DEVELOPMENT OF NEW RESEARCH SITE ON THE ILONGA AGRICULTURAL EXPERIMENT STATION, KILOSA, TANZANIA

by

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1. INTRODUCTION

Agricultural research in Tanzania has suffered from lack of adequate attention to the need for well organized and managed experimental farms. Initially this problem was not too serious because each research station studied a limited number of crops, usually commercial type, which made organization simpler. In recent years each station has had to increase the number of crops studied, including food crops, which previously had not been part of major research programs. Yields obtained in the recent studies have in many cases been poor and the coefficient of variability so high that it became hard to evaluate the new findings with confidence. At this stage it was felt necessary to initiate an improvement program for research stations so that consistent and reliable data could be obtained.

Developing and managing research farms is a specialized skill but taken too lightly in most developing countries (Pomeroy, 1970). In addition to organizational techniques, basic knowledge on the climate of the area, types of soils found, kind of crops grown, research objectives, and what is needed to achieve those objectives is required before developing or managing a research farm. No one can be an expert in all the aspects involved but the important thing is to coordinate relevant knowledge of different skilled people to form an integrated and efficient research farm improvement plan and management system.

The purpose of this study is to provide the basic data needed for the planning and layout of a new research site at Ilonga Research Station (Tanzania). These data, about the station and its environment, will provide information and may serve as future reference for information needed for future research projects and for additional station improvement.

The role and requirements for developing a research station are discussed first.

1.1 THE ROLE OF AGRICULTURAL RESEARCH

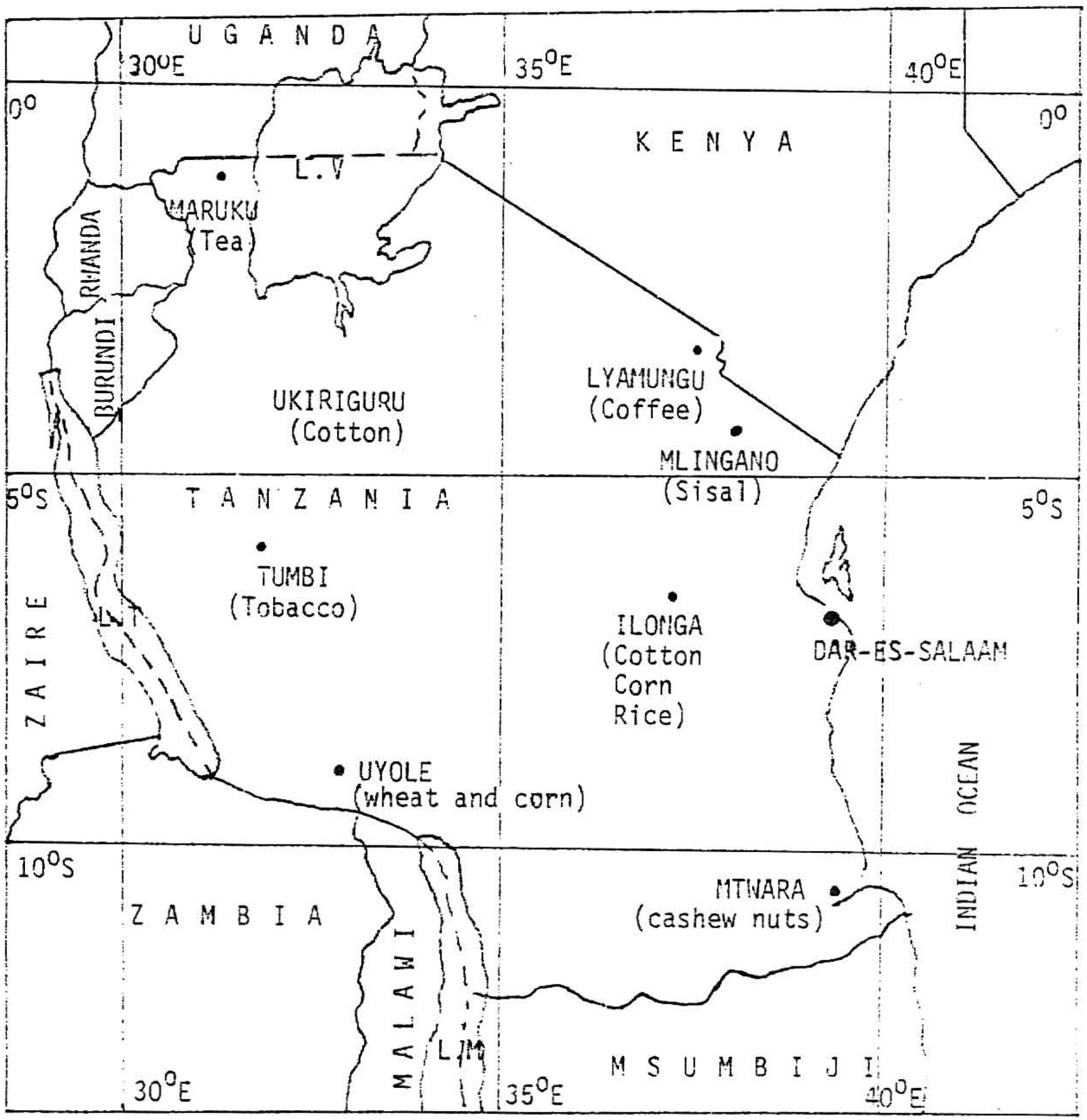
Agricultural research is conducted in order that farming practices and systems can be selected, devised, modified,and used to improve the production of materials which satisfy basic human needs (Daniels et al,,1977). These needs include food, fiber, medicine, ornamental plants. etc. The amount and nature of research conducted in a given area depends on the local agriculture and the need to improve the farming practices and systems (Lee, 1977).

There are always more pressing problems to solve than there is money to solve them. So research should never be undertaken just for the sake of investigation. In fact agricultural research organizations must establish priorities among the many problems needing solution and select the research to be conducted on the basis of these priorities.

In order to meet a country's research needs with reasonable efficiency, agricultural experiment stations usually are assigned specific areas or crops for study. This restricts the alternative priorities from which the final research program must be selected.

1.2 RESEARCH POLICY AND LOCATION OF MAJOR RESEARCH STATIONS IN TANZANIA

Most agricultural research stations were started in the late forties and early fifties. At that time and for a number of years subsequently, all the research stations placed most emphasis on commodity research, mainly on commercial export crops like coffee, sisal, cotton, tobacco, tea, and cashewnuts. This policy paid off handsomely for these crops as evidenced by the fact that Tanzania leads the world in the production of sisal fiber and cashewnuts and is among major producers of coffee, cotton, tobacco, and tea in Africa. Fig. 1 shows the locations of the major research stations started



L.M = Lake Malawi

L.T = Lake Tanganyika

L.V = Lake Victoria

Fig. 1-Major agricultural research stations in Tanzania.

in that period. The major crops studied are also listed under each station. Cash crop research is still going on in these stations as well as at other smaller experiment stations started in the fifties and early sixties.

The national agricultural policy has changed since then. The present policy is to gear production more towards the domestic market while continuing with exports in processed form in order to earn foreign exchange. The research organization has to design programs that are geared towards meeting those objectives.

The domestic market shows an increasing demand for food products among others. The role of the agricultural research stations to increase food crop production in the country, hence boosting the market supply, is therefore obvious.

1.3 REQUIREMENTS FOR THE DEVELOPMENT OF A NEW RESEARCH STATION

When developing and managing an experiment station, it is important that all planning activities be geared towards achieving the objectives for which it was started. Proper initial planning cannot be overemphasized. The success of the research station depends much on how efficiently the initial planning was accomplished. This applies whether a new station is being started or an existing one is being improved.

Problems often exist that may render the station ineffective in terms of meeting its objectives (Pomeroy, 1975, and Sontag et al., 1977). Some of these may include too little financial support, too few qualified staff, administrative ambiguity, and faulty operational techniques. However, if the initial planning is properly done and the plan is followed closely in the course of implementation, these problems are bound to be solved with time.

First and foremost, the need for building a new station or improving an existing one has to be established. Once this is done the following factors must be examined and evaluated during the planning stage:-

i) Objectives of the station in terms of commodities to be researched, and areas of management for each commodity to be emphasized.

ii) Environmental factors; such factors as climate, including drought and/or flood prevalence, soils, topography, pest (weed, insect, disease) prevalence, and damage to crops and livestock that affect the production of the selected commodities.

iii) Utilities and services. Availability and reliability of utilities and services such as electricity, telephone, and postal services, roads, water, local labor, markets, schools, medical care, and recreational facilities.

iv) Suitability of each of the several available sites to meet present needs and allow for future expansion.

Where an existing station is to be improved, much of the information can be gathered from station records. These may indicate where gaps in knowledge exist and point to specific items that need further evaluation. When a new station is to be set up official government and other records will have to be gleaned for information, but much will have to be gathered from interested and informed farmers, local leaders, and government officials in the area. Caution must be exercised in verifying as thoroughly as possible information gained from individuals.

With the final selection of the site made and clear title to the land obtained (not always an easy task in areas where land ownership is vested in the village or community rather than with the individual) the land must be surveyed and its boundaries clearly marked. Then actual planning of the research program can begin, to be followed by implementation.

Step by step procedures for the development of the Ilonga Research Station, Kilosa, Tanzania are described in this report.

2. ILONGA AGRICULTURAL RESEARCH STATION

The Ilonga Agricultural Research Station was established near Kilosa, Tanzania (then Tanganyika) in 1943 on land already operated by the Ministry of Agriculture. The original objective of the station was to improve the cotton production of the eastern area of the country.

2.1 LOCATION, SIZE, AND ENVIRONMENT

The station is located almost 400 km due west of Dar-es-Salaam, the national capital and business center of Tanzania (see Fig. 1).

Region:	Morogoro
District:	Kilosa
Longitude:	37^{o} 02' E
Latitude:	6^{o} 42' S
Altitude:	506 m
Postal Address:	Ilonga A. R. S. Private Bag, Kilosa
Telegraphic Address:	Scientific Kilosa
Telephone:	Kilosa 49
Nearest Railway Station:	Kilosa - 11 km
Bus stop:	Kilosa - 11 km or Station gate
Airport:	Kilosa airstrip (charter flights) -19 km

The total area of the station is about 1060 ha out of which 600 ha is arable land. About 200 ha of land is cultivated with 6 ha presently under irrigation. The remaining arable land is either fallow or used as natural pasture.

At present the station has a labour force of about 200 but the number changes frequently as some leave jobs and others come in. The surrounding villages have a combined population of about 10,000. Many of these depend for livelihood on subsistance farming; others work on nearby state farms and government institutions.

The climate is warm and rainy in summer (November - April) and cool in the dry season (June - September). The annual rainfall is about 1045 mm. The soil is generally deep and fertile sandy clay loam. The vegetative cover consists of grasses with a few shrubs and acacia trees. The climate, the soil, and the vegetation will be discussed more fully in the next two chapters.

Livestock are also raised at the station. These animals are controlled by the Training Division. Currently there are about 300 cattle, 190 lambs, 150 goats, 50 pigs, and 200 laying hens.

2.2 PREVIOUS PROGRAMS

As mentioned earlier cotton was the major crop studied initially. Several high yielding disease resistant cotton varieties, namely, IL_{58}, IL_{62}, and IL_{66} were released in 1958, 1962, and 1966, respectively. These varieties are mainly grown in the eastern areas of the country. Major research work in cotton is still going on. It has not stopped since the station was started, although there were periods when the work slowed down.

In the early fifties the station embarked on food crop research, mainly cereals, in addition to cotton. Grain legumes were introduced later.

One of the major breakthroughs in food crop research in the fifties and early sixties was the development of Ilonga maize composites A, B, and C. These composites are well adapted to warm mid-altitude areas.

Two more programs were added in the late sixties and early seventies. The Nutrition Program initiated in 1967 deals with food crop preservation, addition of supplements to basic foods, and evaluation of storage methods. A training wing was attached to this program in 1970. This was responsible for training agricultural food and nutrition field personnel to meet the manpower demand of the Ministry.

In 1973 the National Foodcrops Research Program was initiated. This program was to be nationwide, but with a central base at Ilonga. Hence the station became the National Center for this program. Maize, grain legumes, and sorghums were to receive major emphasis. A number of new potential varieties developed here are about to be released. Tuxpeno, a maize variety which originated in Mexico, was tested here and proved competitive to Ilonga composites. It was released to farmers in 1975 but due to a few adaptation problems it was recalled and is undergoing further improvement and testing. Rice experiments are also conducted here. Rice research is emphasized less now than it was in the late sixties.

Army worm (Spodoptena exempta) is a problem in the Eastern, Central, and Northern zones. The Station has been the center for studies of army worm control since 1973. Three branch experimental stations are maintained by the station; Hombolo and Bihawana - both near Dodoma - and Wami - near Morogoro. In 1975 the station was selected as the center for the Tanzania-Netherland Child Welfare Project.

From this brief history it is obvious that by 1973 the station was getting more complex in terms of activities and administration. To reduce the complexity and administrative burden the research and training components were split. Each was to be administered by a separate ministerial division instead of both under one, as was the case previously. Research will be administered by a newly formed independent organization but the Ministry of Agriculture will continue to control research policy.

Ilonga Research Station was fairly well planned in the past but many additional facilities were added without reference to any station development plan. This has resulted in facilities being sited in unsuitable areas and has caused considerable duplication of effort in several aspects. This emphasizes the necessity for making and adhering to a station development plan.

As the national demand for agricultural food production increased the need for improved research output also went up. At this stage it was realized that in order to carry out more meaningful research programs, the land and the support facilities needed to be improved. This hopefully would increase research efficiency, reduce the coefficient of variation (C. V.) due to within plot differences, and shorten the time needed to obtain research results.

In view of limited resources the government was forced to choose one station from among the nine major ones, for the initial improvement program. It was finally agreed that the improvement program should begin at Ilonga Research Station. There are several reasons that led to this decision.

i) The station has been concerned with food crops research longer than any other station in the country and a lot of information about the area is available.

ii) Varieties developed and tested here have adapted well to many areas in the country.

iii) The environmental conditions are representative of a fairly large area (the Eastern Zone) which has high potential for warm season grain crops - maize, grain legumes, sorghum, rice, etc.

iv) The climate and soils allow a variety of crops to be grown.

v) Other factors include relatively easy communication, availability of power (hydroelectric), sufficient suitable land, and adequate labour.

The Food Crop Research Program has been funded jointly by the International Aid Development Agency and the Tanzanian Government since its inception. It is hoped that the continuing work at Ilonga will be similarly funded.

3. THE CLIMATE OF ILONGA

The importance of climate to a specific area or region is well known. It affects the environment so much that it requires a thorough investigation before planning any agricultural development programs. The soils of the area chosen will be the result of combination of several environmental factors including climate. The kind of crops grown and even the way of life is highly influenced by climate. Ignoring this factor may cause total failure. One commonly cited example is the East African Groundnut Scheme at Nachingwea (Tanzania) which was started in an attempt to alleviate the shortage of oils and fats after World War II. The reasons for the total failure of the scheme were many, but the most important was the inadequate attention given to the climatic conditions in the selected areas. Well over 600 million shillings (US $75 million) that was invested ended up being wasted.

Agricultural experiment stations, like any agricultural schemes, require proper climatic consideration before investing heavily in their development. In fact this should be given the highest priority as it will greatly influence where the station needs to be located - the best choice being where the climate is most representative of the zone it serves.

Elements of climate which should be considered include rainfall, temperature, relative humidity, wind, radiation, sunshine hours, and evaporation.

The climatic feature of most significance at Ilonga, and indeed over the rest of Tanzania, is rainfall. Temperature is a rather constant element showing a relatively small annual range. Wind speed is generally low compared to other areas such as the temperate regions.

3.1 RAINFALL

Ilonga has a dry semi-hot type of climate which has only one wet and one dry season. In general, considering its position in relation to the

Equator and the movement of the Inter Tropical Convergence Zone (I. T. C. Z.) over the area, the station does not receive as much rainfall as it should. This is mainly due to the geographical and seasonal wind pattern of the area.

Morogoro Region depends on the Monsoon Winds for its rainfall. From May to October the prevailing winds are from the northeast. These bring some rain to the northeastern part of the country but not much because of the relatively small area of sea they cross. After crossing the Equator, they change course due to the earth's rotation, first blowing in the north-south direction (parallel to the coast) and finally becoming northwesterly winds. Having crossed over a relatively large land mass, some of which is mountainous, they are now dry and carry little or no rain by the time they blow over the station area.

From November to April the Monsoon Winds are from the southeast (South East Monsoons) which after crossing the Indian Ocean bring rain to many parts of Tanzania. The coastal plain receives the highest rainfall. Ilonga receives less rain than the coastal belt because of the reduced effect of the monsoons with increasing distance from the ocean.

The total amount of rain received and its distribution throughout the year have a great effect on farming. Table 1 gives a summary of rainfall data for Ilonga Station. The station receives just over 1,000 mm annually most of which falls between December and April. The mean monthly rainfall given in column 2 of the table is the average for the last 34 years (1946 - 1979). Fig. 2 is a graphical representation of the seasonal distribution through the year.

The annual pattern can be divided into two periods.

1. The period from November to April (rainy season).
2. The period from June to September (dry season).

May and October are considered to be transitional months.

The seasonal rainfall distribution suggests a pattern with double

Table 1-Rainfall data for Ilonga Station, Tanzania.

Month	Rainfall						
	Mean (mm)	Max. (mm)	Min. (mm)	Mean max. 24h (mm)	Days with >0.1 (mm)	Mean max. dry days between rains	$f_{\geq \bar{x}_i}$ #
1	2	3	4	5	6	7	8
January	133	306	4	117	12	11	0.44
February	123	262	9	93	10	11	0.50
March	209	434	53	163	14	6	0.49
April	225	430	34	219	17	5	0.45
May	70	219	7	58	10	10	0.33
June	11	65	1	33	3	22	0.31
July	8	41	1	18	2	26	0.34
August	13	75	1	26	4	26	0.42
September	17	104	1	53	3	29	0.32
October	26	157	1	45	4	26	0.30
November	75	344	1	152	7	19	0.34
December	132	378	4	136	11	13	0.42
Total	1045	1620	475				0.45
Record years	34	34	34	20	20	20	34

#Probability of getting rainfall equal to or greater than the monthly mean.

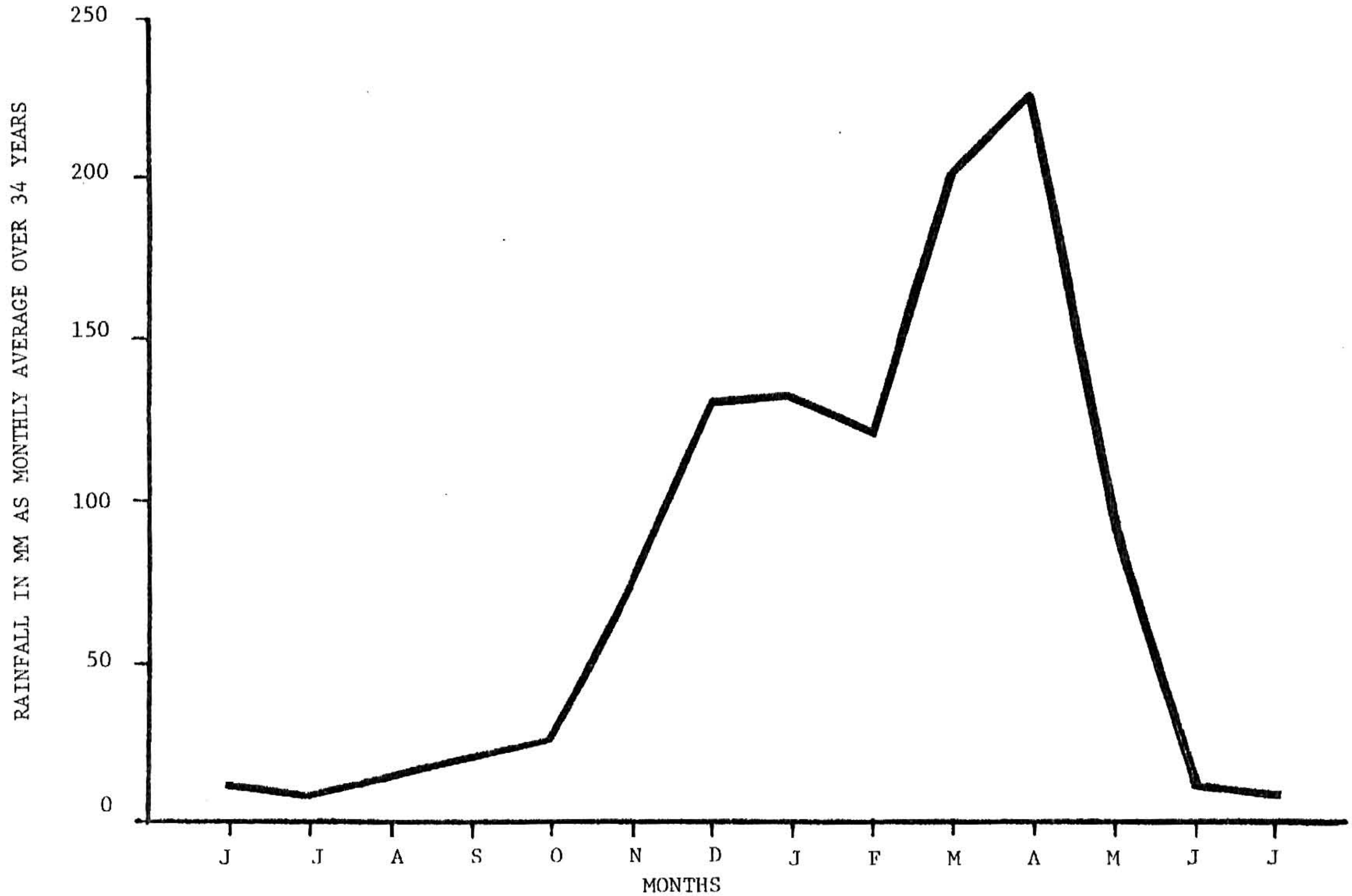


Fig. 2-Average monthly rainfall for Ilonga Station, Tanzania.

maxima but this is caused by February having 10 mm less rainfall than January. A suggestion of double periodicity is bound to be subjective in a situation like this. This does not mean the drop is to be neglected. In fact it has always been advisable to postpone planting in this area till towards the end of February, despite favourable rainfall amounts in December and January. The lower rainfall in February has, in most cases, caused an imbalance between rainfall and cropwater needs unless supplementary moisture can be applied through irrigation. The amount shown in the table may seem good enough for most crops, but it is an average figure and as we shall see later is very unreliable. The rainfall is at its peak between March and April, then begins to drop in May. This marks the end of the growing season. The total rainfall between February and May in normal years is enough to grow many different types of crops like maize (corn), grain legumes, sorghum, and a number of other food crops. Rice does well in the flatter and flooded areas. Cotton grows well (satisfactorily) as does sisal. The period June through November is usually dry and few crops would grow unless water is applied artificially.

So far I have discussed the factors influencing the total amount of rainfall and the seasonal distribution through the year. Of equal importance is the reliability of the rainfall. In addition to the wide variation in the time of the year at which the rain falls, the station and the surrounding area has great year to year variation in rainfall amounts. In Table 1 columns 3 and 4 the maximum and the minimum rainfall for the period between 1946 and 1979 are given. There are differences of 396 mm in April and 381 mm in March. The highest total rainfall ever recorded was 1620 mm in 1967 and the lowest was 475 in 1949. What a wide range!

In column 8 the probability ($f \geqslant \bar{x}_i$) of obtaining rainfall equal to or greater than the monthly mean is given for each month. These values were obtained by the cummulative frequency analysis method (Wisler et al., 1959;

Doorenbos, 1976).

$$f \geq \bar{x}_i = m/(n - 1)$$

where $f \geq \bar{x}_i$ = the probability of obtaining rainfall equal to or greater than the monthly mean ($\bar{x}_i$),

m = the rank number of the year when data are in descending order,

and n = the number of years of record.

From the table it is noted that the probabilities of obtaining rainfall equal to or greater than the mean range from 3 to 5 years out of 10 which indicate very low reliability. As a result of this unreliability the following approaches to solving the area's crop production problems are suggested:-

1. The research program for the station must include screening for varieties which can withstand temporary moisture stress.

2. An irrigation facility must be set up so that the most valuable research materials can be saved when rainfall fails.

3. An intensive study of moisture conservation and other essential soil management practices must be included.

Columns 6 and 7 of Table 1 show the average number of rainy days and the average number of maximum consecutive dry days. It is observed that for the months May through November if crops are to be grown most of the water required has to be supplied artificially.

Finally column 5 of Table 1 shows the maximum 24-hour rainfall ever recorded in each month since 1960. The highest was 219 mm which was recorded on 16 Apr. 1960. Daily falls in excess of 100 mm occurred in one out of three years.

Rainfall intensities in excess of 50 mm per hour have been recorded but usually last for a shorter time. Table 2 shows the highest intensities recorded since 1960. Most heavy rains fall with intensities ranging from 10 to 25 mm/hour.

Table 2-Maximum rainfall intensities for Ilonga Station.

Date	Amount (mm)	Duration (min)	Intensity (mm/hr)
1 Jan. 1960	42.2	120	21
26 Dec. 1961	67.8	75	54
22 Jan. 1964	39.3	220	11
16 Mar. 1966	84.8	200	25
7 Mar. 1967	80.8	210	23
14 Apr. 1967	143.5	405	22
6 Mar. 1969	53.2	195	16
24 Mar. 1969	143.5	352	24

The weather station on which the data were collected is about 3 km away from the center of the proposed experimental site. Rainfall measurements were made at the site during early 1980 for comparison purposes. Some differences in the amounts recorded were noted. However, the differences were rarely more than 5 mm and the recording period was too short to warrant any adjustments.

3.2 TEMPERATURE

The variation of the mean monthly air temperature through the year at Ilonga Station is relatively small. The range between the monthly maximum and minimum temperatures hardly exceeds 12^{o}C. The difference between the average temperature of the coldest month and the hottest month is about 5^{o}C. Columns 2 and 3 of Table 3 show the mean maximum and mean minimum temperatures for each month. June and July are the coldest months. The hot period is spread over the months November through March. This period, as would be expected, coincides with the rainy season. The mean maximum and mean minimum air temperatures are shown graphically in Fig. 3. The highest average maximum monthly temperature is about 32^{o}C whereas the lowest average minimum monthly temperature is about 15^{o}C.

The effect of altitude is not clearly marked here as it is in the highlands, nor is the influence of the sea very noticeable. But in view of its elevation and the distance from the sea, the possibility of minor influence can not be ruled out. Griffiths (1968) worked out the correlations of average annual temperatures with elevation for East Africa and reported the following equations:

$$T(max) = 34 - 5.6h,$$

and $$T(min) = 24.5 - 6.3h,$$

where temperatures are in ^{o}C and h is the elevation in thousands of meters. For the station (506 m above sea level) the calculated maximum and minimum annual average temperatures would be 31.2^{o}C and 21.3^{o}C, respectively. These

Table 3-Average climatic data for Ilonga Station, Tanzania.

Month	Temperature (^oC)		Humidity %		Wind speed (km/day)	Sunshine hours/day	Radiation cal cm^{-2} day^{-1}	Class A pan evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum				
1	2	3	4	5	6	7	8	9
January	31.2	20.9	83	58	115	6.5	496	4.6
February	31.3	20.6	81	57	110	7.1	524	5.2
March	30.9	20.8	83	60	99	7.2	489	4.2
April	29.5	20.5	84	68	88	6.3	438	4.3
May	28.3	18.8	83	65	98	6.5	407	3.9
June	27.5	15.9	79	60	115	7.0	408	4.4
July	27.4	15.5	75	52	126	7.1	405	4.4
August	28.1	16.5	75	50	135	6.7	419	4.7
September	29.4	18.1	74	50	155	6.8	460	5.5
October	30.9	19.7	72	48	175	7.5	503	6.6
November	32.1	21.1	74	49	159	8.1	524	6.6
December	31.8	21.2	80	54	136	7.4	524	6.1
Annual	29.9	19.1	79	56	126	7.0	466	5.0
Record years	20	20	11	11	15	18	18	11

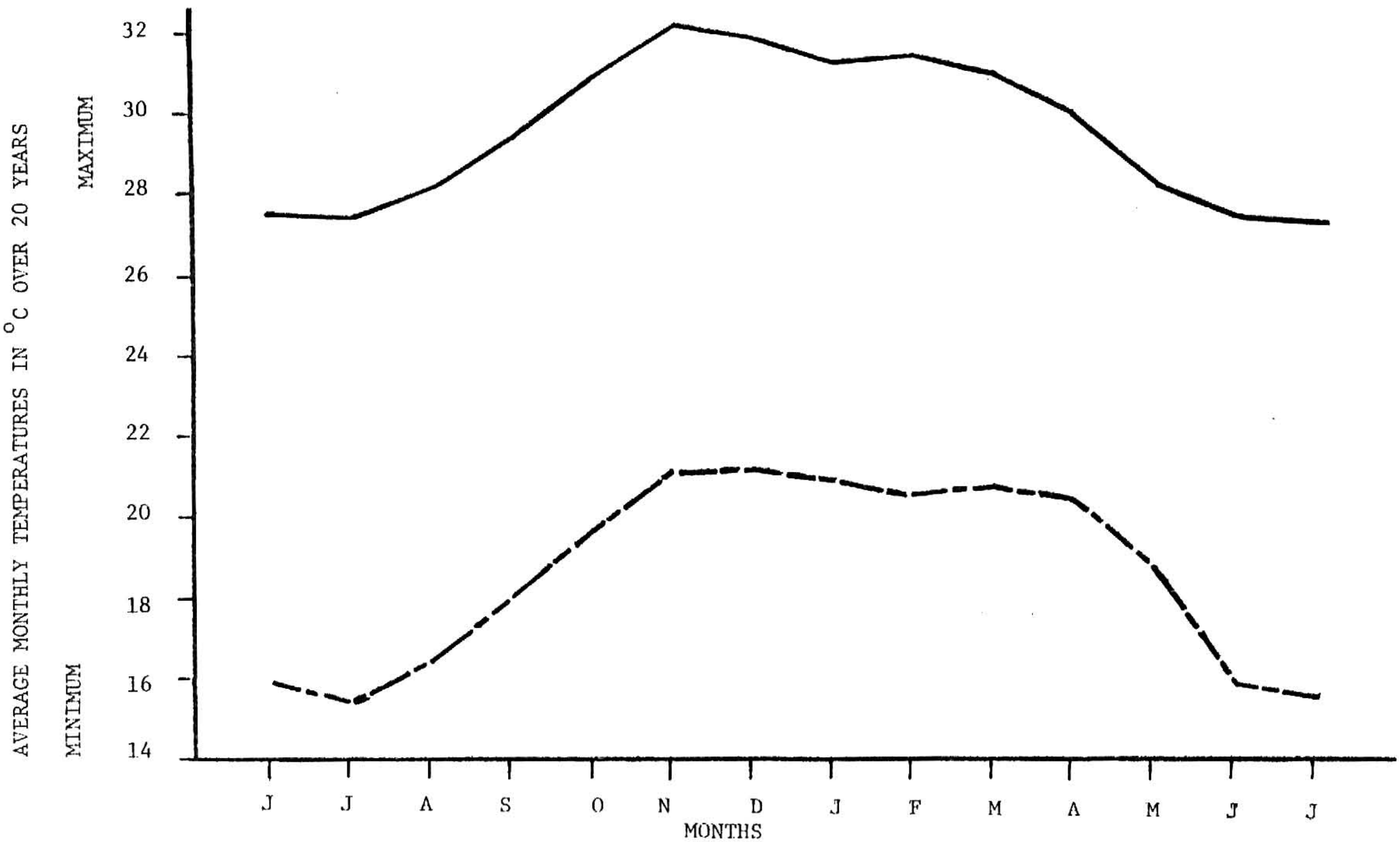


Fig. 3-Maximum and minimum temperatures for Ilonga Station, Tanzania.

values depart by about +2^{o}C from the annual average temperatures given in Table 3. The difference may thus be due to the influence of the sea which is about 400 km away.

3.3 RELATIVE HUMIDITY

Columns 4 and 5 of Table 3 show the percent relative humidity (R. H.) at 09:00 and at 15:00. Incidentally for almost every day over the record period the 09:00 recording was higher than the 15:00 reading.

The variation of the monthly mean humidity, like temperatures, is quite small (about 15%). At 09:00 readings range from 72 to 84% and at 15:00 from 48 to 68%. The lower values are for the driest month (October).

3.4 WIND

Usually wind speed measured at 2 m above the surface is not high. The annual average run is about 125 km/day. The seasonal variation is about 30 to 40%. March, April and May are the calmest months, while October and November are fairly windy (Table 3, column 6). Mostly winds blow during the day; nights and early mornings are calm. As would be expected, the winds begin to strengthen during the afternoon.

3.5 RADIATION

The amount of radiation received at any point largely determines the amount of evapotranspiration that takes place. Although temperature and radiation are related, higher temperature is not necessarily associated with higher radiation; sunshine duration affects radiation most. At any point on the earth's surface, the amount of radiation received under clear skies is usually constant. Cloud cover reflects and absorbs some of the incoming radiation causing fluctuations in the amount that reaches the surface (Doorenbos et al., 1977). This relationship is discussed further in the next section.

From Table 3 column 8, it can be seen that Ilonga receives radiation in excess of 400 cal $cm^{-2}day^{-1}$ throughout the year with over 500 cal cm^{-2} day^{-1} during the warmest months.

3.6 SUNSHINE HOURS

The importance of sunshine in determining the radiation load received at any point has already been mentioned. Actually it is the ratio of the number of sunshine hours to the maximum possible that counts. For any latitude there is a maximum possible sunshine period measured in hours for a given season. These figures are given in standard books (Doorenbos et al., 1977; Israelsen et al., 1962) for different latitudes and months.

The relationship between radiation and sunshine percent ratio has been shown to be of the form (Doorenbos et al., 1977)

$$R_s/R_a = a \cdot \cos\gamma + b \cdot n/N$$

where R_s = actual radiation reaching the earth's surface at the station (latitude γ),

R_a = solar radiation received at the top of the atmosphere by a horizontal surface at latitude γ,

a and b = are constants determined locally,

n/N = the percentage ratio of the actual (measured) sunshine hours (n) to the annual maximum possible sunshine hours (N).

If R_s and n are known, as in this case, columns 7 and 8 of Table 3, a and b can be calculated by substituting the values into the equation; R and N may be obtained from standard books. Generally a = 0.29 and b = 0.52, and these may be used where the constants have not been determined.

3.7 EVAPORATION

A number of methods can be used to estimate the amount of evaporation that occurs at any one station. Some employ empirically determined equations with climatic data to arrive at a given evaporation value (Doorenbos et al., 1977; Israelsen et al., 1962). The pan evaporation method used at Ilonga measures directly the integrated effect of radiation, wind, temperature, and humidity on evaporation from a specific open water surface (US Weather Bureau Class A pan) (column 9, Table 3). These results can be translated to evapotranspiration using experimentally determined correction factors. The rate of evaporation increases with increasing radiation and decreasing cloudiness at Ilonga except for the wettest months.

Each method for estimating evaporation is suitable for use under specific conditions. No attempt will be made here to define which of them is better for Ilonga conditions. However, the evaporation rates estimated by the radiation method are given for comparison. This method has proved to be fairly accurate for most cases when the needed data are available.

The radiation method involves determination of evapotranspiration for a given area from data on measured air temperature, radiation, wind speed, and relative humidity. If radiation data are not available, sunshine or cloudiness can be used to predict its value using the relationship discussed in the previous section.

The relationship representing mean evaporation over the given period as expressed by Doorenbos et al., (1977) is:

$$ETo = C(W \cdot R_s) \text{ mm/day}$$

where ETo = potential evapotranspiration in mm/day for the period considered,

C = adjustment factor which depends on mean relative humidity and daytime wind speed,

W = weighting factor which depends on mean temperature and altitude,

R_s = solar radiation as equivalent evaporation in mm/day. R_s is measured or may be calculated using sunshine duration ratio.

The monthly radiation values for Ilonga station (Table 2) were converted to equivalent evaporation (mm/day) by multiplying the value by the factor 1/59 mm/cal. For example, the average radiation for January was given as 496 cal $cm^{-2} day^{-1}$. The equivalent evaporation is 8.41 mm/day.

The weighting factor was determined from tabulated values as given by Doorenbos et al., (1977). The table from this publication is attached in Appendix 1 Table B for reference. For January the mean temperature was 26.1°C and from the table, at elevation 500 m, the weighting factor W is 0.76. Then for January $W \cdot R_s$ = 8.41 (0.76) mm/day = 6.44 mm/day.

The adjustment factor C was estimated by using graphical nomograph presented in the same paper as shown in Appendix 1 Fig. A. For January the mean relative humidity was 70.5% (graph IV) and the average daytime wind speed was estimated to be twice the night time speed as most of the winds at the station blow during the day. For $W \cdot R_s$ of 6.4 mm/day, the adjusted potential evapotranspiration was found to be 4.7 mm/day from the graph. The rest of the average monthly values were determined as above and recorded in Table 4. For comparison purposes the ETo values measured by the pan method (Table 3) are reproduced in this table.

Table 4-Monthly evaporation values for Ilonga Station as determined by two methods - radiation (R) and pan evaporation (P).

Month	J	F	M	A	M	J	J	A	S	O	N	D
R (mm/day)	4.7	5.4	4.3	4.0	3.7	4.0	4.0	4.3	5.0	5.5	6.0	6.0
P (mm/day)	4.6	5.2	4.2	4.3	3.9	4.4	4.4	4.7	5.5	6.6	6.6	6.1

A quick glance through the values suggests the results obtained by the two methods are very similar; however, a statistical analysis showed the two groups differ significantly ($S_{\bar{D}}$ = 0.011 and P <0.001). In spite of this, it appears that either method may be used effectively for Ilonga conditions because both involve empirical calculations and many unavoidable errors are involved in measuring the climatic variables used in the calculations. To obtain the actual evapotranspiration (ETp), by either method the ETo must be multiplied by the appropriate crop coefficient factors. These factors vary with area, kind of crop, stage of development, and weather conditions (humidity, wind, temperature, etc.). Many publications give the maximum crop coefficient for maize as about 1.05 and for sorghum as about 1.0 (Doorenbos et al., 1977; Doorenbos et al., 1979).

4. SOILS OF THE PROPOSED EXPERIMENTAL FARM

Soils is another item which needs careful consideration in experimental station development. Plants' performance depends on the ability of the soil to supply the needed nutrients, water, and air in the proper amounts. In any given area soils vary because of differences in the parent materials, in factors that act on these materials, in age, or in a combination of these. Crops usually respond differently to specific treatments on different soils. Hence, it is important that the experimenter knows the kind of soil his crop is growing on. Researchers would like to plant their experiments on uniform soil but this is not always possible. When the differences are known however, an experiment can be planned so that differences due to soil variation can be separated from those due to treatments during the analysis of results and before the final interpretations are made. Knowledge about the soil is also important in soil management and irrigation.

A detailed soil survey of the 200 ha of land considered best for research at Ilonga was carried out in March 1980. The purpose of the survey was to establish the differences that exist in the area in order to assist in the planning of the plot arrangement, layout of experiments, and soil and water management practices to be used.

The influences of climate, vegetation, and relief on the characteristics of a soil at any place have long been known. Hence, these are important in any soils study. The climate of Ilonga has already been discussed (Chapter 3). Vegetation, geomorphology, and geology will be discussed briefly in the following sections.

4.1 VEGETATION

The station falls within the Savanna, a major ecological region in Tropical Africa; the Sub-region is Dry Savanna, sometimes known as Acacia-tall grass Savanna. It is characterized by an even distribution of tall grasses one to two meters high forming an almost continuous grassland through which are scattered trees, 3 to 15 m tall.

The composition of this type of vegetation is remarkably uniform though the trees may or may not be thorny and range from small to relatively large ones. Hyparrhenia spp. are the predominant grasses but Andropogon spp. and Heteropogon spp. are not uncommon. Acacia is the major tree species in this area but many broad leaved trees occur, for example, Combretum and Terurinalia spp.

During the long dry season the grasses are dry and pale yellow. At this time they are extremely vulnerable to fires which, if allowed to occur, leave the interspaces between the trees blackened and barren. In the dry periods most of the trees are leafless except those growing in the lower valley-land areas. Usually the trees and large rooted perennials begin growth just before the rainy season (November - December). Rainfall is often heavy and the growth of the grasses is unusually luxuriant. On the experimental farm most of the trees have been uprooted and only a few are to be found, mainly in the southeastern portion.

4.2 GEOMORPHOLOGY

Kilosa District, and indeed most of the Morogoro Region, forms part of the East African Marginal Region called the Masai Steppes in Tanzania. This region consists of low plateaus and hills ranging in elevation from less than 100 to over 700 m above sea level, west of the Coastal Plain. The Masai Steppes is flanked by the Eastern Mountain system. In the south this region (the Masai Steppes) extends to the Southern Highlands while in the west it is flanked by the Rubeho and Ukaguru Mountains. To the north it is surrounded by Mt. Meru and Mt. Kilimanjaro and to the northeast by the Usambara Mountains. In the east the region is separated from the Coastal Plain by the

Uluguru Mountains.

As already mentioned, the proposed experimental farm and the rest of the station is located at the foot of the Ukaguru Mountain range. The landscape around Ilonga can be described generally as an almost flat plain that gently descends from the Ukaguru Mountains down to the Tendiga Swamp which is about 40 to 50 km east of the station. The mountain range rises 300 to 500 m above the plain. The plain itself, which extends several kilometers east of the station, slopes gently from an altitude of about 480 to 440 m above sea level and joins the Mkata Plain, a flat lake-like receiving area which is often flooded during the rainy season. Parts of the Ilonga Plain are partially waterlogged during the rainy season as a result of its lowland character. This is evidenced by soils that are generally dark colored, an abundance of paddy rice fields even on the gently sloping land, tall and dense Hyparrhenia grass cover in uncultivated areas, and rivers that disappear before reaching an outlet. In general the slopes are very gentle, ranging from about 1% nearest to the foothills to almost 0% near the Swamp.

One of the most surprising features of the area is the lack of well developed foot slopes. The transition from the steep hills, with rock or gravel cover, to the almost flat plain with lowland characteristics is very abrupt. This may indicate that the plain is aggradational in character and that accumulation predominates over erosion as a geomorphic process.

4.3 GEOLOGY

Geologically, Ilonga falls in the Mozambique Belt which is part of the African Basement complex of lower pre-cambrian age (UNESCO-ASGA, 1964). According to D'Hoore (1964) this basement complex underlies the whole of Africa and outcrops on over one third of the continent. Complex mesozoic and tertiary sediments were deposited over the basal rocks and later were consolidated. During the latter era, intense faulting and in some parts buckling, lifting, and folding formed the Great Rift Valley and the associated mountain formations. The Ukaguru Mountains, which stand at the edge of the eastern arm of the valley, are a result of the above processes and are estimated to be about 600 million years old.

The rocks that make up the Ukaguru Mountains are highly crystalline and complex in composition. Rocks such as sandstone, crystalline limestone, shale, gneiss, schists with muscovite and biotite, and kyanite in association with quartz and potassic granites are commonly found in the area. The nature of the rocks has greatly influenced the fertility level of the soils of the Ilonga plain.

4.4 SOILS

On the world map (FAO, 1974) the soils of the Ilonga Plain are listed as Eutric Fluvisols. These are fertile soils formed from recent alluvial and colluvial deposits brought down by floods from the nearby hills (Ukaguru Mountains). Because of the complex nature of the Ukaguru Mountain rocks, the soils formed as these materials weather are bound to vary considerably. The soils here indicate a lot of variation with depth in the profile, caused by seasonal deposition of different materials. A lot of variations are also noticed within short distances across the plain - possibly due to different levels of deposition and moisture regimes. So complex are these soils that it is not practical to define all the soil units in the area. Efforts were made to group the soils with more similarities than differences in one series without jeopardizing the purpose for which the survey was conducted.

As mentioned before, waterlogging characteristics are noticeable in many parts of the farm site. Generally the soils have dark colours and have either ground water within a meter or two of the surface in the wet season or bear evidence of seasonal high ground-water levels. This is probably due to the virtual absence of deep foot-hill soils to absorb the runoff from the steep, rocky hills. Because of the nature of the plain, this runoff cannot be evacuated readily. Part of it infiltrates into the soil saturating it above a shallow groundwater table. This water moves laterally through the soil down the slope. Part of the excess water flows over the plain eroding unprotected land as it goes. The erosion hazard from overland flow prompted the construction of contour banks on these gentle slopes in the early sixties. These structures were very effective; they not only checked erosion but also prevented evacuation of the runoff, thus increasing the waterlogging problems in and around the farm site.

During the soil survey, 10 pits were excavated and described. The surface soils vary from dark brown sandy clay loams to dark gray brown sandy loams. All soils belonged to the two subgroups Pachic and Aquic of the Great Group Haplustoll. Five different soil series were recognized. Later over 200 borings were made with an auger to establish the boundaries of the series. Representative profiles of the two subgroups were described and samples taken for laboratory analysis. These descriptions and analytical results are given in Appendix 2. Soil bulk densities were determined from eight pits at 15 cm increments to 60 cm and every 30 cm from there to 150 cm. In addition, infiltration tests for the surface and subsoil (just below the A horizon) were run at nine locations.

The different soil series are shown in Fig. 4.

4.4.1 The soil subgroups

i) Pachic Haplustoll

This soil is well drained, dark coloured, friable sandy clay loam at the surface to sandy clay at 25 to 30 cm, with high organic matter content and high base supply. This soil is characteristically dark coloured throughout, with no distinct mottling, but with a few faint and fine mottles; it contains many mica flakes at all depths, and contained ground water

ILONGA RESEARCH FARM SOIL MAP LEGEND (FIG. 4)

SOIL SERIES

1 = ILO-11	(The last digit referring to the particular soil series
2= ILO-12	may be accompanied by a lower case letter a, b, c, d, e,
3 = ILO-13	or f indicating localized differences or phases.)
4 = ILO-24	
5 = ILO-25	

SLOPE CLASS

A = 0 - 1%

B = 1 - 4%

SURFACE THICKNESS

1 = Thickness of A + B_1 exceeds 30 cm.

2 = Thickness of A + B_1 exceeds 15 cm but less than 30 cm.

ILLEGIBLE DOCUMENT

THE FOLLOWING DOCUMENT(S) IS OF POOR LEGIBILITY IN THE ORIGINAL

THIS IS THE BEST COPY AVAILABLE

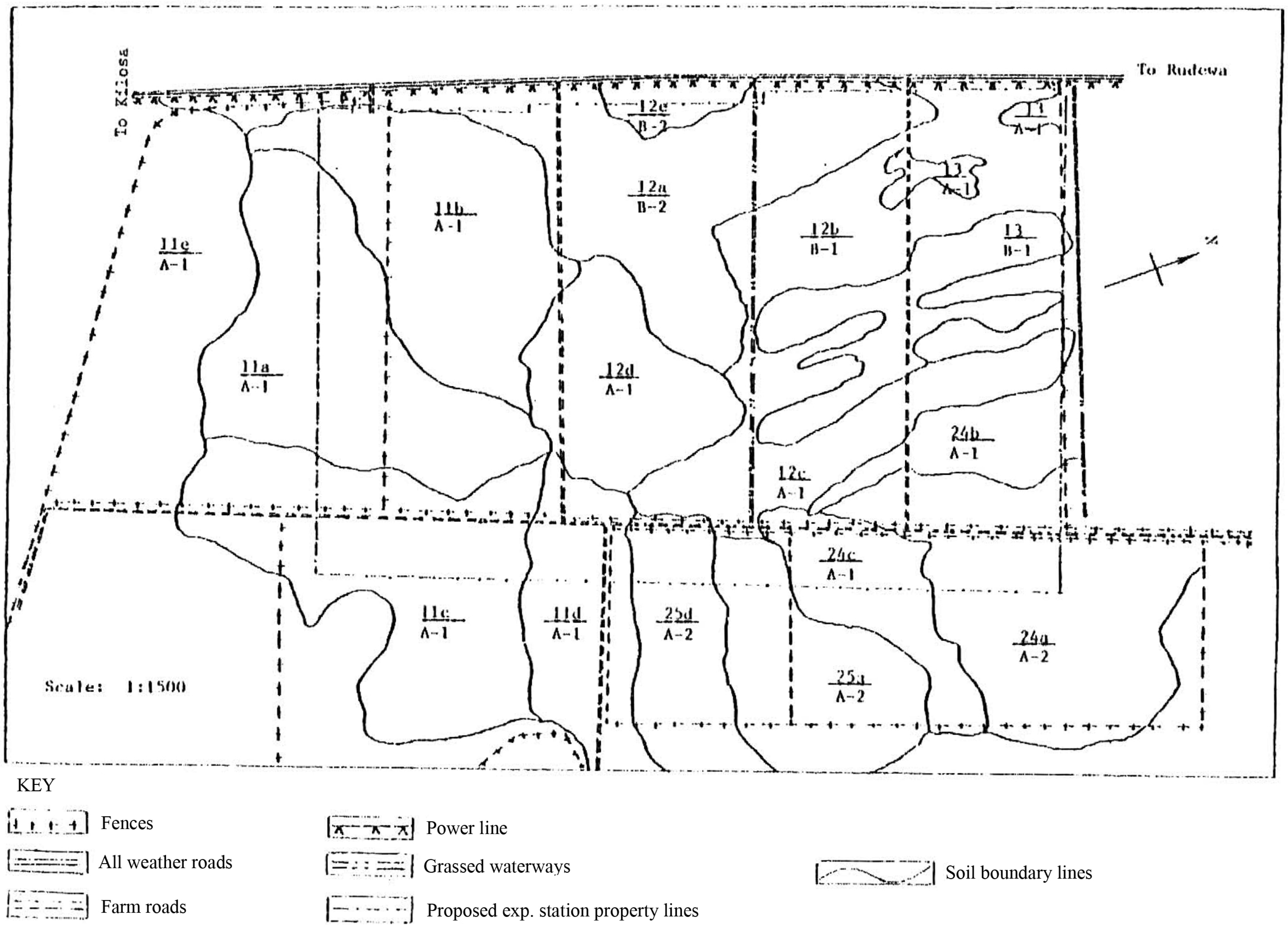


Fig. 4-Soils map of the proposed Ilonga research farm.

at one meter depth.

Despite its rather fine texture, this soil has moderately well developed structure and is fairly porous and permeable. In the field some variability was observed in this soil type especially in texture with alternations of more clayey and more sandy strata.

This soil occurs on the convex, gentle crest in the central part and the southern portion of the farm. It is classified as Pachic Haplustoll in the USDA Soil Taxonomy and Haplic Phaeozem in the FAO/UNESCO Soil Classification System. The moisture characteristics of this soil type appear favorable. The absence of mottling in the subsoil indicates that the seepage water does not cause oxygen deficiencies. On the contrary, the presence of groundwater in the subsoil is probably beneficial as capillary rise may keep the profile moist during dry spells. The high organic matter content throughout the profile points to the availability of moisture in most years. The available water holding capacity is high.

The chemical properties of the soil appear to be equally favourable. The fertility status is high with pH ranging from neutral to moderately alkaline, high organic carbon, total nitrogen, and exchangeable potassium levels, especially in the top soil. Average C/N ratio is 11. The exchangeable base content, CEC, and base saturation are also high, indicating good potential for retaining and supplying plant nutrients. Low phosphorous levels may limit productivity unless the native level is supplemented by phosphorous fertilizer applications. A large response to added nitrogen will not likely be obtained initially.

ii) Aquic Haplustoll

This soil is moderately well drained, dark coloured, firm sandy clay loam with high to moderate organic matter content and high base supply. The major differences between this soil and the Pachic Haplustoll are the presence of distinct mottling in the profile, a lighter colored subsoil, and the absence of noticeable mica flakes. Manganese dioxide and calcium carbonate concentrations are found in horizons below 120 cm. At the time of examination, this soil had no ground water in the profile. This was very surprising as this soil is found in the less well drained, northeast area of the farm. It seems the seepage water does not pass through this area. This is due to the less permeable nature of this soil. It has a weaker structure and firmer consistence than the Pachic member.

The Aquic Haplustoll is found in the water receiving, lower lying northeastern part of the farm. It is classified as Aquic Haplustoll in the USDA Soil Taxonomy and as Haplic Phaeozem in the FAO/UNESCO Soil Classification System.

The moisture characteristics of this soil are not as favorable as those of the first soil. Permeability and structure are not as good and seasonal waterlogging with serious oxygen deficiency is much more likely as evidenced by mottling near the surface. The consistence of this soil is poor. It is very hard when dry and sticky when wet. However, the hardness may have been exaggerated. Continuous grazing by livestock over the area and poor tillage practices in the past may have caused temporary compaction. The available water holding capacity is lower than that of the first type (181 mm in the upper 120 cm of the first soil and only 148 mm in this type).

The soil chemical properties are comparable to those of the other subgroup. The pH is neutral to slightly alkaline, organic matter and nitrogen content are high expecially in the top soil. The average C/N ratio is 10; exchangeable base content, CEC, and base saturation are high. The exchange complex is dominated by calcium and magnesium; exchangeable hydrogen is very small; phosphorous content is low; salinity is very low with sodium ranging from 0.03 in the top soil to 0.9 meq/100 g of soil in the B-horizon.

4.4.2 Soil series

Two groups of series were identified. Those associated with the first subgroup (the Pachic Haplustoll) and those associated with the second subgroup (the Aquic Haplustoll). Since the Tanzania National Soil Service has not established names for specific soil series, coded names will be used instead.

ILO-1 will be used for Ilonga soil series Subgroup 1, those associated with the Pachic Haplustoll (dark colored, sandy clay loams, very friable to friable, deep, and well drained).

ILO-2 will be used for the series associated with the Aquic Haplustoll (Subgroup 2) (dark colored medium to coarse sandy clay loams, friable to firm consistence, deep, and poorly to moderately well drained).

The specific series will be identified by addition of a second digit (1, 2, 3, ... etc.) after the major code names for example, ILO-13. This refers to soil series number three of Subgroup 1 (Pachic Haplustoll). On the map (Fig. 4) the soil series are represented by the appropriate digit. The slope class and the depths of the A and B horizon are also shown on the map, following the USDA Soil Taxonomy System. Where top soil depth differences or textural variation within series are noticeable, the series number is accompanied by a small letter (a, b, c, d, etc.) designating different phases.

i) The Subgroup 1 series (ILO-1)

This group consists of deep, level to nearly level soils that are formed in medium and coarse alluvium. In a representative profile the surface layer is very dark greyish brown sandy clay loam 30 to 80 cm thick, with fine mica flakes (5%) and quartz fragments some 2 to 5 mm. The next layer is mixed greyish brown and dark brown sandy clay with thickness ranging from 20 to 50 cm. The soils are friable when moist and slightly hard when dry. Few faint and medium brown mottles occur regularly. Mica flakes and quartz fragments (1 - 2%) are common in this layer. In some instances a thin layer (5 - 10 cm thick) of dark brown sandy loam or fine sandy loam is encountered at a depth of 90 to 100 cm. These soil series are well drained and moderately permeable in general. The following series are included in this group.

a) ILO-11. Dark grey and dark greyish brown sandy clay loam with high organic matter content (>3%) in the A horizon. The surface soil is greater than 60 cm deep and has slopes ranging from 0 to 1%. Five phases were noted in this series - 1a, 1b, 1c, 1d, and 1e. Phase 1a has the thickest top soil (70 - 80 cm) and is well drained except for a few patches. Phase 1b is also well drained but has shallower surface soil and less organic matter. Phase 1c is similar to 1b but has a finer sand fraction. Phase 1d and 1e have top soil thickness greater than 60 cm but are partially waterlogged for more than 4 months a year in the wet season. They occupy very flat receiving areas where water stands for extended periods.

b) ILO-12. Dark geyish brown sandy clay loam with deep soil but shallower top soil (30 - 60 cm). This soil is found on slopes ranging from 0.5 to 1.5%; is well drained and has mobile groundwater at 1 to 2 m depth during the wet season; a few gravel fragments (diam.>5 mm) and some very coarse sand exists particularly in the subsurface horizons. The subsoil is very porous. Five phases were distinguished in this series - 2a, 2b, 2c, 2d, and 2e. Phase 2a is found on the steeper slope (>1.5%). It has shallower surface soil (less than 50 but greater than 40 cm). Phase 2b occupies a flatter slope (1.0 to 1.2%) and has fewer gravel fragments in the profile. The suface soil is thicker than 2a (50 - 55 cm). Phase 2c is very similar to 2b except it occupies areas with less than 1% slope and has greater organic matter content (2.5 to 3% in the A horizon). Phase 2d occupies an almost flat area. It has less clay (20 to 25%) and finer sand fraction and, therefore, is finer textured. Phase 2e is very similar to 2a except that it has greater proportion of gravel and coarse sand and occupies a flatter area at the higher side of the crest.

c) ILO-13. This soil is deep and closely related to series ILO-12 but has very poor surface drainage. This soil is partially waterlogged in the wet season due to water standing on the area. This problem has been aggravated by the presence of poorly maintained contour ridges which have not allowed excess runoff water to drain away. The top soil is dark greyish brown sandy clay loam while the AB horizon is mixed dark brown and dark yellowish brown sandy clay. The whole of the AB horizon and below has common, distinct, fine and medium mottles. This is a sign of temporary waterlogging. This series is less permeable than the rest in this group but with proper surface drainage and tillage practices, it is bound to improve tremendously.

ii) The Subgroup 2 series (ILO-2)

These series have shallower top soils than Subgroup 1 series and no water seeping laterally through the deeper layers of the subsoil. Soils range from dark greyish brown below the surface to olive brown in the lower horizons. They are sandy clay loams with less organic matter and less nitrogen. The surface is moderately well drained, firm when moist and hard when dry. The lower horizons, below 45 cm, contain considerable coarse sand and show accumulation of black manganese dioxide and calcium carbonate concretions. The common presence of fine, distinct, brown mottles suggests temporary waterlogging. Most of the series in this group occupy the northeastern portion of the farm.

a) ILO-24. Imperfectly drained shallow sandy clay loam. Three phases were distinguished in this series: 4a, 4b, and 4c. Phase 4a is found on a flat area, and has the shallowest top soil (25 - 30 cm). It is very dark grey sandy clay loam, hard when dry and firm when moist. Phase 4b has mixed dark brown and very dark grey sandy clay loam with 30 to 35 cm deep surface soil. Phase 4c is very similar to 4b but has thicker top soil (35 - 40 cm) and finer sand fraction.

b) ILO-25. Moderately well drained, shallow sandy clay loam, very weak structure. This is an intermediate phase between the two subgroup series (ILO-1 and ILO-2). The surface soil is dark grey fine sandy loam which changes to very dark grey brown sandy clay loam within 10 to 15 cm. This soil is found at the head of a waterway, originally natural, hence continuously receiving fresh alluvium materials. The profile is deep and weakly developed. The subsoil is mixed greyish brown sandy clay and dark grey sandy clay loam with common fine and medium distinct brown mottles. During the wet season the water table is within 1.5 to 2 m. Phase 5a occupies an almost flat portion while 5b has 1.3 - 1.5% slope.

The soil is not as firm as the ILO-24 series but not as friable as the ILO-13 series. However, the shallow surface soil, the general weak structure, and the similarity in colors suggest closer association to Subgroup 2 series than Subgroup 1 series.

Outside the farm the soils vary considerably. The northern area on which the existing irrigation facility is located has sandy loams with appreciable sandy fraction and lower organic matter content. The subsoil is gravelly with a fair clay fraction mixed with iron concretions due to the fluctuating water table. The steep hill sides on the northwest contain gravelly soil that is unsuitable for cultivation. In the east and south the slopes give way to heavier soils with higher clay content and much cracking during the dry season. The characteristics of this soil are close to those of the vertisols found in the Mkata Plain.

4.4.3 Other soil parameters

In order to complete the needed data for the design of the irrigation system, bulk density and infiltration measurements were taken at several locations on the farm. In addition, samples for determining water retention capacities were collected.

i) Bulk density (B.D)

The B.D. data were obtained by driving core cylinders (5.35 cm diameter and 6.00 cm long) into the appropriate depths to obtain undisturbed samples (two for every depth). The samples were weighed then dried in an oven for 24 hours at 105°C. After cooling in a descicator, the samples were reweighed. The B.D. was calculated in the conventional manner after deducting the weight of the cylinder, that is,

$$B.D. = \frac{\text{weight of dry soil (g)}}{\text{volume of core (cm3)}}$$

The samples were taken when the soil surface was beginning to dry while the subsoil was still wet (close to field capacity).

The results are recorded in Table 5. From the data it appears the B.D. increases with depth. This may be due to the subsoil being more sandy than the top soil.

ii) Infiltration measurements

Each selected test area was wetted to saturation 24 hours before the test. This was done to shorten the time needed to attain constant infiltration rate and to soften the soil so that the cylinder infiltrometers could be driven into the soil easily. It was assumed the 24-hour period was enough for all the gravitational water to drain off and that each test was begun when the surface wetness was about field capacity.

Double cylinder infiltrometers (30 cm inner and 45 cm outer ring) were driven into the soil and filled with water. The water level in the inner cylinder was measured using a hook gage after every -

a) 10 min in the first hour,

b) 20 min during the second hour,

Table 5-Results of bulk density measurements.

Subgroup	Series	Phase	Bulk density (g/cm^3) at						
			15 cm	30 cm	45 cm	60 cm	90 cm	120 cm	150 cm
ILO-1	ILO-11	11a	1.40	1.50	1.35	1.45	1.47	1.40	1.53
		11b	1.42	1.45	1.25	1.41	1.46	1.38	1.50
		11c	-	-	-	-	-	-	-
		11d	1.39	1.37	1.54	1.55	1.59	1.65	1.60
		11e							
	ILO-12	12a	1.24	1.64	1.50	1.51	1.64	1.57	1.57
		12b	1.46	1.43	1.47	1.46	1.52	1.56	1.63
		12c	1.31	1.42	1.56	1.70	1.33	1.55	1.55
		12d	1.49	1.57	-	1.60	1.65	-	-
		12e							
	ILO-13								
ILO-2	ILO-24	24a	1.59	1.59	1.65	1.79	1.87	1.73	1.67
		24b							
		24c							
	ILO-25	25a							
		25b							

c) 30 min during the third hour,

d) 40 and 50 min during the fourth, fifth and sixth hours, and

e) 60 min during the last two hours.

The accumulated infiltration after each recording was obtained and the results plotted against time. A smooth curve was drawn through the points. For each time measurements were taken, the corrected accumulated infiltration (mm) was read from the graph and the change used to calculate the average infiltration rate during that period; that is,

$$\frac{\text{change in depth (mm)}}{\text{change in time (min)}} \quad \times \quad \frac{60 \text{ (min)}}{\text{(hr)}}$$

The results were also plotted (infiltration rate vs. time). Each calculated rate was assumed to represent the instantaneous infiltration rate halfway through that period and thus plotted against middle of the time interval. A smooth curve was drawn through the points. The data and curves for series ILO-11b are shown in Appendix 3 for reference.

In most cases the infiltration rate approached the steady state after 120 - 180 min. From the curves (infiltration rate vs time) the rates after 120, 240, 360, and 480 min were obtained and recorded in Table 6.

In order to estimate the permeability of the subsoil, the top soil (A horizon) was removed from several locations and infiltration measurements similar to those made on the surface were conducted. The results are also recorded in Table 6.

The results indicate some variation from one soil to another. The Subgroup ILO-1 (Pachic Haplustull) indicated high rates but lower on the areas that have been under continuous cultivation. Compaction and loss of structure may have caused the lowered infiltration rates. The subsoil shows high infiltration rates for all the series tested in this subgroup.

The Subgroup ILO-2 (Aquic Haplustoll) showed very low infiltration rates

Table 6-Infiltration Rates.

Subgroup	Series	Phase	Surface infiltration rate (mm/hr) at				Subsurface infiltration rate (mm/hr) at			
			120 min	240 min	360 min	480 min	120 min	240 min	360 min	480 min
ILO-1	ILO-11	11a	16.0	15.0	11.0	9.0	59.0	47.0	46.0	43.0
		11b	27.0	21.0	21.0	20.0	62.0	59.0	56.0	53.0
		11c								
		11d								
		11e								
	ILO-12	12a	92.0	76.0	60.0	44.0	135.0	100.0	85.0	65.0
		12b	62.0	60.0	59.0	58.0	135.0	120.0	110.0	110.0
		12c								
		12d	120.0	105.0	98.0	85.0	136.0	134.0	132.0	130.0
		12e					340.0	280.0	220.0	190.0
	ILO-13	13	7.0	6.0	5.9	5.8	7.7	7.5	7.2	7.0
ILO-2	ILO-24	24a	3.2	3.0	3.0	3.0	4.6	4.0	4.0	4.0
		24b	5.0	4.0	3.5	3.0	6.0	4.5	4.0	4.0
		24c								
	ILO-25	25a								
		25b								

both on the surface and in the subsoil (6 mm/hr or less after 120 min). This confirms the low permeability of this soil subgroup predicted in the previous section.

iii) Water retention capacities

Due to technical problems, only limited moisture retention capacities could be obtained. Table 7 shows the moisture content at -1/3 bar (FC) and -15 bar (PWP) for the two subgroups (ILO-1 and ILO-2) at different horizons. Although the ILO-2 has lower FC and PWP values, the available moisture is fairly close to that of ILO-1.

4.4.4 Recommendations

Generally the station contains excellent farming land. At the proper moisture content, its soils are workable - rather lighter at the surface owing to high proportion of fine grained sand and organic matter content. However, the moisture range over which the soil is workable is very narrow (between 12 and 15%). When wetter, it becomes too plastic and sticky; when drier it is too hard. Much of the land has good internal drainage properties if surface water can be safely evacuated. The soils have considerable capacity for moisture retention. The outstanding features of the soils are their deep and permeable top soils (A and B_1), their great overall depth to impenetrable material, and the good surface drainage. Little erosion has occurred. Solid rock was not encountered in any of the pits or borings.

The southern part (ILO-11), which covers about one third of the proposed farm, has especially deep soils with greater than 60 cm of good top soil. This portion is particularly uniform and has gentle slopes. Except for the extreme southern portion (ILO-11e soil), which tends to be marshy during the wet season, this series is well drained. It constitutes about 60% of the best land in the farm.

From the standpoint of laying out experiments, the southern portion is

Table 7-Soil moisture content at -1/3 bar and -15 bar water potential.

Subgroup	Series	Phase	Depth (cm)	% Soil mositure content by weight at	
				-1/3 bar (FC)	-15 bar (PWP)
ILO-1	ILO-12	12c	0 - 30	17.97	10.12
			30 - 60	26.39	14.77
			60 - 90	23.89	12.99
			90 -130	22.35	13.68
ILO-2	ILO-24	24a	0 - 30	22.04	13.62
			30 - 45	15.47	11.29
			45 - 65	19.34	12.91
			65 - 95	18.25	11.78
			95 -120	22.08	13.57
			120 -160+	27.46	15.97

exceptionally good because of the land uniformity and fertility. Except for ILO-3 patches near the northeastern part, the Subgroup 1 series are distributed in fairly extensive stretches which should facilitate laying out of experiments. The few patches belonging to Subgroup 2 series should provide no difficulty if properly managed.

The soil series represented are fairly closely related to one another and not dissimilar in most of their important characteristics. With proper management, most of the grain crops should do well in the selected area.

High productivity can be expected on the land occupied by Subgroup 1 series. In addition to high fertility, the series present no physical limitations for agriculture. Structure is relatively stable, permeability and infiltration capacity are good, waterlogging appears unlikely if standing water can be eliminated where this problem exists. Seepage water in the subsoil is not likely to cause damage to crops and capillary rise might keep the profile moist during dry spells.

The Subgroup 2 series present physical limitations that may restrict their suitability to certain crops. They will require more careful management practices to reduce the limitations. During the land forming process, special care is needed on these soils as they are fairly shallow with massive or very weak structure. Luckily most of the soils in this group have relatively gentle slopes and should require no excessive cuts and fills.

Where the slope is greater, efforts should be made to stay within the natural gradient as close as possible to minimize the amount of cuts and fills. On the other hand, when this is done, there will be plots with gradients of about 0.5% or slightly higher. Though this may not be excessive for this type of soil, precautions need to be taken to ensure that runoff does not cause erosion. Should this happen, corrective measures must be taken immediately.

There is bound to be lowered fertility the first few years after land shaping because of reduced top soil in the upper parts and mixing (top soil with subsoil). In addition to fertilization, leguminous crops which will later be plowed under may speed up the rate at which the fertility is restored.

Continuous good soil management practices will be required if the productivity of the soil is to remain high. Loss of organic matter should be prevented and good management of crop residues maintained. This is important for good structure, improved infiltration, better percolation of water, and reduction of soil erosion. The use of chisel plows and tine cultivators is recommended to avoid creating plow pans. The depth of tillage needs to be varied from time to time.

A suitable cropping pattern with rotations that include legumes is needed. A rotation such as two years of corn, one year of sorghum, and a fourth year of legume seems to be attractive. Deep rooted legumes should help to improve water intake in addition to restoring fertility.

Good drainage ways are required over the entire farm since the contour ridges which used to check runoff will be worked down. Open grassed waterways should be adequate but need careful maintenance.

The excess runoff from the hills must be prevented from encroaching on the farm. The recently constructed storm drain on the western side of the farm seems to be working all right but needs widening.

The area selected for buildings has a water table, often within 1.5 to 2 m of the surface. This may cause foundation troubles particularly for larger buildings. As a precaution, a tile drainage system within the area may probably be needed to lower the water table. Alternatively the foundations could be raised above ground. In this case the fill below the floor will need to be compacted. Also gutters and downspouts are needed to carry the roof runoff away from buildings. This water should be drained into nearby open drains by pipe or other suitable means. Machinery maintenance area will include a ramp, not a pit, because of the groundwater problem.

Rapid machinery tool wear is a problem in this area. This is caused by the crystal nature and hardness of the sand fraction in the soil. Tillage cutting tools, therefore, need hardening from time to time in order to extend farm machinery life.

5. DEVELOPMENT ASPECTS

The development project is planned to cater for six crop programs: maize, grain legumes, sorghums, and three others to be named later. Emphasis will be on food crops. A training section for agricultural field staff is to be initiated along with research programs.

5.1 LAND REQUIREMENTS, PLOT LAYOUT, AND LAND GRADING

The gently sloping land east of the Kilosa-Rudewa road is the best portion of the whole station. It was earmarked for the new experimental site.

5.1.1 Area and site for experiments

Considering the size of the project, it was estimated that each of the six crop projects would require at least 20 ha (120 in total). An additional 25 ha was added for special requirements (for example, isolation, fallow land for insect and disease studies, etc.) and future expansion. Two reservoirs and building area will take about 6 ha. Field drains, major drains, headlands, and roads will cover 30 ha. Four hectares will be reserved for possible adjustments. The total land requirement, then, is about 185 ha.

A reconnaissance survey of the area selected was made. A rentis around the best land area was staked and a flying level taken to obtain an indication of the general land slope. It was found that the 185 ha could best fit in the block 1775 m x 1100 m marked in Fig. 5. It was planned to divide the experimental land into two-hectare plots (109 x 200 m) which is standard plot size very convenient to work with (see under plot layout).

A detailed topographic survey was conducted. There are several methods that are used to carry out topographic surveys, but to obtain the kind of details needed the grid system was used. A temporary bench mark was established at the northwestern corner to which all the levels were referenced. Then, two base lines were established, one running north-south parallel to the Kilosa-Rudewa road and the other running west-east both intersecting at the reference bench mark at an angle of 90° (Fig. 6). The baseline along the

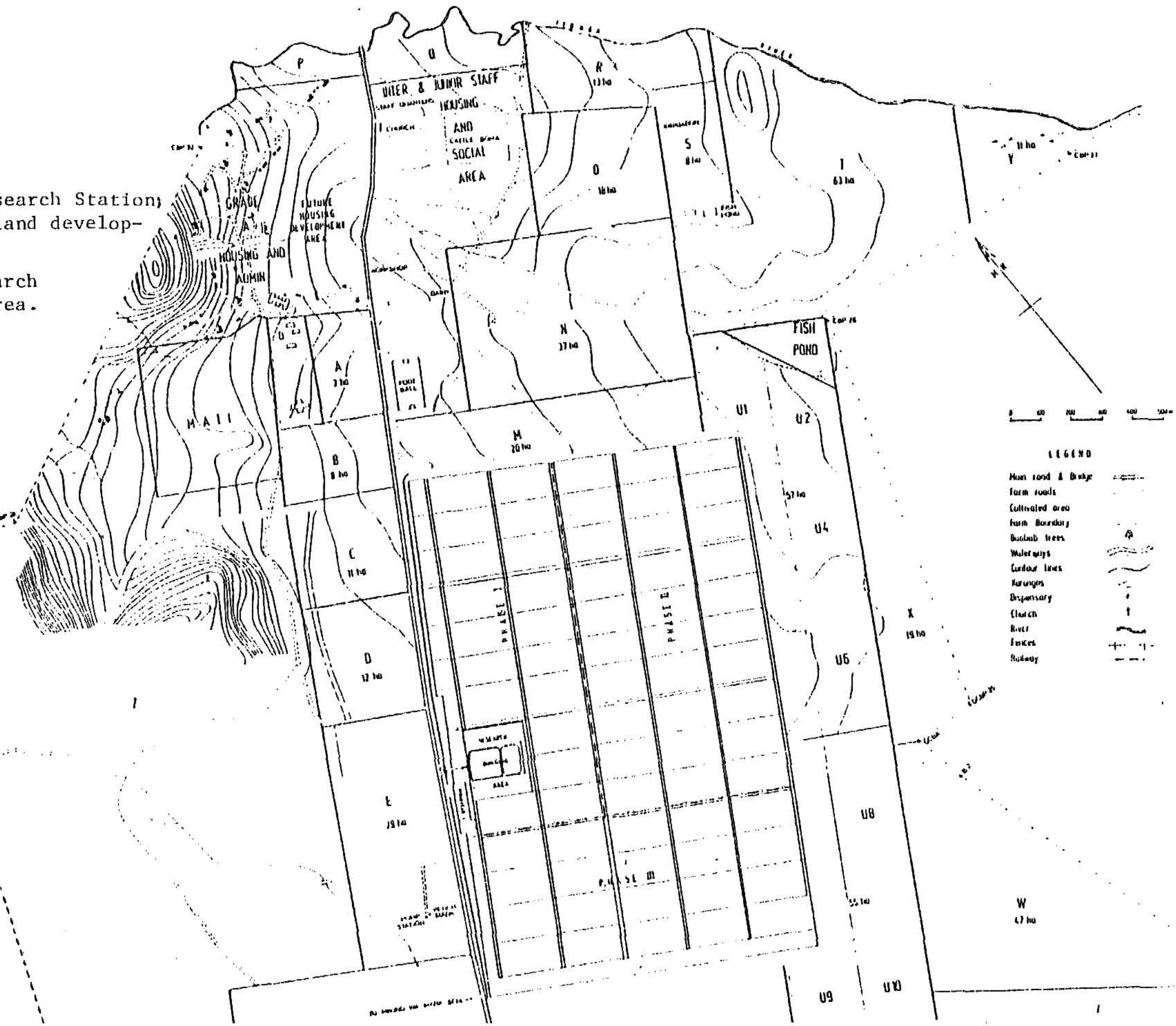
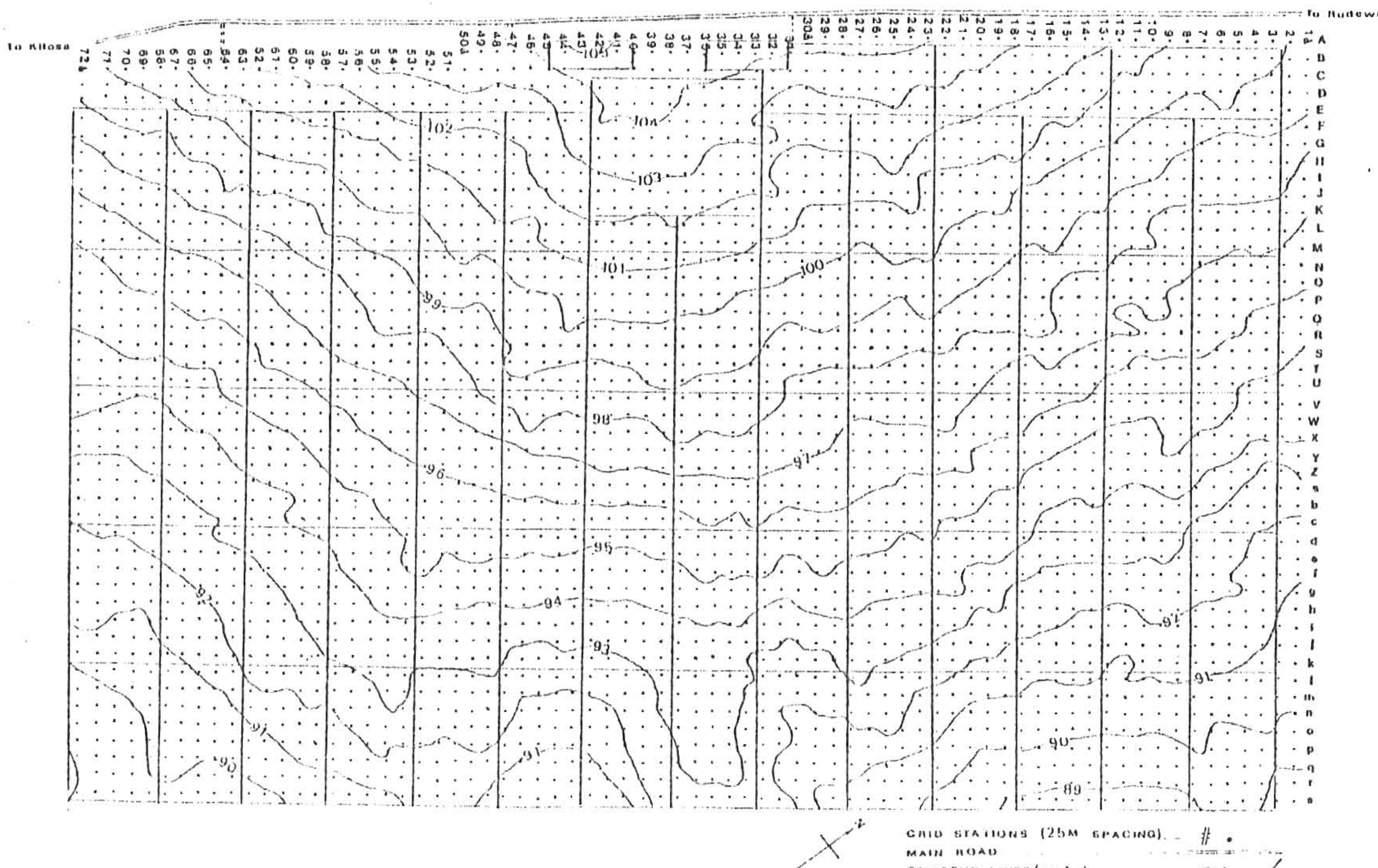


Fig. 5—

Ilonga Research Station; proposed land development,

Crop research Kilosa area.



#The elevations of all the grid stations are given in Appendix 4.

Fig. 6-Ilonga Research Station; topographic map of the proposed research farm.

western boundary was chained and pegged at 25-m intervals. The pegs were labeled from 1 to 72 starting from the reference point, covering a total distance of 1775 m. In order to be off the power company's rights-of-way, the base line had to be stepped in 25 m at peg 30 and another 25 m at peg 50 (Fig. 6). The west-east base line was also chained at 25-m intervals and pegged. The pegs were labeled "A" to "Z" and "a" to "s" covering a total distance of 1100 m as shown on the map.

Using the two base lines the whole farm was staked at 25-m grids and labeled from A_1, A_2, ..,s_{72}. Levels were taken on each peg starting from the temporary bench mark at A_1 (100.11 m). Then the elevation of each peg relative to A_1 was calculated and the topomap of the area drawn at one-meter vertical intervals (V.I.).

As seen on the map (Fig. 6), the land slopes gently to the east with a crest at the middle which grades downward very gently towards the north and south.[1/] Most of the slopes range between 0 - 1% but increase to about 1.5% on the higher side close to the western boundary.

The western boundary is about 50 m off the main road. A 33,000 kV power line runs almost parallel and in between the road and the boundary. The power company (TANESCO) has the rights-of-way of the 10 m strip along which the powerline runs.

5.1.2 Plot layout

The selected site will be laid out on the square for easy management and convenient field operations. There are no physical reasons why this should not be done. In fact, there are water management advantages to this layout. Major plot size selected was 109 by 200 m with 70 plots in the selected area as indicated in Fig. 5. Crops will be seeded in rows parallel to the shorter major plot dimension (north-south). Fig. 7 shows the

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[1/] These levels are not tied to a permanent bench mark, hence are not referenced to sea level datum.

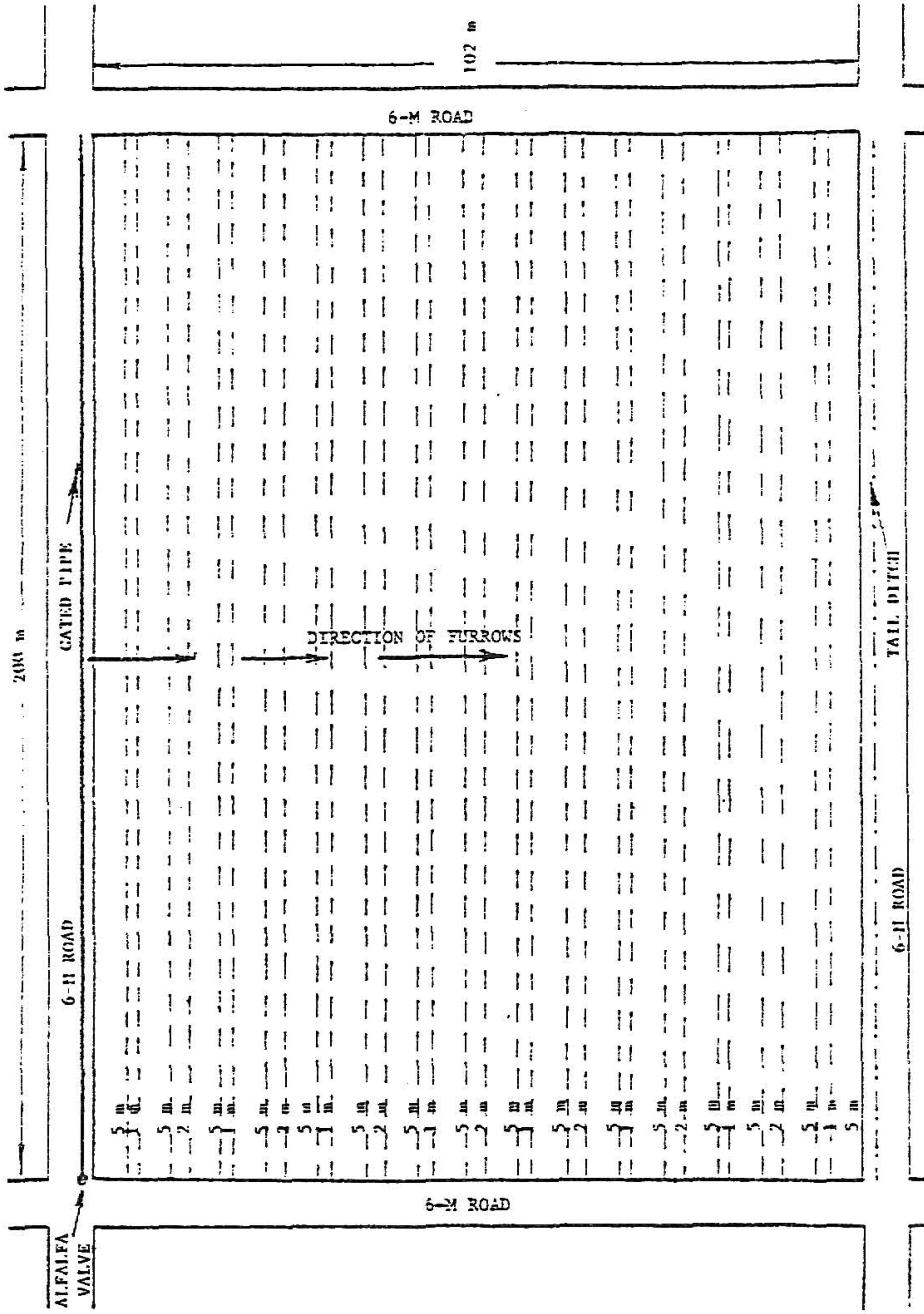


Fig. 7-Plot layout.

proposed layout for a single major plot. There is room within each plot for 16 ranges 5 m wide by 200 m long. These ranges are separated alternately by one- and two- meter alleys, or a total distance of 102 m:

16 ranges of 5- m width =	80 m
8 alleys of 1- m width =	8 m
7 alleys of 2- m width =	14 m
	102 m

With a tail ditch one-meter wide at the bottom, a one-meter border for laying down irrigation pipes on the upstream side, and a 5-m road, the total plot width becomes 109 m. This type of arrangement is very convenient in many ways.

a) Field movement through the plots for data taking and crossing is easy.

b) Mechanized operations like inter-row cultivations, spraying, etc. can be accomplished easily.

c) Dimensions are suited to irrigation runs and the use of gated pipes. Pipes come in standard lengths of about 6.7 m. The 200 m run will require 30 lengths.

d) The area is large enough to accommodate practically all larger experiments or multiples of smaller ones.

For example, in a maize progeny trial 16 x 16 simple lattice (256 entries), single row plots, replicated twice, the layout might be arranged as shown in Fig. 8. Starting from the lower left corner, the first 32 entries are planted one on each alternate ridge in the first range with one guard row in between two entries. If the ridges are spaced at 0.75 m then the first 32 entries will occupy 32 x 2 x 0.75 m = 48 m. The next 32 entries will occupy the next range and so on. In such an arrangement, the 256 entries will occupy 8 ranges; and together with the one- and two-meter

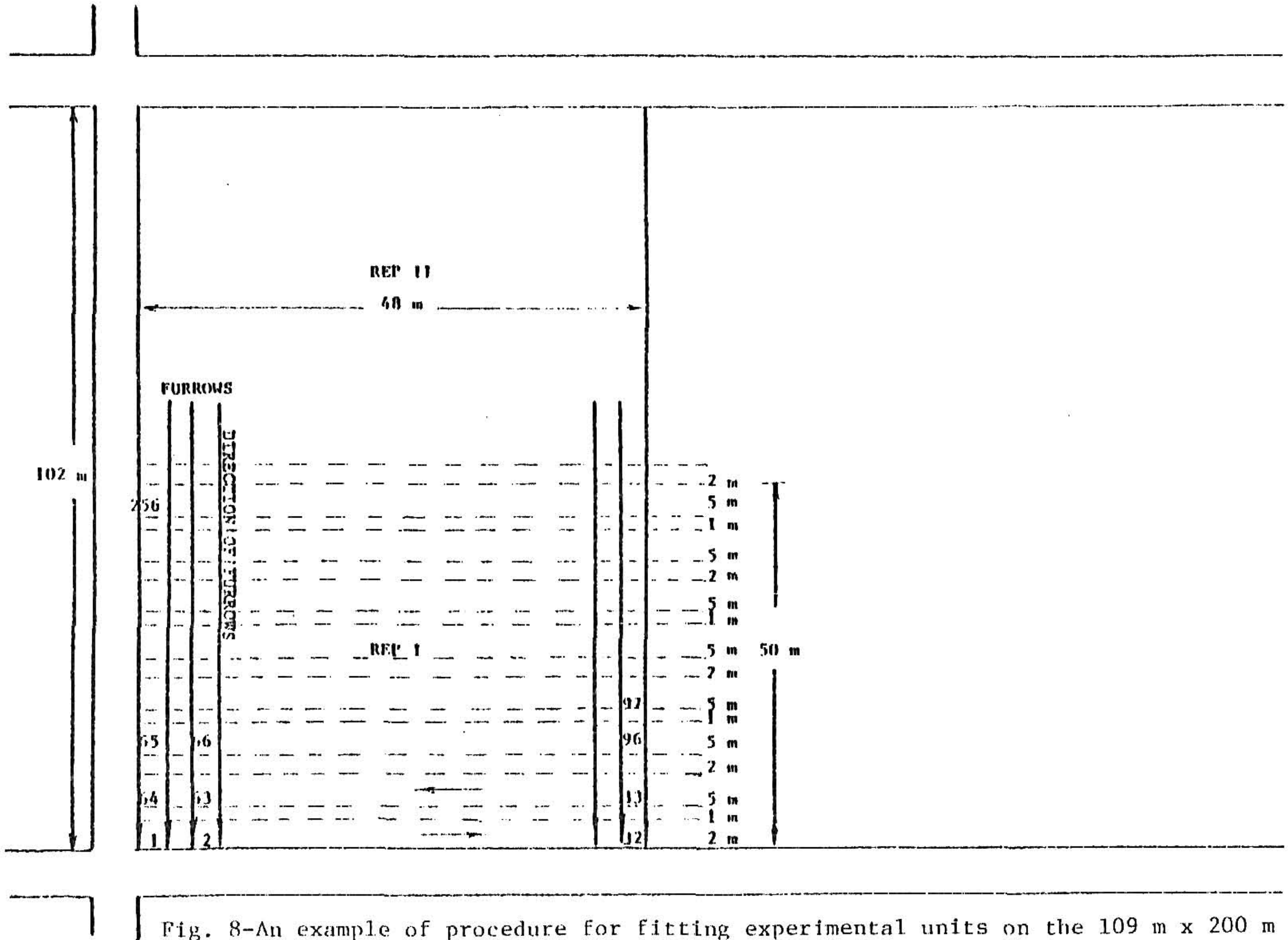


Fig. 8-An example of procedure for fitting experimental units on the 109 m x 200 m plot (16 x 16 = 256 entries).

alleys the total length will be 51 m. The second replication might be fitted on the next 8 ranges. The 109 x 200-m plot may thus accommodate 4 experiments of this size (48 m x 50 m).

5.1.3 Land grading

Land grading involves moving soil from high spots and placing it on low spots providing a more uniform plane to the surface of the land (Booher, 1974).

This is done to allow uniform water distribution where the land is irrigated and to provide for drainage of excess surface water. Grades need to be low enough to prevent erosion but high enough to take out excess water without undue delay.

The land surveys of the Ilonga experiment farm showed many low spots that accumulate runoff causing deterioration of the soil structure and rendering these areas unsuitable for experimentation. The soils in these lower lying spots are not inherently all that poorly drained, as shown by subsoil characteristics. Accordingly since the site has deep top soils, fairly gentle slopes and generally uniform soils, a little land forming will help to minimize ecological differences over the experimental area. However, it will not be possible to maintain a standard slope in either direction for all the plots due to the terrain and shallower soils in some portions of the farm. Hence, each plot will have to be worked individually in order that soil movement is kept to a minimum; then matched with the adjoining plots to avoid too abrupt changes in terrain. In a few cases the plot slope may end up being as steep as 1% but with good management, erosion can be controlled.

Using the elevations from the topographic data, Appendix 4, the cuts and fills were calculated for each plot individually. There are several methods commonly used in land grading calculations. Among them the most popular are, the "Least-Square and Average Profiles Method," the "Cross Section Method" and the "Two-way Profile Method" (Marr, 1947). In view of its accuracy, the Least Squares and Average Profiles Method was adapted. This is a statistical procedure for estimating the best fit plane to a group of points (Givan, 1940). A step by step procedure of the method as used to calculate the cuts and fills for each of the two-hectare plots is outlined below.

For easy reference the plots were systematically named as indicated in Fig. 9 using grid system. The calculation example given is for Plot A6. The elevations for this plot were recorded on a grid paper as shown in Table 8 (middle number). For ease of computation, the Least Squares and Average Profiles Method requires that the plot be rectangular and that each side should lie exactly midway between two grid lines so that every grid elevation in the plot represents equal area.

The elevations column and line totals were worked out and their averages calculated.

Next, the centroid or the exact center of the grid (Hm) and its elevation were determined. The location of Hm is the intersection of the average station distances from "O", the origin, on the X and Y axes. In this case

$$X_m = \frac{1 + 2 + 3 + 4 + 5}{5} = 3; \quad \text{and}$$

$$Y_m = \frac{1 + 2 + 3 + 4 + 5 + 6 + 7 + 8}{8} = 4.5$$

Note the distances are in 25-m units. The elevation of the centroid (Hm) is the average of all the grid points in the plot. In this case it was 101.54 m.

The third step involved determining the slopes of the lines which most nearly fit the average profiles in the two coordinate directions (X and Y). Initially the average line elevations and the average column elevations were illustrated graphically as shown in Fig. 10. The coordinates of the two graphs were designated as "H" for elevations and "S" for station distances

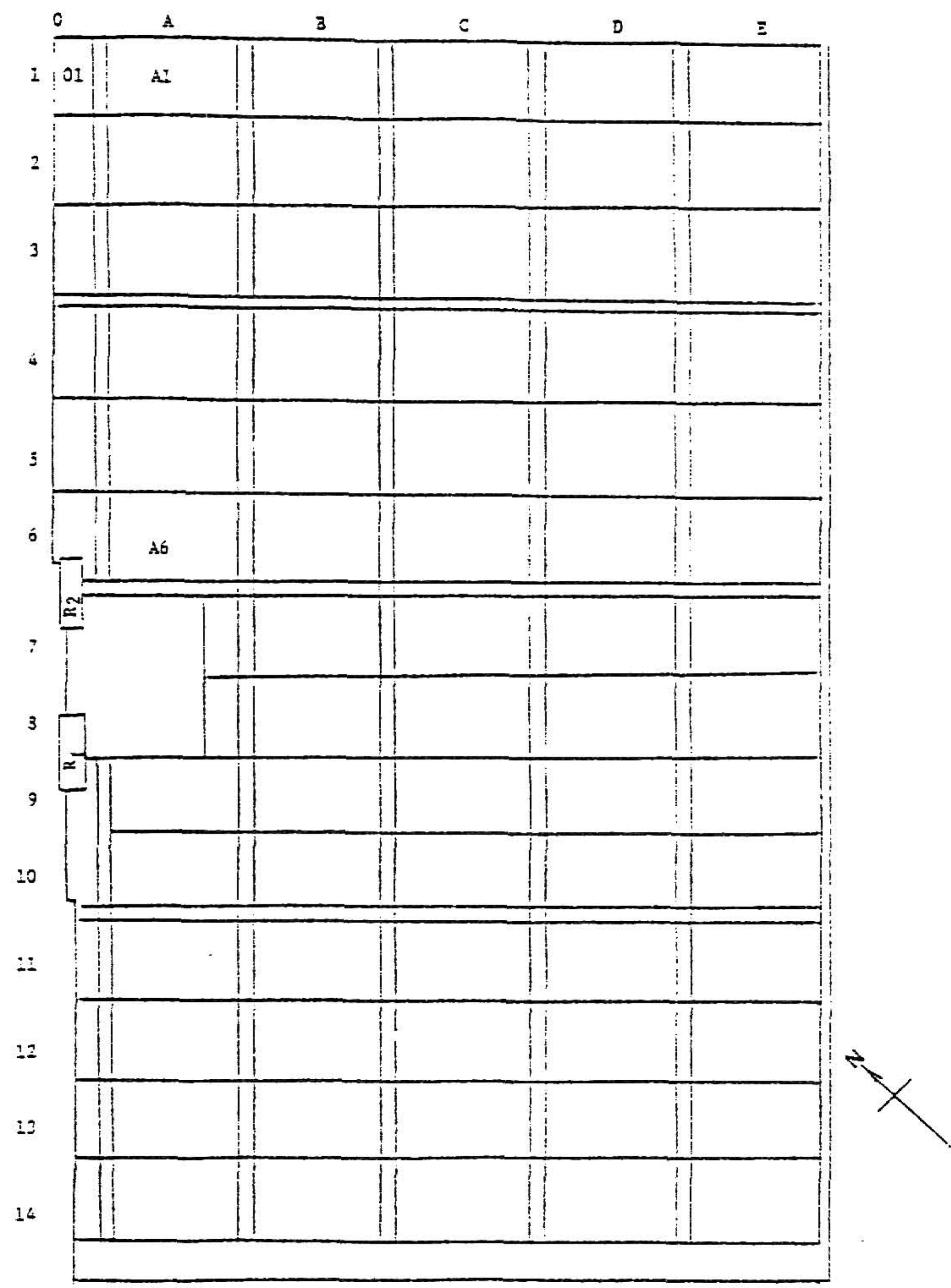


Fig. 9-Proposed arrangement and plot reference numbers.

Table 8-Cut and fill summary table for plot A6.

0 → X ↓ Y; → N

	32	31	30	29	28	Line total	Line mean
F	-0.18 102.73 102.55(1,1) 102.71 -0.16	-0.24 102.57 102.33(2,1) 102.55 -0.22	-0.12 102.40 102.28(3,1) 102.38 -0.10	-0.25 102.24 102.49(4,1) 102.22 +0.27	-0.56 102.08 102.64(5,1) 102.06 +0.58	512.29	102.06
G	-0.91 102.48 103.39(1,2) 102.46 +0.93	-0.16 102.32 102.16(2,2) 102.30 -0.14	-0.14 102.16 102.02(3,2) 102.14 -0.12	+0.12 102.00 102.12(4,2) 101.98 +0.14	+0.45 101.83 102.28(5,2) 101.81 -0.47	511.97	102.39
H	-0.01 102.23 102.24(1,3) 102.21 -0.05	-0.20 102.07 101.87(2,3) 102.05 -0.18	-0.15 101.91 101.76(3,3) 101.89 -0.13	-0.15 101.75 101.90(4,3) 101.73 +0.17	-0.35 101.59 101.94(5,3) 101.57 -0.37	509.71	101.94
I	-0.16 101.99 101.83(1,4) 101.97 -0.14	-0.30 101.83 101.53(2,4) 101.81 -0.28	-0.01 101.66 101.65(3,4) 101.64 +0.01	-0.32 101.50 101.18(4,4) 101.48 -0.30	-0.05 101.34 101.29(5,4) 101.32 -0.03	507.48	101.50
J	+0.94 101.74 102.68(1,5) 101.72 -0.96	-0.21 101.58 101.37(2,5) 101.56 -0.19	-0.20 101.42 101.22(3,5) 101.40 -0.18	-0.04 101.25 101.21(4,5) 101.23 -0.02	+0.15 101.09 101.24(5,5) 101.07 +0.17	507.72	101.54
K	+0.13 101.49 101.62(1,6) 101.47 -0.15	-0.10 101.33 101.23(2,6) 101.31 -0.08	-0.23 101.17 100.94(3,6) 101.15 -0.21	-0.07 101.01 100.94(4,6) 100.99 -0.05	+0.13 100.85 100.98(5,6) 100.83 -0.15	505.71	101.14
L	+0.09 101.25 101.34(1,7) 101.23 +0.11	+0.07 101.08 101.15(2,7) 101.06 -0.09	-0.06 100.92 100.86(3,7) 100.90 -0.04	-0.32 100.76 100.44(4,7) 100.74 -0.30	-0.16 100.60 100.44(5,7) 100.58 -0.14	504.23	100.85
	-0.04 101.00 100.96(1,8) 100.98 -0.02	-0.24 100.84 100.60(2,8) 100.82 -0.22	-0.08 100.68 100.60(3,8) 100.66 -0.06	-0.19 100.51 100.32(4,8) 100.49 -0.17	-0.19 100.35 100.16(5,8) 100.33 -0.17	502.64	100.53
Column totals	816.61	812.24	811.33	810.60	810.97	4061.75	
Column average	102.08	101.53	101.42	101.33	101.37		101.54

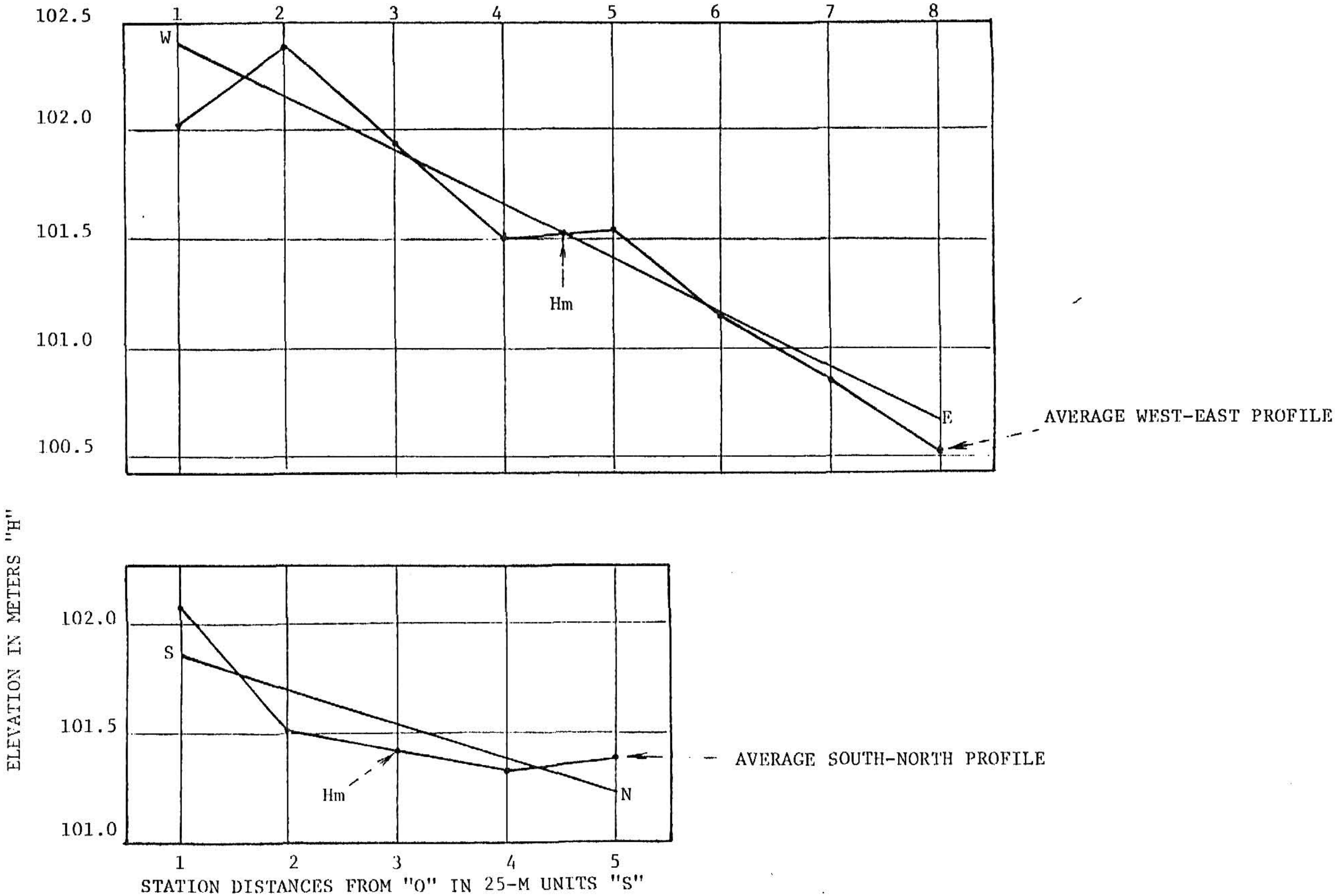


Fig. 10-Average profiles for Plot A6.

(25-m units) from the point of origin "0".

By the Least Squares Method, the slope of the line which best fits the points on each of the two profiles is:

$$G_{SN} \text{ (or } G_{WE}) = \frac{\Sigma(SH) - \frac{(\Sigma S)\ (\Sigma H)}{n}}{\Sigma(S)^2 - \frac{(\Sigma S)^2}{n}}$$

where, G_{SN} = slope which best fits the original topography in south to north direction across the field (rise or drop per 25-m spacing).

G_{WE} = slope which best fits the original topography in a west to east direction across the field (rise or fall per 25-m spacing).

$\Sigma(SH)$ = the sum of the products of the station distance and elevation of the plotted points on each of the graphs.

$(\Sigma S)\ (\Sigma H)$ = the product of the sums of the station distances and the elevations of each of the plotted points on each graph.

n = the number of the plotted points on each graph.

$\Sigma(S)^2$ = the sum of the squares of the station distances of each of the plotted points on each graph.

$(\Sigma S)^2$ = the square of the sum of the station distance of each of the plotted points on each graph.

Computation of G_{SN}:

$$G_{SN} = \frac{1521.57 - \frac{(15)\ (507.73)}{5}}{55 - \frac{225}{5}} = \frac{1521.57 - 1523.19}{55 - 45} = \frac{-1.62}{10}$$

$$= -0.16$$

$$\therefore \text{ Slope} = \frac{-0.16\ (100)}{25} = -0.64\%$$

Hence the change in slope is 0.16 m per 25-m distance, that is, the slope is

0.64%. The negative sign indicates that the slope drops northwards from "O".

Computation of G_{WE}:

$$G_{WE} = \frac{3643.39 - \frac{(36)(811.95)}{8}}{204 - \frac{1296}{8}} = \frac{3643.39 - 3653.78}{204 - 162} = \frac{-10.39}{42}$$

$$= -0.25$$

$$\therefore \text{Slope} = \frac{-0.25\ (100)}{25} = -1.00\%$$

Therefore, the fall is 0.25 m per 25-m distance or 1.00% slope.

The fourth step involved using the slopes G_{SN} and G_{WE} and the elevation of the centroid (Hm) to determine the plane which best fitted all the grid elevations within the plot. The equation of a plane is:

$$Hm = a + (G_{WE})Y_m + (G_{SN})X_m$$

where a = the elevation of the point in the plane at the origin

X_m and Y_m = the horizontal and vertical coordinates of Hm

G_{WE} and G_{SN} = slopes of the plane in the Y and X directions, respectively.

From Table 6 Hm = 101.54, X_m = 3.0 and Y_m = 4.5, therefore

$$a = 101.54 - (-0.25)4.5 - (-0.16)3.0$$

$$= 103.14$$

Thus the elevation of a point (H) on the best fitted plane above or below the corresponding grid point was found by the equation:

$$H = a + (G_{SN})X + (G_{WE})Y$$

$$= 103.14 + (-0.16)X + (-0.25)Y$$

$$= 103.14 - 0.16X - 0.25Y$$

This equation was then used to compute the new elevations of the grid points assuming the land had been graded to the best fitted plane. For example, the new elevation that would correspond with the old elevation 101.87, two stations north and three stations east of "O" (coordinate 2, 3) was found by substituting the coordinate values into the above equation, that is,

$$H = 103.1375 - 0.16(2) - 0.25(3)$$
$$= 102.07$$

These elevations were recorded on the grid paper above the original elevations.

The difference between the original and the new elevation gave the amount of fill (-ve values) or cut (+ve values) at that grid point. The cuts and fills obtained were also recorded on the grid paper above the new elevations. Total fills were 4.16 m and cuts 4.31 m. Theoretically, the two should balance, but there will always be some difference due to rounding off.

In practice the cuts are made to exceed the fills by a certain percentage to cater for compaction and losses of the loose soil. The amount of cut in excess of fills varies with type of soil and grading practice (Booher, 1974). It may range from 10 to 50% or more. In our case, 25 to 30% was considered correct.

To provide the excess of cuts over fills, the grade elevations at each point were lowered 0.01 m (trial and error) but the excess was found to be only 14%. Lowering the grade elevations by 0.02 m resulted in:-

$$\frac{(\text{cuts} - \text{fills}) \times 100}{\text{fills}} = \frac{(4.60 - 3.65) \times 100}{3.65} = 26\%$$

which satisfies the requirements. The final corrected elevations together with the required fills or cuts were also recorded on the grid sheet below the original elevations. The calculations indicate drastic cuts at G_{32} and J_{32} (Table 8), 0.93 and 0.96 m, respectively. This much cut at one spot can cause exposure of the subsoil which is undesirable. But in this case, the two grid points happen to fall on top of ridges at their entrance into a waterway where the soil had been piled to lower the channel elevations so that runoff would not flow back into the field. Removing the ridges will not expose the subsoil in this case.

Finally, the volume of fill to be handled was estimated for cost prediction. Since each area was 25 m x 25 m, the total volume of fill for Plot A6 was 3.65 m x 625 m^2 = 2281.25 m^3 over the two-hectare plot. This is about 1140 m^3 per hectare. The volume of fill ranged from about 400 m^3 in the flattest areas to about 1150 m^3 in the rougher terrains per hectare.

5.2 LAND TO BE IRRIGATED AND IRRIGATION WATER

The importance of having an irrigation system on the experimental farm is twofold. First, irrigation permits growing crops in the dry season, thus the breeding programs can be speeded up. Second, an irrigation system will prevent loss of valuable plant materials which could otherwise disappear should unexpected droughts occur during a rainy season.

In view of the above, the development program is planned to include an irrigation facility to cover about 50 ha. This much irrigated land may seem too large if the system is only intended to prevent loss of breeding stocks and to double the breeding program. The additional land will allow flexibility in the use of the irrigation system. It is intended that future programs will include irrigation studies, hence taking advantage of the same irrigation facility.

In Fig. 11 the plots to be irrigated are shown (shaded) together with the water distribution system. These plots have soils that are well drained and slopes that are within reasonable range.

In addition to finance, there are several factors to be considered before designing an irrigation system. The following facts have to be considered:

a) source of water and amount

b) method of irrigation

c) irrigation time

d) irrigation frequency

e) water quality.

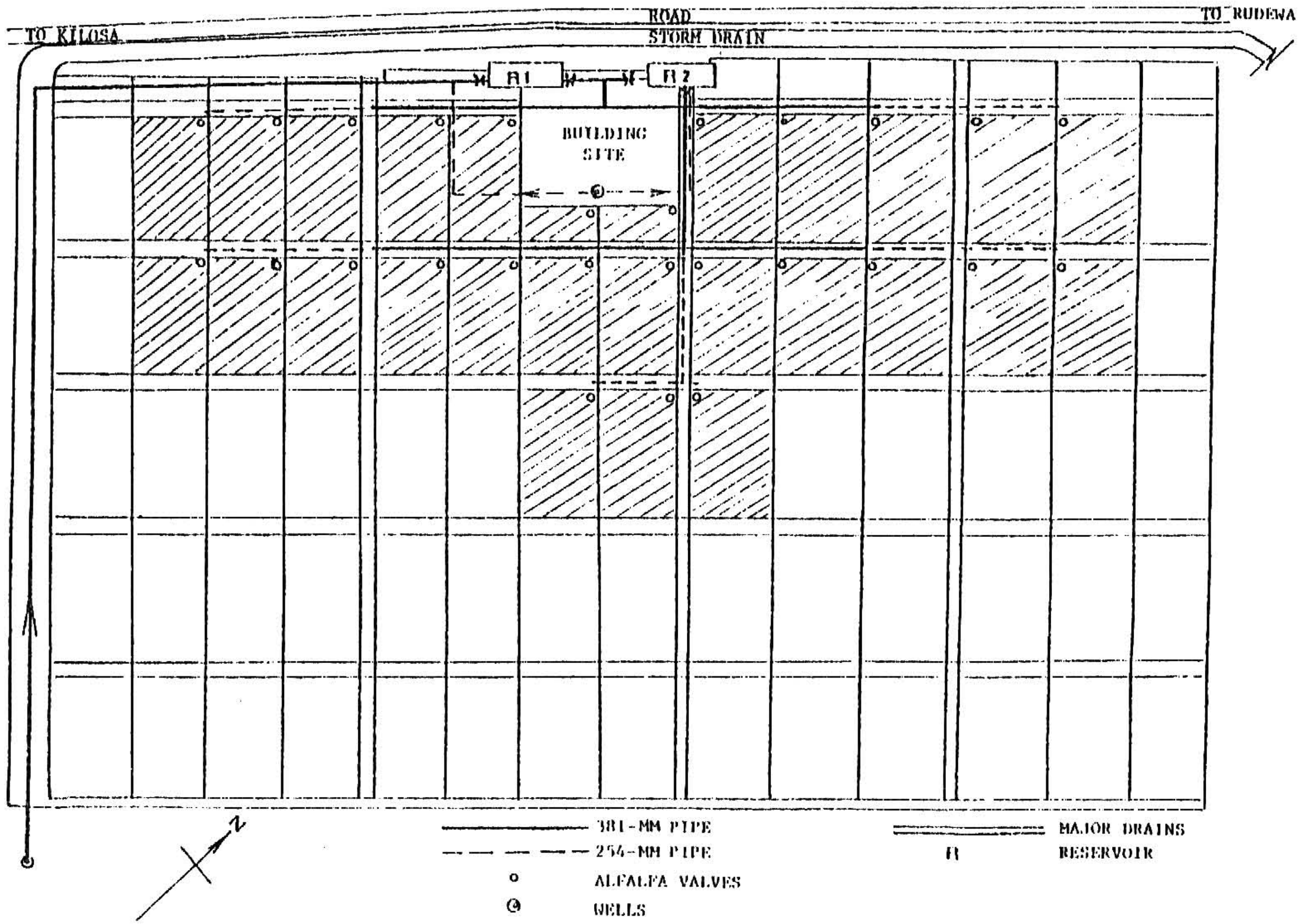


Fig. 11-Plots to be irrigated (shaded), possible location of wells, and the water distribution system.

The facts above will determine whether to have an irrigation system or not, and if yes, how much land can be put under irrigation.

5.2.1 Water supply and irrigation system

The Ilonga Research Station at present runs two spearate overhead irrigation systems located north and northwest of the experimental farm site. Both depend on water drawn from Ilonga River but at separate points. The first system supplies water for citrus and vegetables (14 ha) run by the Horticultural Department of the Training College. A 30-hp engine pumps the water directly from the river to the irrigated land. The second system covers about 6 ha and is the location of the present crop programs breeding nursery. Water is conveyed from the river, 4 km away, by a 200-mm pipe using gravity force to an open ditch at the nursery. The water is then pumped by a 25-hp engine to operate the sprinkler system. In order to allow the water to flow into the pipe, an intake weir had to be built across the river. The original weir built in 1966 was washed away by floods in 1970 and had to be rebuilt in 1973.

According to latest flow records, the minimum flow rate in the river during the driest months is about 100 liters/sec. At the moment the station draws about 28 liters/sec to maintain the irrigation systems and about 3 liters/sec for domestic and livestock use. The station is only allowed to draw about 30 liters/sec because a number of nearby institutions, state farms, and villages depend on this same river for their water supply. Also, the river has a tendency to change course due to the flat nature of the land through which it flows after leaving the Ukaguru Mountains.

From the above it is obvious that if the new experimental farm is to be irrigated, an alternative source must be found. There is no other river within economic range and so the next alternative is to drill wells. Although the soil report indicated a fairly shallow water table, it drops quite fast during the dry season and pumping shallow wells in the area might deplete the moisture from the control profile very rapidly. In addition, shallow wells around the area have only been yielding about 4500 liters/hour which is too low. Hence the proposal to drill deep water wells within the farm.

No data are available on the amount of water that can be obtained in this area. A report on tests carried out at the farm by the Hydrology Unit of Morogoro Region in October 1979 indicated presence of water bearing strata and earmarked three locations suitable to drill deep water wells (Fig. 11). The report pointed out that since the surface investigations are indirect methods, the quantity of water that can be pumped can only be confirmed with certainty after drilling test wells at the site, a task which was started in August 1980. The only similar wells are located at Madoto, some 50 km away. These have been yielding about 13,000 liters/hour. But Ilonga is at the edge of this block faulted area. It is likely to receive much higher recharge than the area cited above and therefore greater well yields. Should actual wells indicate otherwise, supplementary water may have to be obtained from the Ilonga River.

Enough water is required to irrigate 50 ha. Furrow irrigation is preferred to other methods because of less labor requirement, relatively cheaper capital investment compared to other systems, reduced maintenance, and it requires less skill to operate. However, the trade-off here is the low irrigation and distribution efficiencies associated with the method. The soil type and slope of the land are marginal factors in this case according to the survey reports.

The demand for irrigation at this station is highest during the dry season (June - October) when crops are grown out of season. The need for off-season crops has already been discussed. According to previous records, the average maximum potential evapotranspiration (ETo) as determined by the pan evaporation method, is about 7.6 mm/day during the dry period. With an average maximum crop coefficient (K_c) of 1.05, then the crop evapotranspiration demand (ETp) will be

$$ETp = K_c \cdot ETo$$

$$= 1.05 \times 7.6 \text{ mm/day}$$

$$= 7.98 (\cong 8.00) \text{ mm/day}$$

For most crops grown in the area, the root zone depth is about 90 cm. Table 9 shows the available moisture held in the root zone (90 cm) as determined by measurements taken from a profile in plot A5. As seen from the table, the total amount of available water is about 140 mm in the upper 90 cm. To prevent water stress and movement of underground water up the profile (see under water quality), the land will be irrigated after 40% of the available water has been depleted, that is, 140(0.4) mm = 56 mm will be needed during each irrigation. Assuming 60% efficiency for furrows, the amount of water to be applied will be

$$56/0.6 \text{ mm} = 93.3 \text{ mm}$$

Since 56 mm of water is retained in the profile during each application, the irrigation interval will be

$$\frac{\text{water retained}}{ETp} = \frac{56 \text{ mm}}{8.0 \text{ mm/day}} = 6.25 \text{ days},$$

which may be estimated to be 7 days. The irrigation time can only be guessed at this stage. As the tests indicated, there is considerable variation of infiltration rates between one soil series and another. Secondly, when furrows are used the rate measured by cylinder infiltrometer approximates intake rate but the two may not be equal. Furrow intake rates must be measured when the land grading is completed and irrigation water available. From this, the time of irrigation can be predicted more accurately and on a single plot basis.

With 50 ha to be covered then about 8 ha must be irrigated each day. The total daily water demand will, therefore, amount to

Table 9-Available water in the soil (Plot A5)

Depth (cm)	Bulk density (g/cm^3)	FC (% by wt.)	PWP (% by wt.)	Available moisture (% by wt.)	Available moisture (mm)
0 - 15	1.24	17.97	10.12	7.85	14.6
15 - 30	1.64	17.97	10.12	7.85	19.3
30 - 45	1.50	26.39	14.77	11.62	26.2
45 - 60	1.51	26.39	14.77	11.62	26.3
60 - 90	1.64	23.89	12.99	10.90	53.6
Total					140.0

8(ha) x 10,000(m^2/ha) x 93/1000 (m/day) x 100^3 (cm^3/m^3) x (1/1000) (liters/ cm^3) = 7,440,000 liters.

Assuming 10% evaporation and conveyance losses, the total daily demand will then be 7,440,000 x 1/0.9 (liters/day) = 8,266,667 liters/day

= 8.3 million liters/day.

If the water was to be pumped directly to the distribution system, the pump capacity would need to be

$$\frac{8,300,000}{12 \times 60 \times 60} \text{ liters/sec} = 192 \text{ liters/sec}$$

assuming two six-hour shifts in a day. A pump capable of pumping that much water against 100 m lift plus pipe friction losses would need to be very big. Also from the recent preliminary hydrogiolocal survey of the area, it appears (unless proven otherwise) that one single bore hole will not be able to supply all the above water demand and, therefore, a battery of wells may be needed. The yield of the test bore hole(s) will determine the number of wells needed.

In order to reduce the size of pumps and maintain a constant head, a reservoir of approximately 4,000,000 liters has been designed. This will allow the pumps to operate 24 hours a day. In addition if any pump breaks down, irrigation may continue while the defective one is being replaced. Considering the scarcity of repair services, two standby pumps are recommended.

The irrigated plots and distribution system shown in Fig. 11 have been chosen on the basis of soil suitability, slope, and ease to operate. It is assumed that the water will first be pumped into the reservoir and from there it will flow by gravity through underground pipes to the alfalfa valves. Concrete pipes are likely to be cheaper in the long run as they are easily manufactured locally. Gated pipes will then be used to distribute the water into the furrows. A hydrant is used to connect the gated pipe to the valve, hence advantage of easy removal and connection of the former.

The top view of the proposed reservoir is shown in Fig. 12. It is loca-

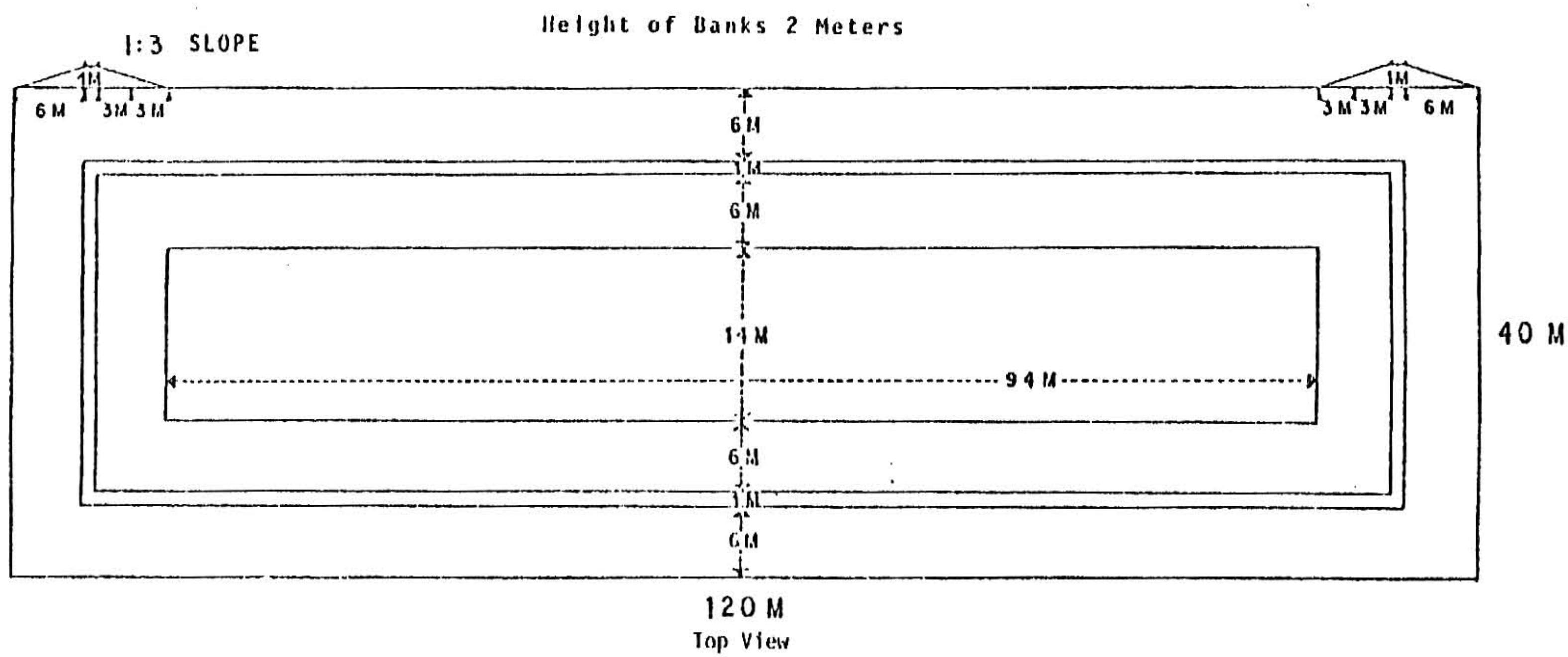


Fig. 12-Proposed reservoir for Ilonga Station.

ted at the highest part of the farm site (R_1, Fig. 11) close to the building area. In order to avoid loss of water by percolation, the reservoir will be lined by plastic material. This has been necessary because the subsoil is very porous and there is no soil around the area impervious enough to slow down the water entry through the surface. Infiltration test conducted at the reservoir site after it had been excavated showed rates in excess of 200 mm/hr even after the third hour.

For future needs a similar area 100 m north of the reservoir has been reserved for location of a second one (R_2, Fig. 11).

5.2.2 Water quality

Water quality is an important aspect in irrigated lands. Few crops can tolerate appreciable amounts of salt especially when sodium is present at high concentrations. As no water samples from the proposed wells were available at the time when the data were compiled, laboratory tests should be carried out as soon as the test wells are completed. The laboratory analysis should test for the presence of sodium, magnesium, calcium, chloride, carbonate, bicarbonate,and sulphate, and electrical conductivity among other things. A detailed procedure of assessing the water quality from the laboratory analysis information is given by Ayers (1976). Crop tolerances to salt concentrations and salinity can be found in the same paper.

Tests carried out on samples from nearby shallow wells in the past indicatedrather high concentrations of salts but sodium is present in relatively smaller amounts. Coupled with the fact that the soils were found to have large amounts of calcium and magnesium and relatively low sodium concentrations, it is hoped that with proper irrigation management salinity problems will be minimal.

One other aspect to consider is the possibility of groundwater movement by capillarity into the root zone. As mentioned in the discussion about soils, a large part of the farm has a relatively shallow water table ranging from 1 meter to 1.5 meters below the surface during rainy seasons. Where the land will be irrigated, the water table level is bound to remain close to that range throughout the year. When the soil dries, the groundwater will move up as evapotranspiration continues. While this may seem good for crops, there is the danger of salts that might have been washed down to the lower horizons being brought back to the root zone. This may be hazardous especially if the water quality proves to be poor.

An attempt was made to estimate the amount of groundwater that may move up the profile using the daily soil moisture balance method adapted by USDA. This method assumes that water getting into the profile and that which gets out must balance in order for equilibrium to be reached (Dastane, 1974). This can be summarized by an equation of the form:

$$\Delta W = M + I_r - N - F - ETp$$ (Hillel, 1971)

where ΔW = storage change in the profile

M = water added by natural rainfall

I_r = water added by irrigation

N = runoff (may be positive if it is coming into the area)

F = drainage out of the root zone (positive if water is moving into the profile from below)

ETp = evapotranspiration term.

When ΔW, M, I_r, N, and ETp are known, F then can be determined indirectly. If the value of F is positive, it means that groundwater is moving up into the profile.

To determine ΔW, gypsum resistance blocks were buried at 15, 30, 45, 60, 90, 120, and 150 cm at two locations (Plot B8 and C10 - Fig. 9) in April 1980. Plot B8 was under sorghum and C10 under cowpeas. After 8 days, resistance readings were taken daily till the end of June, 1980. For calibration soil samples were collected in duplicate after every 14 days from the various depths and dried in an oven for 24 hours at 105°C. The gravimetrically determined soil moisture data and the resistance readings for the same day's samples were used to draw the calibration curves shown in Appendix 5. The two graphs were used to convert the daily resistance readings to soil moisture content. For simplicity the curves have been averaged for the whole profile instead of one for each depth. The moisture content (percent dry weight basis) was converted to depth equivalent (mm of water) using measured values of the bulk density at each depth. Where the moisture content was more than the field capacity, as was the case at lower depths, the field capacity was used instead of the measured moisture content.

Evapotranspiration was estimated by using the radiation method discussed earlier (3·7).

The daily data for the month of June 1980, are represented in Table 10 for Plot B8 and Table 11 for Plot C10. The first column is for the date; the second and third columns represent rainfall and irrigation application; but there was no rainfall or irrigation during that period. The latest rain occurred on 27 May 1980. Column 4 represents the estimated evapotranspiration (ETp) and column 5 is the expected change in moisture due to rainfall, irrigation, and ETp. Column 6 is the expected (calculated) balance of moisture in the soil. This was obtained by substructing the expected storage change in the soil (-ETp in this case) from the previous day's balance.

In column 7 the actual measured soil moisture balance in the soil for each day of that month is given. By substructing each day's measured balance from the previous day's balance and compensating for ETp demand, the value obtained was considered lost from the profile if negative (-) (column 8) or gained into the profile if positive (+) (column 9). For example, on 2 June 1980 the measured storage balance in the soil (Plot B8) was 462.1 mm (from the surface to 150 cm). The measured balance on 1 June 1980 was 457.0 mm.

Table 10-Daily soil moisture balance table for Plot B8 (0 to 150 cm)

1980	Date	Rainfall (mm)	Irrigation (mm)	ETp (mm/day)	Storage change in soil (mm)	Calculated storage balance in soil (-ETp) (mm)	Measured storage balance in soil (mm)	Deep percolation; storage out (mm)	Capillary water from below; storage in (mm)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
May	31	0	0	-	-	486.7	486.7	-	-
June	1	0	0	3.0	-3.0	483.7	457.0	-26.7	0.0
	2	0	0	3.8	-3.8	479.9	462.1	0.0	+ 8.9
	3	0	0	3.7	-3.7	476.2	458.7	0.0	+ 0.3
	4	0	0	3.2	-3.2	473.0	460.1	0.0	+ 4.6
	5	0	0	3.9	-3.9	469.1	459.9	0.0	+ 3.7
	6	0	0	4.1	-4.7	465.0	454.7	-0.5	0.0
	7	0	0	3.9	-3.9	461.1	466.1	0.0	+15.3
	8	0	0	2.7	-2.7	458.4	461.2	-2.2	0.0
	9	0	0	2.8	-2.8	455.6	456.2	-2.2	0.0
	10	0	0	2.6	-2.6	453.0	453.7	0.0	+ 0.1
	11	0	0	4.5	-4.5	448.5	453.4	0.0	+ 4.2
	12	0	0	5.6	-5.6	442.9	450.3	0.0	+ 2.5
	13	0	0	5.0	-5.0	437.9	450.9	0.0	+ 5.6
	14	0	0	6.3	-6.3	431.6	454.7	0.0	+10.1
	15	0	0	5.6	-5.6	426.0	451.2	0.0	+ 2.1
	16	0	0	5.4	-5.4	420.6	448.0	0.0	+ 2.2
	17	0	0	5.0	-5.0	415.6	449.0	0.0	+ 6.0
	18	0	0	4.9	-4.9	410.7	449.2	0.0	+ 5.1
	19	0	0	5.0	-5.0	405.7	449.2	0.0	+ 5.0
	20	0	0	5.5	-5.5	400.2	449.3	0.0	+ 5.6
	21	0	0	4.6	-4.6	395.6	438.5	-6.2	0.0
	22	0	0	3.4	-3.4	392.2	437.5	0.0	+ 2.4
	23	0	0	4.0	-4.0	388.2	435.9	0.0	+ 2.4
	24	0	0	4.7	-4.7	383.5	432.7	0.0	+ 1.5
	25	0	0	3.6	-3.6	379.9	445.6	0.0	+16.5
	26	0	0	4.7	-4.7	375.2	442.4	0.0	+ 1.5
	27	0	0	4.2	-4.2	371.0	442.0	0.0	+ 3.8
	28	0	0	3.0	-3.0	368.0	441.9	0.0	+ 2.9
	29	0	0	2.8	-2.8	365.2	442.1	0.0	+ 3.0
	30	0	0	3.0	-3.0	362.2	438.3	-0.8	0.0
Total								-38.6	+115.3
Balance									+ 76.6

Table 11-Daily soil moisture balance table for Plot C10 (0 to 150 cm)

1980	Date	Rainfall (mm)	Irrigation (mm)	ETp (mm/day)	Storage change in soil (mm)	Calculated storage balance in soil (-ETp) (mm)	Measured storage balance in soil (mm)	Deep percolation; storage out (mm)	Capillary water from below; storage in (mm)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
May	31	0	0	–	–	462.0	462.0	–	–
June	1	0	0	3.2	-3.2	458.8	452.8	-6.0	0.0
	2	0	0	4.0	-4.0	454.8	445.8	-3.0	0.0
	3	0	0	3.9	-3.9	450.9	433.5	-8.4	0.0
	4	0	0	3.4	-3.4	447.5	428.2	-1.9	0.0
	5	0	0	4.1	-4.1	443.4	419.6	-4.5	0.0
	6	0	0	4.3	-4.3	439.1	412.5	-2.8	0.0
	7	0	0	4.1	-4.1	435.0	407.0	-1.4	0.0
	8	0	0	2.8	-2.8	432.0	402.7	-1.5	0.0
	9	0	0	2.9	-2.9	429.3	413.1	0.0	+13.3
	10	0	0	2.7	-2.7	426.6	412.9	0.0	+ 2.5
	11	0	0	4.7	-4.7	421.9	412.9	0.0	+ 4.7
	12	0	0	5.9	-5.9	416.0	412.1	0.0	+ 5.0
	13	0	0	5.3	-5.3	410.7	397.8	-9.0	0.0
	14	0	0	6.6	-6.6	404.1	402.7	0.0	+11.5
	15	0	0	5.9	-5.9	398.2	399.2	0.0	+ 2.4
	16	0	0	5.7	-5.7	392.5	412.6	0.0	+19.1
	17	0	0	5.3	-5.3	387.2	398.6	-8.7	0.0
	18	0	0	5.1	-5.1	382.1	398.2	0.0	+ 4.7
	19	0	0	5.3	-5.3	376.8	397.3	0.0	+ 4.4
	20	0	0	5.8	-5.8	371.0	396.8	0.0	+ 5.3
	21	0	0	4.8	-4.8	366.2	398.3	0.0	+ 6.3
	22	0	0	3.6	-3.6	362.6	400.9	0.0	+ 6.2
	23	0	0	4.2	-4.2	358.4	399.8	0.0	+ 3.1
	24	0	0	4.9	-4.9	353.5	398.5	0.0	+ 3.6
	25	0	0	3.8	-3.8	349.7	400.4	0.0	+ 5.7
	26	0	0	4.9	-4.9	344.8	398.8	0.0	+ 3.3
	27	0	0	4.4	-4.4	340.4	395.0	0.0	+ 0.6
	28	0	0	3.2	-3.2	337.2	395.8	0.0	+ 4.0
	29	0	0	2.9	-2.9	334.3	396.9	0.0	+ 4.0
	30	0	0	3.2	-3.2	331.1	397.6	0.0	+ 3.9
Total								-47.2	+113.7
Balance									+ 66.5

The difference (+5.1 mm) indicate gain in moisture in addition to that day's ETp demand (3.8 mm). Since there was no rain or irrigation this amount (+8.9 mm) must have come from below the profile and therefore it was recorded in column 9 (storage in). Similarly, on 6 June 1980 the measured balance was 454.7 mm and on 5 June 1980 it was 459.9 mm. The difference (-5.2 mm) represents loss from the profile. Part of this loss, however, was due to ETp (4.7mm). The balance (-0.5mm) must have been lost through deep percolation (storage out) column 8.

The totals, gains and losses, were obtained and the balance for the month worked out. It was found that for Plot B8 as much as 115.3 mm of water moved up the profile while 38.6 mm was lost through deep percolation, indicating a net gain of 76.7 mm. In Plot C10 113.7 mm moved up the profile and 47.2 mm was drained away, showing a net gain of 66.5 mm.

In both cases the data indicated that considerable amount of ground water was moving up from below as the soil started to dry. The higher ground water contribution in Plot B8 was expected as the water table there is shallower than under Plot C10 despite being at a higher elevation. The ground water contribution in most days suggests that the flow was continuous. Thus, a relatively constant level of ground water must have been maintained, even though it contributed continuously to the soil above.

If the land is irrigated, the water table in the area is bound to remain at relatively shallow depth. This calls for more frequent irrigation to make sure the soil does not dry up to a level where the ground water moves up the profile and causes salt accumulation in the root zone. On the other hand, the salt problem may not be serious as the ground water was noted to be moving laterally quite rapidly, possibly down the slope and therefore any leached salts are likely to be carried away from the experimental area instead of accumulating in the plots.

As mentioned in the last section, water will be applied when 40% of the available moisture is depleted. This measure is expected to keep the root zone moist throughout, thus avoiding upward movement.

While on the subject of salt concentration, the leaching requirement was considered should the water quality prove to be poorer than anticipated. Assuming a leaching requirement of 15% and taking into account the 56 mm water needs of the irrigated plots (calculated in the previous section) the gross irrigation would need to be

$$\frac{56 \text{ mm}}{1 - 0.15} = 65.88 \text{ mm} \cong 66 \text{ mm per irrigation,}$$

but the system irrigation losses were estimated at 40% which brought the gross irrigation requirement to 93 mm. This application may meet the leaching requirement.

5.3 ROADS AND DRAINS

The need for good and permanent roads within the farm is apparent. Accessibility to all plots is necessary to allow movement to and from every part of the farm and hauling materials such as fertilizers, seeds, harvested materials, etc. As shown on the plot layout map (Fig. 7), there are six meter roads between plots. Some of these are temporary as they are likely to be crossed by implements during farm operations and will need to be smoothed every season. However, more permanent roads on either side of the major drains and around the farm are required so that every part is continuously accessible. These major roads will be covered by laterite materials which are easily obtainable from quarries nearby (3 km away).

As has already been mentioned, proper drains are needed to carry away excess surface water. In terms of soil erosion control, this is a very critical aspect as the contour ridges that had checked erosion so well are being removed. In the north-south direction there will be a major drain every block row and in the west-east direction one after every three or four block columns (Fig. 11); smaller drains will be needed at the end of every plot in both slope directions, which will connect to the major drains.

As the drains will be open trapezoidal waterways, a considerable number of culverts will be required to bridge drains and roads. Concrete culverts 0.9 m in diameter are adequate and can be manufactured in the area. With four culverts per crossing about 200, each 1.8 m long, will be needed.

Concrete crossings may be required at some points where drains intersect to prevent water from eroding the corners.

The size of drains will vary according to the amount of runoff they are expected to handle. These waterways have to be grassed to reduce erosion within the channels and improve their stability. It is essential that these drains are well maintained throughout, otherwise they may end up serving no useful purpose. The grass has to be kept short; any signs of channel erosion has to be stopped and blockages by plant materials from the plots have to be removed from time to time.

Much of the runoff that is likely to erode the land would come from the hills on the western side. In earlier years this problem was realized and a storm drain was constructed across the farm alongside the Kilosa-Rudewa Road. This drain seems to have been effective as no erosion channels are visible within the farm. The drain silted up because of neglect and in recent years, some runoff has been crossing the drain and onto the station land. The present plan calls for improving this drain by widening and stabilizing the sides so that it will continue to divert the runoff away from station land. This should be given first priority before any land development work is started.

5.4 BUILDINGS AND FENCES

The necessity for enough working space, offices, and storage area for research projects is obvious. In view of the expected expansion of research activities with materialization of the development program at Ilonga, the crop research work cannot be accommodated in the existing building facilities.

In addition the present offices are about 3 km away from the experimental site making movement to and from the farm inconvenient. Also, working areas are haphazardly located, some in the existing workshop area and others in the old laboratories near the main office. This makes handling of materials and safety precautions more difficult.

In order to avoid the confusion that might exist with the increased research activities, new buildings to house the research functions are planned. The location of the new buildings has already been mentioned, that is, at the highest portion of the farm site and middle of the crest (Fig. 5). The building area covers about 200 m x 230 m. The number and arrangement of the individual buildings are shown in Fig. 13. Each crop program will have its own working building; the other buildings will be used in common.

For security reasons the building area and the rest of the farm will be fenced with cranked concrete posts and barbed wire. The fence around the farm will also help to control trespassing and keep livestock and wild animals out of the research farms.

There is a great need to increase the number of living quarters on station land as convenient private housing is not available. In the past new houses have been put up at a very slow rate and as a result, new staff stay for months before being allocated housing. At least 30 grade A houses, 60 grade B houses, and 120 grade C houses will be required in the next 5 years. This means 6 A houses, 10 B houses, and 20 C houses will have to be built each year. Sites for these buildings are available in present housing areas except for the grade C houses. The site for these houses must be changed as the current area is too low and receives a lot of runoff from the hills. The area east of the existing B houses could be utilized for this instead.

For safety and special uses, some of the buildings have to meet specific standards and therefore need proper design and construction. These buildings include the chemical store, power house, seed storage buildings, and the

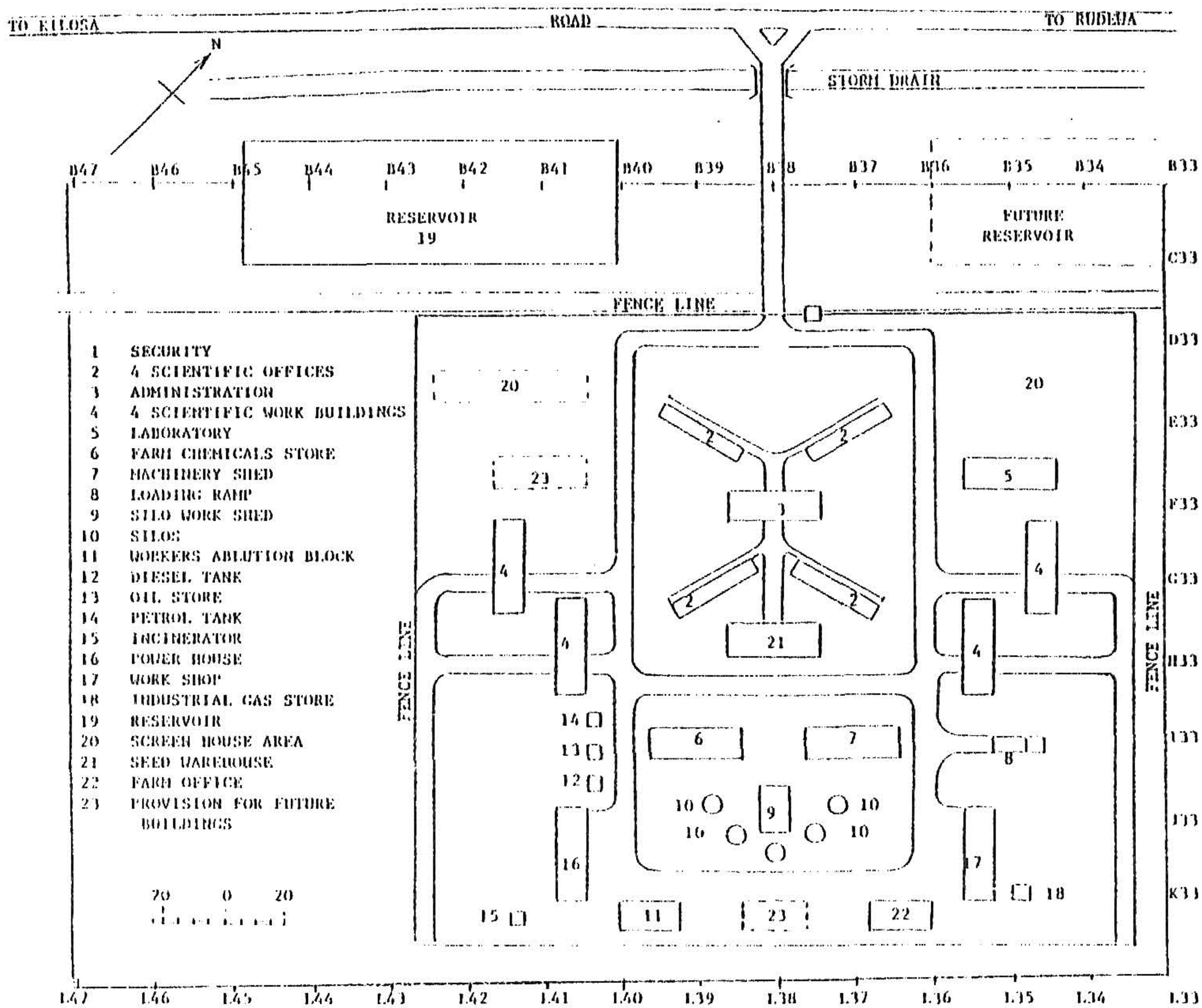


Fig. 13-Building layout.

incinerator.

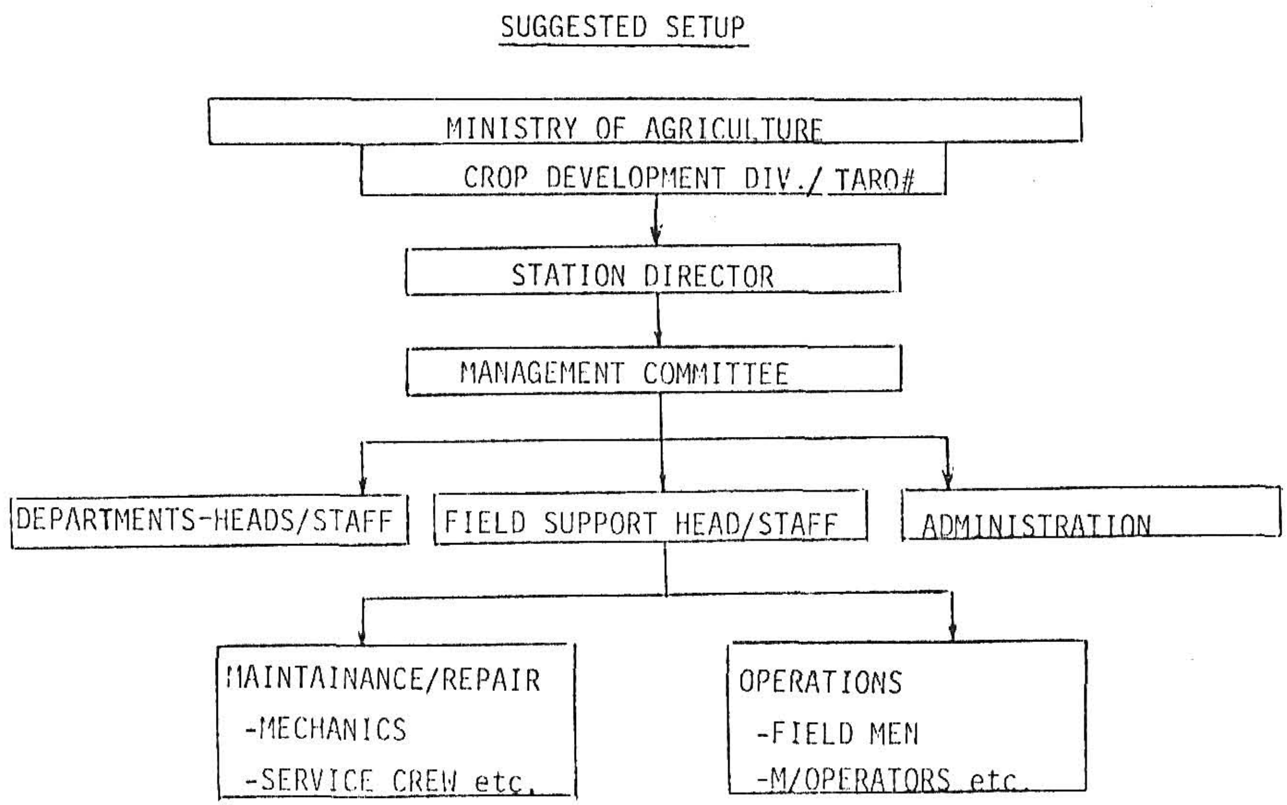
Where waste materials cannot be incinerated, particularly chemicals and their containers, they have to be disposed of safely. As there are not state disposal sites in the area, one of the plots in the northeastern area may be used for burying metal and plastic containers since the water table there is deeper. The same plot could be used for spraying the chemicals over the surface as under normal applications so that they are detoxicated by natural processes. Toxic wastes should never be buried near or within the water table. This is to avoid ground water contamination.

Electricity will be the major source of power for the buildings and for pumping; this being cheaper and available locally. A three phase power line runs very close to the building area. However, the power house should include a standby system to maintain vital functions during power failures.

5.5 ADMINISTRATION

The efficiency of any institution depends much on how well and effectively that organization is administered. Agricultural research organizations are no exception. It is not my purpose to suggest the administrative setup. Many people are usually involved in deciding the pattern or chain of command. In any case the administrative setup of Ilonga Station is very similar to the one found in Fig. 14. But the effectiveness of the different levels of administration has been uneven, poor in some cases, good in others.

The most neglected section of all has been the field support section. As a result, it has performed poorly. Research programs involve experimenters and facilities on which or in which their work is done. Many things must go into the preparation and operation of the facilities to support the experimenters in the conduct of their work. This is usually done by the support section or operations department. At Ilonga this vital section needs improvement if the expected research efficiency is to be realized.



#Tanzania Research Organization.

Fig. 14-Administration setup

In the past administrative staff in most of the sections have been people well educated or trained to a certain level. However, the field support section has not measured up to the same high standards. Tractor operators, for example, have been people who are unrecognized, lowly paid, poorly trained and guided; hence, poorly motivated. Many tractor drivers see the job as a step towards professional truck driving which is more recognized and pays more. They view the job as a temporary occupation and therefore see no need to improve their workmanship, at least in terms of field operations. Yet these men and the systems they operate produce the crops which provide the needed data for analysis.

The poor performance of the common support section has forced certain departments to establish their own support systems. This has caused duplication of effort, more expensive operations and often poorer workmanship.

If the station is to achieve its objectives, the field support section must be boosted to the same level as the other departments. The operations or farm manager should have the same level of training as the researcher. The tractor driver should be trained also so that he knows how to handle the expensive equipment he operates and motivated by recognition and pay so that he is interested in his job and does it well. The same applies to mechanics, irrigators, etc.

5.6 AGRICULTURAL EQUIPMENT, LABOR, AND PROGRAM IMPLEMENTATION

For the purpose of budgeting, the needed equipment has been divided into two groups. Group A includes those machines needed to develop the station. Group B includes those needed to run the station after the development program is completed. Appendix 6 lists the necessary equipment. While the list is obviously incomplete, it should suffice for a take-off.

The need for the development equipment will be over after the work is completed and therefore it was decided to purchase second-hand equipment where they could be found in reasonable condition and obviously at cheaper prices. Most of these machines were ordered from the United States Army surplus property dealers and have just arrived at the station.

The equipment list was made in view of the fact that no quick repair services are available around the area, so that all repairs will be done at the station except where special equipment and expertise is required. This means reasonably well trained repairmen have to be found to do the job. Appendix 7 lists the kind and number of personnel required. Whereas some may be trained on the job, a few qualified repairmen will have to be recruited initially; the same applies to machine operators.

It would be unduly expensive and inconvenient to attempt to put the whole development plan into effect in a single year, so it will have to be executed in phases over 3 years.

The development of experimental plot land, too, is to be accomplished in phases. Approximately 50 ha will be made ready for research work each year beginning in 1981. Fig. 5 shows the areas to be developed each year (I, II, III). The phasing in land preparation is necessary because land must be available for current experimental programs even as the land is being worked on. Since no other suitable and convenient non-station land is available, only a part of the station land can be worked on each year.

Other works to be done during the 3 years are as follows:

Phase I

1. Demarcation and levelling of the building area and reservoir site.
2. Construction of main access roads.
3. Excavation/construction of the reservoir and placement of plastic lining (No. 19).
4. Construction of fencing around the building area.
5. Construction of wells.
6. Installation of irrigation pump and test pumping wells.

7. Construction of loading ramp (No. 8).

Phase II

1. Construction of buildings in the following order (refer to Fig. 13):
2. Farm office building (No. 22)
3. Farm machinery shed (No. 7)
4. Farm and fertilizer store (No. 6)
5. Fuel/oil stores and underground tanks (No's. 12, 13, 14)
6. Power house (No. 16)
7. Workshop (No. 17)
8. Four program work area buildings (No. 4)
9. Four program offices (No. 2)
10. Laboratory (No. 15)
11. Administration building (No. 3)
12. Security building (No. 1)
13. Laying of water and sewage lines.

Phase III

1. Workers ablution facility (No. 11)
2. Industrial gas store (No. 18)
3. Incinerator (No. 15)
4. Two screen houses (No. 20)
5. Four silos and silo-work shed (Nos. 10 and 9)
6. Seed warehouse (No. 21)
7. Roadway surfacing
8. Expansion and improvement of domestic water supply.

5.7 DEVELOPMENT BUDGET

It is difficult to state exactly how much it will cost to develop this large project especially so with rapidly increasing prices. Developing a realistic budget for the project implementation is a job for an expert because a detailed budget summary is necessary to justify the money being requested. Each item has to be listed together with current prices plus allowance for inflation and possible price hikes should there be delays in ordering. The following is a condensed summary extracted from the project appraisal. Hopefully this will give an indication of the size of the project involved.

Costing Summary.

Station machinery	$ 532,200
General	221,250
Irrigation	308,538
Development equipment	347,312
Building and services	2,262,500
Fencing	118,400
Development costs	410,500
Workshop equipment	120,500
	$4,320,745

5.8 FUTURE MANAGEMENT OF THE STATION

Many of the major decisions that will affect the operation and management of the station have or will have been made when the project is completed. However, as has been discussed, the station is planned to handle a number of different crops where a fairly large number of research staff will be involved and a high level of cropping intensity will be used. Hence, the operation of the station is going to be complicated. As already mentioned, a well organized and efficient operations section (or support department) is essential in order to avoid conflicts and duplication of efforts. The duties of the department will include maintenance of experimental areas, operation and maintenance of irrigation and drainage systems, preparation, cultural care, and assistance in planting and harvesting experimental plots, and operation and maintenance of farm machinery and equipment.

Many operations will require on-the-spot decision making. Such decisions as whether to plow or disc-harrow a field, when to do it, when to apply water and how much, etc. are operational decisions that have to be made daily. These will be governed by conditions that prevail at the particular time.

From the above, it is apparent that three important aspects have to be considered right from the start. First the operation leadership must be able to make the correct decisions whenever needed. The leader must know why things were planned as they are. He must understand the researchers' requirements and must be able to plan to meet their needs. At the same time, he must be valued as a knowledgeable and important member of the research team and kept informed of research objectives and plans as well as of field demands. The general station staff must be well trained in their jobs and kept informed of the various research activities so that the decisions made by the research officers and the operations leader can be carried into action smoothly and efficiently. Station activity must be a coordinated program, because if any phase is omitted or undertaken poorly, failures or poor results are bound to follow.

Second, sufficient funds must be provided to run these services every year. If the funds are not forthcoming, the system will collapse. The administration, both on the station and in the Ministry of Agriculture must understand clearly the size of financial commitment the station development will involve and the magnitude of future operating costs which are entailed; if not properly financed, the resources will be wasted. The committee responsible for the development program must point this out clearly right from the start.

Third, careful planning and coordinating in advance by both the researchers and the operation leader are essential. Adherence to agreed plans will enhance efficiency of operations and reduce conflicts. Major changes after plans are agreed on should be kept to a minimum.

5.9 TRAINING

As mentioned earlier, a training department will be initiated along with the crop research programs. The objective of the department is to offer short-term practically oriented courses for research field staff and experimenters from all the research stations in the country. Courses may range from simple layout and management of experiments in the field, to more complex research procedures and methodology. The level of the courses will depend on the group attending the session.

The final setup of this department has not been agreed upon because there are mixed feelings about the issue. Some officials of the ministry feel the existing manpower training college (MATI[2/] - Ilonga) could be asked to set up the research training program. Many, however, feel this is not in the best interest of research because the present syllabus is intended for extension staff and is of 2 years duration. They do not have the staff nor the facilities to organize short-term specialized courses that will meet the research standards required. Hence, it has been agreed in principle that the training department will be initiated as soon as the development program is completed and that the setup will be reviewed then.

5.10 WORKERS' WELFARE

Plans for other welfare needs in addition to housing must be considered as the program begins to take shape. With the expansion of the staff, community medical facilities, schools for children, and recreational facilities such as community hall, playing grounds, and shopping centers will need to be improved. Since such services are not now available near the station, they will have to be developed as the program gets underway.

[2/] Ministry of Agriculture, Training Institute.

Many of the above needs could be met through community efforts on cooperative basis but the station administration will have to assist in organizing such ventures.

Provision of a rest house is included in the development budget but its use may be restricted to visitors because of the limited services that can be provided. This means the existing community center needs to be improved and equipped to provide the recreational and welfare needs of the staff.

6. SUMMARY

Station development is necessary in order to conduct more meaningful research. This is so, whether a new station is being started or an existing one being improved. Associated advantages include precision, valuable results, research efficiency, and improved management. In developing countries the need for well planned experimental farms has not received as serious attention as in the more developed nations. The outcome has been poor and inconsistent results which made interpretation difficult. In recent years many developing countries, including Tanzania, are trying hard to improve their research stations. The need for faster agricultural expansion in these countries and the contribution of research towards achieving that objective have helped the realization of this vital need.

The most important and often difficult part of station development is the planning stage. Enough information about the location of the station is required before the final plan can be drawn up. The planning is usually done by a committee which includes research scientists and development staff in consultation with government officials. The committee is responsible for drawing up the development master plan. Once this is completed, a skilled development staff should be responsible for the execution of the program and for adherence to the master plan.

A step by step procedure for the development of Ilonga Research Station (Tanzania) has been described. The important aspects covered include climatic conditions, soils, and topography. The semi-hot climate of the area is suitable for most warm season crops. Much of the rain falls between November and May but planting time is towards the end of February. Laboratory analysis of the soils from the research site indicated good, rich soils (mostly sandy clay loam) with high supply of plant nutrients except phosphorous. Field surveys showed deep soils with fair to good water holding characteristics

and gentle slopes. The only serious limitation found was the low-lying spots which tend to hold runoff causing temporary waterlogging problems. If the land is properly developed and managed, soil properties or other physical conditions will not restrict research activity.

Land development, plot layout, land grading, irrigation needs, buildings, administration, equipment required, development timetable, budget, future management, training, and staff welfare needs have also been discussed.

Some of the data presented are incomplete. This is caused by a number of problems which existed when the data were being collected. Some of the problems were lack of adequate equipment, lack of easily accessible laboratory facilities, and delay of drilling equipment. These extra data will be collected and studied before the master plan for the station development is completed.

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APPENDIX 1

DATA FOR CALCULATING EVAPOTRANSPIRATION (ETo) USING THE RADIATION METHOD

Table A-Mean daily duration of maximum possible sunshine hours (N) for different months and latitudes[3/].

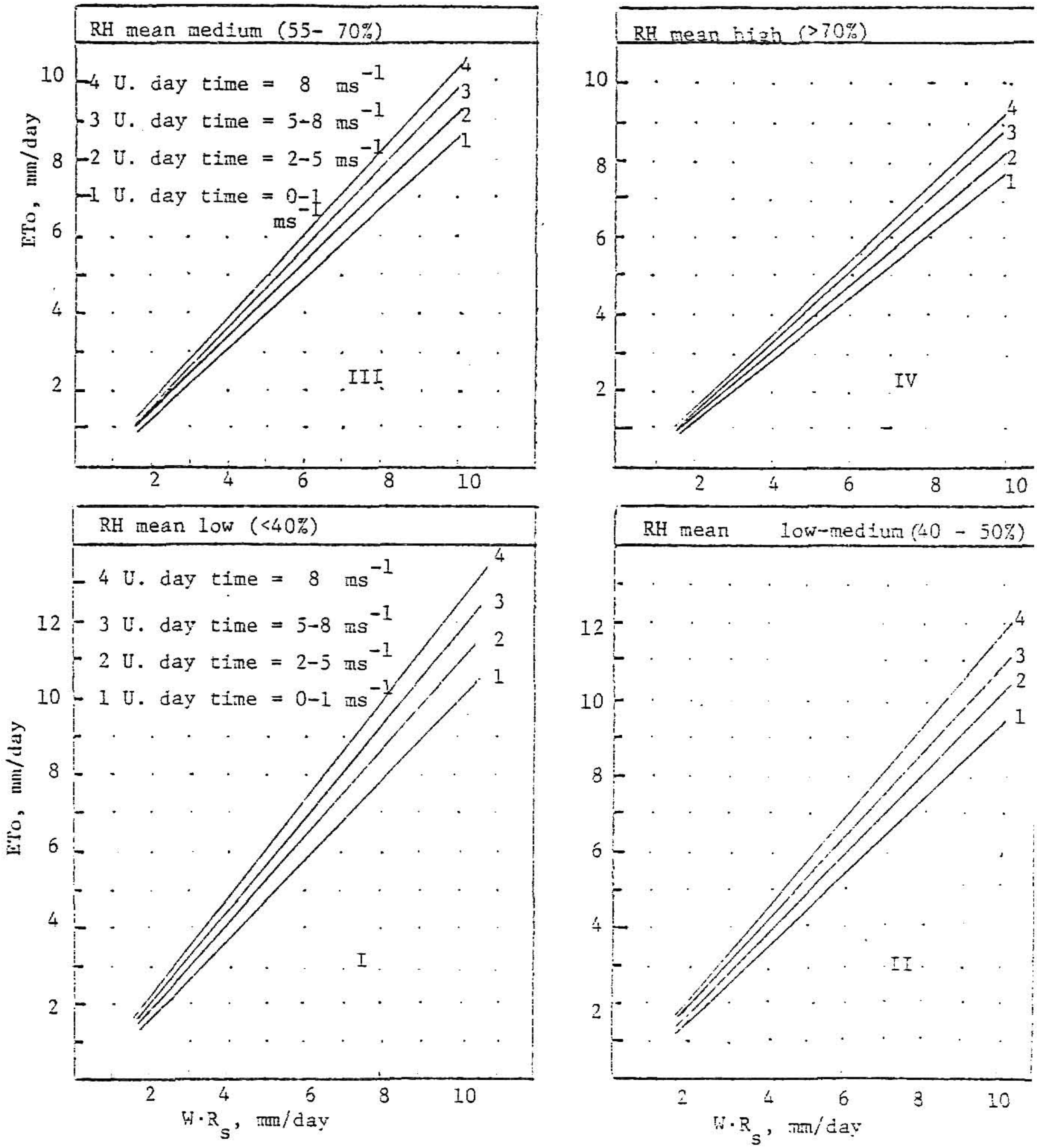
Northern lats / Southern lats	Jan. / July	Feb. / Aug.	Mar. / Sept.	Apr. / Oct.	May / Nov.	June / Dec.	July / Jan.	Aug. / Feb.	Sept. / Mar.	Oct. / Apr.	Nov. / May	Dec. / June
50	8.5	10.1	11.8	13.8	15.4	16.3	15.9	14.5	12.7	10.8	9.1	8.1
48	8.8	10.2	11.8	13.6	15.2	16.0	15.6	14.3	12.6	10.9	9.3	8.3
46	9.1	10.4	11.9	13.5	14.9	15.7	15.4	14.2	12.6	10.9	9.5	8.7
44	9.3	10.5	11.9	13.4	14.7	15.4	15.2	14.0	12.6	11.0	9.7	8.9
42	9.4	10.6	11.9	13.4	14.6	15.2	14.9	13.9	12.6	11.1	9.8	9.1
40	9.6	10.7	11.9	13.3	14.4	15.0	14.7	13.7	12.5	11.2	10.0	9.3
35	10.1	11.0	11.9	13.1	14.0	14.5	14.3	13.5	12.4	11.3	10.3	9.8
30	10.4	11.1	12.0	12.9	13.6	14.0	13.9	13.2	12.4	11.5	10.6	10.2
25	10.7	11.3	12.0	12.7	13.3	13.7	13.5	13.0	12.3	11.6	10.9	10.6
20	11.0	11.5	12.0	12.6	13.1	13.3	13.2	12.8	12.3	11.7	11.2	10.9
15	11.3	11.6	12.0	12.5	12.8	13.0	12.9	12.6	12.2	11.8	11.4	11.2
10	11.6	11.8	12.0	12.3	12.6	12.7	12.6	12.4	12.1	11.8	11.6	11.5
5	11.8	11.9	12.0	12.2	12.3	12.4	12.3	12.3	12.1	11.0	11.9	11.8
0	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1

[3/] (adapted from Doorenbos et al., 1977)

Table B-Values of weighting factor (W) for the effect of radiation on ETo at different temperatures and altitudes[4/].

Temperature°C	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	32	36	38	40
W at altitude																				
m 0	0.43	.46	.49	.52	.55	.58	.61	.64	.66	.68	.71	.73	.75	.77	.78	.80	.82	.83	.84	.85
500	.45	.48	.51	.54	.57	.60	.62	.65	.67	.70	.72	.74	.76	.78	.79	.81	.82	.84	.85	.86
1000	.46	.49	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.80	.82	.83	.85	.86	.87
2000	.49	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.81	.82	.84	.85	.86	.87	.88
3000	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.81	.82	.84	.85	.86	.88	.88	.89
4000	.55	.58	.61	.64	.66	.69	.71	.73	.76	.78	.79	.81	.83	.84	.85	.86	.88	.89	.90	.90

4/ (adapted from Dorrenbos et al., 1977)



(RH = Relative humidity; U = Wind speed)

Fig. A-Prediction of ETo from $W \cdot R_s$ for different conditions of mean relative humidity and daytime wind (Doorenbos et al., 1977).

APPENDIX 2

SOIL PROFILE DESCRIPTIONS AND ANALYTICAL DATA

1. Profile No. ILO-1, Pachic Haplustoll (Haplic Phaeozem).

Location: Ilonga Proposed Experiment Farm, about 50 m from Kilosa-Rudewa road and 500 m from North boundary. Topo-map 182/3 Kimamba, coordinate 9249, 2-282,9.

Date of examination: 11 March 1980

Climate:

i. Soil temperature regime: isohyperthermic

ii. Soil moisture regime: ustic

Topography:

i. Surrounding land form: almost flat plain gently rising to Ilonga Hills.

ii. Site: 1% slope, elevation 485 m.

iii. Microtopography: cultivation ridges.

Land use: cultivation

Drainage: well drained, moderate to slow internal drainage; slow runoff.

Moisture condition: moist throughout; lateral seepage at 1.5 m depth.

Ground water level: ground water at 1.5 m.

Erosion/deposition: none.

Root distribution: normal.

Brief profile description: (courtesy of Dr. E. F. De Pauw)

Dark grey brown sandy clay loam to sandy clay, well drained, friable, neutral, moving ground water at about 1.5 m, high organic matter content throughout, and high base supply.

A 0-30 cm Very dark grey (10 YR 3/1) moist and dark grey brown 10 YR 4/3 dry sandy clay loam; moderate fine angular blocky; slightly hard dry, firm moist; many fine pores; about 5% mica flakes 2-3 mm long and 1-2% quartz fragments 2-3 mm; abrupt smooth boundary.

AB_1 30-90 cm — Dark brown (7.5 YR 3/2) moist sandy clay; non-mottled to very faint, few fine and medium brown mottles; weak to moderate fine angular blocky; friable moist; many fine and very fine pores; about 5-10% mica flakes 2-3 mm long and 1-2% quartz fragments 2-3 mm; gradual smooth boundary.

AB_2 90-120+ cm — Dark brown (7.5 YR 3/2) moist sandy clay; common, medium, faint and distinct clear brown (7.5 YR 4/4) mottles; moderate fine angular blocky; friable moist; many fine and very fine pores.

Table C-Soil analytical data for the Pachic Haplustoll.

Depth cm	pH H_2O	pH $Cacl_2$	Particle size distribution (%) Sand	Silt 50-20 mic.	Silt 20-20 mic.	Clay	Silt/ clay	Tex. class
0-30	7.3	6.3	59.6	8.0	3.2	29.2	0.38	scl
30-60	6.7	5.8	47.6	2.0	8.8	41.6	0.26	sc
60-90	6.7	5.8	49.6	6.0	4.6	39.8	0.27	sc
90-130	8.0	7.0	50.6	3.0	3.2	43.2	0.14	sc

Organic content	N	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	H(+)	Sum bases	CEC soil sum
3.6	0.25	12	0.17	0.23	11.20	4.00	0.00	15.60	15.60
1.15	0.14	8	0.05	0.42	11.40	2.20	1.30	14.07	15.37
1.91	0.17	11	0.09	0.23	11.00	3.60	1.50	14.92	16.42
1.15	0.09	13	0.10	0.44	10.00	4.60	0.00	15.14	15.14

+$BaCl_2$ - triethanoloamine extraction

Table C-ctd.

Sum bases meq/100 g clay	CEC meq/100 g clay	Base sat. %	P ppm	% $CaCO_3$
53	53	100	trace	0.21
34	37	92	1.4	
37	41	91	1.4	
35	35	100	2.8	0.34

2. Profile No. ILO-2, Aquic Haplustoll (Haplic Phaeozem).

Location: Ilonga Proposed Experimental farm about 300 m from east boundary.

Topo-map 182/2 Kimamba, coordinate 9248-50, 282-284.

Date of examination: 11 March 1980

Climate:

i. Soil temperature regime: isohyperthemic

ii. Soil moisture regime: ustic

Topography:

i. Surrounding landform: almost flat plain, very gently rising to Ilonga hills.

ii. Site: 1% slope, elevation about 475 m.

iii. Microtopography: some contour banks and artificial depressions.

Vegetation: Grassland (Hyparrhenia species), some herbs and shrubs.

Land use: Fallow; land used for grazing in the last 5 to 6 years.

Drainage: Moderately well drained; slow runoff; slow internal drainage.

Moisture condition: Moist throughout.

Ground water: No ground water in the profile.

Erosion/deposition: Possibly some deposition.

Root distribution: Many roots in the top 30 cm; few to very few roots deeper down.

Brief profile description: (courtesy of Dr. E. F. De Pauw)

Dark grey brown to olive brown sandy clay loam, moderately well drained, firm, with accumulations of manganese dioxide, and $CaCO_3$ in depth, high organic matter content and high base supply.

A 0-30 cm — Dark to very dark grey (10 YR 2.5/1) moist and very dark grey brown (10 YR 3/2) dry, sandy clay loam: very coarse platy structure on top; weak, coarse angular blocky breaking into moderate, fine and medium angular blocky underneath; hard when dry and firm when moist; common fine pores; many fine roots; abrupt, smooth boundary.

ABg 30-45 cm — Very dark grey brown (10 YR 3/2) moist sandy clay loam, common fine, faint, sharp, brown mottles; weak, coarse subangular blocky breaking into weak, fine, and medium subangular blocky; friable to firm moist; many fine and very fine pores; common fine and very fine roots; clear smooth boundary.

BAgs 65-120 cm — Dark brown (10 YR 3/3) moist sandy clay loam; many fine distinct to prominent, sharp brown mottles; massive with a few cracks; firm moist; common fine and many very fine pores; very few, very fine roots; 2-3 mm diameter; black manganese dioxide concretions 2-5%; clear, smooth boundary.

Bk 120-160+ cm — Olive brown (2.5 YR 4/4) moist sandy clay loam with very coarse sand fraction; weak, fine angular blocky; very hard dry, firm moist; many very fine pores, common fine pores (slightly more porous than previous horizon); very few, very fine roots; grey rounded $CaCO_3$ concretions, about 1 cm diameter; some weathered rock fragments and quartz; slightly calcareous.

Table D-Soil analytical data for the Aquic Haplustoll.

Depth	pH		Particle size distribution (%)					
	H_2O	$CaCl_2$	Sand	Silt		Clay	Silt/ clay	Tex. class
				50-20 mic.	20-20 mic.			
0-30	6.7	5.9	56.6	2.8	9.2	31.4	0.38	scl
30-45	7.0	5.9	63.6	4.0	4.2	28.2	0.29	scl
45-65	7.0	6.0	61.6	3.2	4.0	31.2	0.23	scl
65-95	7.2	6.2	67.6	2.0	1.2	29.2	0.10	scl
95-120	7.5	6.6	62.6	3.0	2.2	32.2	0.16	scl
120-160+	8.4	7.6	60.6	3.0	3.2	33.2	0.18	scl

Table D-ctd.

Organic content	N	C/N	Exchangeable cations (meq/100 g soil) Na	K	Ca	Mg	H(+)	Sum bases	CEC soil sum
2.21	0.24	9	0.03	0.75	11.40	2.00	1.50	14.18	15.68
1.17	0.09	13	0.27	0.12	8.00	3.00	0.50	11.39	11.89
1.78	0.08	10	0.36	0.13	9.00	3.00	0.45	12.49	12.94
1.04	0.08	13	0.52	0.13	7.00	4.40	0.00	12.05	12.05
0.52	0.05	10	0.90	0.12	8.40	5.20	0.00	14.62	14.62
0.26	0.04	7	0.13	0.003	16.00	9.40	0.00	25.53	25.63

+BaCl - triethanolamine extraction

Sum bases meq/100 g clay	Sum bases meq/100 g clay	Base sat. %	P ppm	% $CaCO_3$	E.C (mmho)
45	50	90	2.8	0.27	
40	42	97	9.1		
41	45	100	11.2		
45	45	100	2.8		
77	77	100	0.7	0.75	1.70

APPENDIX 3

RESULTS OF INFILTRATION TEST No. 5 (PLOT A11)

Date: 14 June 1980

Location: Between grid stations J_{56}, J_{57}, K_{56}, and K_{57}.

Soil Type: Sandy clay loam (ILO-11b).

Table E-Infiltration test data for Plot All.

Elapsed time (min)	Time	Hook gauge reading (mm)	Accum. intake (mm)	Adjusted accum. (mm)	Infiltration rate (mm/hr)
0	8:00 am	29	-	-	-
10	8:10	45	16	16	96
20	8:20	55	26	26	60
30	8:30	63	34	34	48
40	8:40	70	41	41	42
50	8:50	78	49	49	48
60	8:60	85	56	55	36
80	9:20	95	66	66	33
100	9:40	105	76	77	33
120	10:00	116	87	87	30
150	10:30	130	101	100	26
180	11:00	141	112	112	24
220	11:40	158	128	128	24
260	12:20 pm	171	141	142	21
310	1:10	190/50	160	159	20
360	2:00	74	184	176	20
420	3:00	97	197	197	21
480	4:00	117	217	218	21

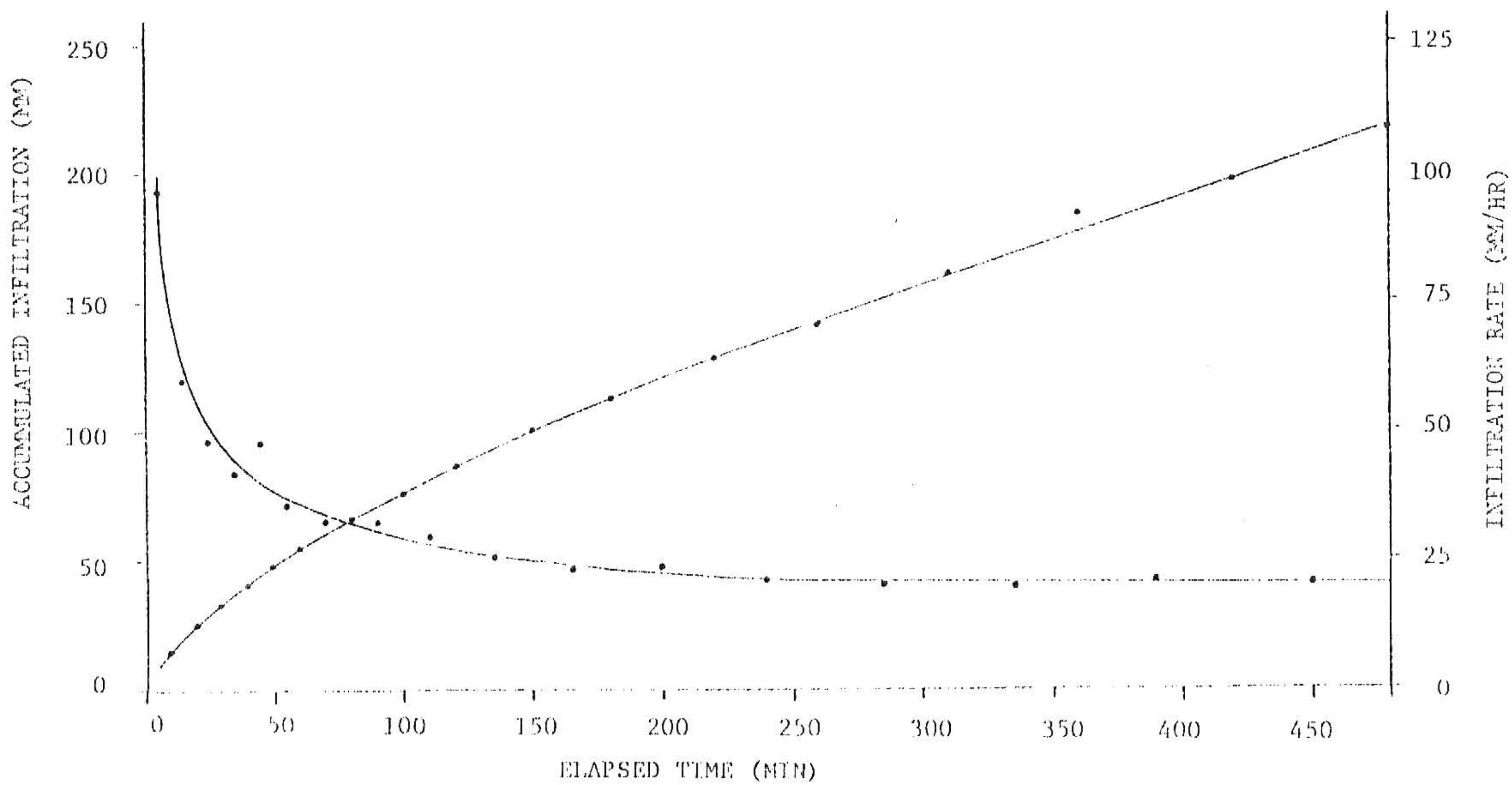


Fig. B-Curves for infiltration test No. 5 (Plot AII).

APPENDIX 4

GRID STATION ELEVATIONS IN METERS

Table F-Elevations (m) for the grid stations shown in Fig. 6.

A 1	100.11	A 37	-	B 1	99.84	B 37	104.86	C 1	98.46	C 37	104.82	D 1	99.14	D 37	103.75
2	97.83	38	-	2	99.81	38	104.62	2	99.71	38	104.87	2	99.54	38	104.42
3	100.33	39	-	3	100.26	39	105.24	3	99.92	39	104.58	3	99.68	39	104.47
4	100.50	40	-	4	100.37	40	104.77	4	100.09	40	104.82	4	99.67	40	104.47
5	100.81	41	-	5	100.26	41	104.86	5	100.15	41	104.56	5	99.94	41	104.26
6	100.99	42	-	6	100.91	42	105.07	6	100.44	42	104.54	6	100.13	42	104.18
7	100.11	43	-	7	100.72	43	105.01	7	100.45	43	104.24	7	100.04	43	103.88
8	100.24	44	-	8	100.86	44	104.74	8	100.41	44	104.16	8	100.01	44	103.36
9	101.19	45	-	9	100.70	45	104.21	9	100.39	45	103.92	9	100.14	45	103.50
10	101.42	46	-	10	100.92	46	103.93	10	100.70	46	103.70	10	100.32	46	103.08
11	101.53	47	-	11	101.11	47	104.04	11	101.05	47	103.26	11	100.35	47	103.01
12	101.79	48	-	12	101.38	48	104.09	12	100.94	48	103.43	12	100.43	48	102.89
13	102.28	49	-	13	101.67	49	104.11	13	101.23	49	103.37	13	101.15	49	103.08
14	102.55	50	-	14	102.01	50	104.08	14	101.69	50	103.54	14	101.22	50	103.20
15	102.95	51	-	15	102.37	51	-	15	101.90	51	103.34	15	101.62	51	103.05
16	102.93	52	-	16	102.07	52	-	16	102.28	52	103.28	16	101.81	52	102.95
17	102.92	53	-	17	102.75	53	-	17	102.33	53	103.21	17	102.02	53	102.84
18	102.10	54	-	18	102.09	54	-	18	102.61	54	103.10	18	102.38	54	102.69
19	103.34	55	-	19	102.95	55	-	19	102.78	55	103.10	19	102.21	55	102.21
20	103.63	56	-	20	103.16	56	-	20	102.96	56	102.82	20	102.48	56	102.44
21	103.33	57	-	21	103.68	57	-	21	102.89	57	102.64	21	102.78	57	102.77
22	104.00	58	-	22	103.48	58	-	22	103.03	58	102.64	22	102.94	58	101.94
23	104.04	59	-	23	103.59	59	-	23	103.25	59	102.42	23	102.94	59	101.90
24	104.21	60	-	24	103.96	60	-	24	103.43	60	102.20	24	102.98	60	101.77
25	104.31	61	-	25	103.32	61	-	25	103.61	61	102.17	25	103.78	61	101.20
26	104.45	62	-	26	104.00	62	-	26	103.63	62	102.07	26	103.35	62	101.91
27	104.39	63	-	27	104.02	63	-	27	103.70	63	102.10	27	103.32	63	101.68
28	104.53	64	-	28	103.93	64	-	28	103.71	64	102.01	28	103.45	64	101.82
29	104.45	65	-	29	104.02	65	-	29	103.61	65	101.76	29	103.24	65	101.47
30	104.59	66	-	30	103.02	66	-	30	103.36	66	101.15	30	102.98	66	100.72
31	-	67	-	31	104.93	67	-	31	103.35	67	100.86	31	102.85	67	100.40
32	-	68	-	32	104.48	68	-	32	103.62	68	100.81	32	103.24	68	100.30
33	-	69	-	33	104.28	69	-	33	103.66	69	100.66	33	103.24	69	100.20
34	-	70	-	34	104.24	70	-	34	104.02	70	100.15	34	102.80	70	99.98
35	-	71	-	35	104.81	71	-	35	104.24	71	100.04	35	103.89	71	99.79
36	-	72	-	36	104.75	72	-	36	104.63	72	99.89	36	103.89	72	98.56

Table F-ctd.

E 1	99.04	E 37	103.63	F 1	98.90	F 37	103.53	G 1	98.11	G 37	103.25	H 1	97.14	H 37	103.47
2	99.47	38	104.05	2	98.90	38	103.82	2	98.67	38	103.53	2	98.08	38	103.36
3	99.66	39	104.16	3	99.20	39	104.04	3	98.81	39	103.71	3	99.08	39	103.35
4	99.45	40	104.32	4	99.32	40	103.82	4	98.74	40	103.71	4	98.71	40	103.51
5	99.68	41	104.15	5	99.38	41	103.68	5	98.77	41	103.73	5	98.55	41	103.43
6	100.01	42	103.99	6	99.16	42	104.01	6	98.76	42	103.46	6	98.64	42	103.30
7	99.27	43	103.50	7	99.27	43	103.56	7	98.82	43	103.39	7	98.70	43	103.04
8	99.60	44	103.29	8	99.37	44	103.28	8	99.30	44	103.16	8	98.88	44	102.94
9	99.81	45	102.95	9	99.57	45	102.70	9	99.14	45	102.66	9	98.99	45	102.60
10	100.56	46	102.75	10	99.70	46	102.45	10	99.40	46	102.25	10	99.46	46	102.12
11	100.16	47	102.57	11	99.93	47	102.24	11	99.70	47	101.95	11	99.47	47	101.83
12	100.40	48	102.67	12	100.45	48	102.29	12	99.91	48	101.97	12	99.97	48	101.81
13	100.69	49	102.63	13	100.46	49	102.14	13	100.75	49	100.85	13	99.78	49	101.58
14	101.18	50	102.18	14	100.88	50	102.22	14	100.51	50	101.81	14	99.88	50	101.48
15	101.26	51	103.62	15	101.08	51	102.18	15	100.90	51	101.71	15	100.04	51	101.40
16	101.42	52	102.59	16	100.92	52	102.28	16	100.71	52	101.72	16	100.51	52	101.31
17	101.52	53	102.36	17	101.23	53	102.03	17	101.12	53	101.63	17	100.67	53	101.16
18	101.80	54	102.34	18	101.51	54	101.91	18	101.32	54	101.37	18	101.27	54	101.13
19	101.78	55	102.14	19	101.92	55	101.72	19	101.42	55	101.30	19	100.89	55	100.03
20	102.19	56	101.90	20	101.71	56	101.52	20	101.45	56	101.06	20	101.08	56	100.68
21	102.78	57	101.68	21	101.94	57	101.25	21	101.69	57	100.63	21	101.43	57	100.45
22	102.23	58	101.59	22	102.07	58	101.22	22	101.72	58	100.72	22	101.41	58	100.29
23	102.27	59	101.47	23	102.28	59	101.17	23	101.97	59	100.77	23	101.44	59	100.30
24	102.71	60	101.37	24	102.31	60	100.90	24	102.20	60	100.59	24	101.90	60	100.90
25	103.11	61	101.24	25	102.63	61	100.87	25	102.09	61	100.80	25	102.09	61	100.04
26	102.77	62	101.90	26	102.72	62	100.80	26	102.33	62	100.43	26	102.00	62	99.95
27	102.87	63	100.90	27	102.66	63	100.33	27	102.27	63	100.11	27	100.84	63	99.86
28	102.82	64	100.78	28	102.64	64	100.06	28	102.28	64	99.80	28	101.94	64	99.69
29	102.65	65	100.75	29	102.49	65	99.92	29	102.12	65	99.74	29	101.90	65	99.32
30	102.65	66	100.30	30	102.28	66	99.90	30	102.02	66	99.57	30	101.76	66	99.16
31	102.70	67	100.11	31	102.33	67	99.74	31	102.16	67	99.78	31	101.87	67	98.72
32	102.71	68	99.87	32	102.55	68	99.47	32	103.39	68	98.45	32	102.24	68	98.72
33	103.20	69	99.77	33	102.86	69	99.32	33	103.28	69	98.90	33	102.39	69	98.45
34	103.56	70	99.79	34	103.21	70	99.17	34	103.02	70	98.72	34	102.68	70	98.35
35	103.73	71	99.69	35	103.35	71	99.02	35	103.07	71	98.46	35	102.67	71	98.12
36	103.53	72	99.79	36	103.27	72	98.75	36	103.08	72	98.35	36	102.92	72	97.91

Table F-ctd.

I 1	97.55	I 37	103.02	J 1	97.21	J 37	102.47	K 1	97.03	K 37	102.18	L 1	96.75	L 37	101.85
2	98.14	38	103.11	2	97.81	38	102.58	2	97.61	38	102.18	2	97.20	38	102.04
3	98.51	39	103.07	3	98.13	39	102.77	3	98.13	39	102.77	3	98.11	39	101.76
4	98.49	40	103.22	4	98.19	40	102.73	4	97.97	40	102.14	4	97.43	40	102.74
5	98.26	41	103.06	5	98.39	41	102.69	5	97.90	41	102.25	5	97.50	41	101.84
6	98.35	42	102.99	6	98.16	42	102.72	6	97.81	42	102.21	6	97.41	42	101.86
7	98.41	43	102.81	7	98.19	43	102.52	7	97.73	43	102.19	7	97.61	43	101.81
8	98.42	44	102.61	8	98.14	44	102.52	8	97.84	44	102.00	8	97.34	44	101.69
9	98.69	45	102.40	9	98.84	45	102.02	9	97.80	45	101.71	9	97.50	45	101.56
10	99.02	46	102.06	10	98.54	46	101.82	10	98.10	46	100.69	10	97.93	46	100.59
11	99.23	47	101.26	11	98.80	47	101.69	11	98.75	47	101.21	11	98.18	47	100.96
12	99.32	48	101.56	12	98.99	48	101.36	12	98.64	48	101.21	12	98.45	48	100.86
13	99.37	49	101.39	13	99.07	49	101.21	13	99.00	49	100.99	13	98.78	49	100.65
14	99.48	50	102.21	14	99.28	50	100.96	14	99.03	50	100.76	14	98.62	50	100.56
15	99.61	51	101.06	15	99.26	51	100.68	15	99.19	51	100.46	15	99.06	51	100.27
16	99.91	52	100.90	16	99.47	52	100.64	16	99.36	52	100.25	16	99.32	52	100.07
17	100.21	53	100.72	17	99.91	53	100.40	17	99.61	53	100.09	17	99.62	53	99.85
18	100.40	54	100.76	18	99.91	54	100.45	18	99.82	54	100.42	18	99.85	54	99.03
19	100.40	55	100.23	19	100.14	55	100.33	19	100.12	55	100.05	19	99.73	55	99.59
20	100.84	56	100.52	20	100.40	56	100.17	20	100.00	56	99.95	20	99.55	56	99.43
21	100.74	57	100.16	21	100.43	57	99.92	21	100.70	57	99.68	21	99.86	57	99.29
22	100.19	58	99.93	22	100.25	58	99.15	22	100.25	58	99.88	22	100.04	58	99.28
23	100.35	59	99.75	23	100.86	59	99.23	23	100.59	59	98.93	23	100.24	59	98.76
24	101.66	60	99.68	24	101.35	60	99.25	24	101.38	60	98.85	24	100.62	60	98.95
25	102.00	61	99.60	25	101.40	61	99.13	25	101.79	61	98.67	25	100.07	61	98.21
26	101.74	62	99.59	26	101.20	62	99.12	26	100.96	62	98.85	26	100.93	62	98.09
27	101.38	63	99.43	27	101.27	63	98.77	27	100.82	63	98.54	27	100.43	63	98.06
28	101.29	64	99.13	28	101.24	64	99.06	28	100.98	64	98.80	28	100.44	64	97.91
29	101.18	65	98.83	29	101.21	65	98.71	29	100.84	65	98.03	29	100.44	65	97.72
30	101.65	66	98.62	30	101.22	66	98.34	30	100.94	66	98.00	30	100.86	66	97.66
31	101.53	67	98.52	31	101.37	67	98.17	31	101.23	67	97.83	31	101.45	67	97.58
32	101.83	68	98.39	32	102.68	68	97.92	32	101.62	68	97.57	32	101.34	68	97.29
33	102.15	69	98.19	33	102.04	69	97.83	33	101.70	69	97.56	33	101.34	69	97.18
34	102.48	70	98.02	34	102.25	70	97.72	34	101.66	70	97.36	34	101.49	70	96.97
35	102.53	71	97.21	35	102.21	71	97.50	35	101.88	71	97.14	35	101.74	71	96.71
36	102.68	72	97.51	36	102.44	72	97.21	36	102.07	72	96.76	36	101.75	72	96.38

Fig. F-ctd.

M 1	96.62	M 37	101.47	N 1	96.36	N 37	101.04	O 1	96.20	O 37	100.82	P 1	95.65	P 37	100.41
2	96.95	38	101.48	2	96.70	38	101.13	2	96.57	38	100.71	2	95.98	38	100.31
3	97.01	39	101.47	3	96.78	39	101.20	3	96.68	39	100.74	3	96.30	39	100.43
4	97.21	40	101.47	4	96.95	40	101.19	4	96.91	40	100.80	4	96.65	40	100.46
5	97.01	41	101.49	5	98.98	41	101.18	5	98.80	41	100.84	5	96.81	41	100.59
6	97.23	42	101.39	6	96.96	42	101.35	6	96.73	42	100.86	6	97.30	42	100.55
7	97.41	43	101.41	7	96.98	43	101.03	7	95.75	43	100.82	7	97.12	43	100.64
8	97.12	44	101.42	8	97.13	44	100.90	8	96.99	44	100.56	8	96.58	44	100.38
9	97.45	45	101.21	9	97.34	45	100.75	9	97.25	45	100.43	9	96.84	45	99.95
10	98.05	46	100.91	10	97.57	46	100.63	10	97.56	46	100.31	10	97.17	46	99.89
11	98.03	47	100.54	11	97.78	47	100.37	11	97.60	47	100.08	11	97.33	47	99.75
12	98.47	48	100.45	12	97.25	48	100.14	12	97.68	48	99.84	12	97.33	48	99.52
13	98.72	49	100.43	13	97.81	49	99.97	13	97.71	49	99.57	13	97.45	49	99.18
14	98.76	50	100.33	14	98.55	50	100.07	14	97.81	50	99.61	14	97.51	50	98.89
15	98.86	51	100.19	15	98.45	51	99.95	15	97.91	51	99.65	15	97.75	51	99.29
16	99.18	52	99.88	16	98.80	52	99.56	16	98.22	52	99.39	16	98.01	52	99.36
17	98.96	53	99.43	17	98.81	53	99.22	17	98.28	53	99.10	17	98.16	53	98.97
18	99.51	54	99.63	18	98.87	54	99.08	18	98.44	54	98.79	18	98.85	54	98.69
19	99.38	55	99.36	19	99.15	55	98.81	19	98.20	55	98.59	19	98.83	55	98.42
20	99.40	56	99.14	20	99.10	56	98.51	20	99.13	56	98.33	20	98.87	56	98.23
21	99.68	57	98.84	21	99.47	57	98.40	21	98.87	57	98.07	21	98.90	57	97.67
22	99.76	58	98.83	22	99.94	58	98.27	22	99.33	58	97.75	22	99.21	58	97.66
23	100.19	59	98.73	23	100.09	59	98.24	23	100.10	59	97.69	23	99.64	59	97.24
24	100.51	60	98.20	24	99.80	60	97.97	24	99.65	60	97.52	24	99.25	60	97.27
25	100.48	61	97.90	25	100.06	61	97.69	25	99.30	61	97.74	25	99.01	61	97.20
26	100.10	62	97.76	26	99.72	62	97.61	26	99.49	62	97.20	26	99.18	62	96.87
27	99.97	63	97.56	27	99.71	63	97.55	27	99.41	63	97.06	27	99.36	63	96.63
28	100.16	64	97.47	28	99.98	64	97.37	28	99.45	64	96.86	28	99.45	64	96.61
29	100.32	65	91.53	29	100.07	65	97.06	29	99.88	65	96.76	29	99.25	65	96.56
30	100.60	66	97.32	30	100.31	66	96.89	30	99.80	66	96.69	30	99.60	66	96.36
31	100.60	67	97.28	31	100.35	67	96.86	31	99.96	67	96.59	31	99.70	67	96.26
32	100.96	68	97.03	32	100.47	68	96.69	32	100.18	68	96.43	32	99.85	68	96.24
33	100.90	69	96.81	33	100.71	69	96.71	33	100.38	69	96.25	33	99.96	69	95.99
34	101.21	70	96.62	34	100.72	70	96.13	34	100.31	70	96.18	34	99.98	70	95.87
35	101.45	71	96.37	35	100.75	71	96.06	35	100.50	71	95.92	35	100.23	71	95.76
36	101.47	72	96.13	36	101.03	72	95.89	36	100.72	72	95.66	36	100.50	72	95.45

Table F-ctd.

Q 1	95.63	Q 37	99.99	R 1	95.32	R 37	99.82	S 1	94.83	S 37	99.48	T 1	94.43	T 37	99.35
2	95.59	38	100.23	2	95.20	38	99.80	2	95.23	38	99.56	2	94.77	38	99.39
3	95.57	39	100.26	3	95.54	39	99.96	3	95.30	39	99.60	3	95.33	39	99.43
4	95.22	40	100.10	4	95.78	40	99.79	4	95.45	40	99.65	4	95.40	40	99.32
5	96.33	41	100.16	5	96.09	41	99.82	5	95.63	41	99.39	5	95.14	41	99.09
6	96.40	42	100.11	6	96.16	42	99.74	6	95.75	42	99.39	6	95.59	42	96.94
7	96.37	43	100.36	7	96.05	43	99.66	7	96.07	43	99.38	7	95.83	43	98.90
8	96.55	44	100.09	8	96.73	44	100.01	8	96.16	44	99.62	8	76.79	44	99.04
9	97.00	45	99.83	9	96.13	45	99.72	9	96.23	45	99.63	9	95.75	45	99.15
10	97.44	46	99.87	10	96.50	46	99.83	10	96.44	46	99.64	10	95.80	46	99.36
11	96.63	47	99.40	11	97.83	47	99.12	11	96.25	47	99.09	11	95.03	47	99.34
12	96.95	48	99.21	12	97.01	48	98.99	12	96.60	48	98.95	12	96.17	48	98.91
13	97.20	49	98.81	13	97.59	49	98.67	13	96.58	49	98.57	13	96.20	49	98.41
14	97.46	50	98.65	14	98.60	50	98.69	14	96.93	50	98.23	14	–	50	98.10
15	97.63	51	98.97	15	97.69	51	98.24	15	97.50	51	98.00	15	96.79	51	97.78
16	98.16	52	98.85	16	98.04	52	98.11	16	97.30	52	97.81	16	97.13	52	97.59
17	98.51	53	98.76	17	98.14	53	98.21	17	97.10	53	97.66	17	96.81	53	97.36
18	98.42	54	98.54	18	98.05	54	98.23	18	97.08	54	97.55	18	96.92	54	92.10
19	98.82	55	98.32	19	98.03	55	98.22	19	97.38	55	97.67	19	97.22	55	97.34
20	98.30	56	97.80	20	98.09	56	97.84	20	97.48	56	97.60	20	97.26	56	97.13
21	98.08	57	97.87	21	98.07	57	97.61	21	97.73	57	97.22	21	98.01	57	97.04
22	98.73	58	97.67	22	98.19	58	97.45	22	98.21	58	97.05	22	97.63	58	96.62
23	99.24	59	97.40	23	98.85	59	97.59	23	98.27	59	96.71	23	97.48	59	96.41
24	98.85	60	97.03	24	98.52	60	96.45	24	98.09	60	96.62	24	97.61	60	96.33
25	98.70	61	96.85	25	98.41	61	96.60	25	98.21	61	96.45	25	97.79	61	96.17
26	98.99	62	96.23	26	98.70	62	96.31	26	98.39	62	96.00	26	98.03	62	96.07
27	99.33	63	96.53	27	98.82	63	96.13	27	97.81	63	95.92	27	98.01	63	95.71
28	99.20	64	96.32	28	98.83	64	95.97	28	98.15	64	95.73	28	98.10	64	95.46
29	99.30	65	96.18	29	99.01	65	95.78	29	98.25	65	95.43	29	98.08	65	95.26
30	99.22	66	96.15	30	98.88	66	95.81	30	98.39	66	95.42	30	98.11	66	95.10
31	99.47	67	95.92	31	98.88	67	95.77	31	98.48	67	95.47	31	98.29	67	95.07
32	99.43	68	95.70	32	99.08	68	95.56	32	98.79	68	95.22	32	98.32	68	94.85
33	99.58	69	95.78	33	99.32	69	95.42	33	99.13	69	95.20	33	98.87	69	94.91
34	99.76	70	95.55	34	99.78	70	95.09	34	99.30	70	95.10	34	99.11	70	94.98
35	99.95	71	95.59	35	99.72	71	95.16	35	99.39	71	95.00	35	99.21	71	95.01
36	100.09	72	95.26	36	99.71	72	95.16	36	99.36	72	94.86	36	99.34	72	94.92

Table F-ctd.

U 1	94.85	U 37	99.00	V 1	94.75	V 37	99.23	W 1	94.37	W 37	98.71	X 1	94.09	X 37	98.35
2	94.39	38	99.48	2	94.92	38	99.29	2	94.28	38	98.70	2	94.13	38	98.24
3	94.74	39	99.13	3	94.82	39	98.76	3	94.14	39	98.18	3	94.08	39	97.73
4	94.84	40	98.72	4	94.77	40	98.43	4	94.50	40	98.00	4	94.08	40	97.73
5	95.02	41	98.65	5	95.84	41	99.45	5	94.78	41	98.04	5	94.43	41	97.65
6	95.18	42	98.66	6	95.45	42	98.36	6	95.30	42	98.11	6	94.71	42	97.67
7	95.68	43	98.48	7	95.57	43	98.22	7	95.51	43	98.07	7	94.89	43	97.69
8	95.81	44	98.46	8	95.66	44	98.28	8	95.37	44	97.84	8	95.20	44	97.53
9	95.83	45	98.69	9	95.67	45	98.44	9	95.15	45	98.04	9	95.04	45	97.94
10	95.65	46	98.72	10	95.40	46	98.57	10	94.92	46	98.18	10	94.71	46	98.09
11	95.66	47	98.95	11	95.37	47	98.51	11	95.01	47	97.92	11	94.78	47	97.60
12	95.50	48	98.43	12	95.56	48	98.22	12	95.41	48	97.72	12	94.86	48	97.32
13	95.20	49	98.11	13	95.75	49	97.95	13	95.39	49	97.47	13	94.97	49	97.00
14	95.11	50	97.82	14	96.07	50	97.65	14	95.88	50	97.18	14	95.15	50	96.89
15	96.20	51	97.62	15	96.10	51	97.30	15	95.68	51	96.99	15	95.27	51	96.69
16	96.98	52	96.40	16	96.13	52	97.23	16	95.65	52	96.78	16	95.47	52	96.61
17	96.49	53	97.11	17	96.36	53	96.95	17	96.04	53	96.76	17	95.64	53	96.48
18	96.53	54	96.98	18	96.44	54	96.56	18	96.10	54	96.49	18	96.02	54	96.27
19	96.84	55	96.86	19	96.67	55	96.44	19	96.36	55	96.37	19	96.05	55	96.07
20	97.84	56	96.78	20	96.62	56	96.28	20	96.49	56	96.14	20	96.35	56	96.00
21	96.95	57	96.56	21	97.10	57	96.17	21	96.87	57	95.87	21	96.58	57	95.64
22	97.36	58	96.37	22	97.82	58	96.16	22	97.27	58	95.97	22	96.95	58	95.45
23	97.42	59	96.10	23	97.17	59	95.75	23	97.13	59	95.60	23	96.69	59	95.25
24	97.39	60	95.96	24	97.40	60	95.63	24	97.20	60	95.25	24	96.85	60	95.01
25	97.62	61	95.82	25	97.49	61	95.60	25	97.16	61	95.25	25	96.99	61	94.97
26	97.74	62	95.71	26	97.32	62	95.36	26	97.13	62	95.09	26	96.75	62	94.96
27	97.88	63	95.59	27	96.60	63	95.22	27	97.09	63	94.82	27	96.91	63	94.61
28	97.80	64	95.22	28	97.61	64	95.02	28	97.16	64	94.65	28	96.96	64	94.23
29	97.79	65	94.77	29	97.55	65	94.90	29	97.39	65	94.68	29	97.31	65	94.09
30	97.99	66	94.83	30	98.02	66	94.42	30	97.83	66	94.31	30	97.46	66	93.98
31	97.89	67	94.60	31	97.97	67	94.29	31	97.80	67	94.08	31	97.38	67	93.82
32	98.13	68	94.56	32	98.27	68	94.14	32	97.98	68	93.79	32	97.74	68	93.68
33	98.46	69	94.45	33	98.36	69	94.02	33	98.15	69	93.75	33	97.75	69	93.44
34	98.74	70	94.47	34	98.73	70	94.16	34	98.29	70	93.59	34	98.07	70	93.29
35	98.82	71	94.66	35	98.51	71	94.24	35	98.48	71	93.92	35	98.03	71	93.48
36	98.80	72	94.76	36	98.98	72	96.36	36	98.62	72	94.04	36	97.99	72	93.22

Table F-ctd.

Y 1	93.64	Y 37	97.70	Z 1	93.06	Z 37	97.14	a 1	92.44	a 37	96.66	b 1	92.20	b 37	96.32
2	93.19	38	97.89	2	92.75	38	97.41	2	92.41	38	96.59	2	92.07	38	96.14
3	93.35	39	97.19	3	92.86	39	97.07	3	92.60	39	96.65	3	92.27	39	96.12
4	93.87	40	97.36	4	93.22	40	96.99	4	92.75	40	96.51	4	92.70	40	96.08
5	94.12	41	97.44	5	93.44	41	97.05	5	93.21	41	96.64	5	92.64	41	96.15
6	94.37	42	97.36	6	93.94	42	97.03	6	93.28	42	96.55	6	93.12	42	96.08
7	94.62	43	97.20	7	94.24	43	96.80	7	93.90	43	96.50	7	93.27	43	96.03
8	94.92	44	97.18	8	94.35	44	96.70	8	94.13	44	96.40	8	93.56	44	96.02
9	95.03	45	97.17	9	94.40	45	96.78	9	94.14	45	96.24	9	93.80	45	95.93
10	94.73	46	97.11	10	94.22	46	96.69	10	93.94	46	96.25	10	93.71	46	95.96
11	94.53	47	96.86	11	94.43	47	96.61	11	93.97	47	96.31	11	93.73	47	95.88
12	94.56	48	96.86	12	94.11	48	96.58	12	94.05	48	96.23	12	93.92	48	95.68
13	94.79	49	96.64	13	94.43	49	96.32	13	94.27	49	96.05	13	94.03	49	95.55
14	94.82	50	96.53	14	94.57	50	96.20	14	94.27	50	95.96	14	93.75	50	95.74
15	94.98	51	96.37	15	94.67	51	96.78	15	94.29	51	95.83	15	93.92	51	95.59
16	95.33	52	96.33	16	94.71	52	96.08	16	94.44	52	95.65	16	94.21	52	95.45
17	95.73	53	96.20	17	94.98	53	95.88	17	94.68	53	95.64	17	94.41	53	95.20
18	85.76	54	96.07	18	95.12	54	95.63	18	94.04	54	95.54	18	94.75	54	95.09
19	95.85	55	95.72	19	95.48	55	95.50	19	95.02	55	95.18	19	94.74	55	95.17
20	95.80	56	95.65	20	95.81	56	95.37	20	95.39	56	95.11	20	95.31	56	95.80
21	96.20	57	95.49	21	96.16	57	95.33	21	95.55	57	95.01	21	95.38	57	94.51
22	96.29	58	95.19	22	96.01	58	95.06	22	95.88	58	94.74	22	95.58	58	94.41
23	96.44	59	95.04	23	96.11	59	94.72	23	95.92	59	94.36	23	95.67	59	94.23
24	96.39	60	94.74	24	96.07	60	94.59	24	95.64	60	94.31	24	95.40	60	93.97
25	96.69	61	94.57	25	96.31	61	94.27	25	95.97	61	94.06	25	95.39	61	93.70
26	96.79	62	94.86	26	96.33	62	94.28	26	96.04	62	93.94	26	96.11	62	93.63
27	96.68	63	94.69	27	94.34	63	94.10	27	96.17	63	93.81	27	95.53	63	93.57
28	96.37	64	94.10	28	96.67	64	93.79	28	96.43	64	93.58	28	96.24	64	93.25
29	97.28	65	93.69	29	96.85	65	93.64	29	96.46	65	93.37	29	96.15	65	93.28
30	97.13	66	93.58	30	96.89	66	93.19	30	96.59	66	93.67	30	96.26	66	93.02
31	97.10	67	93.61	31	96.92	67	93.26	31	96.45	67	93.07	31	96.02	67	92.69
32	97.13	68	93.39	32	97.02	68	93.13	32	96.57	68	92.93	32	96.20	68	92.75
33	97.55	69	93.17	33	97.12	69	93.05	33	96.59	69	92.90	33	96.42	69	92.47
34	97.65	70	93.09	34	97.30	70	92.90	34	96.89	70	92.61	34	96.40	70	92.56
35	97.65	71	93.14	35	97.30	71	92.81	35	96.89	71	92.57	35	98.47	71	92.46
36	97.58	72	93.34	36	97.22	72	92.69	36	96.87	72	92.56	36	96.44	72	92.07

Table F-ctd.

c 1	91.82	c 37	95.86	d 1	91.64	d 37	95.59	e 1	91.22	e 37	95.20	f 1	91.04	f 37	94.87
2	91.85	38	95.87	2	91.58	38	95.57	2	91.44	38	96.04	2	91.09	38	94.72
3	92.04	39	95.81	3	91.88	39	95.40	3	91.50	39	95.06	3	91.41	39	94.66
4	92.27	40	95.73	4	91.95	40	95.23	4	91.90	40	94.87	4	91.52	40	94.69
5	92.69	41	95.65	5	92.24	41	95.32	5	92.11	41	94.81	5	91.92	41	94.59
6	93.15	42	95.73	6	92.54	42	95.28	6	92.41	42	94.74	6	92.23	42	94.49
7	92.97	43	95.81	7	93.75	43	95.36	7	92.66	43	94.92	7	92.46	43	94.50
8	93.32	44	95.65	8	93.01	44	95.30	8	92.95	44	95.01	8	92.68	44	94.57
9	93.48	45	95.66	9	93.28	45	95.46	9	93.21	45	95.08	9	92.90	45	94.67
10	93.33	46	95.70	10	93.33	46	95.48	10	92.98	46	94.99	10	92.85	46	94.72
11	93.50	47	95.71	11	93.42	47	95.61	11	93.04	47	95.16	11	92.92	47	94.65
12	93.52	48	95.59	12	93.33	48	95.33	12	93.07	48	95.04	12	92.82	48	94.67
13	93.55	49	95.56	13	93.35	49	95.53	13	93.06	49	95.28	13	92.81	49	94.77
14	93.56	50	95.56	14	93.38	50	85.38	14	93.07	50	95.15	14	92.70	50	94.87
15	93.64	51	95.46	15	93.45	51	95.48	15	93.13	51	94.97	15	92.77	51	94.72
16	93.75	52	95.49	16	93.55	52	95.35	16	93.20	52	95.27	16	92.91	52	95.09
17	94.17	53	95.22	17	94.06	53	95.08	17	93.77	53	95.13	17	93.15	53	95.08
18	94.15	54	95.14	18	94.12	54	94.85	18	93.63	54	94.94	18	93.40	54	94.56
19	94.58	55	94.95	19	94.77	55	94.84	19	84.87	55	94.58	19	93.63	55	94.37
20	94.78	56	94.86	20	94.61	56	94.68	20	94.14	56	94.43	20	93.74	56	94.24
21	94.95	57	94.67	21	94.76	57	94.41	21	94.28	57	94.35	21	94.01	57	94.00
22	94.95	58	94.40	22	94.93	58	94.05	22	94.59	58	93.91	22	94.17	58	93.63
23	95.30	59	94.20	23	95.04	59	93.92	23	94.54	59	93.59	23	94.18	59	93.44
24	95.12	60	94.11	24	94.85	60	93.83	24	94.64	60	93.62	24	94.46	60	93.45
25	95.44	61	93.63	25	95.12	61	93.76	25	93.76	61	93.34	25	94.60	61	93.13
26	95.48	62	93.29	26	95.31	62	93.63	26	94.91	62	93.04	26	94.71	62	92.96
27	95.62	63	93.30	27	95.78	63	93.47	27	95.02	63	92.92	27	94.65	63	92.75
28	95.62	64	93.05	28	95.29	64	93.27	28	95.07	64	92.74	28	94.54	64	92.55
29	95.86	65	92.97	29	95.46	65	92.89	29	95.70	65	92.46	29	95.10	65	92.30
30	95.58	66	92.95	30	95.39	66	92.61	30	95.04	66	92.43	30	94.54	66	92.19
31	95.64	67	92.81	31	95.30	67	92.56	31	94.93	67	92.27	31	94.52	67	92.03
32	95.92	68	92.63	32	95.56	68	92.45	32	95.30	68	92.08	32	95.01	68	91.81
33	96.30	69	92.51	33	95.76	69	92.24	33	95.41	69	91.98	33	95.07	69	91.63
34	95.04	70	92.39	34	95.74	70	92.04	34	95.29	70	91.71	34	95.70	70	91.92
35	96.09	71	92.36	35	95.64	71	92.04	35	95.42	71	91.78	35	96.04	71	91.55
36	96.13	72	92.12	36	95.82	72	91.94	36	95.72	72	91.65	36	95.36	72	91.45

Table F-ctd.

g 1	90.86	g 37	94.72	h 1	90.82	h 37	94.21	i 1	90.90	i 37	93.94	j 1	90.55	j 37	93.78
2	91.02	38	94.50	2	90.94	38	94.23	2	90.83	38	93.80	2	90.70	38	93.55
3	91.31	39	94.13	3	91.20	39	94.01	3	91.05	39	93.78	3	91.00	39	93.42
4	91.63	40	94.25	4	91.47	40	93.89	4	91.24	40	93.64	4	91.24	40	93.29
5	92.27	41	94.18	5	91.57	41	93.93	5	91.63	41	93.56	5	91.21	41	93.22
6	92.05	42	94.14	6	91.93	42	93.98	6	91.59	42	93.53	6	91.39	42	93.13
7	92.24	43	94.25	7	91.51	43	93.88	7	91.88	43	93.43	7	91.53	43	93.16
8	92.43	44	94.20	8	92.10	44	93.87	8	91.97	44	93.45	8	91.65	44	93.19
9	92.50	45	94.29	9	92.19	45	93.90	9	91.86	45	93.39	9	91.70	45	92.97
10	92.54	46	94.20	10	92.10	46	94.00	10	91.99	46	93.49	10	91.56	46	93.05
11	92.47	47	94.23	11	91.94	47	94.01	11	91.93	47	93.59	11	91.57	47	93.11
12	92.45	48	94.27	12	91.81	48	93.98	12	91.90	48	93.43	12	91.59	48	93.35
13	92.57	49	94.23	13	92.00	49	93.98	13	92.12	49	93.69	13	91.59	49	93.55
14	92.42	50	94.47	14	92.00	50	94.09	14	91.86	50	93.78	14	91.70	50	93.56
15	92.52	51	94.40	15	92.25	51	94.08	15	91.99	51	93.80	15	91.76	51	93.51
16	92.57	52	94.54	16	92.27	52	94.26	16	92.05	52	93.91	16	91.75	52	93.33
17	92.97	53	94.78	17	92.56	53	94.13	17	92.28	53	93.81	17	91.94	53	93.48
18	92.90	54	94.45	18	92.73	54	94.28	18	92.38	54	93.95	18	91.95	54	93.79
19	93.16	55	94.19	19	93.05	55	94.16	19	92.46	55	93.86	19	92.37	55	93.81
20	93.21	56	93.95	20	92.95	56	93.92	20	92.68	56	93.84	20	92.35	56	93.45
21	94.34	57	93.88	21	93.25	57	93.54	21	93.03	57	93.51	21	93.97	57	93.36
22	94.12	58	93.58	22	93.43	58	93.49	22	93.40	58	93.26	22	92.97	58	93.30
23	94.01	59	93.36	23	93.71	59	93.37	23	93.89	59	93.21	23	93.10	59	92.69
24	94.23	60	93.16	24	93.90	60	92.94	24	93.68	60	92.83	24	93.24	60	92.89
25	94.42	61	92.92	25	94.22	61	92.83	25	93.72	61	92.59	25	93.74	61	92.66
26	94.43	62	92.80	26	93.92	62	92.51	26	93.76	62	92.52	26	93.35	62	92.39
27	94.41	63	92.56	27	94.15	63	92.52	27	93.85	63	92.46	27	93.89	63	92.18
28	94.53	64	92.35	28	94.19	64	92.21	28	93.93	64	91.95	28	93.61	64	92.93
29	94.32	65	92.73	29	94.11	65	91.88	29	93.51	65	91.88	29	93.17	65	91.61
30	94.32	66	91.89	30	94.07	66	91.65	30	93.80	66	91.47	30	93.17	66	91.25
31	94.17	67	91.68	31	93.59	67	91.43	31	93.33	67	91.29	31	92.95	67	91.17
32	94.21	68	91.56	32	93.90	68	91.27	32	93.58	68	91.08	32	93.17	68	91.54
33	94.55	69	91.23	33	94.09	69	91.09	33	93.81	69	90.40	33	93.45	69	90.74
34	94.72	70	91.36	34	94.33	70	91.10	34	94.11	70	90.87	34	93.68	70	90.69
35	94.87	71	91.35	35	94.19	71	91.18	35	93.90	71	91.25	35	93.55	71	90.67
36	94.94	72	91.24	36	94.25	72	91.02	36	94.08	72	91.14	36	93.75	72	90.62

Table F-ctd.

k 1	90.50	k 37	93.56	l 1	90.35	l 37	95.53	m 1	90.29	m 37	93.44	n 1	89.89	n 37	93.28
2	90.54	38	93.43	2	90.49	38	93.19	2	89.97	38	93.19	2	89.97	38	93.17
3	90.64	39	93.29	3	90.62	39	92.97	3	90.27	39	92.79	3	90.27	39	92.81
4	90.96	40	93.03	4	90.69	40	92.72	4	90.26	40	92.63	4	90.26	40	92.43
5	90.13	41	92.78	5	90.88	41	92.51	5	90.26	41	92.26	5	90.26	41	91.90
6	91.21	42	92.82	6	90.94	42	92.46	6	90.30	42	92.10	6	90.30	42	91.75
7	91.26	43	92.74	7	90.95	43	92.43	7	90.57	43	91.93	7	90.57	43	91.67
8	91.49	44	92.89	8	91.26	44	92.30	8	90.57	44	91.91	8	90.57	44	91.67
9	91.32	45	92.69	9	91.03	45	92.36	9	90.48	45	92.07	9	90.48	45	91.74
10	91.12	46	92.63	10	90.93	46	92.51	10	90.57	46	92.01	10	90.57	46	91.81
11	90.92	47	92.81	11	91.60	47	91.60	11	90.38	47	92.35	11	90.38	47	92.10
12	90.97	48	93.21	12	90.92	48	93.02	12	90.55	48	92.69	12	90.33	48	92.39
13	91.26	49	93.32	13	91.02	49	92.98	13	90.38	49	92.77	13	90.39	49	92.56
14	91.42	50	93.21	14	91.13	50	92.92	14	90.55	50	92.68	14	90.55	50	92.51
15	91.42	51	93.15	15	91.14	51	92.95	15	90.89	51	92.57	15	90.56	51	92.36
16	91.36	52	93.24	16	91.00	52	92.89	16	90.66	52	92.58	16	90.49	52	92.43
17	92.45	53	93.21	17	91.12	53	93.03	17	90.85	53	93.03	17	90.70	53	92.88
18	91.77	54	93.81	18	91.39	54	93.56	18	91.22	54	93.37	18	90.83	54	93.15
19	92.00	55	93.55	19	91.63	55	93.35	19	91.09	55	92.82	19	90.75	55	92.61
20	91.98	56	93.33	20	91.66	56	92.93	20	91.11	56	92.66	20	90.81	56	92.26
21	92.74	57	93.09	21	91.79	57	92.81	21	91.53	57	92.42	21	91.00	57	92.27
22	92.44	58	93.00	22	92.31	58	92.86	22	91.39	58	92.43	22	91.23	58	91.92
23	92.59	59	92.42	23	92.28	59	92.37	23	91.88	59	92.19	23	91.41	59	92.04
24	92.91	60	92.65	24	92.49	60	92.35	24	92.08	60	91.82	24	90.90	60	91.45
25	93.03	61	92.71	25	92.69	61	92.21	25	92.37	61	92.15	25	92.21	61	91.39
26	93.07	62	92.43	26	92.81	62	92.89	26	91.85	62	91.89	26	92.17	62	91.50
27	93.70	63	92.06	27	-	63	91.80	27	92.88	63	91.59	27	92.49	63	91.31
28	95.31	64	91.72	28	92.71	64	91.43	28	92.54	64	91.20	28	92.06	64	91.00
29	92.88	65	94.44	29	92.45	65	91.18	29	92.23	65	90.92	29	92.02	65	90.85
30	92.72	66	91.10	30	92.44	66	90.96	30	92.29	66	90.82	30	91.88	66	89.96
31	92.81	67	91.00	31	92.36	67	90.85	31	92.20	67	90.63	31	91.98	67	90.56
32	92.90	68	90.78	32	92.56	68	90.67	32	92.47	68	90.48	32	92.79	68	90.27
33	92.96	69	90.62	33	93.05	69	90.56	33	92.79	69	90.38	33	92.80	69	90.04
34	93.21	70	90.40	34	93.11	70	90.33	34	93.04	70	90.02	34	93.14	70	89.87
35	93.37	71	90.38	35	93.30	71	90.18	35	93.38	71	89.89	35	93.53	71	89.57
36	93.57	72	90.40	36	93.44	72	90.08	36	93.64	72	89.86	36	93.51	72	89.68

Table F-ctd.

o 1	89.63	o 37	92.25	p 1	89.29	p 37	93.08	q 1	89.09	q 37	93.05	r 1	88.84	r 37	92.74
2	89.76	38	92.94	2	89.50	38	92.85	2	89.06	38	92.70	2	88.97	38	92.44
3	89.98	39	92.69	3	89.52	39	92.47	3	89.46	39	92.41	3	89.11	39	92.14
4	89.99	40	92.23	4	89.57	40	92.05	4	89.54	40	91.98	4	89.24	40	91.72
5	89.95	41	91.88	5	89.77	41	91.69	5	89.38	41	91.41	5	89.13	41	91.16
6	89.89	42	91.56	6	89.77	42	91.25	6	89.53	42	90.94	6	89.25	42	90.61
7	90.10	43	91.47	7	90.24	43	91.19	7	89.65	43	90.69	7	89.37	43	90.39
8	90.18	44	91.33	8	89.87	44	91.07	8	89.88	44	90.73	8	89.49	44	90.40
9	90.23	45	91.42	9	89.81	45	91.10	9	89.58	45	90.75	9	89.51	45	90.55
10	90.06	46	91.58	10	90.03	46	91.21	10	89.54	46	90.77	10	89.23	46	90.44
11	90.50	47	91.79	11	89.75	47	91.33	11	89.57	47	91.89	11	89.19	47	90.54
12	90.50	48	92.20	12	89.79	48	91.76	12	89.43	48	91.42	12	89.22	48	91.15
13	90.05	49	92.38	13	89.89	49	92.13	13	89.54	49	91.38	13	89.24	49	91.48
14	90.17	50	92.34	14	89.92	50	92.01	14	89.63	50	91.74	14	89.33	50	91.49
15	90.23	51	92.21	15	89.89	51	91.76	15	89.69	51	91.75	15	89.38	51	91.56
16	90.18	52	92.40	16	89.95	52	92.03	16	89.65	52	91.90	16	89.22	52	91.42
17	90.62	53	92.54	17	90.04	53	92.04	17	89.71	53	91.69	17	89.33	53	91.29
18	90.28	54	92.57	18	90.07	54	92.07	18	89.68	54	91.73	18	89.70	54	91.38
19	90.36	55	92.46	19	90.05	55	92.20	19	89.77	55	91.99	19	89.29	55	91.59
20	90.36	56	92.14	20	90.03	56	91.75	20	89.69	56	91.49	20	89.69	56	91.13
21	90.65	57	91.84	21	90.28	57	91.55	21	90.27	57	91.21	21	89.93	57	90.75
22	91.04	58	91.57	22	90.99	58	91.52	22	90.54	58	91.13	22	90.23	58	90.89
23	91.20	59	91.59	23	91.06	59	91.29	23	90.71	59	91.04	23	90.30	59	90.85
24	91.35	60	91.50	24	91.43	60	91.25	24	90.79	60	90.86	24	90.56	60	90.60
25	92.35	61	91.15	25	91.07	61	90.78	25	90.91	61	90.86	25	90.60	61	90.18
26	91.83	62	91.25	26	91.47	62	90.91	26	91.00	62	90.31	26	90.65	62	90.18
27	92.00	63	91.05	27	91.49	63	90.75	27	90.97	63	90.24	27	90.90	63	89.12
28	91.72	64	90.75	28	91.50	64	90.42	28	91.33	64	90.01	28	91.30	64	89.92
29	91.75	65	90.62	29	91.56	65	90.41	29	91.23	65	90.01	29	91.02	65	89.66
30	91.84	66	90.46	30	91.59	66	90.42	30	91.57	66	90.18	30	91.42	66	91.57
31	92.14	67	90.50	31	92.06	67	90.32	31	91.86	67	90.28	31	91.77	67	90.23
32	92.33	68	90.28	32	92.29	68	90.16	32	92.33	68	90.11	32	92.26	68	90.08
33	92.65	69	89.90	33	92.53	69	89.82	33	92.86	69	89.87	33	92.79	69	89.85
34	93.62	70	89.56	34	95.07	70	89.65	34	93.19	70	89.61	34	93.12	70	89.68
35	93.43	71	89.24	35	93.31	71	89.77	35	93.15	71	89.33	35	93.01	71	89.46
36	93.44	72	89.44	36	93.32	72	89.10	36	93.18	72	89.06	36	93.03	72	89.00

Table F-ctd.

s1	88.64	s37	92.50	1	37	1	37	1	37
2	88.88	38	92.23	2	38	2	38	2	38
3	89.08	39	91.97	3	39	3	39	3	39
4	88.99	40	91.43	4	40	4	40	4	40
5	89.02	41	90.98	5	41	5	41	5	41
6	88.93	42	90.56	6	42	6	42	6	42
7	89.01	43	90.10	7	43	7	43	7	43
8	89.26	44	90.03	8	44	8	44	8	44
9	89.18	45	90.17	9	45	9	45	9	45
10	88.99	46	90.25	10	46	10	46	10	46
11	89.02	47	90.27	11	47	11	47	11	47
12	89.04	48	90.69	12	48	12	48	12	48
13	88.73	49	91.06	13	49	13	49	13	49
14	88.92	50	91.11	14	50	14	50	14	50
15	88.89	51	91.31	15	51	15	51	15	51
16	88.71	52	91.02	16	52	16	52	16	52
17	88.91	53	91.74	17	53	17	53	17	53
18	88.95	54	90.87	18	54	18	54	18	54
19	89.18	55	90.96	19	55	19	55	19	55
20	89.32	56	90.72	20	56	20	56	20	56
21	89.56	57	90.47	21	57	21	57	21	57
22	89.83	58	90.33	22	58	22	58	22	58
23	90.60	59	90.36	23	59	23	59	23	59
24	90.20	60	90.26	24	60	24	60	24	60
25	90.31	61	89.89	25	61	25	61	25	61
26	90.35	62	89.71	26	62	26	62	26	62
27	90.49	63	89.42	27	63	27	63	27	63
28	90.57	64	89.36	28	64	28	64	28	64
29	99.97	65	89.25	29	65	29	65	29	65
30	91.16	66	89.33	30	66	30	66	30	66
31	92.67	67	89.55	31	67	31	67	31	67
32	92.74	68	89.72	32	68	32	68	32	68
33	92.53	69	89.67	33	69	33	69	33	69
34	92.83	70	89.58	34	70	34	70	34	70
35	92.80	71	89.36	35	71	35	71	35	71
36	92.76	72	89.16	36	72	36	72	36	72

APPENDIX 5

SOIL MOISTURE CALIBRATION CURVES

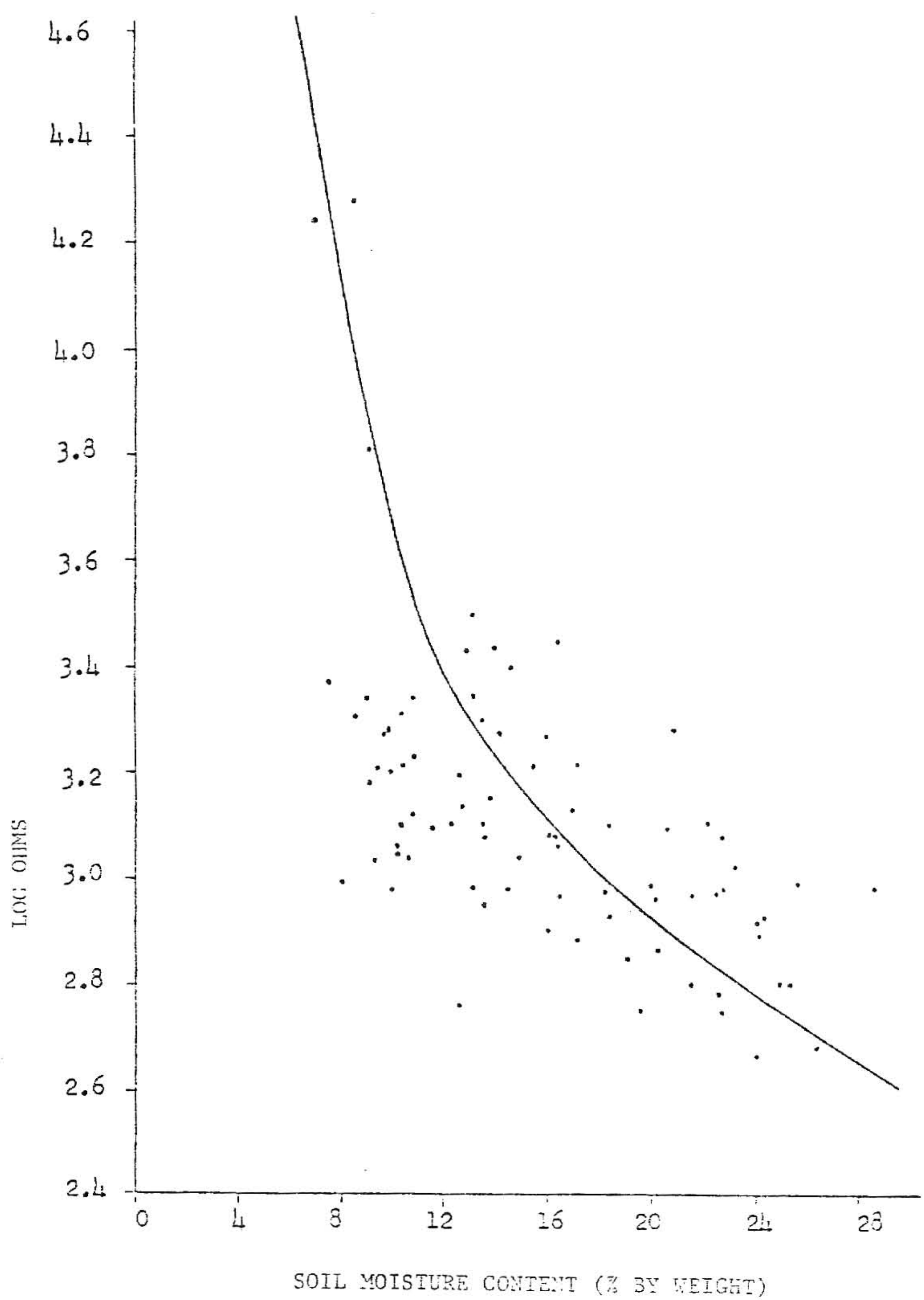


Fig. C-Gypsum block resistance vs soil moisture content for Plot 38.

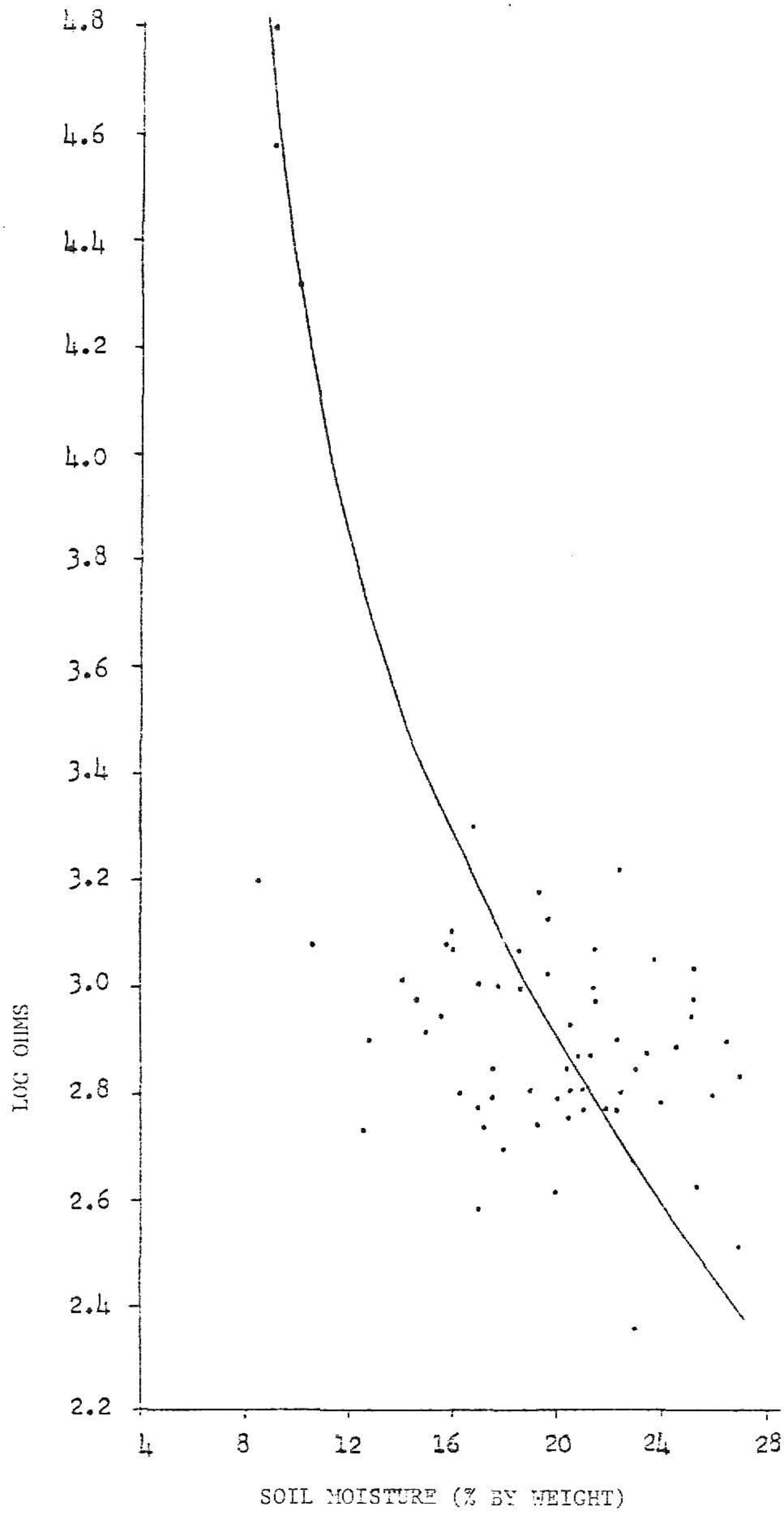


Fig. D-Gypsum block resistance vs soil moisture content for Plot C10.

APPENDIX 6

NEEDED EQUIPMENT, MACHINERY, AND TOOLS

A. DEVELOPMENT EQUIPMENT

1 scraper 4 - 6 yd^3 (3·1 - 4·6 m^3)-tandem earth moving

1 D5-caterpillar

1 tractor with loader and back hoe

1 grader with 8 ft. (2.4 m)-blade (motorized)

2 2½-ton dump trucks

1 40 ft. (12.2 m)—land plane

2 100-hp tractors

2 back fill blades with remote cylinders

2 pick up trucks

1 motor cycle

2 five-ton blocks and tackle with tripods

spare parts for the above machines (30% of the equipment cost).

B. (i) STATION MACHINERY

2 100-hp tractors

4 60-hp tractors

2 40-hp tractors

2 garden tractors

2 front mounted (2-row) cultivators with fertilizer attachment

1 4-disc reversible disc plows (Ransome)

1 spring chisel tiller

2 rear mounted cultivators (two-row)

1 single-row small grain harvester

1 single-row maize harvester

6 knapsack sprayers

4 pipe trailers

2 flail choppers

2 rotary slashers

2 fertilizer broadcasters

2 double shank subsoilers

2 rotary hoes

2 chisel plows

2 bed formers and 1 bedder

1 MF three point hitch disc harrow (22 discs front disc serrated)

1 MF three point hitch disc harrow (18 discs front disc serrated)

3 rear mounted boom sprayers

3 pickups

spare parts (20% of the purchase price).

(ii) IRRIGATION EQUIPMENT

48 200-mm Waterman alfalfa valves

600 m of 150-mm aluminum gated pipe with gates at 75 cm intervals

100 m of 150-mm blind aluminum pipe

48 rubber seals for 150 mm pipe

6 200-mm waterman hydrants with outlet for 150 mm gated pipe

12 150-mm U clips

1 400-mm mainline valve

4 250-mm mainline valves

8 200-mm mainline valves

2,500 m 300-mm reinforced concrete pipe

2,000 m 200-mm reinforced concrete pipe

2 30-hp portable pumps (diesel engine driven).

(iii) WORKSHOP

(a) EQUIPMENT

1. compressor 0 - 200 psi (14.1 kg cm^{-2})
2. bucket type grease gun
3. electrical welding outfit 0-250 amp plus safety equipment
4. Oxy-acetylene set and goggles

5. electrical grinder wheels (2)
6. engine hoist or sling
7. air painting outfit
8. battery charger
9. floor jacks (5-8 ton) (2)
10. work benches with vises
11. hydraulic press (20 ton)
12. lathe
13. drill press (½" or 12.7-mm drill)
14. sheet bending and cutting machine
15. portable grinder
16. tire removal equipment
17. equipment for making hydraulic hose repair.

(b) TOOLS

1. timing light (1)
2. vaccuum tester (1)
3. injector tester (1)
4. sleeve puller (1)
5. hydraulic press tester (1)
6. tachometer (1)
7. torque wrench (1)
8. feeler gages (mm and in. standards) -4
9. one set of pulley extractors
10. one set of drills (mm sizes)
11. one set of drills (in. standards)
12. 2 hacksaws and spare blades
13. one set large socket wrenches
14. one set medium socket wrenches
15. complete set box spanners and air wrenches (mm and in.

standards)

16. complete set open ended spanners (mm and in. standards)
17. complete set combination spanners (mm and in. standards)
18. complete set flat screw drivers
19. complete set phillips screw drivers
20. complete set pin punches
21. set cold chisels
22. set extractors
23. complete set taps and dies for bolts
24. one set tube bending, cutting, and flaring set
25. one set valve spring removers
26. set of various hammers
27. two battery testers
28. two diode testers
29. one set piston ring installers
30. one set tire levers
31. puncture repair outfits
32. 3 tire gauges wet/dry
33. 5 jacks (1½-2 tons) and 10 stands
34. sign making equipment
35. selection of pliers
36. one set internal and external calipers
37. selection of files
38. compression tester
39. brake adjusting spanners (2)
40. tin snips (3)
41. measuring tapes (3) - 50 and 100 m
42. extension cords (2)
43. inspection lamps (2)

44. portable electric hand drills

    heavy duty (1)

    medium (1)

    light (1)

45. micrometers (2), internal and external

46. snap ring removers (2)

47. voltmeter (1)

    (a) inward

    (b) outward

48. Amp meter.

(c) OTHERS

Wood work equipment

1. power driven planer

2. power driven table saw

3. hand tools

    -saws

    -planes

    -nail hammers

    -chisels

    -oil stoves

    -wood files

4. benches with vises

Plumbing equipment

1. set of pipe wrenches

2. pipe vises (2)

3. pipe cutting tools (2)

4. pipe threading tool (with complete set of dies)

A selection of field and garden hand tools.

APPENDIX 7

DEVELOPMENT AND FUTURE OPERATIONAL STAFF

Chief Engineer

Admin. Asst. -1	Farm Development Sr. Engineer -1	Farm Operations Sr. Engineer -1	Engineering Services Sr. Engineer -1	Physical Plant Services Sr. Engineer -1
Supplies & Purchasing Asst. -1	Farm Development Engineer -1	Sr. Equipment Operators -5	Sr. Mechanics -1 Mechanics -4	Plumber -2
	Surveyor -1	Operators -6	Welder -1	Electrician -1
	Sr. Equipment Operators (Sr. E.D.) -3	Irrigators -10 (labor)	Machinist -1	Carpenter -2
	Equipment Operator -8	Asst. Plant Protection -2 (labor) Protection	Tire Repair Mechanic -1	Asst. Supervisor -1
	Mason -1	Asst. Processing Operation -2 (labor)	Asst. Mechanics -2	Labor -
	Rod Man -1			
	Labor -	Asst. Weeding -2 Operation (labor)	Workshop Asst. -4	
	16	28	15	7

Sr. = Senior

DEVELOPMENT OF NEW RESEARCH SITE ON THE ILONGA AGRICULTURAL EXPERIMENT STATION, KILOSA, TANZANIA

by

ERASTO ELISONGUO MLAY

B. S., University of Dar-es-Salaam, 1977

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1981

Experiment station development is an essential part of research programs. In the past developing countries have overlooked this fact. The outcome was poor and inconsistent results which were often difficult to interpret. In recent years many of the developing nations, including Tanzania, have initiated station development programs in order to improve the quality of agricultural research work. This has been necessary because of the need to increase agricultural production to meet the rapidly growing demand for farm products.

This paper describes the important facts to consider when developing a new research station, or improving an existing one, with particular reference to Ilonga Research Station (Tanzania). The station is to become the center for food crops research. The new facility is intended to cater for six major crops - grain legumes, maize, sorghums, and others to be named later. The improvement program is the first of its kind in Tanzania. The other research stations may be improved similarly but later, as finance is limited at present. The decision to initiate the program at Ilonga was favored because of its good climate, fairly uniform and rich soils, suitable topography, and central location within a large area which has good potential for agricultural expansion.

The climate, soils, and topography of the Ilonga Station are described and their suitability for research work pointed out. Other matters discussed include proposed plot area, layout and preparation, irrigation requirements and potential, needed physical facilities, research administration, equipment and labor needs, development timetable and budget, station management setup, field staff training, and staff welfare needs.