.0	0.0	12.7	11.5	14.3	0.0	0.0
17	0.0	0.0	0.0	0.0	0.8	16.5	7.1	0.0	0.0	0.0	0.0	0.0	124.9	0.0
18	0.0	0.0	0.0	0.0	5.3	11.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6
19	0.0	1.3	0.0	0.0	0.0	3.8	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	1.5	5.2	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.0	0.0	0.0	0.0	51.6	3.8
22	0.0	0.0	0.0	0.0	1.0	0.0	3.0	19.6	1.1	1.4	8.3	2.4	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	1.9	11.2	0.0	19.4	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	37.4	0.0	17.8	0.0	0.0	1.2	9.9
25	0.8	0.0	0.0	0.0	0.0	5.6	0.0	0.0	0.0	0.0	0.0	10.3	0.0	0.8
26	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	2.8	4.9
27	0.0	1.3	0.0	0.0	0.0	3.8	0.0	0.0	19.7	0.3	0.0	2.5	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.8	0.0	7.1	0.0	0.0	0.9	0.5
29	0.0	0.0	0.0	0.0	0.0	0.0	8.4	15.4	0.0	0.0	0.0	8.5	1.9	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.0	3.5	0.0	45.3	20.0	0.0	28.1
31	1.5	0.0	0.0	0.0	0.0	0.0	4.3	11.7	0.0	1.5	0.0	9.0	1.4	0.0

TABLE A3.2.2 Continued

DATE	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	1.0	7.1	2.2	0.0	0.0	14.0	0.0	0.0	0.0	0.1	0.0	0.0	2.2	0.0
2	5.7	0.0	0.4	4.3	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.0	0.0	0.0
3	0.0	0.0	0.0	5.4	1.0	0.0	0.0	0.0	0.6	9.0	0.2	0.6	0.0	3.2
4	7.1	0.7	0.0	0.0	0.2	4.3	0.6	0.0	6.0	0.0	0.0	10.5	0.0	24.0
5	0.0	1.0	0.0	0.0	10.0	0.7	0.2	0.0	0.0	0.0	0.0	26.1	6.4	0.0
6	0.0	4.8	1.0	0.2	0.0	5.5	0.0	0.0	0.0	0.0	0.0	7.6	20.3	0.0
7	0.0	0.0	11.2	0.3	0.0	22.7	0.0	26.3	2.6	0.0	0.0	3.5	0.0	0.0
8	0.0	0.0	0.0	0.7	0.1	0.7	0.0	0.0	0.0	0.0	0.0	16.9	0.5	0.0
9	0.0	0.0	1.6	0.0	0.0	1.2	1.5	0.0	0.0	0.0	8.0	16.5	0.0	0.0
10	0.0	0.7	0.0	1.8	0.0	0.0	49.0	0.0	0.0	0.0	10.5	0.0	1.1	0.2
11	0.0	0.0	5.0	2.4	0.0	0.0	0.0	0.0	1.2	0.0	0.2	0.0	0.4	0.3
12	0.0	0.0	6.7	0.0	0.0	12.9	0.0	16.5	0.0	0.0	0.3	0.0	0.0	3.3
13	0.5	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	3.0	3.0
14	0.0	0.3	4.0	0.0	21.0	29.9	0.3	0.0	31.2	0.0	0.0	1.8	0.0	0.0
15	4.4	0.3	0.0	0.2	3.2	15.7	0.0	0.0	6.4	0.0	0.8	0.0	0.0	0.0
16	16.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	0.0	0.5	1.6
17	9.6	38.7	0.0	0.0	0.0	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0
18	1.8	2.3	0.0	0.0	0.0	0.1	17.0	0.0	0.0	1.3	0.1	0.9	14.4	0.0
19	0.0	0.0	0.0	11.3	10.8	0.0	0.0	0.3	0.0	4.0	0.0	0.0	0.3	3.5
20	0.0	12.8	0.0	0.0	0.0	0.0	32.0	0.0	1.5	0.0	12.4	0.0	0.0	7.9
21	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	1.6	2.1	0.0	0.0	1.1
22	0.0	0.3	0.0	0.0	1.3	0.0	0.0	0.0	0.0	2.9	0.0	2.0	0.0	0.0
23	1.2	0.0	0.0	0.0	8.6	0.0	12.4	3.6	0.0	3.4	1.2	7.6	12.6	0.1
24	0.0	0.0	0.0	3.2	0.5	49.6	0.6	3.2	1.5	3.4	0.5	0.0	0.0	0.0
25	0.0	0.0	0.0	5.3	4.0	0.0	0.0	0.0	20.3	0.0	8.2	5.0	0.5	0.0
26	18.2	0.0	0.3	0.0	0.0	0.0	0.9	0.0	0.0	0.0	26.8	1.5	0.0	0.7
27	0.0	0.0	1.8	5.4	2.8	0.0	0.3	10.6	0.9	0.0	0.0	1.5	0.0	1.0
28	2.6	0.0	5.2	1.5	0.0	0.0	3.2	3.0	64.2	0.5	0.0	0.0	0.0	2.1
29	0.0	6.5	0.0	2.7	0.0	0.0	13.9	0.0	1.6	0.0	0.0	2.1	25.2	16.5
30	0.0	0.0	0.0	0.0	25.3	0.0	0.0	0.0	0.0	0.0	1.0	0.0	40.7	0.0
31	0.0	0.0	2.4	0.0	7.5	4.5	0.0	2.5	0.0	0.0	0.0	2.4	0.0	0.0

ANNEX 4

BULK DENSITY

Table A4.1 shows how bulk density (BD) was determined for the various replicates. Soil moisture content was determined through gravimetric method. The obtained values of BD were used in converting moisture content of other samples on weight basis to volume.

TABLE A4.1 DETERMINATION OF BULK DENSITY (BD) IN G/CM³.

Rep.	Depth (cm)	Can N°	Can WT (g)	Field WT Soil+ Can (g)	E-D=WT Field Wet Soil (g)	Oven Dry WT Soil+ Can (g)	G-D=WT Oven Dry Soil (g)	F-H= WT. Water Cont. (g)	(I/H) *100% SMC (%)	Bulk Density BD=H/V (g/cm³)	Porosity P=1-BD/PD (%)
A	B	C	D	E	F	G	H	I	J	K	L
1	0-5	080	155.68	279.09	123.41	239.01	83.33	40.08	48.10	0.83	0.68
2	0-5	140	158.55	299.00	140.45	254.20	95.65	44.80	46.84	0.96	0.63
3	0-5	053	153.70	274.00	120.30	241.58	87.88	32.42	36.89	0.88	0.66
4	0-5	123	154.48	297.23	142.75	250.72	96.24	46.51	48.33	0.96	0.63
5	0-5	044	154.33	297.80	143.47	252.96	98.63	44.84	45.46	0.99	0.62
6	0-5	094	158.32	296.19	137.87	247.41	89.09	48.78	54.75	0.89	0.66
Mean Bulk Density and Porosity for Depth Interval 0-5 cm.										**0.92**	**0.65**
1	15	212	154.23	309.89	155.66	252.92	98.69	56.97	57.73	0.99	0.62
2	15	220	153.40	297.19	143.79	246.80	93.40	50.39	53.95	0.93	0.64
3	15	007	156.60	317.02	160.42	257.10	100.50	59.92	59.62	1.01	0.61
4	15	056	159.02	322.25	163.23	262.00	102.98	60.25	58.51	1.03	0.60
5	15	188	156.52	312.89	156.37	255.90	99.38	56.99	57.35	0.99	0.62
6	15	111	154.51	314.22	159.71	255.50	100.99	58.72	58.14	1.01	0.61
Mean Bulk Density and Porosity for Depth 15 cm.										**0.99**	**0.62**
1	30	171	154.50	306.29	151.79	250.90	96.40	55.39	57.46	0.96	0.63
2	30	274	152.10	313.05	160.95	254.95	102.85	58.10	56.49	1.03	0.60
3	30	038	157.12	319.89	162.77	260.12	103.00	59.77	58.03	1.03	0.60
4	30	158	156.08	319.60	163.52	259.96	103.88	59.64	57.41	1.04	0.60
5	30	045	153.58	312.38	158.80	254.79	101.21	57.59	56.90	1.01	0.61
6	30	135	153.85	313.54	159.69	254.72	100.87	58.82	58.31	1.01	0.61
Mean Bulk Density and Porosity for Depth 30 cm.										**1.01**	**0.61**
1	45	055	154.30	310.11	155.81	254.60	100.30	55.51	55.34	1.00	0.61
2	45	268	153.00	310.20	157.20	253.65	100.65	56.55	56.18	1.01	0.61
3	45	165	155.50	321.30	165.80	261.22	105.72	60.08	56.83	1.06	0.59
4	45	149	155.49	329.70	174.21	265.62	110.13	64.08	58.19	1.10	0.58
5	45	185	152.86	315.08	162.22	254.92	102.06	60.16	58.95	1.02	0.61
6	45	050	154.80	319.00	164.20	260.82	106.02	58.18	54.88	1.06	0.59
Mean Bulk Density Porosity for Depth 45 cm.										**1.04**	**0.60**
1	60	233	154.09	319.55	165.46	261.96	107.87	57.59	53.39	1.08	0.59
2	60	270	153.21	326.02	172.81	263.80	110.59	62.22	56.26	1.11	0.57
3	60	065	154.20	314.21	160.01	258.09	103.89	56.12	54.02	1.04	0.60
4	60	072	155.54	330.19	174.65	269.01	113.47	61.18	53.92	1.13	0.56
5	60	120	153.70	320.42	166.72	263.89	110.19	56.53	51.30	1.10	0.58
6	60	213	153.83	323.55	169.72	263.91	110.08	59.64	54.18	1.10	0.58
Mean Bulk Density Porosity for Depth 60 cm.										**1.09**	**0.58**
Overall Average Bulk Density and Porosity										**1.01**	**0.61**

REMARKS

1. Sampling Date: 17/01/91
2. Ring Volume: V=100 cm³
3. Particle Density PD=2.60
4. WT = Weight
5. SMC = Soil Moisture Content
6. BD = Bulk Density
7. P = Soil Porosidty

ANNEX 5

SOIL MOISTURE CONTENT AND PENETRATION RESISTANCE DATA FROM BLOCK D

PART ONE

Part one comprises Tables A5.1.1 - A5.1.27. These tables give the average SMC (on weight basis) and PR for each sampling day from the various sampling locations and depths. The averages were calculated first over replicates and sampling locations (treatments) and then over depths after combining some treatments. Some treatments (Drain, Middle and Feeder) were combined in order to manage data with ease. The combining of those treatments was made possible by the fact that there was no significant difference in data obtained from them.

PART TWO

Part two of Annexe 5 comprises of Tables A5.2.1 - A5.2.6. These tables show the SMC and PR data after grouping some treatments together and after converting SMC from weight basis to volume basis. Conversion of SMC in weight basis to vloume was necessary because the units of measurements for other parameters (rainfall and evaporation) that were considered in developing a soil drying model for APS were in volume basis. Determination of SMC on voulume basis was not possible due to lack of enough sampling cores.

TABLE A5.1.1 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 19/12/90

FIELD POS. AND DEPTH (cm)	AVER. SMC BY WGT. (%)	AVER. PENET. RESIS. (PR) N/cm²	FIELD POS. AND DEPTH (cm)	OVER-ALL AVER. SMC (%)	OVER-ALL AVER. PR N/cm²
FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	66.7	12.0	00	69.2	12.9
15	69.4	23.0	15	72.6	22.7
30	50.1	46.0	30	51.9	47.8
45	52.4	60.3	45	50.0	62.1
60	41.9	75.5	60	42.5	74.3
MIDDLE			ASHES/STRAW HEAP		
00	70.3	14.0	00	-	-
15	70.0	24.8	15	-	-
30	50.7	48.8	30	-	-
45	46.7	61.5	45	-	-
60	41.9	75.5	60	-	-
FEEDER			FIELD NURSERY		
00	70.6	12.8	00	-	-
15	78.3	20.3	15	-	-
30	54.8	48.8	30	-	-
45	50.8	64.5	45	-	-
60	43.7	72.0	60	-	-

TABLE A5.1.2 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 22/12/90

FIELD POS. AND DEPTH (cm)	AVER. SMC BY WGT. (%)	AVER. PENET. RESIS. (PR) N/cm²	FIELD POS. AND DEPTH (cm)	OVER-ALL AVER. SMC (%)	OVER-ALL AVER. PR N/cm²
FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	60.5	24.5	00	59.4	28.9
15	66.7	36.3	15	64.7	37.9
30	55.3	52.0	30	51.2	60.7
45	48.4	80.5	45	47.7	79.8
60	44.3	98.0	60	44.9	94.8
MIDDLE			ASHES/STRAW HEAP		
00	57.8	32.0	00	-	-
15	61.6	42.8	15	-	-
30	49.6	64.5	30	-	-
45	47.6	81.5	45	-	-
60	45.6	94.3	60	-	-
FEEDER			FIELD NURSERY		
00	59.7	30.3	00	56.6	32.0
15	65.8	34.8	15	74.1	38.0
30	48.8	65.5	30	50.9	66.0
45	47.1	77.3	45	49.0	68.0
60	44.9	92.3	60	44.5	88.0

TABLE A5.1.3 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 26/12/90

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	30.6	122.3	00	34.0	121.3
15	55.2	54.8	15	54.6	54.8
30	51.5	71.3	30	50.0	70.3
45	49.2	86.3	45	48.5	88.8
60	44.6	104.0	60	45.2	99.9
MIDDLE			ASHES/STRAW HEAP		
00	35.5	120.8	00	104	6.5
15	54.4	54.0	15	63.4	20.8
30	48.5	70.8	30	61.3	41.3
45	48.9	86.0	45	50.8	62.8
60	45.9	95.0	60	48.5	83.5
FEEDER			FIELD NURSERY		
00	36.0	121.0	00	45.5	71.0
15	54.2	55.8	15	53.9	64.0
30	49.9	69.0	30	48.0	71.0
45	47.3	94.3	45	46.0	80.0
60	45.2	100.8	60	42.0	98.0

TABLE A5.1.4 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 31/12/90

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	24.9	173.0	00	25.5	173.9
15	62.1	37.5	15	62.3	39.6
30	55.4	64.0	30	52.9	69.2
45	47.7	87.3	45	48.6	88.3
60	44.0	109.5	60	45.1	105.8
MIDDLE			ASHES/STRAW HEAP		
00	24.6	174.5	00	113	3.8
15	63.3	42.3	15	72.1	22.5
30	50.1	74.8	30	51.6	60.8
45	47.4	91.8	45	50.4	73.8
60	44.8	103.8	60	47.3	100.0
FEEDER			FIELD NURSERY		
00	27.1	174.3	00	39.7	136.0
15	61.5	39.0	15	52.3	67.0
30	53.3	68.8	30	49.1	72.0
45	50.7	86.0	45	47.9	94.0
60	46.4	104.3	60	44.2	112.0

TABLE A5.1.5 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 11/01/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	73.2	27.3	00	76.3	21.7
15	71.9	36.5	15	76.1	30.1
30	57.0	63.8	30	56.9	58.3
45	54.2	73.3	45	53.7	75.8
60	50.2	103.3	60	51.0	99.4
MIDDLE			ASHES/STRAW HEAP		
00	82.0	13.8	00	98.1	2.5
15	74.6	30.0	15	71.2	13.0
30	55.7	55.3	30	58.9	47.5
45	51.4	82.0	45	54.7	69.8
60	51.4	95.3	60	50.5	84.8
FEEDER			FIELD NURSERY		
00	73.7	24.0	00	80.4	20.0
15	81.7	23.8	15	55.8	43.0
30	58.1	55.8	30	50.3	69.0
45	55.4	72.0	45	50.3	90.0
60	51.4	99.8	60	49.4	108.0

TABLE A5.1.6 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 21/01/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	22.8	241.5	00	18.9	272.8
15	63.9	60.8	15	62.0	62.7
30	57.0	75.3	30	56.1	77.7
45	56.4	90.5	45	54.4	94.8
60	47.5	117.8	60	48.9	112.5
MIDDLE			ASHES/STRAW HEAP		
00	16.5	319.5	00	77.3	15.0
15	59.5	65.5	15	67.3	32.8
30	53.6	85.5	30	55.8	68.5
45	53.0	97.8	45	53.7	79.5
60	50.0	108.8	60	49.3	95.8
FEEDER			FIELD NURSERY		
00	17.5	257.5	00	16.2	285.0
15	62.5	61.8	15	43.7	115.0
30	57.6	72.3	30	53.7	89.0
45	53.8	96.3	45	50.0	105.0
60	49.1	111.0	60	46.6	126.0

TABLE A5.1.7 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 28/01/91

DRAIN			DRAIN/MID/FEEDER		
00	56.8	51.8	00	51.7	60.1
15	68.5	45.0	15	61.8	59.0
30	58.5	70.5	30	54.9	81.8
45	51.5	102.8	45	50.6	103.4
60	49.2	109.8	60	48.6	113.8
MIDDLE			ASHES/STRAW HEAP		
00	49.3	60.8	00	69.0	11.5
15	57.7	67.3	15	73.2	35.8
30	51.9	92.3	30	57.2	58.0
45	49.1	107.3	45	54.8	74.0
60	49.3	109.5	60	49.8	86.5
FEEDER			FIELD NURSERY		
00	48.9	67.8	00	52.6	57.0
15	59.3	64.8	15	44.7	118.0
30	54.3	82.5	30	44.7	128.0
45	51.1	100.3	45	45.0	124.0
60	47.3	122.0	60	46.3	125.0

TABLE A5.1.8 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 04/02/91

DRAIN			DRAIN/MID/FEEDER		
00	22.8	252.8	00	18.3	310.5
15	54.5	82.8	15	54.1	86.7
30	51.4	94.8	30	51.3	95.4
45	45.9	113.8	45	47.9	106.1
60	43.2	128.8	60	45.5	120.5
MIDDLE			ASHES/STRAW HEAP		
00	13.7	366.5	00	64.3	62.5
15	52.2	87.8	15	66.9	50.5
30	47.6	107.3	30	52.6	82.5
45	47.3	111.3	45	49.9	92.8
60	46.0	120.5	60	46.9	113.8
FEEDER			FIELD NURSERY		
00	18.4	312.3	00	14.3	364.0
15	55.6	89.5	15	38.1	154.0
30	54.7	84.3	30	39.0	150.0
45	50.5	93.3	45	45.6	130.0
60	47.3	112.3	60	44.0	140.0

TABLE A5.1.9 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 11/02/91

DRAIN			DRAIN/MID/FEEDER		
00	73.2	27.3	00	76.3	21.7
15	71.9	36.5	15	76.1	30.1
30	57.0	63.8	30	56.9	58.3
45	54.2	73.3	45	53.7	75.8
60	50.2	103.3	60	51.0	99.4
MIDDLE			ASHES/STRAW HEAP		
00	82.0	13.8	00	98.1	2.5
15	74.6	30.0	15	71.2	13.0
30	55.7	55.3	30	58.9	47.5
45	51.4	82.0	45	54.7	69.8
60	51.4	95.3	60	50.5	84.8
FEEDER			FIELD NURSERY		
00	73.7	24.0	00	80.4	20.0
15	81.7	23.8	15	55.8	43.0
30	58.1	55.8	30	50.3	69.0
45	55.4	72.0	45	50.3	90.0
60	51.4	99.8	60	49.4	108.0

TABLE A5.1.10 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 18/02/91

DRAIN			DRAIN/MID/FEEDER		
00	15.7	413.3	00	18.2	358.9
15	45.5	124.8	15	42.9	133.3
30	43.0	143.3	30	41.2	150.6
45	40.4	151.3	45	42.6	147.0
60	40.7	149.8	60	40.5	150.3
MIDDLE			ASHES/STRAW HEAP		
00	18.4	326.3	00	41.7	25.0
15	38.0	154.3	15	49.0	29.0
30	39.2	162.3	30	45.0	41.0
45	42.0	150.8	45	43.9	72.8
60	40.2	152.3	60	48.9	108.3
FEEDER			FIELD NURSERY		
00	20.5	337.3	00	24.9	269.0
15	45.2	121.0	15	34.3	174.0
30	41.4	146.3	30	33.5	180.0
45	45.3	139.0	45	36.2	162.0
60	40.7	149.0	60	41.3	148.0

TABLE A5.1.11 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 25/02/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	18.1	306.0	00	19.7	295.4
15	39.5	139.5	15	37.5	149.5
30	39.5	139.8	30	39.7	140.4
45	40.5	152.8	45	40.5	150.3
60	39.2	152.0	60	39.7	154.7
MIDDLE			ASHES/STRAW HEAP		
00	19.9	295.0	00	77.5	14.0
15	37.2	151.8	15	58.0	24.8
30	37.8	155.3	30	49.1	62.8
45	40.7	146.0	45	49.3	82.5
60	41.0	147.0	60	45.7	92.5
FEEDER			FIELD NURSERY		
00	21.2	285.3	00	15.2	326.0
15	35.9	157.3	15	38.1	158.0
30	41.9	126.3	30	37.2	178.0
45	40.4	152.0	45	35.5	221.0
60	38.8	165.0	60	36.6	180.0

TABLE A5.1.12 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 01/03/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	21.4	347.0	00	21.6	330.3
15	33.7	260.0	15	32.6	260.6
30	31.9	259.5	30	34.2	224.6
45	29.6	275.0	45	33.0	226.8
60	30.8	269.5	60	32.3	234.5
MIDDLE			ASHES/STRAW HEAP		
00	20.6	327.0	00	50.7	5.0
15	30.6	271.0	15	54.0	11.5
30	34.5	213.3	30	42.3	62.5
45	34.5	215.0	45	40.9	90.0
60	33.1	221.3	60	38.9	101.5
FEEDER			FIELD NURSERY		
00	22.8	317.0	00	16.9	360.0
15	33.5	250.8	15	18.6	346.0
30	36.1	201.0	30	28.4	280.0
45	34.8	190.3	45	31.9	246.0
60	33.1	212.8	60	30.0	270.0

TABLE A5.1.13 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 06/03/91

DRAIN			DRAIN/MID/FEEDER		
00	18.9	351.8	00	17.2	347.7
15	32.6	205.8	15	33.3	196.6
30	37.0	157.5	30	35.9	164.2
45	36.9	170.5	45	37.6	172.2
60	37.2	168.0	60	37.4	173.4
MIDDLE			ASHES/STRAW HEAP		
00	15.5	342.8	00	66.8	2.8
15	32.5	200.8	15	53.5	8.8
30	34.3	172.0	30	51.9	21.8
45	38.6	157.5	45	52.6	56.8
60	37.1	168.3	60	57.3	67.0
FEEDER			FIELD NURSERY		
00	17.4	348.5	00	17.9	345.0
15	34.9	183.3	15	33.1	193.0
30	36.5	163.0	30	34.3	187.0
45	37.3	188.5	45	31.4	201.0
60	37.7	184.0	60	30.7	221.0

TABLE A5.1.14 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 14/03/91

DRAIN			DRAIN/MID/FEEDER		
00	50.6	54.8	00	50.2	61.4
15	41.0	120.8	15	40.6	125.0
30	42.3	122.8	30	42.5	121.8
45	39.7	159.5	45	41.7	143.5
60	39.5	168.5	60	41.2	154.8
MIDDLE			ASHES/STRAW HEAP		
00	48.9	70.0	00	67.0	7.5
15	38.0	147.3	15	56.4	13.0
30	40.2	133.8	30	50.7	32.8
45	42.1	137.8	45	49.2	63.0
60	41.2	150.3	60	46.5	91.3
FEEDER			FIELD NURSERY		
00	51.1	59.5	00	52.9	60.0
15	42.8	107.0	15	34.8	185.0
30	45.0	108.8	30	35.7	180.0
45	43.2	133.3	45	37.3	174.0
60	42.7	145.8	60	38.2	166.0

TABLE A5.1.15 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 18/03/91

DRAIN			DRAIN/MID/FEEDER		
00	14.8	449.0	00	14.4	413.2
15	32.6	262.3	15	30.9	285.5
30	33.6	212.0	30	33.8	209.4
45	35.2	200.3	45	35.8	192.3
60	34.2	206.5	60	35.6	192.2
MIDDLE			ASHES/STRAW HEAP		
00	13.5	432.0	00	74.2	2.3
15	29.5	301.5	15	44.0	17.3
30	34.6	197.0	30	46.1	47.8
45	36.7	178.5	45	45.2	85.0
60	37.7	163.0	60	42.8	103.8
FEEDER			FIELD NURSERY		
00	14.8	358.5	00	15.3	357.0
15	30.6	292.8	15	21.3	318.0
30	33.3	219.3	30	26.4	298.0
45	35.5	198.0	45	31.4	203.0
60	34.8	207.0	60	33.2	207.0

TABLE A5.1.16 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 25/03/91

DRAIN			DRAIN/MID/FEEDER		
00	43.7	105.8	00	39.7	132.3
15	26.7	298.5	15	26.7	289.4
30	27.0	289.0	30	27.9	291.2
45	27.0	341.5	45	27.5	330.5
60	27.2	350.0	60	27.6	336.1
MIDDLE			ASHES/STRAW HEAP		
00	40.8	122.8	00	56.4	4.5
15	28.3	265.8	15	52.9	4.0
30	28.9	275.5	30	39.1	18.8
45	25.5	366.0	45	40.6	38.3
60	27.7	347.3	60	39.7	54.5
FEEDER			FIELD NURSERY		
00	34.7	168.3	00	39.4	130.0
15	25.2	304.0	15	23.1	330.0
30	27.9	309.0	30	24.2	336.0
45	30.0	284.0	45	24.5	336.0
60	28.0	311.0	60	21.1	380.0

TABLE A5.1.17 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 01/04/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	44.6	93.8	00	46.7	82.5
15	36.4	162.0	15	34.3	188.6
30	39.0	162.5	30	34.1	206.8
45	36.4	195.0	45	35.7	204.1
60	33.7	216.8	60	34.4	223.8
MIDDLE			ASHES/STRAW HEAP		
00	45.1	90.5	00	56.1	2.5
15	30.1	236.5	15	45.1	32.5
30	29.5	250.5	30	43.5	73.8
45	37.3	177.3	45	40.3	125.0
60	36.5	198.0	60	35.8	153.8
FEEDER			FIELD NURSERY		
00	50.5	63.3	00	50.5	88.0
15	36.5	167.3	15	34.1	189.0
30	33.8	207.5	30	28.9	280.0
45	33.4	240.0	45	28.7	320.0
60	33.0	256.5	60	30.9	293.0

TABLE A5.1.18 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 07/04/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	52.5	84.3	00	52.9	84.1
15	41.7	149.0	15	44.1	134.8
30	44.4	129.0	30	45.2	118.6
45	42.2	149.5	45	43.4	140.9
60	41.8	140.3	60	41.1	145.9
MIDDLE			ASHES/STRAW HEAP		
00	54.3	79.5	00	54.4	1.3
15	47.2	122.0	15	48.3	3.8
30	48.1	100.8	30	47.8	37.0
45	46.0	122.5	45	45.7	77.3
60	41.1	145.5	60	44.6	96.5
FEEDER			FIELD NURSERY		
00	51.8	88.5	00	55.5	60.0
15	43.5	133.5	15	46.8	115.0
30	43.1	126.0	30	39.6	150.0
45	42.0	150.8	45	37.6	180.0
60	40.4	152.0	60	36.8	230.0

TABLE A5.1.19 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 12/04/91

DRAIN			DRAIN/MID/FEEDER		
00	44.4	123.0	00	42.7	130.9
15	47.3	117.5	15	46.9	118.6
30	47.9	118.5	30	46.7	124.4
45	42.6	142.5	45	43.6	137.1
60	41.5	155.0	60	42.1	150.4
MIDDLE			ASHES/STRAW HEAP		
00	41.8	131.8	00	55.0	13.0
15	48.9	107.5	15	57.1	16.0
30	48.4	115.5	30	52.0	34.0
45	44.9	130.0	45	47.9	57.5
60	43.2	145.0	60	45.5	96.3
FEEDER			FIELD NURSERY		
00	41.9	138.0	00	45.1	100.0
15	44.4	130.8	15	39.7	140.0
30	43.8	139.3	30	46.4	140.0
45	43.3	138.8	45	42.4	142.0
60	41.7	151.3	60	40.7	145.0

TABLE A5.1.20 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 18/04/91

DRAIN			DRAIN/MID/FEEDER		
00	28.8	242.1	00	28.1	247.0
15	41.8	139.3	15	40.0	148.3
30	41.6	155.0	30	41.8	155.5
45	43.2	139.0	45	42.4	144.8
60	44.0	138.0	60	41.4	147.8
MIDDLE			ASHES/STRAW HEAP		
00	27.3	242.5	00	53.3	20.0
15	37.9	163.8	15	55.9	41.5
30	39.1	181.0	30	48.0	48.8
45	41.5	149.5	45	46.0	106.0
60	39.2	157.0	60	43.1	125.3
FEEDER			FIELD NURSERY		
00	28.3	256.3	00	32.5	187.0
15	40.5	142.0	15	43.3	128.0
30	44.5	130.5	30	43.6	130.0
45	42.4	146.0	45	43.0	140.0
60	41.0	148.5	60	40.3	160.0

TABLE A5.1.21 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 22/04/91

DRAIN			DRAIN/MID/FEEDER		
00	34.2	184.3	00	34.3	184.7
15	43.2	120.5	15	41.0	132.3
30	47.3	95.8	30	44.5	109.7
45	44.5	102.0	45	45.3	101.5
60	42.1	112.3	60	43.5	111.5
MIDDLE			ASHES/STRAW HEAP		
00	32.4	211.0	00	57.2	28.8
15	38.3	151.8	15	56.3	55.8
30	41.9	125.5	30	51.7	76.3
45	45.4	104.0	45	49.6	82.5
60	44.0	112.3	60	48.0	87.5
FEEDER			FIELD NURSERY		
00	36.3	158.8	00	39.2	150.0
15	41.5	124.8	15	35.9	155.0
30	44.2	107.8	30	38.8	165.0
45	46.0	98.5	45	40.2	145.0
60	44.3	110.0	60	38.5	145.0

TABLE A5.1.22 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 26/04/91

DRAIN			DRAIN/MID/FEEDER		
00	18.1	321.8	00	18.3	327.3
15	40.9	129.5	15	38.4	156.5
30	40.8	143.8	30	40.3	157.3
45	39.9	156.8	45	40.5	158.1
60	37.5	161.3	60	38.8	155.8
MIDDLE			ASHES/STRAW HEAP		
00	18.8	327.5	00	49.5	80.0
15	35.8	175.0	15	55.8	78.8
30	39.9	151.5	30	47.5	83.8
45	41.6	147.8	45	47.1	99.8
60	40.4	150.3	60	46.0	104.5
FEEDER			FIELD NURSERY		
00	18.1	332.5	00	17.0	338.0
15	38.4	165.0	15	38.0	150.0
30	40.1	176.8	30	39.4	154.0
45	40.0	169.8	45	39.2	164.0
60	38.6	155.8	60	37.0	175.0

TABLE A5.1.23 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 30/04/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	17.3	350.8	00	18.9	313.9
15	37.5	157.5	15	36.8	167.8
30	40.7	131.3	30	40.5	128.3
45	41.2	134.3	45	41.7	127.1
60	39.1	136.5	60	40.1	133.9
MIDDLE			ASHES/STRAW HEAP		
00	20.1	282.3	00	53.8	62.5
15	34.4	189.5	15	53.2	68.0
30	39.4	132.5	30	47.9	69.8
45	41.8	122.0	45	48.2	86.8
60	40.4	134.0	60	45.0	111.0
FEEDER			FIELD NURSERY		
00	19.4	308.8	00	17.5	328.0
15	38.4	156.3	15	35.9	171.0
30	41.4	121.0	30	39.3	160.0
45	42.1	125.0	45	40.2	150.0
60	40.7	131.3	60	38.3	175.0

TABLE A5.1.24 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 04/05/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	36.1	178.0	00	34.7	198.3
15	38.3	148.0	15	37.4	156.2
30	39.6	149.0	30	39.3	148.7
45	39.6	143.3	45	40.3	143.2
60	39.3	151.3	60	40.1	146.3
MIDDLE			ASHES/STRAW HEAP		
00	31.9	238.8	00	40.7	27.5
15	36.1	167.3	15	54.0	76.0
30	38.8	148.8	30	51.8	87.5
45	40.6	139.5	45	49.7	95.0
60	40.0	147.5	60	48.3	98.3
FEEDER			FIELD NURSERY		
00	36.2	178.0	00	36.3	160.0
15	37.8	153.3	15	37.9	152.0
30	39.6	148.3	30	39.5	145.0
45	40.7	146.8	45	42.0	130.0
60	41.1	140.0	60	40.9	152.0

TABLE A5.1.25 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 08/05/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	18.6	328.0	00	21.9	286.3
15	36.5	163.8	15	38.5	150.5
30	39.1	146.0	30	40.3	140.0
45	38.2	152.3	45	39.7	142.4
60	37.6	156.5	60	39.5	144.8
MIDDLE			ASHES/STRAW HEAP		
00	21.5	285.3	00	42.2	109.5
15	36.5	162.8	15	52.8	79.3
30	39.0	147.5	30	50.3	88.5
45	39.0	149.0	45	48.1	93.3
60	39.4	143.5	60	47.1	96.3
FEEDER			FIELD NURSERY		
00	25.5	245.5	00	21.5	295.0
15	42.6	125.0	15	33.5	200.0
30	42.7	126.5	30	34.8	180.0
45	41.8	126.0	45	35.0	185.0
60	41.4	134.5	60	35.1	185.0

TABLE A5.1.26 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 12/05/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	47.4	123.0	00	50.9	94.9
15	37.7	153.3	15	37.2	153.8
30	41.5	124.8	30	40.6	130.6
45	40.4	135.3	45	40.9	128.5
60	39.9	135.8	60	40.9	129.8
MIDDLE			ASHES/STRAW HEAP		
00	53.6	73.5	00	63.7	17.5
15	36.3	152.5	15	63.1	56.0
30	39.8	129.8	30	51.9	59.8
45	41.4	116.5	45	51.1	81.3
60	41.3	129.0	60	47.9	93.8
FEEDER			FIELD NURSERY		
00	51.8	88.3	00	52.2	60.0
15	37.5	155.5	15	34.8	158.0
30	40.5	137.3	30	41.0	128.0
45	40.9	133.8	45	41.9	130.0
60	41.4	124.8	60	40.6	130.0

TABLE A5.1.27 AVERAGE SMC AND PR - BLOCK D

SAMPLING DATE: 18/05/91

DRAIN			DRAIN/MID/FEEDER		
00	27.8	231.0	00	26.7	234.2
15	38.5	142.8	15	36.3	173.1
30	39.4	147.5	30	38.1	165.8
45	38.9	160.3	45	39.6	157.1
60	38.9	151.3	60	38.5	161.5
MIDDLE			ASHES/STRAW HEAP		
00	27.2	238.8	00	47.1	60.0
15	34.3	180.0	15	53.3	69.0
30	37.1	162.5	30	50.7	86.3
45	38.5	169.5	45	48.4	96.8
60	38.2	168.8	60	50.6	94.8
FEEDER			FIELD NURSERY		
00	25.2	232.8	00	25.1	263.0
15	36.0	196.5	15	29.8	205.0
30	37.7	187.3	30	33.5	193.0
45	41.4	141.5	45	34.4	185.0
60	38.4	164.5	60	35.8	178.0

TABLE A5.2.1 OBSERVED MOISTURE CONTENT (BY WEIGHT) AND PENETRATION RESISTANCE FROM THE DMF, BLOCK N/407.

No.	Sampling Date	Time	Sampling Depth (cm) 0-5		15		30		45		60		Mean SMC in 0-30cm Depth	Mean PR in 0-30cm Depth	Mean SMC in 0-60cm Depth	Mean PR in 0-60cm Depth
		(day)	SMC (%)	PR (N/cm²)	SMC (%)	PR (N/cm²)	SMC (%)	PR (N/cm²)	SMC (%)	PR (N/cm²)	SMC (%)	PR (N/cm²)	(%)	(N/cm²)	(%)	(N/cm²)
0	24/11/90	0	-	-	-	-	-	-	-	-	-	-	-	-		
1	19/12/90	25	69.2	12.9	72.6	22.7	51.9	47.8	50.0	62.1	42.5	74.3	64.5	27.8	57.2	44.0
2	22/12/90	28	59.4	28.9	64.7	37.9	51.2	60.7	47.7	79.8	44.9	94.8	58.4	42.5	53.6	60.4
3	26/12/90	32	34.0	121.3	54.6	54.8	50.0	70.3	48.5	88.8	45.2	99.9	46.2	82.2	46.4	87.1
4	31/12/90	37	25.5	173.9	62.3	39.6	52.9	69.2	48.6	88.3	45.1	105.8	46.9	94.2	46.9	95.4
5	11/01/91	48	76.3	21.7	76.1	30.1	56.9	58.3	53.7	75.8	51.0	99.4	69.8	36.7	62.8	57.0
6	21/01/91	58	18.9	272.8	62.0	62.7	56.1	77.7	54.4	94.8	48.9	112.5	45.7	137.7	48.0	124.1
7	28/01/91	65	51.7	60.1	61.8	59.0	54.9	81.8	50.6	103.4	48.6	113.8	56.1	66.9	53.5	83.6
8	04/02/91	72	18.3	310.5	54.1	86.7	51.3	95.4	47.9	106.1	45.5	120.5	41.2	164.2	43.4	143.8
9	11/02/91	79	23.0	258.8	47.0	107.5	47.8	111.3	45.1	127.7	43.5	142.9	39.2	159.2	41.3	149.6
10	18/02/91	86	18.2	358.9	42.9	133.3	41.2	150.6	42.6	147.0	40.5	150.3	34.1	214.3	37.1	188.0
11	25/02/91	93	19.7	295.4	37.5	149.5	39.7	140.4	40.5	150.3	39.7	154.7	32.3	195.1	35.4	178.1
12	01/03/91	97	21.6	330.3	32.6	260.6	34.2	224.6	33.0	226.8	32.3	234.5	29.5	271.8	30.7	255.4
13	06/03/91	102	17.2	347.7	33.3	196.6	35.9	164.2	37.6	172.2	37.4	173.4	28.8	236.1	32.3	210.8
14	14/03/91	110	50.2	61.4	40.6	125.0	42.5	121.8	41.7	143.5	41.2	154.8	44.4	102.7	43.2	121.3
15	18/03/91	114	14.4	413.2	30.9	285.5	33.8	209.4	35.8	192.3	35.6	192.2	26.4	302.7	30.1	258.5
16	25/03/91	121	39.7	132.3	26.7	289.4	27.9	291.2	27.5	330.5	27.6	336.1	31.4	237.6	29.9	275.9
17	01/04/91	128	46.7	82.5	34.3	188.6	34.1	206.8	35.7	204.1	34.4	223.8	38.4	159.3	37.1	181.2
18	07/04/91	134	52.9	84.1	44.1	134.8	45.2	118.6	43.4	140.9	41.1	145.9	47.4	112.5	45.3	124.9
19	12/04/91	139	42.7	130.9	46.9	118.6	46.7	124.4	43.6	137.1	42.1	150.4	45.4	124.6	44.4	132.3
20	18/04/91	145	28.1	247.0	40.0	148.3	41.8	155.5	42.4	144.8	41.4	147.8	36.6	183.6	38.7	168.7
21	22/04/91	149	34.3	184.7	41.0	132.3	44.5	109.7	45.3	101.5	43.5	111.5	39.9	142.2	41.7	127.9
22	26/04/91	153	18.3	327.3	38.4	156.5	40.3	157.3	40.5	158.1	38.8	155.8	32.3	213.7	35.3	191.0
23	30/04/91	157	18.9	313.9	36.8	167.8	40.5	128.3	41.7	127.1	40.1	133.9	32.1	203.3	35.6	174.2
24	04/05/91	161	34.7	198.3	37.4	156.2	39.3	148.7	40.3	143.2	40.1	146.3	37.2	167.7	38.4	158.5
25	08/05/91	165	21.9	286.3	38.5	150.5	40.3	140.0	39.7	142.4	39.5	144.8	33.6	192.3	36.0	172.8
26	12/05/91	169	50.9	94.9	37.2	153.8	40.6	130.6	40.9	128.5	40.9	129.8	42.9	126.4	42.1	127.5
27	18/05/91	175	26.7	234.2	36.3	173.1	38.1	165.8	39.6	157.1	38.5	161.5	33.7	191.0	35.8	178.3

TABLE A5.2.2 OBSERVED MOISTURE CONTENT (BY VOLUME) AND PENETRATION RESISTANCE FROM THE DMF, BLOCK D/157.

No.	Sampling Date	Time	Sampling Depth (cm) 0-5		15		30		45		60		Mean SMC in 0-30cm Depth	Mean PR in 0-30cm Depth	Mean SMC in 0-60cm Depth	Mean PR in 0-60cm Depth
		(day)	SMC (mm)	PR (N/cm²)	SMC (mm)	PR (N/cm²)	SMC (mm)	PR (N/cm²)	SMC (mm)	PR (N/cm²)	SMC (mm)	PR (N/cm²)	(mm)	(N/cm²)	(mm)	(N/cm²)
0	24/11/90	0	-	-	-	-	-	-	-	-	-	-	-	-		
1	19/12/90	25	47.7	12.9	108.1	22.7	78.9	47.8	78.1	62.1	69.7	74.3	234.6	27.8	382.4	44.0
2	22/12/90	28	40.9	28.9	96.4	37.9	77.9	60.7	74.5	79.8	73.7	94.8	215.2	42.5	363.4	60.4
3	26/12/90	32	23.4	121.3	81.3	54.8	76.0	70.3	75.7	88.8	74.2	99.9	180.7	82.2	330.6	87.1
4	31/12/90	37	17.6	173.9	92.9	39.6	80.4	69.2	76.0	88.3	73.9	105.8	190.9	94.2	340.7	95.4
5	11/01/91	48	52.5	21.7	113.3	30.1	86.5	58.3	83.8	75.8	83.7	99.4	252.4	36.7	419.9	57.0
6	21/01/91	58	13.0	272.8	92.3	62.7	85.2	77.7	85.0	94.8	80.1	112.5	190.6	137.7	355.7	124.1
7	28/01/91	65	35.6	60.1	92.1	59.0	83.5	81.8	79.0	103.4	79.7	113.8	211.1	66.9	369.8	83.6
8	04/02/91	72	12.6	310.5	80.7	86.7	77.9	95.4	74.8	106.1	74.7	120.5	171.2	164.2	320.7	143.8
9	11/02/91	79	15.8	258.8	70.0	107.5	72.6	111.3	70.5	127.7	71.4	142.9	158.4	159.2	300.3	149.6
10	18/02/91	86	12.5	358.9	63.9	133.3	62.6	150.6	66.5	147.0	66.5	150.3	139.0	214.3	272.0	188.0
11	25/02/91	93	13.6	295.4	55.9	149.5	60.4	140.4	63.3	150.3	65.1	154.7	129.8	195.1	258.3	178.1
12	01/03/91	97	14.9	330.3	48.6	260.6	52.0	224.6	51.5	226.8	53.0	234.5	115.4	271.8	220.0	255.4
13	06/03/91	102	11.9	347.7	49.6	196.6	54.7	164.2	58.7	172.2	61.3	173.4	116.2	236.1	236.2	210.8
14	14/03/91	110	34.6	61.4	60.5	125.0	64.6	121.8	65.1	143.5	67.5	154.8	159.7	102.7	292.3	121.3
15	18/03/91	114	9.9	413.2	46.1	285.5	51.5	209.4	55.9	192.3	58.4	192.2	107.4	302.7	221.7	258.5
16	25/03/91	121	27.4	132.3	39.8	289.4	42.5	291.2	42.9	330.5	45.3	336.1	109.6	237.6	197.8	275.9
17	01/04/91	128	32.2	82.5	51.2	188.6	51.9	206.8	55.7	204.1	56.5	223.8	135.2	159.3	247.4	181.2
18	07/04/91	134	36.4	84.1	65.8	134.8	68.7	118.6	67.8	140.9	67.4	145.9	170.9	112.5	306.1	124.9
19	12/04/91	139	29.4	130.9	69.8	118.6	71.0	124.4	68.1	137.1	69.1	150.4	170.2	124.6	307.5	132.3
20	18/04/91	145	19.4	247.0	59.7	148.3	63.5	155.5	66.2	144.8	67.9	147.8	142.5	183.6	276.7	168.7
21	22/04/91	149	23.6	184.7	61.1	132.3	67.6	109.7	70.8	101.5	71.3	111.5	152.3	142.2	294.4	127.9
22	26/04/91	153	12.6	327.3	57.2	156.5	61.3	157.3	63.2	158.1	63.7	155.8	131.1	213.7	257.9	191.0
23	30/04/91	157	13.0	313.9	54.8	167.8	61.6	128.3	65.1	127.1	65.7	133.9	129.4	203.3	260.2	174.2
24	04/05/91	161	23.9	198.3	55.7	156.2	59.8	148.7	63.0	143.2	65.8	146.3	139.4	167.7	268.3	158.5
25	08/05/91	165	15.1	286.3	57.4	150.5	61.2	140.0	62.0	142.4	64.8	144.8	133.6	192.3	260.4	172.8
26	12/05/91	169	35.1	94.9	55.4	153.8	61.7	130.6	63.9	128.5	67.0	129.8	152.2	126.4	283.1	127.5
27	18/05/91	175	18.4	234.2	54.0	173.1	57.9	165.8	61.9	157.1	63.2	161.5	130.3	191.0	255.4	178.3

TABLE A5.2.3 OBSERVED MOISTURE CONTENT (BY WEIGHT) AND PENETRATION RESISTANCE FROM NURSERY, BLOCK D/157.

No.	Sampling Date	Time (day)	0-5 SMC (%)	0-5 PR (N/cm²)	15 SMC (%)	15 PR (N/cm²)	30 SMC (%)	30 PR (N/cm²)	45 SMC (%)	45 PR (N/cm²)	60 SMC (%)	60 PR (N/cm²)	Mean SMC in 0-30cm Depth (%)	Mean PR in 0-30cm Depth (N/cm²)	Mean SMC in 0-60cm Depth (%)	Mean PR in 0-60cm Depth (N/cm²)
0	24/11/90	0	-	-	-	-	-	-	-	-	-	-	-	-		
1	22/12/90	28	56.6	32.0	74.1	38.0	50.9	66.0	49.0	68.0	44.5	88.0	60.5	45.3	55.0	58.4
2	26/12/90	32	45.5	71.0	53.9	64.0	48.0	71.0	46.0	80.0	42.0	98.0	49.1	68.7	47.1	76.8
3	31/12/90	37	39.7	136.0	52.3	67.0	49.1	72.0	47.9	94.0	44.2	112.0	47.0	91.7	46.6	96.2
4	11/01/91	48	80.4	20.0	55.8	43.0	50.3	69.0	50.3	90.0	49.4	108.0	62.1	44.0	57.2	66.0
5	21/01/91	58	16.2	285.0	43.7	115.0	53.7	89.0	50.0	105.0	46.6	126.0	37.9	163.0	42.1	144.0
6	28/01/91	65	52.6	57.0	44.7	118.0	44.7	128.0	45.0	124.0	46.3	125.0	47.3	101.0	46.6	110.4
7	04/02/91	72	14.3	364.0	38.1	154.0	39.0	150.0	45.6	130.0	44.0	140.0	30.5	222.7	36.2	187.6
8	11/02/91	79	22.6	262.0	42.9	136.0	42.9	135.0	43.3	130.0	43.3	130.0	36.1	177.7	39.0	158.6
9	18/02/91	86	24.9	269.0	34.3	174.0	33.5	180.0	36.2	162.0	41.3	148.0	30.9	207.7	34.1	186.6
10	25/02/91	93	15.2	326.0	38.1	158.0	37.2	178.0	35.5	221.0	36.6	180.0	30.2	220.7	32.5	212.6
11	01/03/91	97	16.9	360.0	18.6	346.0	28.4	280.0	31.9	246.0	30.0	270.0	21.3	328.7	25.2	300.4
12	06/03/91	102	17.9	345.0	33.1	193.0	34.3	187.0	31.4	201.0	30.7	221.0	28.4	241.7	29.5	229.4
13	14/03/91	110	52.9	60.0	34.8	185.0	35.7	180.0	37.3	174.0	38.2	166.0	41.1	141.7	39.8	153.0
14	18/03/91	114	15.3	357.0	21.3	318.0	26.4	298.0	31.4	203.0	33.2	207.0	21.0	324.3	25.5	276.6
15	25/03/91	121	39.4	130.0	23.1	330.0	24.2	336.0	24.5	336.0	21.1	380.0	28.9	265.3	26.5	302.4
16	01/04/91	128	50.5	88.0	34.1	189.0	28.9	280.0	28.7	320.0	30.9	293.0	37.8	185.7	34.6	234.0
17	07/04/91	134	55.5	60.0	46.8	115.0	39.6	150.0	37.6	180.0	36.8	230.0	47.3	108.3	43.3	147.0
18	12/04/91	139	45.1	100.0	39.7	140.0	46.4	140.0	42.4	142.0	40.7	145.0	43.7	126.7	42.9	133.4
19	18/04/91	145	32.5	187.0	43.3	128.0	43.6	130.0	43.0	140.0	40.3	160.0	39.8	148.3	40.5	149.0
20	22/04/91	149	39.2	150.0	35.9	155.0	38.8	165.0	40.2	145.0	38.5	145.0	38.0	156.7	38.5	152.0
21	26/04/91	153	17.0	338.0	38.0	150.0	39.4	154.0	39.2	164.0	37.0	175.0	31.5	214.0	34.2	196.2
22	30/04/91	157	17.5	328.0	35.9	171.0	39.3	160.0	40.2	150.0	38.3	175.0	30.9	219.7	34.2	196.8
23	04/05/91	161	36.3	160.0	37.9	152.0	39.5	145.0	42.0	130.0	40.9	152.0	37.9	152.3	39.3	147.8
24	08/05/91	165	21.5	295.0	33.5	200.0	34.8	180.0	35.0	185.0	35.1	185.0	29.9	225.0	32.0	209.0
25	12/05/91	169	52.2	60.0	34.8	158.0	41.0	128.0	41.9	130.0	40.6	130.0	42.7	115.3	42.1	121.2
26	18/05/91	175	25.1	263.0	29.8	205.0	33.5	193.0	34.4	185.0	35.8	178.0	29.5	220.3	31.7	204.8

TABLE A5.2.4 OBSERVED MOISTURE CONTENT (BY VOLUME) AND PENETRATION RESISTANCE FROM NURSERY, BLOCK D/157.

No.	Sampling Date	Time (day)	0-5 SMC (mm)	0-5 PR (N/cm²)	15 SMC (mm)	15 PR (N/cm²)	30 SMC (mm)	30 PR (N/cm²)	45 SMC (mm)	45 PR (N/cm²)	60 SMC (mm)	60 PR (N/cm²)	Mean SMC in 0-30cm Depth (mm)	Mean PR in 0-30cm Depth (N/cm²)	Mean SMC in 0-60cm Depth (mm)	Mean PR in 0-60cm Depth (N/cm²)
0	24/11/90	0	-	-	-	-	-	-	-	-	-	-	-	-		
1	22/12/90	28	38.9	32.0	110.4	38.0	77.3	66.0	76.5	68.0	73.0	88.0	226.7	45.3	376.1	58.4
2	26/12/90	32	31.3	71.0	80.3	64.0	72.9	71.0	71.8	80.0	68.9	98.0	184.5	68.7	325.3	76.8
3	31/12/90	37	27.4	136.0	78.0	67.0	74.7	72.0	74.8	94.0	72.5	112.0	180.0	91.7	327.3	96.2
4	11/01/91	48	55.3	20.0	83.1	43.0	76.4	69.0	78.6	90.0	81.1	108.0	214.9	44.0	374.5	66.0
5	21/01/91	58	11.2	285.0	65.1	115.0	81.7	89.0	78.1	105.0	76.4	126.0	158.0	163.0	312.5	144.0
6	28/01/91	65	36.2	57.0	66.6	118.0	68.0	128.0	70.3	124.0	75.9	125.0	170.8	101.0	317.0	110.4
7	04/02/91	72	9.8	364.0	56.7	154.0	59.3	150.0	71.3	130.0	72.2	140.0	125.9	222.7	269.3	187.6
8	11/02/91	79	15.6	262.0	63.9	136.0	65.2	135.0	67.6	130.0	70.9	130.0	144.7	177.7	283.3	158.6
9	18/02/91	86	17.1	269.0	51.1	174.0	51.0	180.0	56.6	162.0	67.7	148.0	119.3	207.7	243.6	186.6
10	25/02/91	93	10.5	326.0	56.7	158.0	56.6	178.0	55.4	221.0	60.0	180.0	123.8	220.7	239.1	212.6
11	01/03/91	97	11.6	360.0	27.7	346.0	43.2	280.0	49.8	246.0	49.2	270.0	82.6	328.7	181.6	300.4
12	06/03/91	102	12.3	345.0	49.3	193.0	52.1	187.0	49.1	201.0	50.4	221.0	113.7	241.7	213.3	229.4
13	14/03/91	110	36.4	60.0	51.8	185.0	54.3	180.0	58.2	174.0	62.7	166.0	142.5	141.7	263.4	153.0
14	18/03/91	114	10.5	357.0	31.7	318.0	40.2	298.0	49.1	203.0	54.4	207.0	82.4	324.3	185.9	276.6
15	25/03/91	121	27.1	130.0	34.5	330.0	36.9	336.0	38.3	336.0	34.7	380.0	98.5	265.3	171.5	302.4
16	01/04/91	128	34.8	88.0	50.9	189.0	43.9	280.0	44.9	320.0	50.7	293.0	129.5	185.7	225.1	234.0
17	07/04/91	134	38.2	60.0	69.7	115.0	60.1	150.0	58.8	180.0	60.4	230.0	168.1	108.3	287.3	147.0
18	12/04/91	139	31.1	100.0	59.2	140.0	70.6	140.0	66.3	142.0	66.7	145.0	160.8	126.7	293.8	133.4
19	18/04/91	145	22.3	187.0	64.6	128.0	66.3	130.0	67.2	140.0	66.1	160.0	153.2	148.3	286.6	149.0
20	22/04/91	149	27.0	150.0	53.5	155.0	59.0	165.0	62.8	145.0	63.2	145.0	139.5	156.7	265.5	152.0
21	26/04/91	153	11.7	338.0	56.6	150.0	60.0	154.0	61.3	164.0	60.8	175.0	128.3	214.0	250.4	196.2
22	30/04/91	157	12.1	328.0	53.5	171.0	59.7	160.0	62.8	150.0	62.8	175.0	125.3	219.7	250.9	196.8
23	04/05/91	161	25.0	160.0	56.5	152.0	60.1	145.0	65.6	130.0	67.2	152.0	141.6	152.3	274.3	147.8
24	08/05/91	165	14.8	295.0	49.9	200.0	52.9	180.0	54.7	185.0	57.6	185.0	117.6	225.0	229.9	209.0
25	12/05/91	169	36.0	60.0	51.9	158.0	62.3	128.0	65.5	130.0	66.6	130.0	150.1	115.3	282.2	121.2
26	18/05/91	175	17.3	263.0	44.5	205.0	50.9	193.0	53.7	185.0	58.8	178.0	112.6	220.3	225.1	204.8

TABLE A5.2.5 OBSERVED MOISTURE CONTENT (BY WEIGHT) AND PENETRATION RESISTANCE FOR ASH/STRAW, BLOCK D/157.

No.	Sampling Date	Time	Sampling Depth (cm) 0-5		15		30		45		60		Mean SMC in 0-30cm Depth	Mean PR in 0-30cm Depth	Mean SMC in 0-60cm Depth	Mean PR in 0-60cm Depth
		(day)	SMC (%)	PR (N/cm²)	SMC (%)	PR (N/cm²)	SMC (%)	PR (N/cm²)	SMC (%)	PR (N/cm²)	SMC (%)	PR (N/cm²)	(%)	(N/cm²)	(%)	(N/cm²)
0	24/11/90	0	-	-	-	-	-	-	-	-	-	-	-	-		
1	26/12/90	32	103.8	6.5	63.4	20.8	61.3	41.3	50.8	62.8	48.5	83.5	76.2	22.8	65.6	43.0
2	31/12/90	37	113.1	3.8	72.1	22.5	51.6	60.8	50.4	73.8	47.3	100.0	78.9	29.0	66.9	52.2
3	11/01/91	48	98.1	2.5	71.2	13.0	58.9	47.5	54.7	69.8	50.5	84.8	76.1	21.0	66.7	43.5
4	21/01/91	58	77.3	15.0	67.3	32.8	55.8	68.5	53.7	79.5	49.3	95.8	66.8	38.8	60.7	58.3
5	28/01/91	65	69.0	11.5	73.2	35.8	57.2	58.0	54.8	74.0	49.8	86.5	66.5	35.1	60.8	53.2
6	04/02/91	72	64.3	62.5	66.9	50.5	52.6	82.5	49.9	92.8	46.9	113.8	61.3	65.2	56.1	80.4
7	11/02/91	79	79.4	10.0	56.5	25.0	50.9	46.0	50.4	61.3	45.2	103.0	62.3	27.0	56.5	49.1
8	18/02/91	86	41.7	25.0	49.0	29.0	45.0	41.0	43.9	72.8	48.9	108.3	45.2	31.7	45.7	55.2
9	25/02/91	93	77.5	14.0	58.0	24.8	49.1	62.8	49.3	82.5	45.7	92.5	61.5	33.8	55.9	55.3
10	01/03/91	97	50.7	5.0	54.0	11.5	42.3	62.5	40.9	90.0	38.9	101.5	49.0	26.3	45.4	54.1
11	06/03/91	102	66.8	2.8	53.5	8.8	51.9	21.8	52.6	56.8	57.3	67.0	57.4	11.1	56.4	31.4
12	14/03/91	110	67.0	7.5	56.4	13.0	50.7	32.8	49.2	63.0	46.5	91.3	58.0	17.8	53.9	41.5
13	18/03/91	114	74.2	2.3	44.0	17.3	46.1	47.8	45.2	85.0	42.8	103.8	54.8	22.4	50.4	51.2
14	25/03/91	121	56.4	4.5	52.9	4.0	39.1	18.8	40.6	38.3	39.7	54.5	49.5	9.1	45.8	24.0
15	01/04/91	128	56.1	2.5	45.1	32.5	43.5	73.8	40.3	125.0	35.8	153.8	48.2	36.3	44.1	77.5
16	07/04/91	134	54.4	1.3	48.3	3.8	47.8	37.0	45.7	77.3	44.6	96.5	50.1	14.0	48.1	43.2
17	12/04/91	139	55.0	13.0	57.1	16.0	52.0	34.0	47.9	57.5	45.5	96.3	54.7	21.0	51.5	43.4
18	18/04/91	145	53.3	20.0	55.9	41.5	48.0	48.8	46.0	106.0	43.1	125.3	52.4	36.8	49.2	68.3
19	22/04/91	149	57.2	28.8	56.3	55.8	51.7	76.3	49.6	82.5	48.0	87.5	55.1	53.6	52.6	66.2
20	26/04/91	153	49.5	80.0	55.8	78.8	47.5	83.8	47.1	99.8	46.0	104.5	50.9	80.8	49.2	89.4
21	30/04/91	157	53.8	62.5	53.2	68.0	47.9	69.8	48.2	86.8	45.0	111.0	51.6	66.8	49.6	79.6
22	04/05/91	161	40.7	27.5	54.0	76.0	51.8	87.5	49.7	95.0	48.3	98.3	48.8	63.7	48.9	76.9
23	08/05/91	165	42.2	109.5	52.8	79.3	50.3	88.5	48.1	93.3	47.1	96.3	48.4	92.4	48.1	93.4
24	12/05/91	169	63.7	17.5	63.1	56.0	51.9	59.8	51.1	81.3	47.9	93.8	59.6	44.4	55.5	61.7
25	18/05/91	175	47.1	60.0	53.3	69.0	50.7	86.3	48.4	96.8	50.6	94.8	50.4	71.8	50.0	81.4

TABLE A5.2.6 OBSERVED MOISTURE CONTENT (BY VOL.) AND PENETRATION RESISTANCE FROM ASH/STRAW, BLOCK D/157.

No.	Sampling Date	Time	Sampling Depth (cm) 0-5		15		30		45		60		Mean SMC in 0-30cm Depth	Mean PR in 0-30cm Depth	Mean SMC in 0-60cm Depth	Mean PR in 0-60cm Depth
		(day)	SMC (mm)	PR (N/cm²)	SMC (mm)	PR (N/cm²)	SMC (mm)	PR (N/cm²)	SMC (mm)	PR (N/cm²)	SMC (mm)	PR (N/cm²)	(mm)	(N/cm²)	(mm)	(N/cm²)
0	24/11/90	0	-	-	-	-	-	-	-	-	-	-	-	-		
1	26/12/90	32	71.5	6.5	94.4	20.8	93.2	41.3	79.4	62.8	79.6	83.5	259.1	22.8	418.1	43.0
2	31/12/90	37	77.9	3.8	107.4	22.5	78.4	60.8	78.7	73.8	77.5	100.0	263.7	29.0	420.0	52.2
3	11/01/91	48	67.5	2.5	106.1	13.0	89.6	47.5	85.4	69.8	82.8	84.8	263.3	21.0	431.5	43.5
4	21/01/91	58	53.3	15.0	100.3	32.8	84.8	68.5	83.9	79.5	80.9	95.8	238.3	38.8	403.1	58.3
5	28/01/91	65	47.5	11.5	109.1	35.8	86.9	58.0	85.6	74.0	81.7	86.5	243.5	35.1	410.8	53.2
6	04/02/91	72	44.3	62.5	99.7	50.5	80.0	82.5	77.9	92.8	76.9	113.8	223.9	65.2	378.8	80.4
7	11/02/91	79	54.7	10.0	84.2	25.0	77.3	46.0	78.7	61.3	74.2	103.0	216.2	27.0	369.1	49.1
8	18/02/91	86	28.7	25.0	72.9	29.0	68.5	41.0	68.6	72.8	80.2	108.3	170.1	31.7	318.8	55.2
9	25/02/91	93	53.3	14.0	86.4	24.8	74.6	62.8	77.0	82.5	75.0	92.5	214.3	33.8	366.3	55.3
10	01/03/91	97	34.9	5.0	80.4	11.5	64.4	62.5	63.9	90.0	63.9	101.5	179.8	26.3	307.5	54.1
11	06/03/91	102	46.0	2.8	79.7	8.8	78.9	21.8	82.2	56.8	94.0	67.0	204.6	11.1	380.8	31.4
12	14/03/91	110	46.1	7.5	84.0	13.0	77.0	32.8	76.9	63.0	76.2	91.3	207.2	17.8	360.3	41.5
13	18/03/91	114	51.1	2.3	65.6	17.3	70.0	47.8	70.5	85.0	70.2	103.8	186.7	22.4	327.5	51.2
14	25/03/91	121	38.9	4.5	78.7	4.0	59.5	18.8	63.5	38.3	65.2	54.5	177.1	9.1	305.7	24.0
15	01/04/91	128	38.6	2.5	67.2	32.5	66.2	73.8	62.9	125.0	58.8	153.8	171.9	36.3	293.6	77.5
16	07/04/91	134	37.4	1.3	71.9	3.8	72.7	37.0	71.4	77.3	73.1	96.5	182.0	14.0	326.5	43.2
17	12/04/91	139	37.8	13.0	85.1	16.0	79.0	34.0	74.9	57.5	74.6	96.3	201.9	21.0	351.4	43.4
18	18/04/91	145	36.7	20.0	83.3	41.5	73.0	48.8	71.8	106.0	70.7	125.3	192.9	36.8	335.4	68.3
19	22/04/91	149	39.4	28.8	83.9	55.8	78.6	76.3	77.5	82.5	78.7	87.5	202.0	53.6	358.1	66.2
20	26/04/91	153	34.1	80.0	83.2	78.8	72.3	83.8	73.6	99.8	75.4	104.5	189.5	80.8	338.5	89.4
21	30/04/91	157	37.0	62.5	79.2	68.0	72.8	69.8	75.3	86.8	73.9	111.0	189.0	66.8	338.1	79.6
22	04/05/91	161	28.0	27.5	80.5	76.0	78.7	87.5	77.7	95.0	79.2	98.3	187.2	63.7	344.1	76.9
23	08/05/91	165	29.1	109.5	78.7	79.3	76.4	88.5	75.1	93.3	77.3	96.3	184.2	92.4	336.5	93.4
24	12/05/91	169	43.9	17.5	94.0	56.0	78.8	59.8	79.8	81.3	78.5	93.8	216.7	44.4	375.1	61.7
25	18/05/91	175	32.4	60.0	79.4	69.0	77.1	86.3	75.7	96.8	83.0	94.8	188.9	71.8	347.5	81.4

ANNEX 6

SOIL MOISTURE CONTENT AND PENETRATION RESISTANCE DATA FROM BLOCK N

PART ONE

Part one comprises Tables A6.1.1 - A6.1.24. These tables give the average SMC (on weight basis) and PR for each sampling day from the various sampling locations and depths. The averages were calculated first over replicates and sampling locations (treatments) and then over depths after combining some treatments. Some treatments (Drain, Middle and Feeder) were combined in order to manage data with ease. The combining of those treatments was made possible by the fact that there was no significant difference in data obtained from them.

PART TWO

Part two of Annexe 6 comprises of Tables A6.2.1 - A6.2.6. These tables show the SMC and PR data after grouping some treatments together and after converting SMC from weight basis to volume basis. Conversion of SMC in weight basis to vloume was necessary because the units of measurements for other parameters (rainfall and evaporation) that were considered in developing a soil drying model for APS were in volume basis. Determination of SMC on voulume basis was not possible due to lack of enough sampling cores.

TABLE A6.1.1 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 20/12/90

FIELD POS. AND DEPTH (cm)	AVER. SMC BY WGT. (%)	AVER. PENET. RESIS. (PR) N/cm²	FIELD POS. AND DEPTH (cm)	OVER-ALL AVER. SMC (%)	OVER-ALL AVER. PR N/cm²
FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	32.9	114.3	00	37.0	110.3
15	63.3	45.0	15	60.1	60.4
30	61.7	55.7	30	57.6	71.8
45	53.8	74.7	45	50.7	81.7
60	49.3	82.7	60	48.4	88.3
MIDDLE			ASHES/STRAW HEAP		
00	39.6	109.7	00	-	-
15	57.9	66.0	15	-	-
30	55.5	67.3	30	-	-
45	49.7	73.7	45	-	-
60	49.2	84.7	60	-	-
FEEDER			FIELD NURSERY		
00	38.4	107.0	00	-	-
15	59.0	70.3	15	-	-
30	55.7	92.3	30	-	-
45	48.6	96.7	45	-	-
60	46.6	97.7	60	-	-

TABLE A6.1.2 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 23/12/90

FIELD POS. AND DEPTH (cm)	AVER. SMC BY WGT. (%)	AVER. PENET. RESIS. (PR) N/cm²	FIELD POS. AND DEPTH (cm)	OVER-ALL AVER. SMC (%)	OVER-ALL AVER. PR N/cm²
FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	23.2	155.3	00	23.6	171.8
15	63.0	69.0	15	59.3	80.6
30	57.5	81.3	30	52.8	89.0
45	53.0	87.0	45	51.7	95.4
60	50.1	99.8	60	49.6	105.7
MIDDLE			ASHES/STRAW HEAP		
00	24.5	162.8	00	-	-
15	56.5	95.8	15	-	-
30	48.6	94.5	30	-	-
45	51.7	98.0	45	-	-
60	50.1	108.3	60	-	-
FEEDER			FIELD NURSERY		
00	23.1	197.3	00	-	-
15	58.5	77.0	15	-	-
30	52.3	91.3	30	-	-
45	50.4	101.3	45	-	-
60	48.6	109.0	60	-	-

TABLE A6.1.3 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 27/12/90

DRAIN			DRAIN/MID/FEEDER		
00	22.6	196.5	00	21.7	216.9
15	53.9	91.8	15	54.5	95.8
30	54.9	78.8	30	51.7	97.3
45	47.9	81.3	45	49.6	103.3
60	48.0	97.5	60	48.5	110.5
MIDDLE			ASHES/STRAW HEAP		
00	20.3	230.3	00	71.4	20.5
15	53.5	99.0	15	67.7	41.5
30	49.5	101.8	30	60.8	83.0
45	50.9	112.8	45	51.5	101.5
60	49.2	115.8	60	53.1	93.5
FEEDER			FIELD NURSERY		
00	22.2	224.0	00	14.2	240.0
15	56.1	96.8	15	50.3	97.0
30	50.8	111.5	30	51.6	95.0
45	49.9	115.8	45	53.5	93.0
60	48.4	118.3	60	54.9	91.0

TABLE A6.1.4 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 02/01/91

DRAIN			DRAIN/MID/FEEDER		
00	48.3	68.3	00	46.1	76.9
15	56.0	71.8	15	54.9	68.2
30	52.1	71.0	30	51.2	71.8
45	49.2	88.5	45	48.4	88.3
60	47.6	102.8	60	46.7	103.8
MIDDLE			ASHES/STRAW HEAP		
00	48.3	70.0	00	82.9	3.3
15	56.0	53.8	15	71.4	29.5
30	50.5	68.3	30	56.5	55.8
45	48.7	81.0	45	51.1	71.0
60	46.8	92.0	60	50.3	90.3
FEEDER			FIELD NURSERY		
00	41.8	92.5	00	47.0	60.0
15	52.8	79.0	15	56.4	56.0
30	50.9	76.0	30	49.6	76.0
45	47.4	95.5	45	50.8	75.0
60	45.6	116.8	60	50.1	83.0

TABLE A6.1.5 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 14/01/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	23.6	170.5	00	20.9	202.2
15	65.1	72.5	15	58.8	78.1
30	67.5	62.8	30	56.7	74.4
45	50.6	90.5	45	50.0	87.3
60	48.5	90.3	60	47.5	99.2
MIDDLE			ASHES/STRAW HEAP		
00	17.6	231.0	00	75.9	17.3
15	57.5	76.0	15	65.9	29.5
30	52.4	72.3	30	55.0	61.0
45	51.0	82.5	45	57.0	79.3
60	48.8	97.5	60	55.4	91.0
FEEDER			FIELD NURSERY		
00	21.5	205.0	00	19.9	240.0
15	53.8	85.8	15	53.1	70.0
30	50.3	88.3	30	53.6	88.0
45	48.6	89.0	45	53.3	93.0
60	45.3	109.8	60	52.1	96.0

TABLE A6.1.6 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 24/01/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	18.3	355.0	00	17.8	318.1
15	31.0	227.0	15	34.8	193.3
30	48.3	122.0	30	48.5	119.4
45	52.3	113.3	45	51.1	111.2
60	49.8	128.8	60	49.9	119.2
MIDDLE			ASHES/STRAW HEAP		
00	18.1	270.5	00	72.6	20.8
15	38.0	162.3	15	64.7	46.3
30	52.0	108.5	30	60.1	64.0
45	51.9	107.0	45	55.9	73.3
60	50.8	111.5	60	52.3	92.3
FEEDER			FIELD NURSERY		
00	17.0	328.8	00	19.3	332.0
15	35.4	190.8	15	43.9	152.0
30	45.4	127.8	30	47.9	131.0
45	49.0	113.3	45	51.1	120.0
60	49.2	117.3	60	53.5	130.0

TABLE A6.1.7 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 30/01/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	32.7	205.5	00	33.0	175.8
15	58.6	66.3	15	56.0	72.6
30	57.2	81.3	30	54.6	77.7
45	51.8	73.3	45	52.6	78.3
60	50.0	106.8	60	49.3	103.7
MIDDLE			ASHES/STRAW HEAP		
00	33.7	158.3	00	48.9	72.3
15	55.7	84.8	15	68.5	30.3
30	54.0	86.3	30	58.2	71.3
45	53.1	89.8	45	55.5	93.0
60	49.7	104.0	60	54.0	106.8
FEEDER			FIELD NURSERY		
00	32.5	163.5	00	35.2	139.0
15	53.8	66.8	15	57.6	88.0
30	52.6	65.5	30	54.8	94.0
45	52.9	72.0	45	50.3	111.0
60	48.3	100.3	60	51.4	121.0

TABLE A6.1.8 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 07/02/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	20.5	314.5	00	20.4	317.3
15	45.7	139.8	15	47.8	122.5
30	48.5	113.8	30	46.9	116.8
45	51.7	107.5	45	47.7	115.5
60	45.0	120.8	60	44.6	127.5
MIDDLE			ASHES/STRAW HEAP		
00	20.6	300.5	00	60.9	18.3
15	47.3	115.8	15	56.5	35.0
30	45.0	117.3	30	53.1	54.8
45	45.3	116.5	45	52.4	61.5
60	44.0	128.3	60	51.3	89.3
FEEDER			FIELD NURSERY		
00	20.1	336.8	00	24.3	264.0
15	50.4	112.0	15	44.0	120.0
30	47.1	119.5	30	46.8	111.0
45	46.1	122.5	45	44.6	122.0
60	44.8	133.5	60	47.2	119.0

TABLE A6.1.9 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 13/02/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	26.0	265.5	00	22.1	293.3
15	42.5	118.0	15	45.3	105.4
30	44.7	119.0	30	46.3	109.3
45	45.8	122.5	45	47.0	122.3
60	45.4	133.0	60	46.1	127.1
MIDDLE			ASHES/STRAW HEAP		
00	22.7	311.3	00	82.9	6.5
15	47.1	118.3	15	68.6	17.8
30	47.2	124.5	30	56.3	33.3
45	47.0	125.3	45	54.9	49.3
60	46.8	127.5	60	52.7	62.0
FEEDER			FIELD NURSERY		
00	17.7	303.3	00	24.1	249.0
15	46.1	80.0	15	44.3	127.0
30	47.1	84.5	30	46.1	127.0
45	48.1	119.0	45	46.7	119.0
60	46.2	120.8	60	43.6	137.0

TABLE A6.1.10 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 21/02/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	35.5	166.5	00	36.3	181.0
15	38.5	156.3	15	38.8	154.8
30	37.3	160.5	30	37.7	162.7
45	37.2	174.8	45	38.2	165.3
60	34.2	206.3	60	38.3	176.2
MIDDLE			ASHES/STRAW HEAP		
00	34.9	184.8	00	59.4	37.8
15	41.4	145.8	15	57.7	43.0
30	38.9	158.0	30	49.3	65.3
45	37.9	160.5	45	50.9	72.8
60	39.1	166.0	60	46.9	107.8
FEEDER			FIELD NURSERY		
00	38.5	191.8	00	41.6	140.0
15	36.6	162.3	15	37.5	160.0
30	36.8	169.5	30	37.5	198.0
45	39.5	160.8	45	34.3	220.0
60	41.5	156.3	60	34.3	241.0

TABLE A6.1.11 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 27/02/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	23.1	278.5	00	21.9	275.8
15	43.6	134.5	15	40.6	146.0
30	39.9	140.3	30	39.7	145.7
45	39.2	161.5	45	40.1	153.9
60	37.8	163.8	60	38.2	159.7
MIDDLE			ASHES/STRAW HEAP		
00	22.1	278.0	00	58.7	81.5
15	37.8	159.3	15	58.1	69.5
30	39.7	149.5	30	51.4	83.5
45	41.0	145.0	45	50.7	90.3
60	38.9	152.5	60	48.2	104.0
FEEDER			FIELD NURSERY		
00	20.5	271.0	00	26.9	236.0
15	40.4	144.3	15	38.9	154.0
30	39.6	147.3	30	39.0	154.0
45	40.1	155.3	45	38.5	161.0
60	38.0	162.8	60	37.2	183.0

TABLE A6.1.12 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 04/03/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	15.2	347.3	00	17.8	329.5
15	33.8	189.3	15	36.2	183.1
30	35.9	193.8	30	36.6	187.0
45	37.6	195.5	45	37.1	190.3
60	36.5	203.8	60	36.0	192.5
MIDDLE			ASHES/STRAW HEAP		
00	22.4	296.8	00	65.0	6.8
15	39.1	163.5	15	59.6	31.5
30	40.4	163.0	30	50.9	80.3
45	39.3	173.8	45	49.8	93.3
60	38.3	176.5	60	48.4	106.3
FEEDER			FIELD NURSERY		
00	15.8	344.5	00	23.8	319.0
15	35.7	196.5	15	37.2	169.0
30	33.5	204.3	30	38.2	185.0
45	34.4	201.8	45	39.5	187.0
60	33.3	197.3	60	40.2	186.0

TABLE A6.1.13 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 11/03/91

DRAIN			DRAIN/MID/FEEDER		
00	16.4	374.0	00	16.3	375.8
15	35.8	170.3	15	34.3	187.2
30	37.7	164.5	30	36.7	173.2
45	39.8	159.0	45	38.9	170.3
60	39.9	164.0	60	39.3	167.9
MIDDLE			ASHES/STRAW HEAP		
00	19.5	325.3	00	49.5	53.8
15	32.0	210.8	15	60.6	56.8
30	38.3	161.0	30	53.2	75.8
45	40.5	167.8	45	49.6	91.3
60	38.1	175.0	60	48.0	98.3
FEEDER			FIELD NURSERY		
00	12.9	428.3	00	15.8	380.0
15	35.0	180.5	15	35.8	170.0
30	33.9	194.0	30	37.0	168.0
45	36.5	184.3	45	37.1	174.0
60	39.9	164.8	60	37.9	176.0

TABLE A6.1.14 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 15/03/91

DRAIN			DRAIN/MID/FEEDER		
00	47.0	164.5	00	46.8	129.3
15	38.5	150.0	15	36.7	151.8
30	35.3	177.0	30	35.2	184.6
45	35.1	197.0	45	35.2	193.8
60	34.0	197.0	60	35.0	191.8
MIDDLE			ASHES/STRAW HEAP		
00	47.8	110.0	00	60.7	11.3
15	38.4	141.8	15	53.5	17.5
30	35.6	184.0	30	49.8	30.0
45	35.4	184.3	45	49.8	42.0
60	34.4	196.3	60	44.2	111.3
FEEDER			FIELD NURSERY		
00	45.6	113.5	00	51.3	119.0
15	33.4	163.8	15	34.1	218.0
30	34.8	192.8	30	34.0	221.0
45	35.2	200.0	45	35.2	189.0
60	36.7	182.3	60	35.0	190.0

TABLE A6.1.15 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 20/03/91

DRAIN			DRAIN/MID/FEEDER		
00	18.3	307.0	00	17.4	299.3
15	28.3	231.8	15	32.4	211.6
30	34.7	205.5	30	34.3	211.4
45	32.7	211.0	45	33.4	216.8
60	34.7	205.0	60	33.7	214.6
MIDDLE			ASHES/STRAW HEAP		
00	21.0	272.5	00	50.9	40.0
15	35.2	187.0	15	52.2	80.3
30	35.5	200.3	30	48.6	84.8
45	35.6	207.8	45	44.5	116.0
60	34.4	214.0	60	44.4	129.5
FEEDER			FIELD NURSERY		
00	12.9	318.3	00	13.7	295.0
15	33.5	216.0	15	36.0	190.0
30	32.7	228.5	30	36.9	190.0
45	31.7	231.8	45	35.3	193.0
60	32.1	224.8	60	34.0	225.0

TABLE A6.1.16 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 28/03/91

DRAIN			DRAIN/MID/FEEDER		
00	17.2	293.5	00	19.3	255.4
15	30.0	215.0	15	30.6	204.6
30	36.1	215.5	30	31.9	227.9
45	33.3	230.5	45	31.4	235.5
60	31.4	235.0	60	31.1	237.9
MIDDLE			ASHES/STRAW HEAP		
00	21.4	240.0	00	46.6	56.8
15	30.2	209.0	15	40.8	80.3
30	27.4	255.5	30	42.1	114.0
45	29.3	259.3	45	41.3	131.3
60	30.2	258.3	60	41.8	132.0
FEEDER			FIELD NURSERY		
00	19.3	232.8	00	22.3	235.0
15	31.5	189.8	15	30.9	222.0
30	32.1	212.8	30	32.0	225.0
45	31.7	216.8	45	34.2	225.0
60	31.7	220.5	60	35.1	206.0

TABLE A6.1.17 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 03/04/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	52.4	66.0	00	53.4	58.5
15	45.9	121.3	15	43.6	138.3
30	43.2	137.5	30	40.2	164.6
45	36.6	177.5	45	37.3	184.6
60	36.5	189.8	60	35.3	203.3
MIDDLE			ASHES/STRAW HEAP		
00	57.2	47.8	00	50.0	27.5
15	42.3	140.3	15	56.4	31.3
30	37.2	181.3	30	44.1	56.3
45	38.2	184.8	45	45.5	94.5
60	36.9	192.3	60	42.9	132.0
FEEDER			FIELD NURSERY		
00	50.7	61.8	00	49.1	78.0
15	42.4	153.3	15	37.0	165.0
30	40.4	175.0	30	31.8	188.0
45	37.2	191.5	45	32.4	193.0
60	32.5	227.8	60	27.8	276.0

TABLE A6.1.18 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 09/04/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	47.1	56.3	00	44.7	60.6
15	54.9	95.0	15	51.1	101.1
30	48.0	128.0	30	45.3	133.3
45	44.5	130.8	45	42.9	152.3
60	41.5	130.5	60	40.9	155.5
MIDDLE			ASHES/STRAW HEAP		
00	45.0	56.8	00	46.0	7.5
15	46.7	85.5	15	53.6	7.5
30	46.2	119.0	30	51.0	37.0
45	43.2	153.5	45	46.5	107.8
60	40.3	162.0	60	44.9	126.0
FEEDER			FIELD NURSERY		
00	42.1	68.8	00	45.7	54.0
15	51.5	122.8	15	51.7	115.0
30	41.6	152.8	30	42.6	141.0
45	41.0	172.8	45	39.2	154.0
60	40.8	174.0	60	36.3	173.0

TABLE A6.1.19 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 16/04/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	35.1	109.0	00	35.3	97.8
15	49.3	100.8	15	49.2	99.4
30	45.8	144.5	30	44.5	146.9
45	40.2	150.8	45	39.7	164.8
60	40.0	149.0	60	39.4	170.8
MIDDLE			ASHES/STRAW HEAP		
00	36.4	85.5	00	68.3	31.3
15	50.4	76.8	15	65.4	46.0
30	44.7	143.8	30	49.9	69.5
45	41.3	168.5	45	49.8	98.5
60	40.0	170.3	60	47.7	120.3
FEEDER			FIELD NURSERY		
00	34.4	99.0	00	33.8	175.0
15	48.1	120.8	15	45.8	120.0
30	42.9	152.5	30	38.7	186.0
45	37.5	175.3	45	35.4	204.0
60	38.1	193.0	60	34.0	210.0

TABLE A6.1.20 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 20/04/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	49.1	77.0	00	47.9	79.3
15	40.0	148.5	15	42.2	133.9
30	39.0	159.0	30	41.4	147.9
45	36.6	179.3	45	38.8	161.8
60	33.0	201.5	60	35.2	182.4
MIDDLE			ASHES/STRAW HEAP		
00	46.5	83.0	00	50.4	56.3
15	42.8	125.3	15	58.4	51.0
30	40.9	145.0	30	48.0	76.3
45	40.0	149.3	45	47.9	92.3
60	36.8	171.8	60	44.5	117.5
FEEDER			FIELD NURSERY		
00	48.3	78.0	00	47.8	79.0
15	43.8	128.0	15	48.6	70.0
30	44.3	139.8	30	44.1	128.0
45	39.7	157.0	45	35.1	166.0
60	35.7	174.0	60	38.2	187.0

TABLE A6.1.21 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 24/04/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	39.0	147.3	00	42.3	112.9
15	45.4	142.3	15	43.5	133.3
30	45.4	148.5	30	42.8	152.8
45	41.5	150.8	45	40.0	160.3
60	40.2	170.8	60	38.3	171.8
MIDDLE			ASHES/STRAW HEAP		
00	45.4	88.0	00	50.8	51.8
15	42.0	128.3	15	58.4	62.0
30	40.2	161.0	30	46.9	82.8
45	38.9	166.8	45	45.6	110.5
60	37.3	179.0	60	44.0	124.5
FEEDER			FIELD NURSERY		
00	42.5	103.5	00	39.3	126.0
15	43.2	129.5	15	47.3	106.0
30	42.9	149.0	30	39.3	154.0
45	39.6	163.5	45	36.7	198.0
60	37.4	165.5	60	35.0	209.0

TABLE A6.1.22 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 28/04/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	46.1	97.8	00	45.4	98.1
15	45.4	135.3	15	43.6	145.4
30	43.4	160.5	30	43.5	151.6
45	39.1	177.3	45	40.5	166.9
60	38.3	184.8	60	39.6	173.8
MIDDLE			ASHES/STRAW HEAP		
00	48.0	88.8	00	50.0	51.3
15	41.6	159.0	15	57.3	70.3
30	41.9	150.0	30	55.7	103.0
45	40.6	163.8	45	51.0	117.3
60	41.2	170.0	60	48.5	132.0
FEEDER			FIELD NURSERY		
00	42.1	107.8	00	36.1	160.0
15	43.8	142.0	15	40.5	160.0
30	45.3	144.3	30	40.3	160.0
45	41.8	159.8	45	40.2	165.0
60	39.4	166.5	60	39.0	178.0

TABLE A6.1.23 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 02/05/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	46.9	89.8	00	48.3	78.3
15	40.4	152.0	15	40.1	137.5
30	40.4	169.5	30	38.4	155.7
45	36.7	181.0	45	36.4	170.9
60	39.6	177.3	60	37.3	176.6
MIDDLE			ASHES/STRAW HEAP		
00	50.6	61.8	00	59.2	49.8
15	38.7	127.8	15	52.0	73.5
30	35.6	152.5	30	51.0	90.5
45	37.8	149.5	45	48.8	112.5
60	37.7	164.3	60	45.0	131.8
FEEDER			FIELD NURSERY		
00	47.5	83.5	00	48.7	78.0
15	41.3	132.8	15	44.6	135.0
30	39.2	145.0	30	42.4	145.0
45	34.5	182.3	45	40.6	149.0
60	34.7	188.3	60	39.1	150.0

TABLE A6.1.24 AVERAGE SMC AND PR - BLOCK N

SAMPLING DATE: 06/05/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	30.6	191.0	00	29.6	179.8
15	43.6	169.0	15	44.9	145.9
30	42.2	170.5	30	44.1	156.0
45	39.5	183.3	45	41.8	167.0
60	38.6	188.8	60	40.9	174.1
MIDDLE			ASHES/STRAW HEAP		
00	27.5	179.0	00	40.0	76.3
15	46.5	129.8	15	58.7	62.5
30	44.0	163.8	30	51.3	81.5
45	43.4	161.0	45	49.5	100.5
60	42.6	166.0	60	49.7	117.0
FEEDER			FIELD NURSERY		
00	30.7	169.3	00	34.4	165.0
15	44.6	139.0	15	41.7	172.0
30	46.0	133.8	30	37.7	190.0
45	42.5	156.8	45	37.4	190.0
60	41.4	167.5	60	39.7	160.0

TABLE A6.2.1 ***OBSERVED MOISTURE CONTENT (BY WEIGHT) AND PENETRATION RESISTANCE FROM THE DMF, BLOCK N/407.***

No.	Sampling Date	Time (day)	0-5 SMC (%)	0-5 PR (N/cm²)	15 SMC (%)	15 PR (N/cm²)	30 SMC (%)	30 PR (N/cm²)	45 SMC (%)	45 PR (N/cm²)	60 SMC (%)	60 PR (N/cm²)	Mean SMC in 0-30cm Depth (%)	Mean PR in 0-30cm Depth (N/cm²)	Mean SMC in 0-60cm Depth (%)	Mean PR in 0-60cm Depth (N/cm²)
0	12/11/90	0	-	-	-	-	-	-	-	-	-	-	-	-		
1	20/12/90	38	36.9	110.3	60.1	60.4	57.6	71.8	50.7	81.7	48.4	88.3	51.6	80.9	50.7	82.5
2	23/12/90	41	23.6	171.8	59.3	80.6	52.8	89.0	51.7	95.4	49.6	105.7	45.2	113.8	47.4	108.5
3	27/12/90	45	21.7	216.9	54.5	95.8	51.7	97.3	49.6	103.3	48.5	110.5	42.6	136.7	45.2	124.8
4	02/01/91	51	46.1	76.9	54.9	68.2	51.2	71.8	48.4	88.3	46.7	103.8	50.8	72.3	49.5	81.8
5	14/01/91	63	20.9	202.2	58.8	78.1	56.7	74.4	50.0	87.3	47.5	99.2	45.5	118.2	46.8	108.2
6	24/01/91	73	17.8	318.1	34.8	193.3	48.5	119.4	51.1	111.2	49.9	119.2	33.7	210.3	40.4	172.2
7	30/01/91	79	33.0	175.8	56.0	72.6	54.6	77.7	52.6	78.3	49.3	103.7	47.9	108.7	49.1	101.6
8	07/02/91	87	20.4	317.3	47.8	122.5	46.9	116.8	47.7	115.5	44.6	127.5	38.4	185.5	41.5	159.9
9	13/02/91	93	22.1	293.3	45.3	105.4	46.3	109.3	47.0	122.3	46.1	127.1	37.9	169.4	41.4	151.5
10	21/02/91	101	36.3	181.0	38.8	154.8	37.7	162.7	38.2	165.3	38.3	176.2	37.6	166.1	37.8	168.0
11	27/02/91	107	21.9	275.8	40.6	146.0	39.7	145.7	40.1	153.9	38.2	159.7	34.1	189.2	36.1	176.2
12	04/03/91	112	17.8	329.5	36.2	183.1	36.6	187.0	37.1	190.3	36.0	192.5	30.2	233.2	32.7	216.5
13	11/03/91	119	16.3	375.8	34.3	187.2	36.7	173.2	38.9	170.3	39.3	167.9	29.1	245.4	33.1	214.9
14	15/03/91	123	46.8	129.3	36.7	151.8	35.2	184.6	35.2	193.8	35.0	191.8	39.6	155.3	37.8	170.3
15	20/03/91	128	17.4	299.3	32.4	211.6	34.3	211.4	33.4	216.8	33.7	214.6	28.0	240.8	30.2	230.7
16	28/03/91	136	19.3	255.4	30.6	204.6	31.9	227.9	31.4	235.5	31.1	237.9	27.3	229.3	28.9	232.3
17	03/04/91	142	53.4	58.5	43.6	138.3	40.2	164.6	37.3	184.6	35.3	203.3	45.7	120.4	42.0	149.8
18	09/04/91	148	44.7	60.6	51.1	101.1	45.3	133.3	42.9	152.3	40.9	155.5	47.0	98.3	45.0	120.6
19	16/04/91	155	35.3	97.8	49.2	99.4	44.5	146.9	39.7	164.8	39.4	170.8	43.0	114.7	41.6	136.0
20	20/04/91	159	47.9	79.3	42.2	133.9	41.4	147.9	38.8	161.8	35.2	182.4	43.8	120.4	41.1	141.1
21	24/04/91	163	42.3	112.9	43.5	133.3	42.8	152.8	40.0	160.3	38.3	171.8	42.9	133.0	41.4	146.2
22	28/04/91	167	45.4	98.1	43.6	145.4	43.5	151.6	40.5	166.9	39.6	173.8	44.2	131.7	42.5	147.2
23	02/05/91	171	48.3	78.3	40.1	137.5	38.4	155.7	36.4	170.9	37.3	176.6	42.3	123.8	40.1	143.8
24	06/05/91	175	29.6	179.8	44.9	145.9	44.1	156.0	41.8	167.0	40.9	174.1	39.5	160.6	40.3	164.6

TABLE A6.2.2 ***OBSERVED MOISTURE CONTENT (BY VOLUME) AND PENETRATION RESISTANCE FROM THE DMF, BLOCK N/407.***

No.	Sampling Date	Time (day)	0-5 SMC (mm)	0-5 PR (N/cm²)	15 SMC (mm)	15 PR (N/cm²)	30 SMC (mm)	30 PR (N/cm²)	45 SMC (mm)	45 PR (N/cm²)	60 SMC (mm)	60 PR (N/cm²)	Mean SMC in 0-30cm Depth (mm)	Mean PR in 0-30cm Depth (N/cm²)	Mean SMC in 0-60cm Depth (mm)	Mean PR in 0-60cm Depth (N/cm²)
0	12/11/90	0	-	-	-	-	-	-	-	-	-	-				
1	20/12/90	38	25.5	110.3	89.2	60.4	87.3	71.8	79.1	81.7	79.1	88.3	202.1	80.9	360.2	82.5
2	23/12/90	41	16.3	171.8	88.1	80.6	80.0	89.0	80.6	95.4	81.1	105.7	184.4	113.8	346.1	108.5
3	27/12/90	45	14.9	216.9	80.9	95.8	78.3	97.3	77.3	103.3	79.3	110.5	174.2	136.7	330.9	124.8
4	02/01/91	51	31.8	76.9	81.6	68.2	77.6	71.8	75.5	88.3	76.3	103.8	191.0	72.3	342.8	81.8
5	14/01/91	63	14.4	202.2	87.3	78.1	86.0	74.4	78.1	87.3	77.7	99.2	187.7	118.2	343.5	108.2
6	24/01/91	73	12.3	318.1	51.7	193.3	73.5	119.4	79.7	111.2	81.6	119.2	137.5	210.3	298.8	172.2
7	30/01/91	79	22.8	175.8	83.2	72.6	82.7	77.7	82.0	78.3	80.6	103.7	188.6	108.7	351.3	101.6
8	07/02/91	87	14.1	317.3	71.0	122.5	71.0	116.8	74.4	115.5	72.9	127.5	156.1	185.5	303.4	159.9
9	13/02/91	93	15.3	293.3	67.2	105.4	70.2	109.3	73.3	122.3	75.4	127.1	152.7	169.4	301.3	151.5
10	21/02/91	101	25.0	181.0	57.7	154.8	57.1	162.7	59.6	165.3	62.6	176.2	139.8	166.1	261.9	168.0
11	27/02/91	107	15.1	275.8	60.3	146.0	60.2	145.7	62.6	153.9	62.5	159.7	135.5	189.2	260.6	176.2
12	04/03/91	112	12.3	329.5	53.7	183.1	55.4	187.0	57.9	190.3	58.9	192.5	121.4	233.2	238.2	216.5
13	11/03/91	119	11.2	375.8	50.9	187.2	55.5	173.2	60.7	170.3	64.3	167.9	117.7	245.4	242.7	214.9
14	15/03/91	123	32.3	129.3	54.6	151.8	53.4	184.6	55.0	193.8	57.3	191.8	140.2	155.3	252.5	170.3
15	20/03/91	128	12.0	299.3	48.1	211.6	52.0	211.4	52.0	216.8	55.1	214.6	112.0	240.8	219.2	230.7
16	28/03/91	136	13.3	255.4	45.4	204.6	48.3	227.9	49.0	235.5	50.9	237.9	107.0	229.3	206.9	232.3
17	03/04/91	142	36.9	58.5	64.7	138.3	60.9	164.6	58.2	184.6	57.7	203.3	162.5	120.4	278.3	149.8
18	09/04/91	148	30.9	60.6	75.8	101.1	68.6	133.3	66.9	152.3	66.8	155.5	175.3	98.3	309.0	120.6
19	16/04/91	155	24.3	97.8	73.1	99.4	67.4	146.9	61.9	164.8	64.3	170.8	164.9	114.7	291.1	136.0
20	20/04/91	159	33.1	79.3	62.7	133.9	62.7	147.9	60.5	161.8	57.5	182.4	158.5	120.4	276.4	141.1
21	24/04/91	163	29.2	112.9	64.6	133.3	64.9	152.8	62.4	160.3	62.6	171.8	158.7	133.0	283.7	146.2
22	28/04/91	167	31.3	98.1	64.7	145.4	65.9	151.6	63.2	166.9	64.8	173.8	162.0	131.7	290.0	147.2
23	02/05/91	171	33.3	78.3	59.6	137.5	58.2	155.7	56.7	170.9	61.0	176.6	151.1	123.8	268.8	143.8
24	06/05/91	175	20.4	179.8	66.7	145.9	66.8	156.0	65.2	167.0	66.8	174.1	153.9	160.6	285.9	164.6

TABLE A6.2.3 OBSERVED MOISTURE CONTENT (BY WEIGHT) AND PENETRATION RESISTANCE FROM NURSERY, BLOCK N/407.

No.	Sampling Date	Time	Sampling Depth (cm) 0-5		15		30		45		60		Mean SMC in 0-30cm Depth	Mean PR in 0-30cm Depth	Mean SMC in 0-60cm Depth	Mean PR in 0-60cm Depth
		(day)	SMC (%)	PR (N/cm²)	SMC (%)	PR (N/cm²)	SMC (%)	PR (N/cm²)	SMC (%)	PR (N/cm²)	SMC (%)	PR (N/cm²)	(%)	(N/cm²)	(%)	(N/cm²)
0	12/11/90	0	-	-	-	-	-	-	-	-	-	-	-	-		
1	27/12/90	45	14.2	240.0	50.3	97.0	51.6	95.0	53.5	93.0	54.9	91.0	38.7	144.0	44.9	123.2
2	02/01/91	51	47.0	60.0	56.4	56.0	49.6	76.0	50.8	75.0	50.1	83.0	51.0	64.0	50.8	70.0
3	14/01/91	63	19.9	240.0	53.1	70.0	53.6	88.0	53.3	93.0	52.1	96.0	42.2	132.7	46.4	117.4
4	24/01/91	73	19.3	332.0	43.9	152.0	47.9	131.0	51.1	120.0	53.5	130.0	37.0	205.0	43.2	173.0
5	30/01/91	79	35.2	139.0	57.6	88.0	54.8	94.0	50.3	111.0	51.4	121.0	49.2	107.0	49.8	110.6
6	07/02/91	87	24.3	264.0	44.0	120.0	46.8	111.0	44.6	122.0	47.2	119.0	38.4	165.0	41.4	147.2
7	13/02/91	93	24.1	249.0	44.3	127.0	46.1	127.0	46.7	119.0	43.6	137.0	38.2	167.7	41.0	151.8
8	21/02/91	101	41.6	140.0	37.5	160.0	37.5	198.0	34.3	220.0	34.3	241.0	38.9	166.0	37.0	191.8
9	27/02/91	107	26.9	236.0	38.9	154.0	39.0	154.0	38.5	161.0	37.2	183.0	34.9	181.3	36.1	177.6
10	04/03/91	112	23.8	319.0	37.2	169.0	38.2	185.0	39.5	187.0	40.2	186.0	33.0	224.3	35.8	209.2
11	11/03/91	119	15.8	380.0	35.8	170.0	37.0	168.0	37.1	174.0	37.9	176.0	29.5	239.3	32.7	213.6
12	15/03/91	123	51.3	119.0	34.1	218.0	34.0	221.0	35.2	189.0	35.0	190.0	39.8	186.0	37.9	187.4
13	20/03/91	128	13.7	295.0	36.0	190.0	36.9	190.0	35.3	193.0	34.0	225.0	28.9	225.0	31.2	218.6
14	28/03/91	136	22.3	235.0	30.9	222.0	32.0	225.0	34.2	225.0	35.1	206.0	28.4	227.3	30.9	222.6
15	03/04/91	142	49.1	78.0	37.0	165.0	31.8	188.0	32.4	193.0	27.8	276.0	39.3	143.7	35.6	180.0
16	09/04/91	148	45.7	54.0	51.7	115.0	42.6	141.0	39.2	154.0	36.3	173.0	46.7	103.3	43.1	127.4
17	16/04/91	155	33.8	175.0	45.8	120.0	38.7	186.0	35.4	204.0	34.0	210.0	39.4	160.3	37.5	179.0
18	20/04/91	159	47.8	79.0	48.6	70.0	44.1	128.0	35.1	166.0	38.2	187.0	46.8	92.3	42.8	126.0
19	24/04/91	163	39.3	126.0	47.3	106.0	39.3	154.0	36.7	198.0	35.0	209.0	41.9	128.7	39.5	158.6
20	28/04/91	167	36.1	160.0	40.5	160.0	40.3	160.0	40.2	165.0	39.0	178.0	38.9	160.0	39.2	164.6
21	02/05/91	171	48.7	78.0	44.6	135.0	42.4	145.0	40.6	149.0	39.1	150.0	45.2	119.3	43.1	131.4
22	06/05/91	175	34.4	165.0	41.7	172.0	37.7	190.0	37.4	190.0	39.7	160.0	37.9	175.7	38.2	175.4

TABLE A6.2.4 OBSERVED MOISTURE CONTENT (BY VOLUME) AND PENETRATION RESISTANCE FROM NURSERY, BLOCK N/407.

No.	Sampling Date	Time	Sampling Depth (cm) 0-5		15		30		45		60		Mean SMC in 0-30cm Depth	Mean PR in 0-30cm Depth	Mean SMC in 0-60cm Depth	Mean PR in 0-60cm Depth
		(day)	SMC (mm)	PR (N/cm²)	SMC (mm)	PR (N/cm²)	SMC (mm)	PR (N/cm²)	SMC (mm)	PR (N/cm²)	SMC (mm)	PR (N/cm²)	(mm)	(N/cm²)	(mm)	(N/cm²)
0	12/11/90	0	-	-	-	-	-	-	-	-	-	-	-	-		
1	27/12/90	45	9.8	240.0	74.7	97.0	78.2	95.0	83.5	93.0	89.8	91.0	162.7	144.0	336.1	123.2
2	02/01/91	51	32.4	60.0	83.7	56.0	75.1	76.0	79.2	75.0	81.9	83.0	191.2	64.0	352.3	70.0
3	14/01/91	63	13.8	240.0	78.8	70.0	81.2	88.0	83.2	93.0	85.1	96.0	173.7	132.7	342.1	117.4
4	24/01/91	73	13.3	332.0	65.3	152.0	72.6	131.0	79.8	120.0	87.4	130.0	151.2	205.0	318.4	173.0
5	30/01/91	79	24.3	139.0	85.5	88.0	83.0	94.0	78.5	111.0	84.0	121.0	192.7	107.0	355.2	110.6
6	07/02/91	87	16.8	264.0	65.3	120.0	70.9	111.0	69.5	122.0	77.2	119.0	153.0	165.0	299.7	147.2
7	13/02/91	93	16.6	249.0	65.8	127.0	69.9	127.0	72.8	119.0	71.3	137.0	152.3	167.7	296.4	151.8
8	21/02/91	101	28.7	140.0	55.7	160.0	56.9	198.0	53.5	220.0	56.0	241.0	141.3	166.0	250.8	191.8
9	27/02/91	107	18.5	236.0	57.7	154.0	59.0	154.0	60.1	161.0	60.9	183.0	135.3	181.3	256.3	177.6
10	04/03/91	112	16.4	319.0	55.2	169.0	57.8	185.0	61.6	187.0	65.8	186.0	129.5	224.3	256.8	209.2
11	11/03/91	119	10.9	380.0	53.1	170.0	56.1	168.0	57.9	174.0	62.0	176.0	120.2	239.3	240.1	213.6
12	15/03/91	123	35.4	119.0	50.6	218.0	51.5	221.0	54.9	189.0	57.2	190.0	137.4	186.0	249.6	187.4
13	20/03/91	128	9.5	295.0	53.4	190.0	56.0	190.0	55.1	193.0	55.6	225.0	118.9	225.0	229.6	218.6
14	28/03/91	136	15.4	235.0	45.9	222.0	48.5	225.0	53.3	225.0	57.3	206.0	109.8	227.3	220.4	222.6
15	03/04/91	142	33.9	78.0	55.0	165.0	48.2	188.0	50.6	193.0	45.5	276.0	137.0	143.7	233.1	180.0
16	09/04/91	148	31.5	54.0	76.8	115.0	64.6	141.0	61.2	154.0	59.3	173.0	172.9	103.3	293.3	127.4
17	16/04/91	155	23.3	175.0	68.0	120.0	58.6	186.0	55.2	204.0	55.6	210.0	149.9	160.3	260.7	179.0
18	20/04/91	159	33.0	79.0	72.2	70.0	66.8	128.0	54.8	166.0	62.5	187.0	172.0	92.3	289.2	126.0
19	24/04/91	163	27.1	126.0	70.2	106.0	59.5	154.0	57.3	198.0	57.2	209.0	156.8	128.7	271.3	158.6
20	28/04/91	167	24.9	160.0	60.1	160.0	61.0	160.0	62.7	165.0	63.8	178.0	146.0	160.0	272.5	164.6
21	02/05/91	171	33.6	78.0	66.3	135.0	64.2	145.0	63.3	149.0	63.9	150.0	164.1	119.3	291.3	131.4
22	06/05/91	175	23.8	165.0	62.0	172.0	57.0	190.0	58.4	190.0	64.9	160.0	142.8	175.7	266.1	175.4

TABLE A6.2.5 OBSERVED MOISTURE CONTENT (BY WEIGHT) AND PENETRATION RESISTANCE FOR ASH/STRAW, BLOCK N/407.

No.	Sampling Date	Time	Sampling Depth (cm) 0-5		15		30		45		60		Mean SMC in 0-30cm Depth	Mean PR in 0-30cm Depth	Mean SMC in 0-60cm Depth	Mean PR in 0-60cm Depth
		(day)	SMC (%)	PR (N/cm^2)	SMC (%)	PR (N/cm^2)	SMC (%)	PR (N/cm^2)	SMC (%)	PR (N/cm^2)	SMC (%)	PR (N/cm^2)	(%)	(N/cm^2)	(%)	(N/cm^2)
0	12/11/90	0	-	-	-	-	-	-	-	-	-	-	-	-		
1	27/12/90	45	71.4	20.5	67.7	41.5	60.8	83.0	51.5	101.5	53.1	93.5	66.6	48.3	60.9	68.0
2	02/01/91	51	82.9	3.3	71.4	29.5	56.5	55.8	51.1	71.0	50.3	90.3	70.3	29.5	62.4	50.0
3	14/01/91	63	75.9	17.3	65.9	29.5	55.0	61.0	57.0	79.3	55.4	91.0	65.6	35.9	61.8	55.6
4	24/01/91	73	72.6	20.8	64.7	46.3	60.1	64.0	55.9	73.3	52.3	92.3	65.8	43.7	61.1	59.3
5	30/01/91	79	48.9	72.3	68.5	30.3	58.2	71.3	55.5	93.0	54.0	106.8	58.5	57.9	57.0	74.7
6	07/02/91	87	60.9	18.3	56.5	35.0	53.1	54.8	52.4	61.5	51.3	89.3	56.8	36.0	54.8	51.8
7	13/02/91	93	82.9	6.5	68.6	17.8	56.3	33.3	54.9	49.3	52.7	62.0	69.3	19.2	63.1	33.8
8	21/02/91	101	59.4	37.8	57.7	43.0	49.3	65.3	50.9	72.8	46.9	107.8	55.5	48.7	52.8	65.3
9	27/02/91	107	58.7	81.5	58.1	69.5	51.4	83.5	50.7	90.3	48.2	104.0	56.1	78.2	53.4	85.8
10	04/03/91	112	65.0	6.8	59.6	31.5	50.9	80.3	49.8	93.3	48.4	106.3	58.5	39.5	54.8	63.6
11	11/03/91	119	49.5	53.8	60.6	56.8	53.2	75.8	49.6	91.3	48.0	98.3	54.4	62.1	52.2	75.2
12	15/03/91	123	60.7	11.3	53.5	17.5	49.8	30.0	49.8	42.0	44.2	111.3	54.7	19.6	51.6	42.4
13	20/03/91	128	50.9	40.0	52.2	80.3	48.6	84.8	44.5	116.0	44.4	129.5	50.6	68.3	48.1	90.1
14	28/03/91	136	46.6	56.8	40.8	80.3	42.1	114.0	41.3	131.3	41.8	132.0	43.2	83.7	42.5	102.9
15	03/04/91	142	50	27.5	56.4	31.3	44.1	56.3	45.5	94.5	42.9	132.0	50.2	38.3	47.8	68.3
16	09/04/91	148	46	7.5	53.6	7.5	51.0	37.0	46.5	107.8	44.9	126.0	50.2	17.3	48.4	57.2
17	16/04/91	155	68.3	31.3	65.4	46.0	49.9	69.5	49.8	98.5	47.7	120.3	61.2	48.9	56.2	73.1
18	20/04/91	159	50.4	56.3	58.4	51.0	48.0	76.3	47.9	92.3	44.5	117.5	52.3	61.2	49.8	78.7
19	24/04/91	163	50.8	51.8	58.4	62.0	46.9	82.8	45.6	110.5	44.0	124.5	52.0	65.5	49.2	86.3
20	28/04/91	167	50.0	51.3	57.3	70.3	55.7	103.0	51.0	117.3	48.5	132.0	54.3	74.8	52.5	94.8
21	02/05/91	171	59.2	49.8	52.0	73.5	51.0	90.5	48.8	112.5	45.0	131.8	54.1	71.3	51.2	91.6
22	06/05/91	175	40.0	76.3	58.7	62.5	51.3	81.5	49.5	100.5	49.7	117.0	50.0	73.4	49.8	87.6

TABLE A6.2.6 OBSERVED MOISTURE CONTENT (BY VOL.) AND PENETRATION RESISTANCE FROM ASH/STRAW, BLOCK N/407.

No.	Sampling Date	Time	Sampling Depth (cm) 0-5		15		30		45		60		Mean SMC in 0-30cm Depth	Mean PR in 0-30cm Depth	Mean SMC in 0-60cm Depth	Mean PR in 0-60cm Depth
		(day)	SMC (mm)	PR (N/cm^2)	SMC (mm)	PR (N/cm^2)	SMC (mm)	PR (N/cm^2)	SMC (mm)	PR (N/cm^2)	SMC (mm)	PR (N/cm^2)	(mm)	(N/cm^2)	(mm)	(N/cm^2)
0	12/11/90	0	-	-	-	-	-	-	-	-	-	-	-	-		
1	27/12/90	45	49.3	20.5	100.5	41.5	92.1	83.0	80.3	101.5	86.8	93.5	241.8	48.3	408.9	68.0
2	02/01/91	51	57.2	3.3	106.0	29.5	85.6	55.8	79.7	71.0	82.2	90.3	248.8	29.5	410.7	50.0
3	14/01/91	63	52.4	17.3	97.9	29.5	83.4	61.0	88.8	79.3	90.6	91.0	233.6	35.9	413.0	55.6
4	24/01/91	73	50.1	20.8	96.0	46.3	91.0	64.0	87.3	73.3	85.6	92.3	237.1	43.7	410.0	59.3
5	30/01/91	79	33.7	72.3	101.7	30.3	88.2	71.3	86.6	93.0	88.3	106.8	223.7	57.9	398.6	74.7
6	07/02/91	87	42.1	18.3	83.8	35.0	80.5	54.8	81.7	61.5	83.9	89.3	206.4	36.0	371.9	51.8
7	13/02/91	93	57.2	6.5	101.9	17.8	85.3	33.3	85.7	49.3	86.2	62.0	244.4	19.2	416.3	33.8
8	21/02/91	101	41.0	37.8	85.7	43.0	74.6	65.3	79.4	72.8	76.7	107.8	201.3	48.7	357.5	65.3
9	27/02/91	107	40.5	81.5	86.2	69.5	77.8	83.5	79.1	90.3	78.9	104.0	204.6	78.2	362.5	85.8
10	04/03/91	112	44.8	6.8	88.6	31.5	77.1	80.3	77.7	93.3	79.2	106.3	210.5	39.5	367.5	63.6
11	11/03/91	119	34.1	53.8	89.9	56.8	80.7	75.8	77.3	91.3	78.4	98.3	204.7	62.1	360.4	75.2
12	15/03/91	123	41.9	11.3	79.5	17.5	75.4	30.0	77.6	42.0	72.2	111.3	196.8	19.6	346.6	42.4
13	20/03/91	128	35.1	40.0	77.6	80.3	73.7	84.8	69.4	116.0	72.6	129.5	186.4	68.3	328.4	90.1
14	28/03/91	136	32.2	56.8	60.6	80.3	63.8	114.0	64.4	131.3	68.4	132.0	156.6	83.7	289.3	102.9
15	03/04/91	142	34.5	27.5	83.8	31.3	66.8	56.3	71.0	94.5	70.2	132.0	185.0	38.3	326.2	68.3
16	09/04/91	148	31.8	7.5	79.7	7.5	77.3	37.0	72.6	107.8	73.3	126.0	188.7	17.3	334.6	57.2
17	16/04/91	155	47.1	31.3	97.2	46.0	75.5	69.5	77.7	98.5	77.9	120.3	219.8	48.9	375.4	73.1
18	20/04/91	159	34.8	56.3	86.7	51.0	72.8	76.3	74.7	92.3	72.8	117.5	194.2	61.2	341.7	78.7
19	24/04/91	163	35.1	51.8	86.8	62.0	71.0	82.8	71.2	110.5	72.0	124.5	192.9	65.5	336.0	86.3
20	28/04/91	167	34.5	51.3	85.0	70.3	84.4	103.0	79.5	117.3	79.3	132.0	204.0	74.8	362.7	94.8
21	02/05/91	171	40.9	49.8	77.2	73.5	77.3	90.5	76.2	112.5	73.7	131.8	195.4	71.3	345.2	91.6
22	06/05/91	175	27.6	76.3	87.1	62.5	77.8	81.5	77.2	100.5	81.3	117.0	192.5	73.4	350.9	87.6

ANNEX 7

SOIL MOISTURE CONTENT AND PENETRATION RESISTANCE DATA FROM BLOCK A

PART ONE

Part one comprises Tables A7.1.1 - A7.1.7. These tables give the average SMC (on weight basis) and PR for each sampling day from the various sampling locations and depths. The averages were calculated first over replicates and sampling locations (treatments) and then over depths after combining some treatments. Some treatments (Drain, Middle and Feeder) were combined in order to manage data with ease. The combining of those treatments was made possible by the fact that there was no significant difference in data obtained from them.

PART TWO

Part two of Annexe 7 comprises of Tables A7.2.1 - A7.2.6. These tables show the SMC and PR data after grouping some treatments together and after converting SMC from weight basis to volume basis. Conversion of SMC in weight basis to vloume was necessary because the units of measurements for other parameters (rainfall and evaporation) that were considered in developing a soil drying model for APS were in volume basis. Determination of SMC on voulume basis was not possible due to lack of enough sampling cores.

TABLE A7.1.1 AVERAGE SMC AND PR - BLOCK A

SAMPLING DATE: 10/05/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	102	0.8	00	93.8	0.3
15	91.1	12.5	15	82.4	9.6
30	66.2	35.8	30	64.5	24.8
45	65.2	49.5	45	61.3	49.2
60	53.0	76.3	60	55.1	79.9
MIDDLE			ASHES/STRAW HEAP		
00	96.6	0.0	00	72.6	0.0
15	80.5	5.8	15	70.8	17.5
30	61.7	15.8	30	62.8	26.5
45	56.0	42.0	45	48.3	54.0
60	56.7	77.8	60	55.4	53.5
FEEDER			FIELD NURSERY		
00	83.1	0.0	00	90.3	3.0
15	75.6	10.5	15	65.8	3.0
30	65.6	23.0	30	60.5	48.0
45	62.8	56.0	45	50.5	78.0
60	55.6	85.8	60	49.7	88.0

TABLE A7.1.2 AVERAGE SMC AND PR - BLOCK A

SAMPLING DATE: 14/05/91

FP&D	SMC	PR	FP&D	SMC	PR
DRAIN			DRAIN/MID/FEEDER		
00	82.5	1.3	00	82.7	1.6
15	63.9	1.3	15	76.6	3.5
30	67.5	5.0	30	69.0	13.3
45	62.7	45.0	45	63.8	32.5
60	60.5	75.8	60	64.3	48.2
MIDDLE			ASHES/STRAW HEAP		
00	80.7	0.8	00	93.2	0.0
15	88.2	5.0	15	80.4	1.7
30	68.8	11.5	30	67.1	12.0
45	64.9	22.0	45	63.1	31.0
60	59.8	32.0	60	60.7	32.0
FEEDER			FIELD NURSERY		
00	84.8	2.8	00	87.2	5.0
15	77.6	4.3	15	73.4	8.0
30	70.8	23.3	30	60.7	48.0
45	63.9	30.5	45	63.0	50.0
60	72.5	36.8	60	58.3	85.0

TABLE A7.1.3 AVERAGE SMC AND PR - BLOCK A

SAMPLING DATE: 16/05/91

DRAIN			DRAIN/MID/FEEDER		
00	83.3	7.3	00	83.8	3.6
15	79.5	10.5	15	77.6	9.3
30	70.0	23.3	30	66.0	24.3
45	60.1	54.0	45	60.3	45.0
60	57.9	72.0	60	56.6	59.3
MIDDLE			ASHES/STRAW HEAP		
00	79.2	2.8	00	85.5	5.3
15	77.4	15.5	15	75.6	6.0
30	64.6	32.5	30	62.5	22.3
45	61.6	41.5	45	62.1	51.7
60	55.1	51.3	60	59.9	52.7
FEEDER			FIELD NURSERY		
00	89.0	0.8	00	78.5	8.0
15	76.0	1.8	15	66.4	38.0
30	63.4	17.0	30	52.6	40.0
45	59.0	39.5	45	52.0	45.0
60	56.8	54.5	60	48.4	70.0

TABLE A7.1.4 AVERAGE SMC AND PR - BLOCK A

SAMPLING DATE: 21/05/91

DRAIN			DRAIN/MID/FEEDER		
00	64.3	13.5	00	69.3	15.6
15	75.9	18.5	15	76.5	20.8
30	67.0	29.0	30	67.8	33.9
45	53.2	67.5	45	56.3	59.3
60	51.5	73.0	60	53.3	67.3
MIDDLE			ASHES/STRAW HEAP		
00	68.4	17.0	00	88.6	4.0
15	74.6	21.5	15	84.5	12.0
30	61.7	39.0	30	61.6	37.8
45	58.3	51.5	45	59.8	45.5
60	55.3	63.3	60	55.0	53.3
FEEDER			FIELD NURSERY		
00	75.0	16.3	00	67.1	18.0
15	78.9	22.3	15	66.7	30.0
30	74.6	33.8	30	58.1	57.0
45	57.3	59.0	45	50.0	75.0
60	53.3	65.8	60	49.3	78.0

TABLE A7.1.5 AVERAGE SMC AND PR - BLOCK A

SAMPLING DATE: 23/05/91

DRAIN			DRAIN/MID/FEEDER		
00	71.5	9.0	00	68.0	10.3
15	79.4	10.0	15	79.7	13.8
30	69.9	27.0	30	66.5	38.4
45	54.7	53.8	45	55.4	63.5
60	50.6	77.5	60	53.0	78.6
MIDDLE			ASHES/STRAW HEAP		
00	65.8	8.3	00	88.7	0.0
15	81.1	12.0	15	77.9	19.3
30	65.1	46.3	30	65.6	36.5
45	56.2	66.8	45	56.6	60.0
60	55.3	76.8	60	55.1	65.0
FEEDER			FIELD NURSERY		
00	66.8	13.8	00	67.2	25.0
15	78.4	19.5	15	58.5	48.0
30	64.5	42.0	30	59.1	65.0
45	55.3	70.0	45	53.7	76.0
60	53.0	81.5	60	49.0	89.0

TABLE A7.1.6 AVERAGE SMC AND PR - BLOCK A

SAMPLING DATE: 25/05/91

DRAIN			DRAIN/MID/FEEDER		
00	76.8	6.8	00	82.5	4.1
15	84.2	11.8	15	85.1	8.1
30	76.3	32.0	30	74.3	26.5
45	68.4	36.8	45	65.0	41.7
60	61.1	54.5	60	59.9	57.8
MIDDLE			ASHES/STRAW HEAP		
00	82.8	3.0	00	85.4	2.5
15	85.1	5.0	15	82.9	10.0
30	71.6	17.5	30	69.1	40.0
45	61.9	49.5	45	62.0	49.0
60	59.7	58.3	60	57.7	60.5
FEEDER			FIELD NURSERY		
00	88.0	2.5	00	93.0	0.0
15	86.1	7.5	15	75.2	20.0
30	74.9	30.0	30	69.4	30.0
45	64.7	38.8	45	63.6	45.0
60	59.0	60.8	60	59.3	55.0

TABLE A7.1.7 AVERAGE SMC AND PR - BLOCK A

SAMPLING DATE:					28/05/91
DRAIN			DRAIN/MID/FEEDER		
00	88.8	5.0	00	85.8	4.9
15	78.6	9.3	15	81.6	8.1
30	73.3	27.0	30	70.5	32.0
45	62.0	50.8	45	65.7	44.3
60	57.6	60.0	60	59.9	56.7
MIDDLE			ASHES/STRAW HEAP		
00	90.7	2.0	00	103.5	2.5
15	81.3	8.8	15	83.6	9.0
30	68.9	33.8	30	68.0	28.3
45	65.1	42.8	45	64.5	41.3
60	60.7	60.0	60	67.0	48.8
FEEDER			FIELD NURSERY		
00	77.9	7.8	00	77.8	8.0
15	85.0	6.3	15	70.8	12.0
30	69.3	35.3	30	61.7	25.0
45	70.1	39.3	45	59.2	40.0
60	61.6	50.0	60	57.5	55.0

TABLE A7.2.1 OBSERVED MOISTURE CONTENT (BY WEIGHT) AND PENETRATION RESISTANCE FROM THE DMF, BLOCK A/041.

No.	Sampling Date	Time	Sampling Depth (cm) 0-5		15		30		45		60		Mean SMC in 0-30cm Depth	Mean PR in 0-30cm Depth	Mean SMC in 0-60cm Depth	Mean PR in 0-60cm Depth
		(day)	SMC (%)	PR (N/cm^2)	SMC (%)	PR (N/cm^2)	SMC (%)	PR (N/cm^2)	SMC (%)	PR (N/cm^2)	SMC (%)	PR (N/cm^2)	(%)	(N/cm^2)	(%)	(N/cm^2)
0	02/05/91	0	-	-	-	-	-	-	-	-	-	-	-	-		
1	10/05/91	8	93.8	0.3	82.4	9.6	64.5	24.8	61.3	49.2	55.1	79.9	80.2	11.6	71.4	32.8
2	14/05/91	12	82.7	1.6	76.6	3.5	69.0	13.3	63.8	32.5	64.3	48.2	76.1	6.1	71.3	19.8
3	16/05/91	14	83.8	3.6	77.6	9.3	66.0	24.3	60.3	45.0	56.6	59.3	75.8	12.4	68.9	28.3
4	21/05/91	19	69.3	15.6	76.5	20.8	67.8	33.9	56.3	59.3	53.3	67.3	71.2	23.4	64.6	39.4
5	23/05/91	21	68.0	10.3	79.7	13.8	66.5	38.4	55.4	63.5	53.0	78.6	71.4	20.9	64.5	40.9
6	25/05/91	23	82.5	4.1	85.1	8.1	74.3	26.5	65.0	41.7	59.9	57.8	80.6	12.9	73.4	27.6
7	28/05/91	26	85.8	4.9	81.6	8.1	70.5	32.0	65.7	44.3	59.9	56.7	79.3	15.0	72.7	29.2

TABLE A7.2.2 OBSERVED MOISTURE CONTENT (BY VOL.) AND PENETRATION RESISTANCE FROM THE DMF, BLOCK A/041.

No.	Sampling Date	Time	Sampling Depth (cm) 0-5		15		30		45		60		Mean SMC in 0-30cm Depth	Mean PR in 0-30cm Depth	Mean SMC in 0-60cm Depth	Mean PR in 0-60cm Depth
		(day)	SMC (mm)	PR (N/cm^2)	SMC (mm)	PR (N/cm^2)	SMC (mm)	PR (N/cm^2)	SMC (mm)	PR (N/cm^2)	SMC (mm)	PR (N/cm^2)	(mm)	(N/cm^2)	(mm)	(N/cm^2)
0	02/05/91	0	-	-	-	-	-	-	-	-	-	-	-	-		
1	10/05/91	8	64.7	0.3	122.3	9.6	97.7	24.8	95.7	49.2	89.0	79.9	284.8	11.6	469.4	32.8
2	14/05/91	12	57.0	1.6	113.7	3.5	104.6	13.3	99.6	32.5	105.1	48.2	275.3	6.1	480.0	19.8
3	16/05/91	14	57.8	3.6	115.3	9.3	100.0	24.3	97.1	45.0	92.6	59.3	273.0	12.4	462.7	28.3
4	21/05/91	19	47.8	15.6	113.6	20.8	102.7	33.9	87.8	59.3	87.2	67.3	264.1	23.4	439.1	39.4
5	23/05/91	21	46.9	10.3	118.3	13.8	100.7	38.4	86.4	63.5	86.6	78.6	266.0	20.9	439.0	40.9
6	25/05/91	23	56.9	4.1	126.4	8.1	112.5	26.5	104.1	41.7	100.0	57.8	295.9	12.9	500.0	27.6
7	28/05/91	26	59.2	4.9	121.2	8.1	106.8	32.0	100.8	44.3	98.0	56.7	287.2	15.0	486.0	29.2

TABLE A7.2.3 OBSERVED MOISTURE CONTENT (BY WEIGHT) AND PENETRATION RESISTANCE FROM NURSERY, BLOCK A/041.

No.	Sampling Date	Time (day)	0-5 SMC (%)	0-5 PR (N/cm²)	15 SMC (%)	15 PR (N/cm²)	30 SMC (%)	30 PR (N/cm²)	45 SMC (%)	45 PR (N/cm²)	60 SMC (%)	60 PR (N/cm²)	Mean SMC in 0-30cm Depth (%)	Mean PR in 0-30cm Depth (N/cm²)	Mean SMC in 0-60cm Depth (%)	Mean PR in 0-60cm Depth (N/cm²)
0	02/05/91	0	-	-	-	-	-	-	-	-	-	-	-	-		
1	10/05/91	8	90.3	3.0	65.8	3.0	60.5	48.0	50.5	78.0	49.7	88.0	72.2	18.0	63.3	44.0
2	14/05/91	12	87.2	5.0	73.4	8.0	60.7	48.0	63.0	50.0	58.3	85.0	73.8	20.3	68.5	39.2
3	16/05/91	14	78.5	8.0	66.4	38.0	52.6	40.0	52.0	45.0	48.4	70.0	65.9	28.7	59.6	40.2
4	21/05/91	19	67.1	18.0	66.7	30.0	58.1	57.0	50.0	75.0	49.3	78.0	63.9	35.0	58.2	51.6
5	23/05/91	21	67.2	25.0	58.5	48.0	59.1	65.0	53.7	76.0	49.0	89.0	61.6	46.0	57.5	60.6
6	25/05/91	23	93.0	0.0	75.2	20.0	69.4	30.0	63.6	45.0	59.3	55.0	79.2	16.7	72.1	30.0
7	28/05/91	26	77.8	8.0	70.8	12.0	61.7	25.0	59.2	40.0	57.5	55.0	70.1	15.0	65.4	28.0

TABLE A7.2.4 OBSERVED MOISTURE CONTENT (BY VOLUME) AND PENETRATION RESISTANCE FROM NURSERY, BLOCK A/041.

No.	Sampling Date	Time (day)	0-5 SMC (mm)	0-5 PR (N/cm²)	15 SMC (mm)	15 PR (N/cm²)	30 SMC (mm)	30 PR (N/cm²)	45 SMC (mm)	45 PR (N/cm²)	60 SMC (mm)	60 PR (N/cm²)	Mean SMC in 0-30cm Depth (mm)	Mean PR in 0-30cm Depth (N/cm²)	Mean SMC in 0-60cm Depth (mm)	Mean PR in 0-60cm Depth (N/cm²)
0	02/05/91	0	-	-	-	-	-	-	-	-	-	-	-	-		
1	10/05/91	8	62.3	3.0	97.7	3.0	91.6	48.0	78.8	78.0	81.2	88.0	251.6	18.0	411.7	44.0
2	14/05/91	12	60.1	5.0	109.0	8.0	92.0	48.0	98.4	50.0	95.2	85.0	261.1	20.3	454.7	39.2
3	16/05/91	14	54.2	8.0	98.6	38.0	79.7	40.0	81.2	45.0	79.2	70.0	232.5	28.7	392.9	40.2
4	21/05/91	19	46.3	18.0	99.0	30.0	88.0	57.0	78.0	75.0	80.7	78.0	233.3	35.0	391.9	51.6
5	23/05/91	21	46.3	25.0	86.8	48.0	89.5	65.0	83.7	76.0	80.1	89.0	222.7	46.0	386.4	60.6
6	25/05/91	23	64.2	0.0	111.6	20.0	105.1	30.0	99.3	45.0	96.9	55.0	280.9	16.7	477.1	30.0
7	28/05/91	26	53.7	8.0	105.2	12.0	93.5	25.0	92.4	40.0	94.1	55.0	252.4	15.0	438.8	28.0

TABLE A7.2.5 OBSERVED MOISTURE CONTENT (BY WEIGHT) AND PENETRATION RESISTANCE FOR ASH/STRAW, BLOCK A/041.

No.	Sampling Date	Time (day)	0-5 SMC (%)	0-5 PR (N/cm²)	15 SMC (%)	15 PR (N/cm²)	30 SMC (%)	30 PR (N/cm²)	45 SMC (%)	45 PR (N/cm²)	60 SMC (%)	60 PR (N/cm²)	Mean SMC in 0-30cm Depth (%)	Mean PR in 0-30cm Depth (N/cm²)	Mean SMC in 0-60cm Depth (%)	Mean PR in 0-60cm Depth (N/cm²)
0	02/05/91	0	-	-	-	-	-	-	-	-	-	-	-	-		
1	10/05/91	8	72.6	0.0	70.8	17.5	62.8	26.5	48.3	54.0	55.4	53.5	68.7	14.7	62.0	30.3
2	14/05/91	12	93.2	0.0	80.4	1.7	67.1	12.0	63.1	31.0	60.7	32.0	80.2	4.6	72.9	15.3
3	16/05/91	14	85.5	5.3	75.6	6.0	62.5	22.3	62.1	51.7	59.9	52.7	74.5	11.2	69.1	27.6
4	21/05/91	19	88.6	4.0	84.5	12.0	61.6	37.8	59.8	45.5	55.0	53.3	78.2	17.9	69.9	30.5
5	23/05/91	21	88.7	0.0	77.9	19.3	65.6	36.5	56.6	60.0	55.1	65.0	77.4	18.6	68.8	36.2
6	25/05/91	23	85.4	2.5	82.9	10.0	69.1	40.0	62.0	49.0	57.7	60.5	79.1	17.5	71.4	32.4
7	28/05/91	26	103.5	2.5	83.6	9.0	68.0	28.3	64.5	41.3	67.0	48.8	85.0	13.3	77.3	26.0

TABLE A7.2.6 OBSERVED MOISTURE CONTENT (BY VOL.) AND PENETRATION RESISTANCE FOR ASH/STRAW, BLOCK A/041.

No.	Sampling Date	Time (day)	0-5 SMC (mm)	0-5 PR (N/cm²)	15 SMC (mm)	15 PR (N/cm²)	30 SMC (mm)	30 PR (N/cm²)	45 SMC (mm)	45 PR (N/cm²)	60 SMC (mm)	60 PR (N/cm²)	Mean SMC in 0-30cm Depth (mm)	Mean PR in 0-30cm Depth (N/cm²)	Mean SMC in 0-60cm Depth (mm)	Mean PR in 0-60cm Depth (N/cm²)
0	02/05/91	0	-	-	-	-	-	-	-	-	-	-	-	-		
1	10/05/91	8	50.1	0.0	105.1	17.5	95.1	26.5	75.3	54.0	90.5	53.5	250.3	14.7	416.1	30.3
2	14/05/91	12	64.3	0.0	119.4	1.7	101.7	12.0	98.4	31.0	99.3	32.0	285.4	4.6	483.2	15.3
3	16/05/91	14	59.0	5.3	112.2	6.0	94.7	22.3	96.9	51.7	98.0	52.7	265.9	11.2	460.8	27.6
4	21/05/91	19	61.2	4.0	125.4	12.0	93.3	37.8	93.2	45.5	89.9	53.3	279.9	17.9	463.0	30.5
5	23/05/91	21	61.2	0.0	115.7	19.3	99.4	36.5	88.3	60.0	90.1	65.0	276.3	18.6	454.8	36.2
6	25/05/91	23	58.9	2.5	123.1	10.0	104.6	40.0	96.7	49.0	94.3	60.5	286.6	17.5	477.6	32.4
7	28/05/91	26	71.4	2.5	124.1	9.0	103.0	28.3	100.7	41.3	109.5	48.8	298.5	13.3	508.7	26.0

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