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REPORT OF THE 1992 ANNUAL MEETING

ON

AFRICALAND
Management of Vertisols in Africa

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11-13 June 1992

IBSRAM
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Variability in soil and climatic conditions in IBSRAM's Vertisol network sites in Africa

HARI ESWARAN and PAUL REICH*

In the semiarid tropics, climate is perhaps the most important component controlling crop performance. The IBSRAM African Vertisol network, with seven sites on the same kind of soil, has had the opportunity of evaluating the role of climate in soil management. An analysis of the soil moisture regimes at each of the sites is presented to show the climatic differences between the sites, and the need to design cropping systems according to the climatic conditions.

A second important factor which controls crop performance is the soil, and specifically the microvariability of the soil. Vertisols are extremely variable, and this should be borne in mind when designing field experiments. Examples of variability and methods of evaluating it are presented. The full potential of a network is only realized when each component is well characterized, using similar methods, and when the performance of each site is compared with that of the others.

An agricultural research network comprises a number of sites located in similar or different agroenvironments, with each working on a similar theme. The network members usually have a set of core experiments which are designed to test a hypothesis in the different environments, and experiments designed to address constraints specific to that environment. The advantages of a network mode of research is that each participant benefits from the information generated by the others, and each of course contributes to the total effort.

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The IBSRAM network on the management of Vertisols in Africa has now approached a stage where some initial comparisons can be made between sites. Each site is at a different stage of development, and so will have different kinds of results. However, most sites have information on the resource base, and in the near future it would be useful to collate all this information and analyze it. Such an analysis would help to explain some of the differences between sites, and would also provide an assessment of the heterogeneity of the network. This will dispel the notion that all Vertisols are the same and should be expected to respond similarly.

The purpose of this presentation is first to illustrate some agroclimatic differences between the sites, and secondly to show an example of micro-variability at a site

Agroclimatic variations

Information about soil moisture and temperature regimes (SMR and STR) for land use and for other applications of climatic data is just as useful as information about air temperature and rainfall. SMRs and STRs are studied by meteorologists, climatologists, ecologists, agronomists, soil scientists, civil engineers, farmers, and many others who use soils. Both the SMR and STR affect physical, chemical and biological processes in soils. The growth, multiplication, and activities of soil-borne organisms are influenced by soil climate. Seed germination is determined by both the availability of adequate moisture and by the limited range of soil temperature. Soil temperatures above or below critical limits severely inhibit seed germination, even if there is adequate soil moisture. The life-cycles of many soil-borne pests and diseases are dictated by the SMR and the STR.

The soil is a kind of buffering system. When rain falls on the soil, the moisture is absorbed by soil aggregates and is retained. Excess water is either lost through runoff or drained away. If there are impermeable layers in the soil and there is no water discharge out of the soil, the water accumulates and a water table develops in the soil. For some uses, such as growing rice, a water table maintains a water-saturated media in the rooting zone, and this is a useful property of the soil. But for most other uses, such as the use of the soil as a septic-tank filter, excess water is a constraint. In soils with a deep water table or no water table, when rain stops, the soil may still have water for the plants; so if the dry spell is short, the soil enables the plant to survive until the next rains. This buffering capacity of the soil is a basic reason for evaluating soil moisture and temperature conditions.

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Soils also buffer temperature. The soil temperature at 100 cm or more is relatively constant throughout the year. In fact the easiest way to obtain a good measurement of the mean annual soil temperature is to measure the temperature of well water at any time of the year.

The temperature of the top few centimetres of the soil fluctuates considerably during the year. The surface soil can get very hot or very cold. In the dry tropics, surface soil temperatures of more than 50°C have been measured, and at this temperature many plant tissues are killed. When the surface soil temperature is very low, uptake of mineral nutrients is significantly reduced. In the cold regions of the world, where the surface soil temperature remains at about 1°C for long periods, the trees are dwarfed, and if it gets much colder plants do not grow at all. The day-night (diurnal) fluctuations in soil temperature is maximum at the soil surface and decreases with depth, reaching a minimum at 50 cm or more. Many rodents burrow to 1-m depth, where it is much warmer than on the soil surface. Some desert lizards and beetles stand on their feet during the early morning so that the morning dew condenses on their body and provides them with life-saving moisture; during the heat of the day, they also stand on their feet so that their body is not scorched by the hot sand, but is cooled by the flow of air on the soil surface. Although the soil temperature in the upper few centimetres of the soil is important in some situations, for global or regional assessments it is conventional to give the temperature at a depth of 50 cm.

Measuring soil moisture and temperatures

SMR and STR are measured at different depths in the soil; the usual depths are 5, 10, 20, 50, and 100 cm. Moisture and temperature sensors are available to continuously monitor moisture and temperatures throughout the year. These, however, are expensive (about US$1500 each), so there are only few installations around the world. Prior to the availability of these instruments, soil moisture was measured by taking soil samples and measuring their moisture content gravimetrically - by weighing them. Soil temperature can also be measured manually by inserting thermometers at critical depths in the soil.

In order to make global assessments of soil moisture and temperature conditions, it is necessary to have a good density of stations. In many countries of the world, particularly developing countries, the desirable density of stations is not available, and SMR and STR conditions can only be assessed by using a model.

In 1972, Franklin D. Newhall of the Soil Conservation Service (SCS) developed a computer-based mathematical model to estimate SMR and STR

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regimes from atmospheric precipitation and temperature data, but the procedure was only published as an SCS internal report. Later, Dr. A. Van Wambeke (currently at Cornell University) developed a personal computer version of Newhall's Fortran model (Van Wambeke, 1981, 1982, 1985), and incorporated some proposals for subdivisions of the SMR as defined in *Soil Taxonomy* (Soil Survey Staff, 1975). Minor changes to Van Wambeke's model were made recently at SCS, and the results presented here are based on this revised model.

The model was never intended to provide site-specific information or to be a substitute for actual field measurements. It is, however, very useful in showing the geographical distribution of the SMR and STR classes on small-scale maps. It uses monthly data which could be processed annually for 30 years or more to estimate the SMR class on a probability basis.

Application of the model

Data from climatic stations close to the network sites were processed to evaluate the global geographic distribution of SMR and STR.

Tables 1a, b, c, d, e, f, g, and h, show some examples of printouts from individual stations. The model also estimates the duration, commencement, and end of the growing season. The growing season is considered as the period when there is no temperature or moisture stress.

The classes of SMRs have special names, and a key to their identification is given in Appendix I. Four basic terms are used and are explained below:

- Aridic - the soil is almost continuously dry; these are the SMRs of deserts.
- Ustic - soils with this SMR receive rains for about three to six months a year. They are semiarid.
- Xeric - this describes the SMR of soils in Mediterranean regions, where the rainfall, and consequently soil moistening, takes place in winter.
- Udic - the dry season is usually very short and does not exceed two months.
- Perudic - or continuously moist.

The STRs also have special terms. The mean annual soil temperature and the difference between mean summer and mean winter soil temperatures characterize the different classes, as illustrated in Table 2.

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DETERMINATION OF CLIMATIC REGIME ACCORDING TO SOIL TAXONOMY (USDA,1974) USING FRANK NEWHALL SYSTEM OF COMPUTATION

Country: WORLD DATA (FAO)
Station: DEBRE ZEIT (ETHIOPIA)
Lat/Lon: 8°43'N 38°56'E
Elevation: 1850 m

Precipitation: 833 mm
Evaporation (Thornthwaite): 831 mm

Avg. air temp. : 18.5 °C
Avg. soil temp.: 21.0 °C
Avg. soil temp.(Summer): 21.0 °C
Avg. soil temp.(Winter): 20.6 °C

Soil temp. regime : Isothermic
Soil moisture regime : Ustic
Tentative subdivision: Udic tropustic
Code : S3k

Growing season: 287 days ,JUN 16 - APR 2
MSSI: 0.27 TSSI: 0.00 CSSI: 0.27

TEMPERATURE CALENDAR
(- : T<5) (5 : 5<T<8) (8 : T>8)

MOISTURE CALENDAR
(▒: DRY) (▓:M/D) (▒: MOIST)

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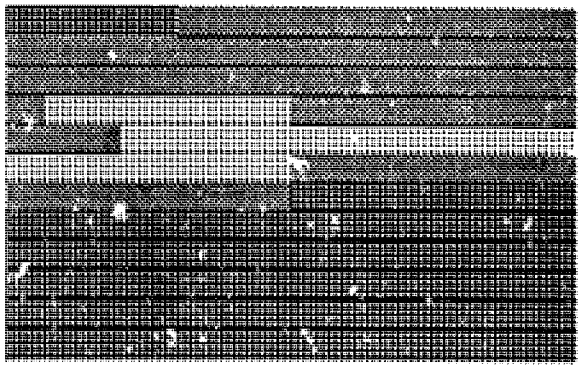

TABLE SOIL MOISTURE REGIME

Number of cumulative days that the moisture control section						Highest number of consecutive days that the m.c.s is			
during one year is			when soil temp is above 5 °C			moist in some parts		dry after summer solstice	moist after winter solstice
DRY	M/D	MOIST	DRY	M/D	MOIST	YEAR	T>8		
52	134	174	52	134	174	287	287	0	9

Table 1. Soil climate data for stations in IBSRAM's Vertisol network computed using a simulation model.†

Table 1a. Debre Zeit (Ethiopia).

† Climatic regime according to *Soil Taxonomy*, using FAO world data, and the Frank Newhall system of computation.

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DETERMINATION OF CLIMATIC REGIME ACCORDING TO SOIL TAXONOMY (USDA,1974) USING FRANK NEWHALL SYSTEM OF COMPUTATION

Country: WORLD DATA (FAO)
Station: ACCRA (GHANA)
Lat/Lon: 5°36'N 0°10'W

Elevation: 68 m

Precipitation: 765 mm

Evaporation (Thornthwaite): 1568 mm

Avg. air temp. : 26.4 °C
Avg. soil temp.: 28.9 °C
Avg. soil temp.(Summer): 26.9 °C
Avg. soil temp.(Winter): 30.3 °C

Soil temp. regime : Isohyperthermic
Soil moisture regime : Ustic
Tentative subdivision: Aridic tropustic
Code : S1m

Growing season: 119 days ,MAY 16 - SEP 14
MSSI: 0.64 TSSI: 0.00 CSSI: 0.64

TEMPERATURE CALENDAR
(- : T<5) (5 : 5<T<8) (8 : T>8)

MOISTURE CALENDAR
(▒: DRY) (▓:M/D) (▒: MOIST)

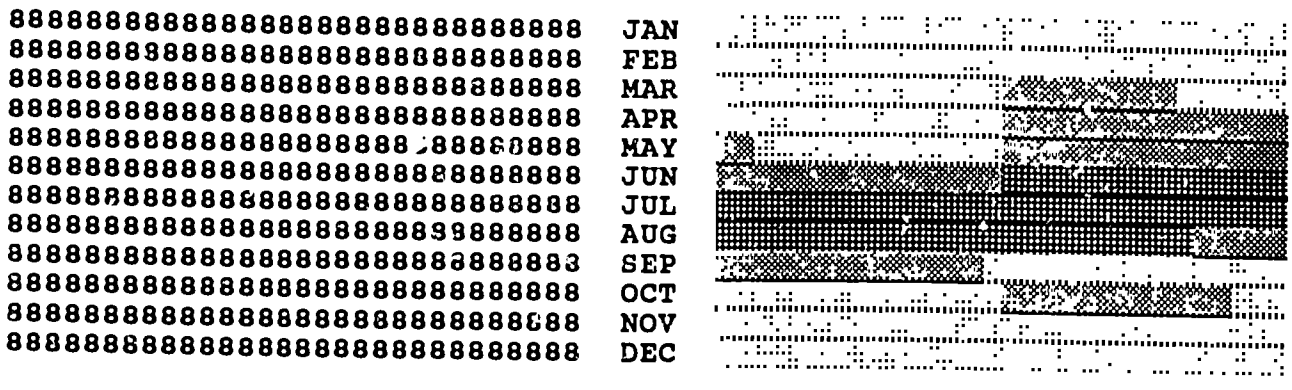

TABLE SOIL MOISTURE REGIME

Number of cumulative days that the moisture control section						Highest number of consecutive days that the m.c.s is			
during one year is			when soil temp is above 5 °C			moist in some parts		dry after summer solstice	moist after winter solstice
DRY	M/D	MOIST	DRY	M/D	MOIST	YEAR	T>8		
203	87	70	203	87	70	119	119	31	0

Table 1b. Accra (Ghana).

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DETERMINATION OF CLIMATIC REGIME ACCORDING TO SOIL TAXONOMY (USDA,1974) USING FRANK NEWHALL SYSTEM OF COMPUTATION

Country: WORLD DATA (FAO)
Station: AKUSE (GHANA)
Lat/Lon: 6° 6'N 0° 7'E

Elevation: 17 m

Precipitation: 1171 mm

Evaporation (Thornthwaite): 1688 mm

Avg. air temp. : 27.2 °C
Avg. soil temp.: 29.7 °C
Avg. soil temp.(Summer): 28.0 °C
Avg. soil temp.(Winter): 30.8 °C

Soil temp. regime : Isohyperthermic
Soil moisture regime : Ustic
Tentative subdivision: Aridic tropustic
Code : S1m

Growing season: 118 days ,MAY 16 - SEP 13
MSSI: 0.45 TSSI: 0.00 CSSI: 0.45

TEMPERATURE CALENDAR
(- : T<5) (5 : 5<T<8) (8 : T>8)

MOISTURE CALENDAR
(▒: DRY) (▓:M/D) (▒: MOIST)

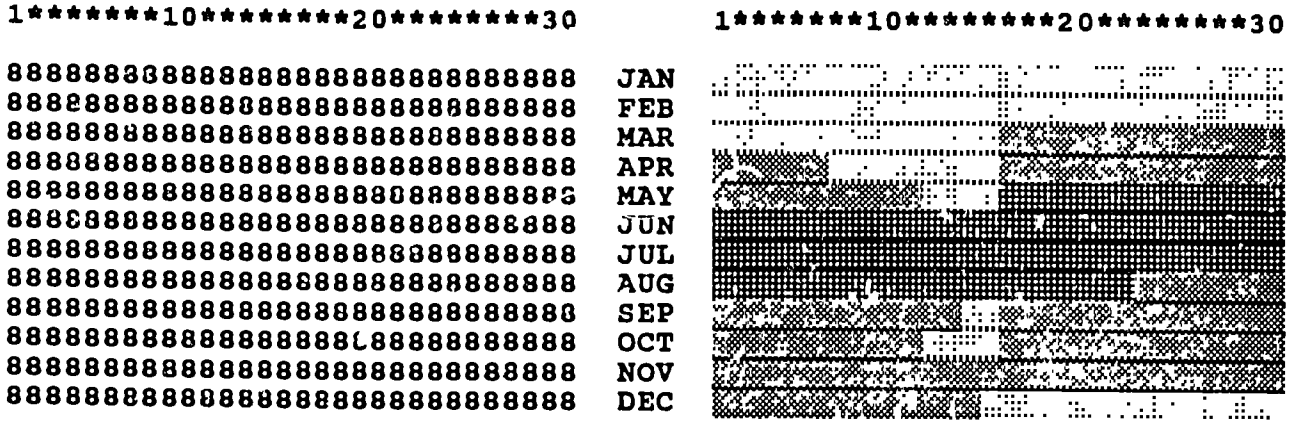

TABLE SOIL MOISTURE REGIME

Number of cumulative days that the moisture control section						Highest number of consecutive days that the m.c.s is			
during one year is			when soil temp is above 5 °C			moist in some parts		dry after summer solstice	moist after winter solstice
DRY	M/D	MOIST	DRY	M/D	MOIST	YEAR	T>8		
110	153	97	110	153	97	118	118	4	0

Table 1c. Akuse (Ghana).

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DETERMINATION OF CLIMATIC REGIME ACCORDING TO SOIL TAXONOMY (USDA,1974) USING FRANK NEWHALL SYSTEM OF COMPUTATION

Country: WORLD DATA (FAO)
Station: THIKA (KENYA)
Lat/Lon: 1° 1'S 37° 6'E

Elevation: 1463 m

Precipitation: 858 mm

Evaporation (Thornthwaite): 892 mm

Avg. air temp. : 19.7 °C
Avg. soil temp.: 22.2 °C
Avg. soil temp.(Summer): 22.0 °C
Avg. soil temp.(Winter): 20.9 °C

Soil temp. regime : Isohyperthermic
Soil moisture regime : Udic
Tentative subdivision: Dry tropudic
Code : U2m

Growing season: 360 days
MSSI: 0.04 TSSI: 0.00 CSSI: 0.04

TEMPERATURE CALENDAR
(- : T<5) (5 : 5<T<8) (8 : T>8)

MOISTURE CALENDAR
(▒: DRY) (▓:M/D) (▒: MOIST)

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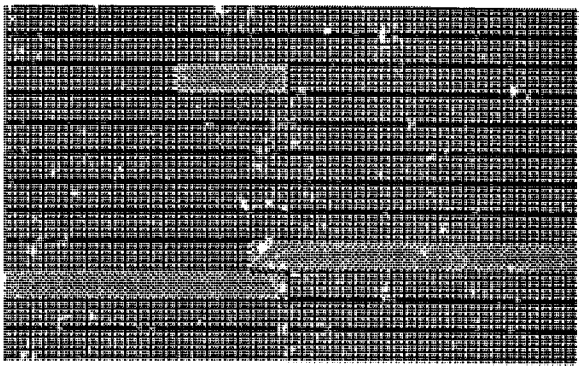

TABLE SOIL MOISTURE REGIME

Number of cumulative days that the moisture control section						Highest number of consecutive days that the m.c.s is			
during one year is			when soil temp is above 5 °C			moist in some parts		dry after summer solstice	moist after winter solstice
DRY	M/D	MOIST	DRY	M/D	MOIST	YEAR	T>8		
0	38	322	0	38	322	360	360	0	73

Table 1d. Thika (Kenya).

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DETERMINATION OF CLIMATIC REGIME ACCORDING TO SOIL TAXONOMY (USDA,1974) USING FRANK NEWHALL SYSTEM OF COMPUTATION

Country: WORLD DATA (FAO)
Station: MAIDUGURI (NIGERIA)
Lat/Lon: 11°51'N 13° 5'E

Elevation: 354 m

Precipitation: 644 mm

Evaporation (Thornthwaite): 1559 mm

Avg. air temp. : 26.8 °C
Avg. soil temp.: 29.3 °C
Avg. soil temp.(Summer): 29.1 °C
Avg. soil temp.(Winter): 26.0 °C

Soil temp. regime : Isohyperthermic
Soil moisture regime : Ustic
Tentative subdivision: Aridic tropustic
Code : S1m

Growing season: 126 days ,JUL 16 - NOV 21
MSSI: 0.65 TSSI: 0.00 CSSI: 0.65

TEMPERATURE CALENDAR
(- : T<5) (5 : 5<T<8) (8 : T>8)

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MOISTURE CALENDAR
(▒: DRY) (▓:M/D) (▒: MOIST)

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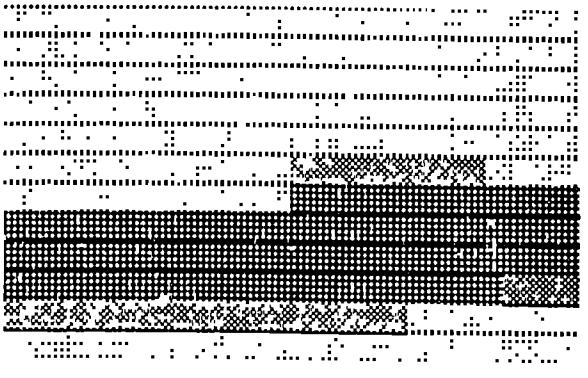

TABLE SOIL MOISTURE REGIME

Number of cumulative days that the moisture control section						Highest number of consecutive days that the m.c.s is			
during one year is			when soil temp is above 5 °C			moist in some parts		dry after summer solstice	moist after winter solstice
DRY	M/D	MOIST	DRY	M/D	MOIST	YEAR	T>8		
224	35	101	224	35	101	126	126	15	0

Table 1e. Maiduguri (Nigeria).

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DETERMINATION OF CLIMATIC REGIME ACCORDING TO SOIL TAXONOMY (USDA,1974) USING FRANK NEWHALL SYSTEM OF COMPUTATION

Country: WORLD DATA (FAO)
Station: MWANZA AIRFIELD (TANZANIA)
Lat/Lon: 2°28'S 32°55'E

Elevation: 1140 m

Precipitation: 1002 mm

Evaporation (Thornthwaite): 1108 mm

Avg. air temp. : 22.8 °C
Avg. soil temp.: 25.3 °C
Avg. soil temp.(Summer): 25.2 °C
Avg. soil temp.(Winter): 24.7 °C

Soil temp. regime : Isohyperthermic
Soil moisture regime : Ustic
Tentative subdivision: Udic tropustic
Code : S3m

Growing season: 311 days ,NOV 16 - SEP 26
MSSI: 0.16 TSSI: 0.00 CSSI: 0.16

TEMPERATURE CALENDAR
(- : T<5) (5 : 5<T<8) (8 : T>8)

MOISTURE CALENDAR
(▒: DRY) (▓:M/D) (▒: MOIST)

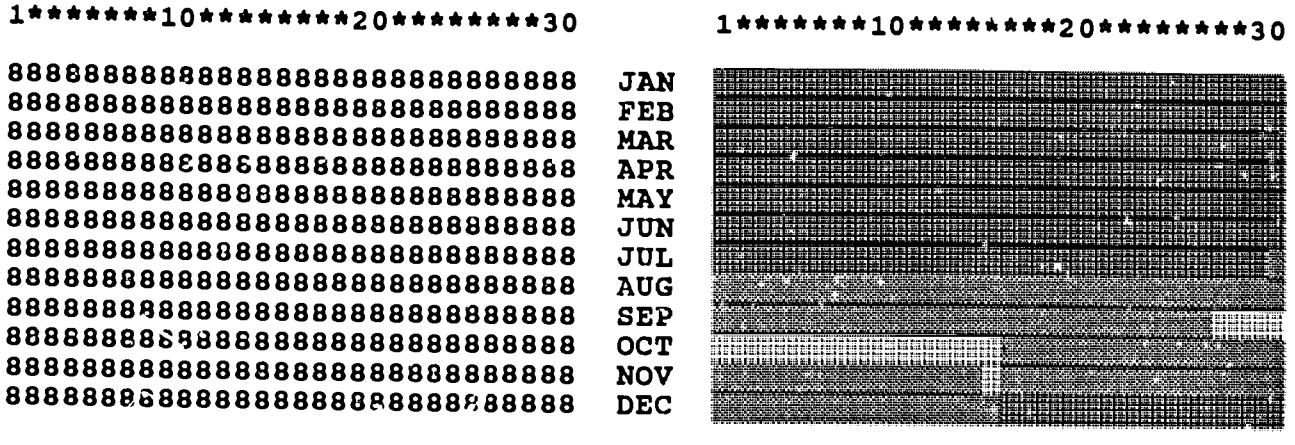

TABLE SOIL MOISTURE REGIME

Number of cumulative days that the moisture control section						Highest number of consecutive days that the m.c.s is			
during one year is			when soil temp is above 5 °C			moist in some parts		dry after summer solstice	moist after winter solstice
DRY	M/D	MOIST	DRY	M/D	MOIST	YEAR	T>8		
20	116	224	20	116	224	311	311	0	29

Table 1f. Mwanza Airfield (Tanzania).

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DETERMINATION OF CLIMATIC REGIME ACCORDING TO SOIL TAXONOMY (USDA,1974) USING FRANK NEWHALL SYSTEM OF COMPUTATION

Country: WORLD DATA (FAO)
Station: ATAKPAME (TOGO)
Lat/Lon: 7°35'N 1° 7'E

Elevation: 402 m

Precipitation: 1375 mm

Evaporation (Thornthwaite): 1481 mm

Avg. air temp. : 25.8 °C
Avg. soil temp.: 28.3 °C
Avg. soil temp.(Summer): 26.4 °C
Avg. soil temp.(Winter): 29.9 °C

Soil temp. regime : Isohyperthermic
Soil moisture regime : Ustic
Tentative subdivision: Typic tropustic
Code : S2m

Growing season: 264 days ,APR 16 - JAN 9
MSSI: 0.31 TSSI: 0.00 CSSI: 0.31

TEMPERATURE CALENDAR
(- : T<5) (5 : 5<T<8) (8 : T>8)

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MOISTURE CALENDAR
(▒: DRY) (▓:M/D) (▦: MOIST)

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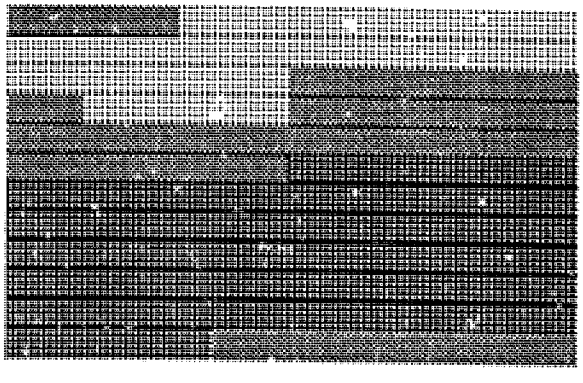

TABLE SOIL MOISTURE REGIME

Number of cumulative days that the moisture control section						Highest number of consecutive days that the m.c.s is			
during one year is			when soil temp is above 5 °C			moist in some parts		dry after summer solstice	moist after winter solstice
DRY	M/D	MOIST	DRY	M/D	MOIST	YEAR	T>8		
77	107	176	77	107	176	264	264	0	0

Table 1g. Atakpame (Togo).

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DETERMINATION OF CLIMATIC REGIME ACCORDING TO SOIL TAXONOMY (USDA,1974) USING FRANK NEWHALL SYSTEM OF COMPUTATION

Country: WORLD DATA (FAO)
Station: TRIANGLE HILL (ZIMBABWE)
Lat/Lon: 20°57'S 31°22'E

Elevation: 421 m

Precipitation: 586 mm

Evaporation (Thornthwaite): 1114 mm

Avg. air temp. : 21.8 °C
Avg. soil temp.: 24.3 °C
Avg. soil temp.(Summer): 26.4 °C
Avg. soil temp.(Winter): 20.3 °C

Soil temp. regime : Hyperthermic
Soil moisture regime : Aridic
Tentative subdivision: Weak aridic
Code : A3f

Growing season: 89 days ,JAN 16 - APR 14
MSSI: 0.76 TSSI: 0.00 CSSI: 0.76

TEMPERATURE CALENDAR
(- : T<5) (5 : 5<T<8) (8 : T>8)

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MOISTURE CALENDAR
(▒: DRY) (▓:M/D) (▒: MOIST)

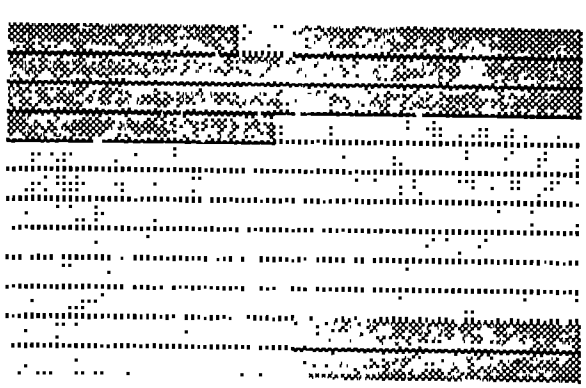

TABLE SOIL MOISTURE REGIME

Number of cumulative days that the moisture control section						Highest number of consecutive days that the m.c.s is			
during one year is			when soil temp is above 5 °C			moist in some parts		dry after summer solstice	moist after winter solstice
DRY	M/D	MOIST	DRY	M/D	MOIST	YEAR	T>8		
229	131	0	229	131	0	89	89	16	0

Table 1h. Triangle Hill (Zimbabwe).

Table 2. Classes of soil temperature regimes (STR).

Name	Soil temperature at 50-cm depth (°C)	
	Mean annual	Difference between mean summer and winter temperatures
Pergelic	<0	
Cryic/Frigid	0-8	
Mesic	8-15	
Thermic	15-22	
Hyperthermic	>22	
Isofrigid	0-8	<5
Isomesic	8-15	<5
Isothermic	15-22	<5
Isohyperthermic	>22	<5

Figures 1a, b, c, d, e, f, g, and h, show the distribution of the dry, partly dry, and humid periods at a station. The beginning, end, and duration of the growing season is also given. These figures illustrate the complexity of the SMRs and the significant differences between sites. The differences show the need for different kinds of cropping systems, different kinds of farming systems, and the relevance of specific technologies.

The very high and almost continuous rain in Thikka, Kenya, resulting in a long growing season (LGS), has different constraints than the low LGS situation in Nigeria and Zimbabwe. In the former, prevention of periodic waterlogging is an important problem, while in the latter, water-harvesting may be the most important concern. In Zimbabwe, water availability at the end of the growing season is an important problem. Short duration crops or crops requiring short growing seasons may be an option.

Table 1 and Figure 1 only serve to illustrate the average situation at each site. To perform a comprehensive analysis, it is necessary to have climatic data for as many years as possible. In most cases, these would not be available for the actual site, and so one would have to rely on data from the nearest climatic station. With long-term data, other kinds of analysis can be performed, and usually one would expect a qualified climatologist to oversee this work. At all events, an analysis based on long-term data should be made for all network sites.

Table 1 provides information on some other parameters. The moisture stress severity index' (MSSI) has values ranging from 0 to 1. In the tropics, the 'temperature stress severity index' (TSSI) is not relevant, and so the 'climate

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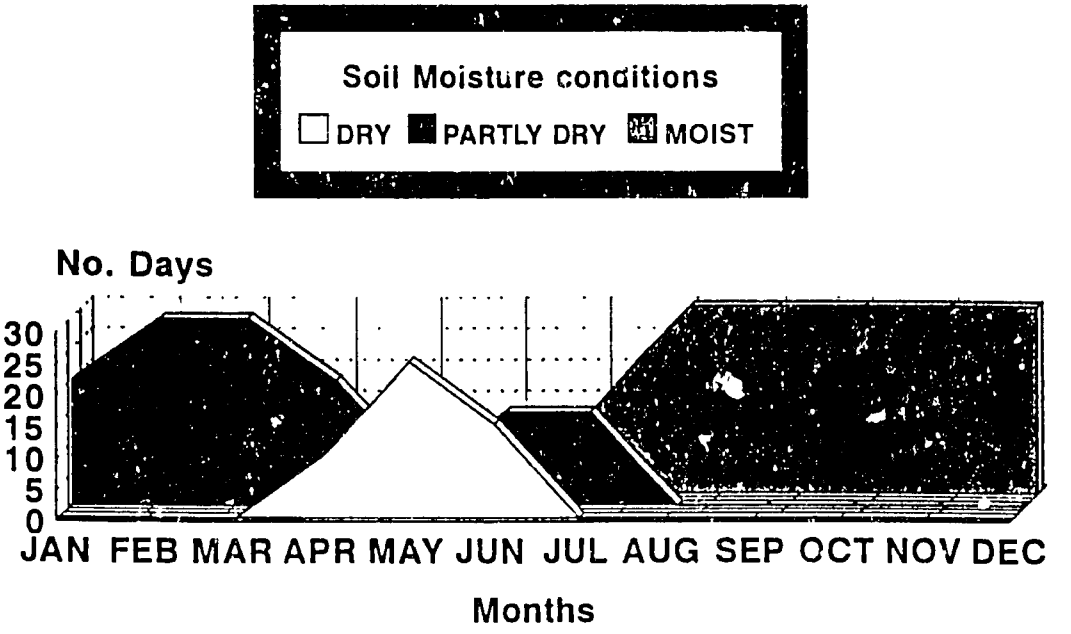
Figure 1a.

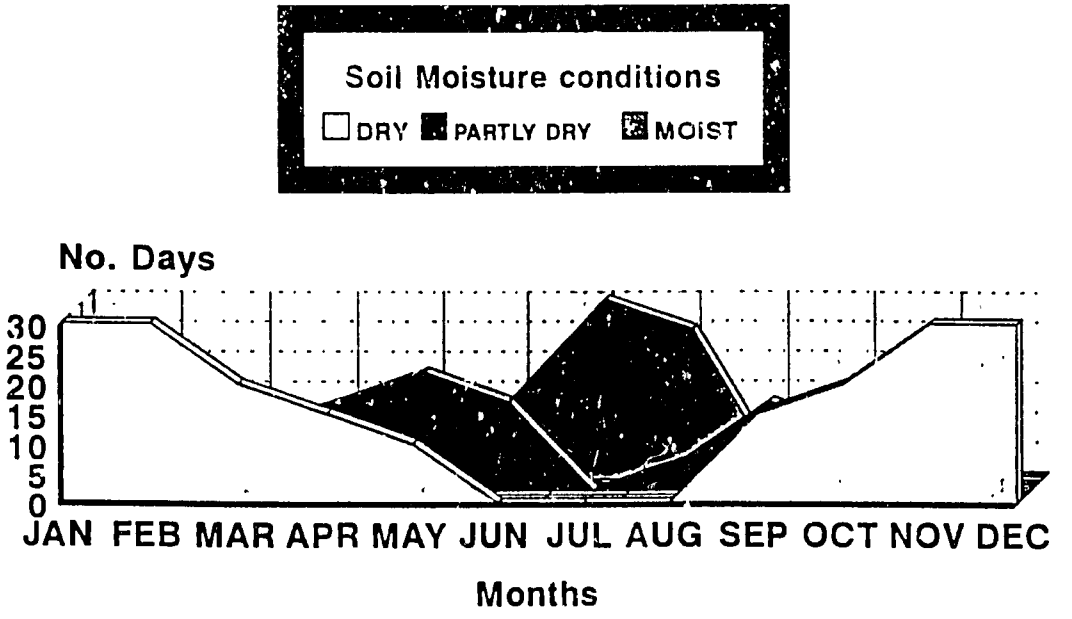
SOIL CLIMATE OF DEBRE ZEIT (ETHIOPIA)



Growing Season: Jun 16 - Apr 2 (287 days)
MSSI = 0.27
Ustic, Isothermic

Figure 1b.

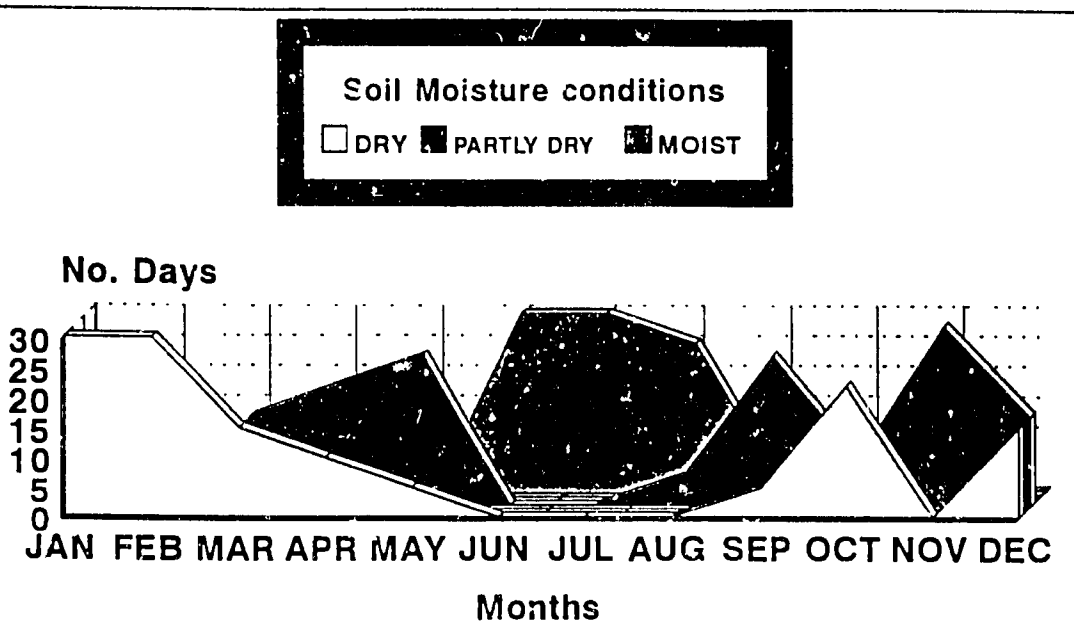
SOIL CLIMATE OF ACCRA (GHANA)



Growing Season: May 16 - Sep 14 (119 days)
MSSI = 0.64
Ustic, Isohyperthermic

Figure 1c.

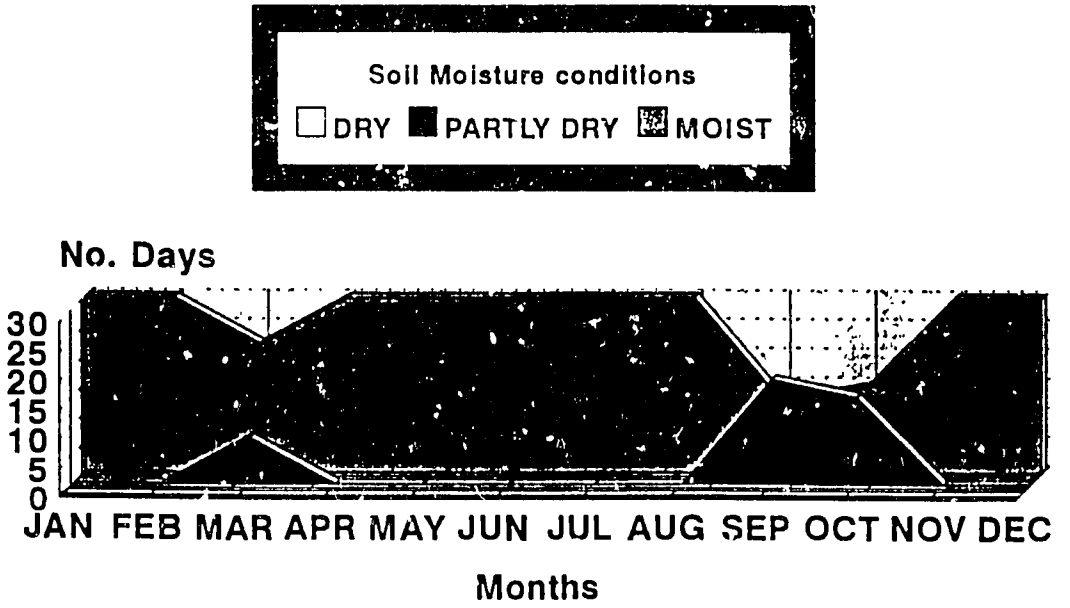
SOIL CLIMATE OF AKUSE (GHANA)



Growing Season: May 16 - Sep 13 (118 days)
MSSI = 0.45
Ustic, Isohyperthermic

Figure 1d.

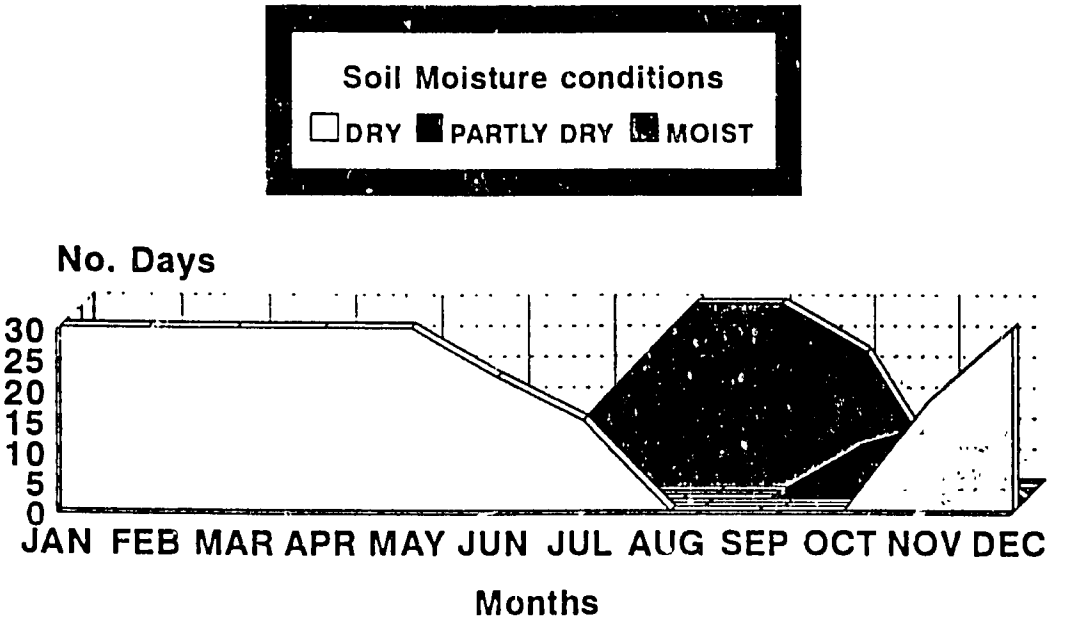
SOIL CLIMATE OF THIKA (KENYA)



Growing Season: (360 days)
MSSI = 0.04
Udic, Isohyperthermic

Figure 1e.

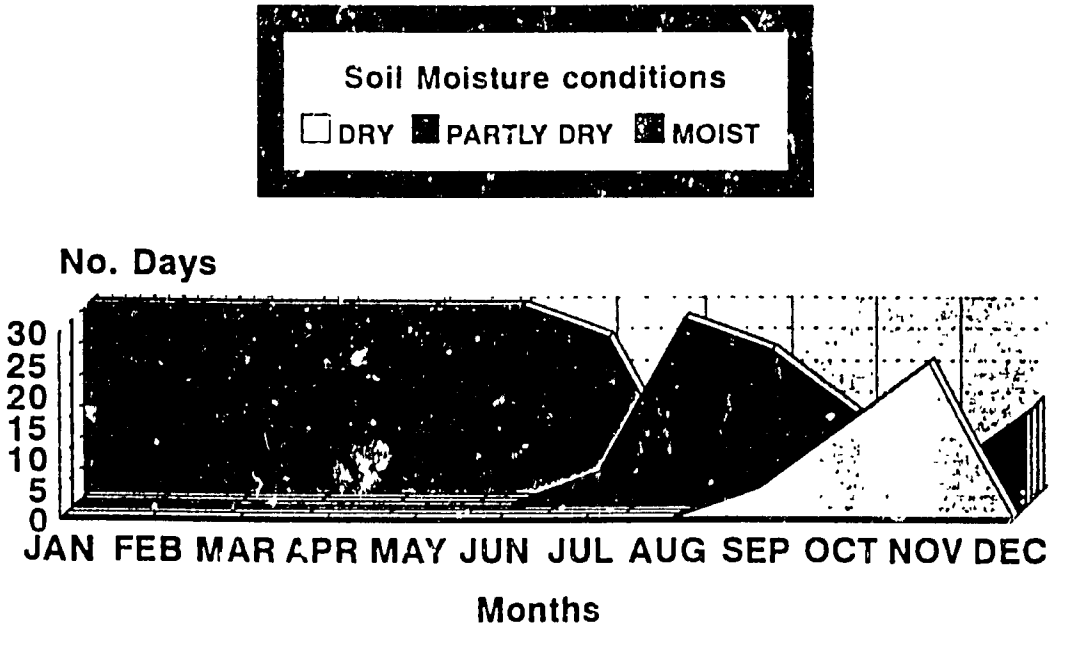
SOIL CLIMATE OF MAIDUGURI (NIGERIA)



Growing Season: Jul 16 - Nov 21. (126 days)
MSSI = 0.65
Ustic, Isohyperthermic

Figure 1f.

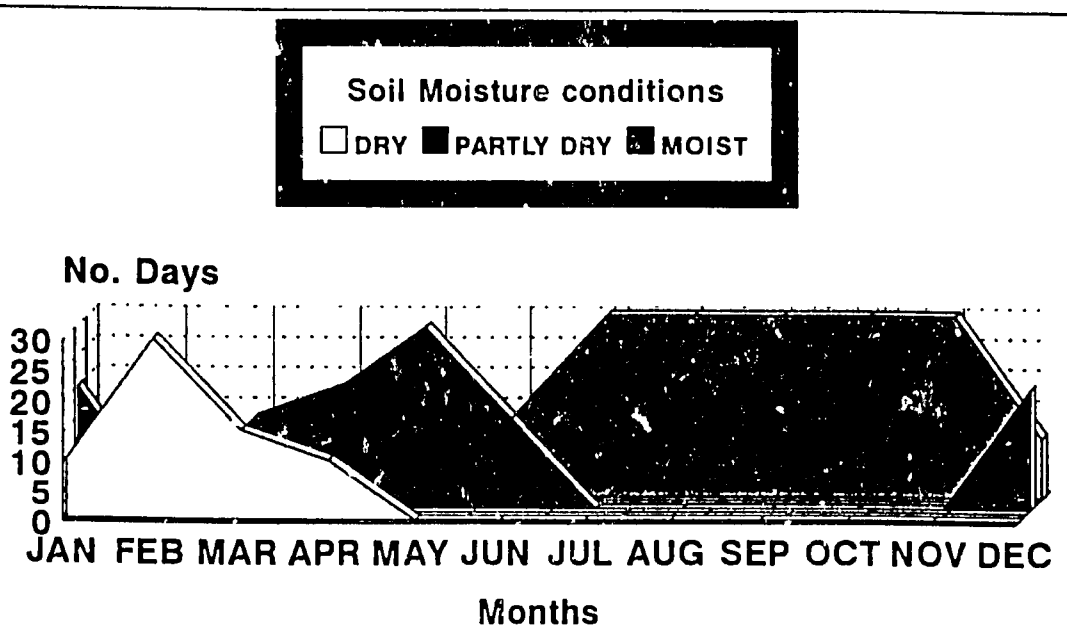
SOIL CLIMATE OF MWANZA (TANZANIA)



Growing Season: Nov 16 - Sep 26 (311 days)
MSSI = 0.16
Ustic, Isohyperthermic

Figure 1g.

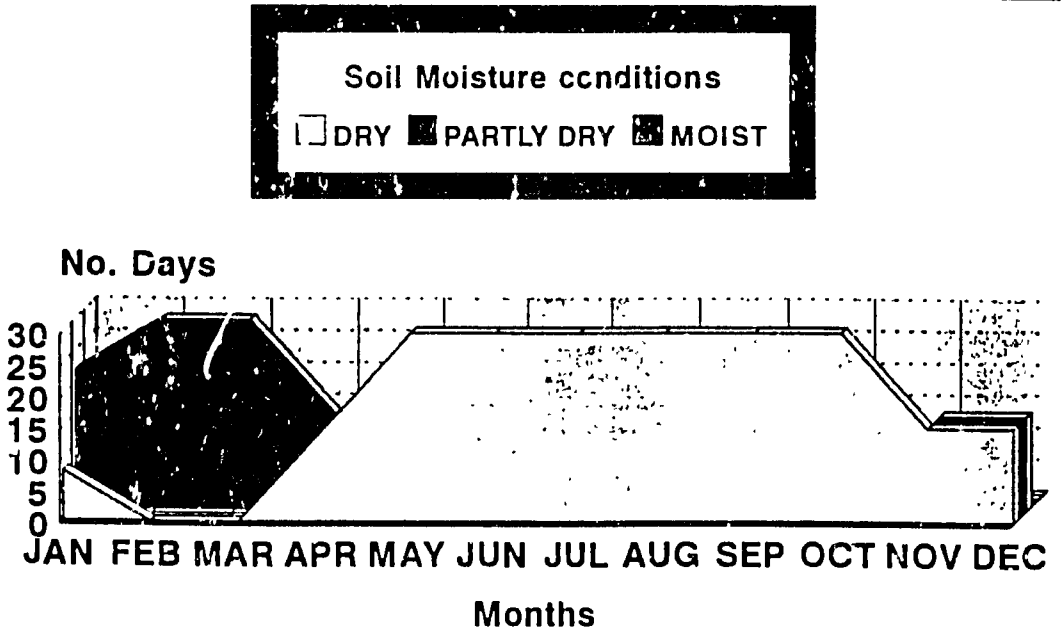
SOIL CLIMATE OF ATAKPAME (TOGO)



Growing Season: Apr 16 - Jan 09 (263 days)
MSSI = 0.31
Ustic, Isohyperthermic

Figure 1h.

SOIL CLIMATE OF TRIANGLE HILL (ZIMBABWE)



Growing Season: Jan 16 - Apr 14 (89 days)
MSSI = 0.76
Aridic, Hyperthermic

stress severity index (CSSI) equals the MSSI. These parameters may also be employed to compare sites.

The length of the growing season is the period when there is no temperature stress and their is adequate moisture for the growth of most plants. In Table 1, the length, beginning, and end of the growing season are given. Predicting the actual beginning and end of the growing season is fraught with difficulties, and consequently the data show only an average situation. If daily data for a number of years are used, more reliable estimates may be obtained.

Microvariability

The soils in the network are all classified as Vertisols, indicating that they have certain properties and lack others, which therefore place them in this class at the 'order' level in *Soil Taxonomy*. If the soils are classified to lower categoric levels, particularly to the 'series' level, significant differences exist between the sites in the network. The site at Maiduguri, Nigeria, for example has sandy materials at less than 1 m, and this will control the internal hydrology of the soil. By comparison, the Vertisol at Akuse in Ghana has rock at shallow depths, and this soil is different from the deep Vertisols at Thikka in Kenya.

A network shows the variability of the same 'kind of soil' at different sites. For the management of the soils, such variability must be recognized, and each soil must be managed according to its unique properties.

The concept of soil microvariability deals with short-range changes, specifically in experimental plots. It is necessary to know and appreciate this variability as it would help in the interpretation of results. If there is variability of important properties in the field, the experimental layout can be designed to take this variability into account. This depends on the property. If it is a permanent feature of the soils, such as depth to gravel, appropriate design changes can be made. If there are temporal properties or the variability does not follow a manageable pattern, this can only be reported in the experiment report, and few preventive measures can be taken.

The gilgai microrelief seen on Vertisol landscapes illustrates the variability that can be expected at a site. The surface microtopography is reflected within the soil by the arrangement of soil features (Dudal and Eswaran, 1988). Figure 2 shows an extreme expression of this internal variability in a Vertisol from Texas. The slickensides are distributed in a synclinal form. As a consequence of this, the centre of the bowl is more moist and for longer periods of time than the 'chimneys' at either end. The chimneys in this soil are more gravelly, have less clay, and thus have less nutrients and moisture than the

sowi. If the soil is [illegible] the microrelief is masked; but if plants are grown on the soil, the growth [illegible] This microvariability can reduce the effective yield of a soil. However, it is more important for field trials as it introduces errors between replicates. Field plots must be at least twice the amplitude of the gilgai to reduce the errors.

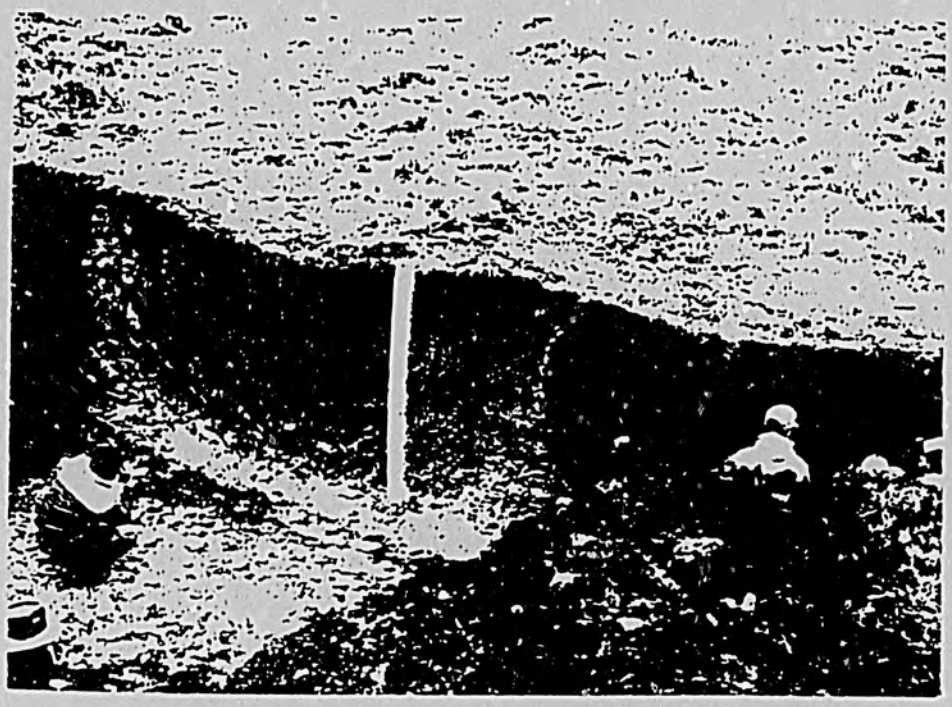


Figure 2. Microvariability in a Vertisol.

This microvariability can be evaluated by detailed sampling. The following is a preliminary study to illustrate the use of [illegible] statistics in evaluating microvariability. Figure [illegible] shows the layout of the field at Thikka in Kenya. The points show the location of the samples taken. (Apparently more samples were taken, but the results were not available when this study was made.) The sampling points are clustered in the northern part of the field, so the results will be skewed. A good density of points is essential for a valid study. The accuracy desired will determine the total number and density of points.

Figures 3, 4, 5, and [illegible] illustrate a range of properties which were examined. Any property which can be quantified can be used for such a study. Due to the

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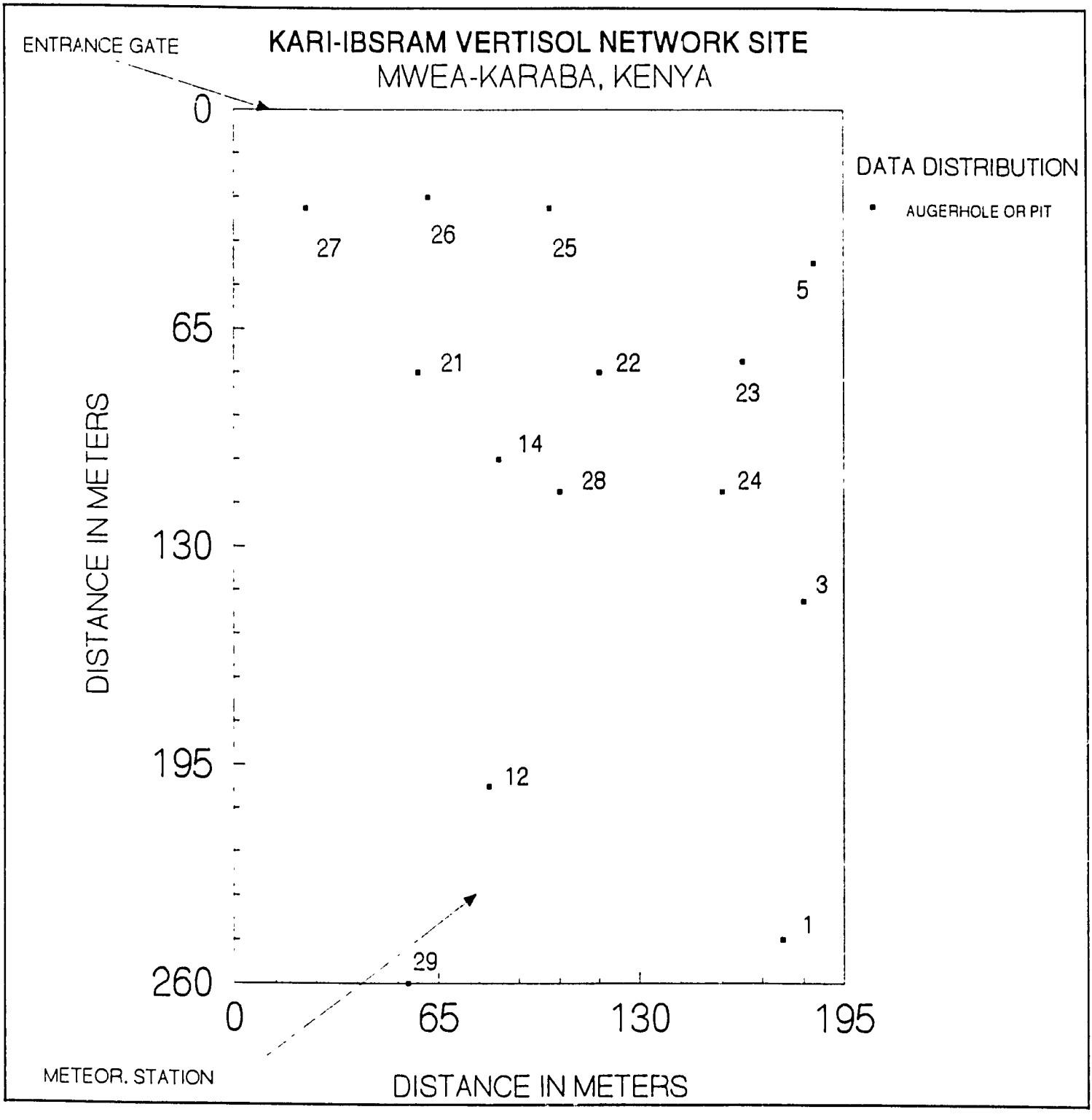

Figure 3. Data points for the Vertisol experimental site in Kenya.

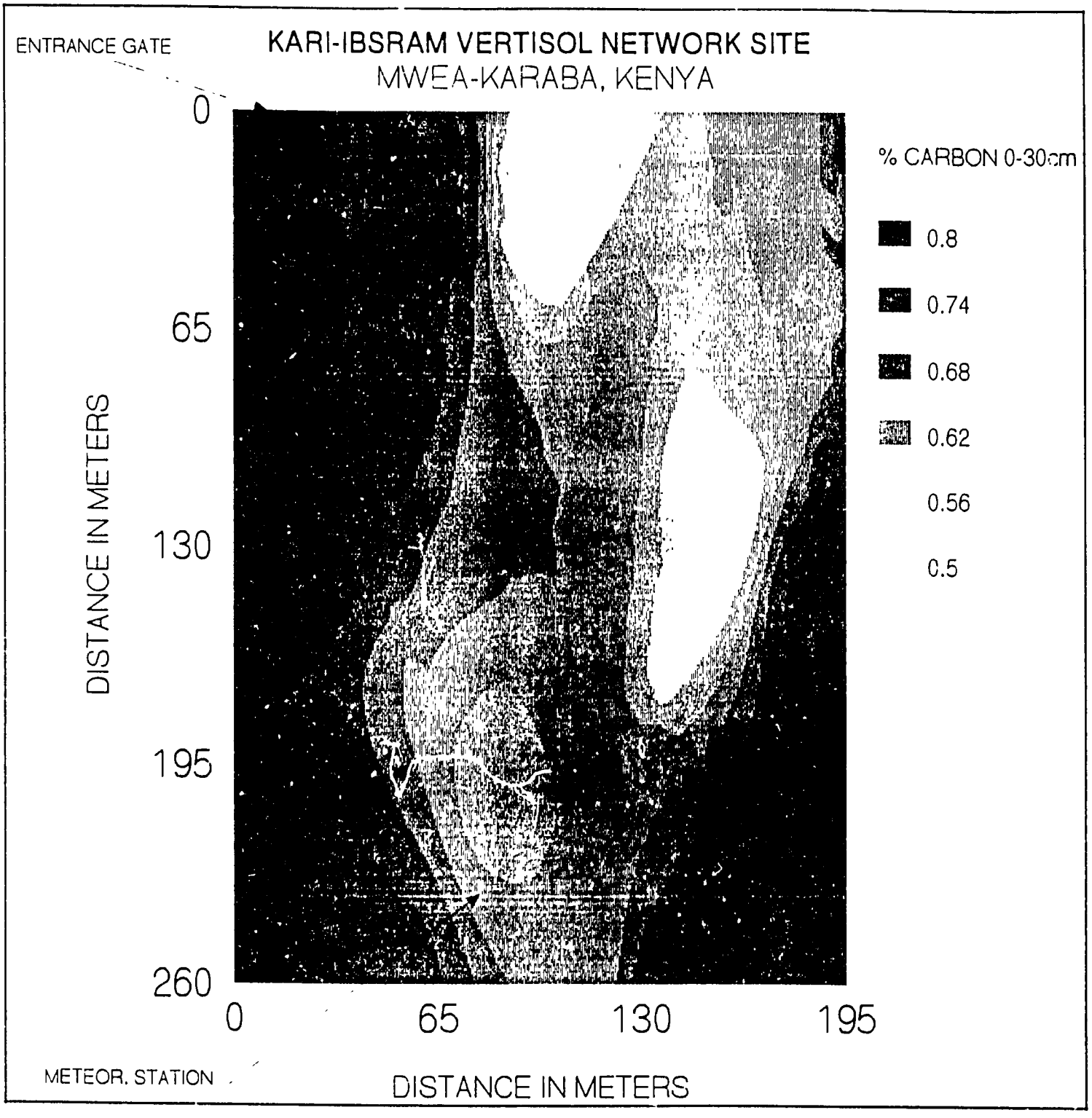

Figure 4. Distribution of organic carbon in the 0-30 cm depth at the site in Kenya.

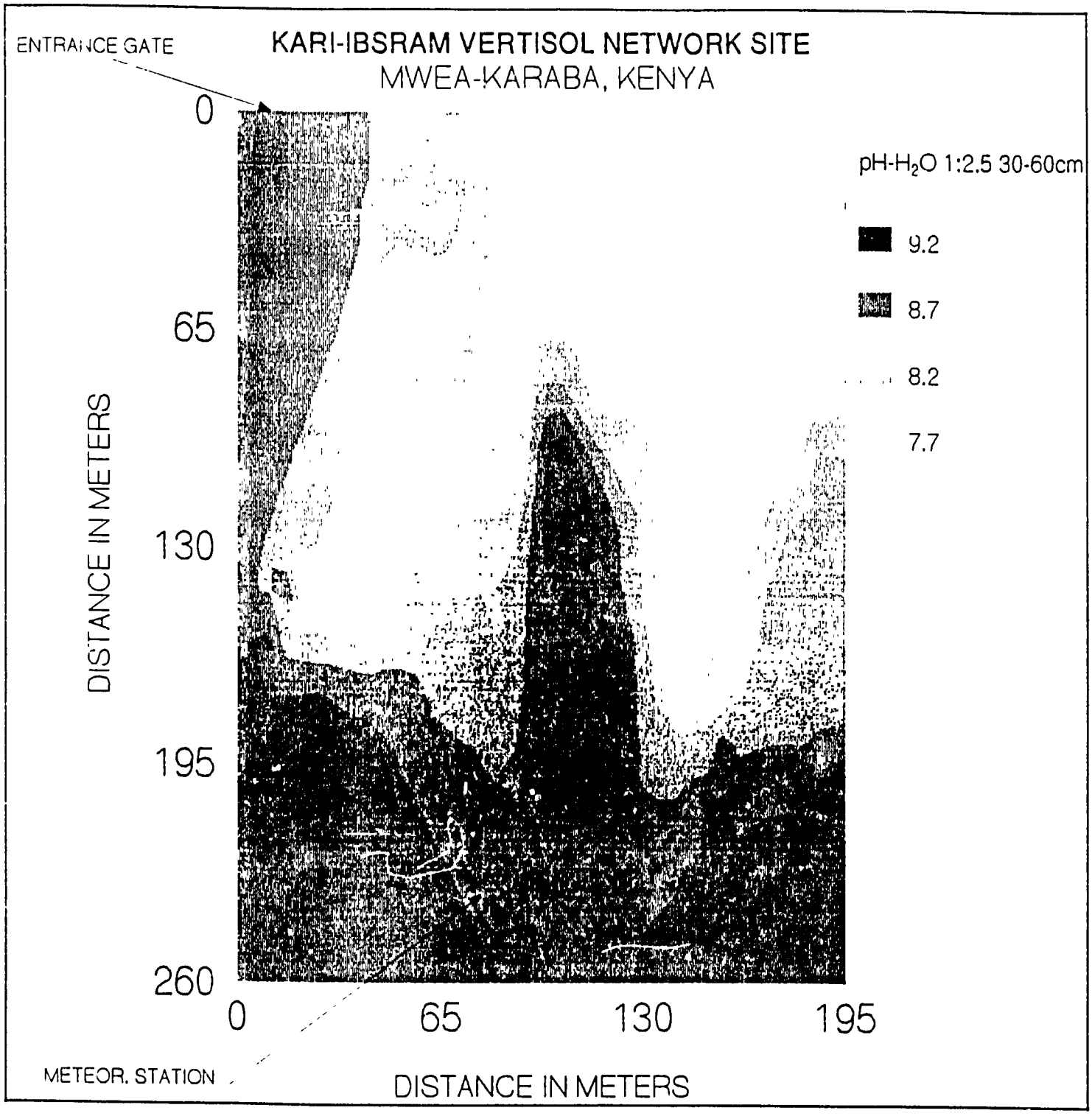

Figure 5. Distribution of pH in the 30-60 cm depth at the site in Kenya.

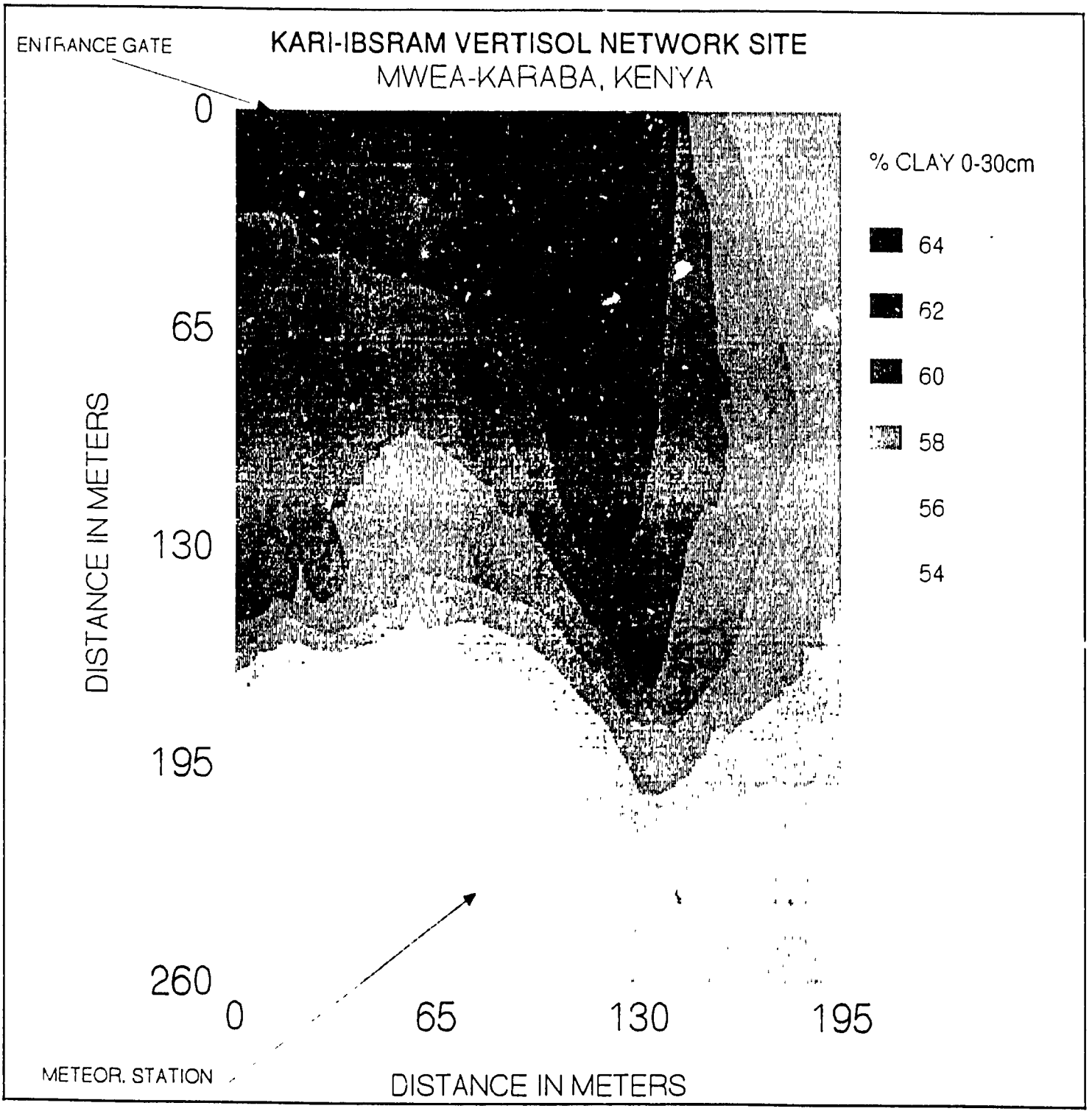

Figure 6. Distribution of percent clay in the 0-30 cm depth at the site in Kenya.

low density and inappropriate distribution of points, we will not make any conclusions from this study. These examples are provided to show the potentials of the technique.

Appendix I
Key to tentative subdivisions of SMR

Key to subdivision of aridic SMR

1. Soils with aridic SMR in which the moisture control section (MCS) is completely dry during the whole year:

   Extreme aridic

2. Other soils with aridic SMR in which the MCS is moist in some or all parts for 45 consecutive days or less during the period that the soil temperature at 50-cm depth is more than 8°C.

   Typic aridic

3. Other soils with aridic SMR:

   Weak aridic

Keys to subdivision of xeric SMR

1. Soil with xeric SMR in which the MCS is dry in all parts for more than 90 consecutive days during the four months following the summer solstice:

   Dry xeric

2. Other soils with xeric SMR:

   Typic xeric

Keys to subdivision of ustic SMR

1. Soils with ustic SMR and iso-STR in which the number of consecutive days that the MCS is completely or partly moist when the soil temperature at 50-cm depth is more than 8°C - as follows:
   a. less than 180 days:

      Aridic tropustic

   b. 180 to 270 days:

      Typic tropustic

   c. 270 or more days:

      Udic tropustic

2. Other soils with an ustic SMR:
   a. Soils in which the MCS is dry in all parts for more than 45 consecutive days during 4 months following the summer solstice, and where the MCS is moist in all parts for more than 45 consecutive days during the four months following the winter solstice:

      Xeric tempustic

   b. Other soils where the MCS is moist in all parts for more than 45 consecutive days during the four months following the winter solstice, and where the MCS is not completely dry for more than 45 consecutive days during the four months following the summer solstice:

      Wet tempustic

   c. Other soils.

      Typic tempustic

Keys to subdivision of ustic SMR

1. Soils with udic SMR in which the MCS is dry in some or all parts for less than 30 cumulative days:

   Typic udic

2. Other soils with udic SMR in which the MCS is dry in some or all parts for 30 or more cumulative days and has:
   a. an iso-STR.

      Dry tropudic

   b. other soils:

      Dry tempudic

References

DUDAL, R. and ESWARAN, H. 1988. Distribution, properties and classification of Vertisols. In: *Vertisols: their distribution, properties, classification and management*, ed. L.P. Wilding and R. Puentes, 1-22. Soil Management Support Services, USDA. Technical Monograph no. 18. Washington DC: Government Printing Office.

NEWHALL, F. 1972. Calculation of soil moisture regimes from climatic records. Soil Conservation Service, USDA. Washington DC. Mimeo.

SOIL SURVEY STAFF. 1975. *Soil taxonomy: a basic system of soil classification for making and interpreting soil surveys.* Soil Conservation Service, USDA. Agriculture Handbook no. 436. Washington DC: Government Printing Office.

VAN WAMBEKE, A. 1981. *Calculated soil moisture and temperature regimes of South America.* Soil Management Support Services, USDA. SMSS Technical Monograph no. 2. Washington DC: Government Printing Office.

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VAN WAMBEKE, A. 1982. *Calculated soil moisture and temperature regimes of Africa*. Soil Management Support Services, USDA. SMSS Tecanical Monograph no. 3. Washington DC: Government Printing Office.

VAN WAMBEKE, A. 1985 *Calculated soil moisture and temperature regimes of Asia* Soil Management Support Services, USDA. SMSS Technical Monograph no. 9 Washington DC: Government Printing Office.