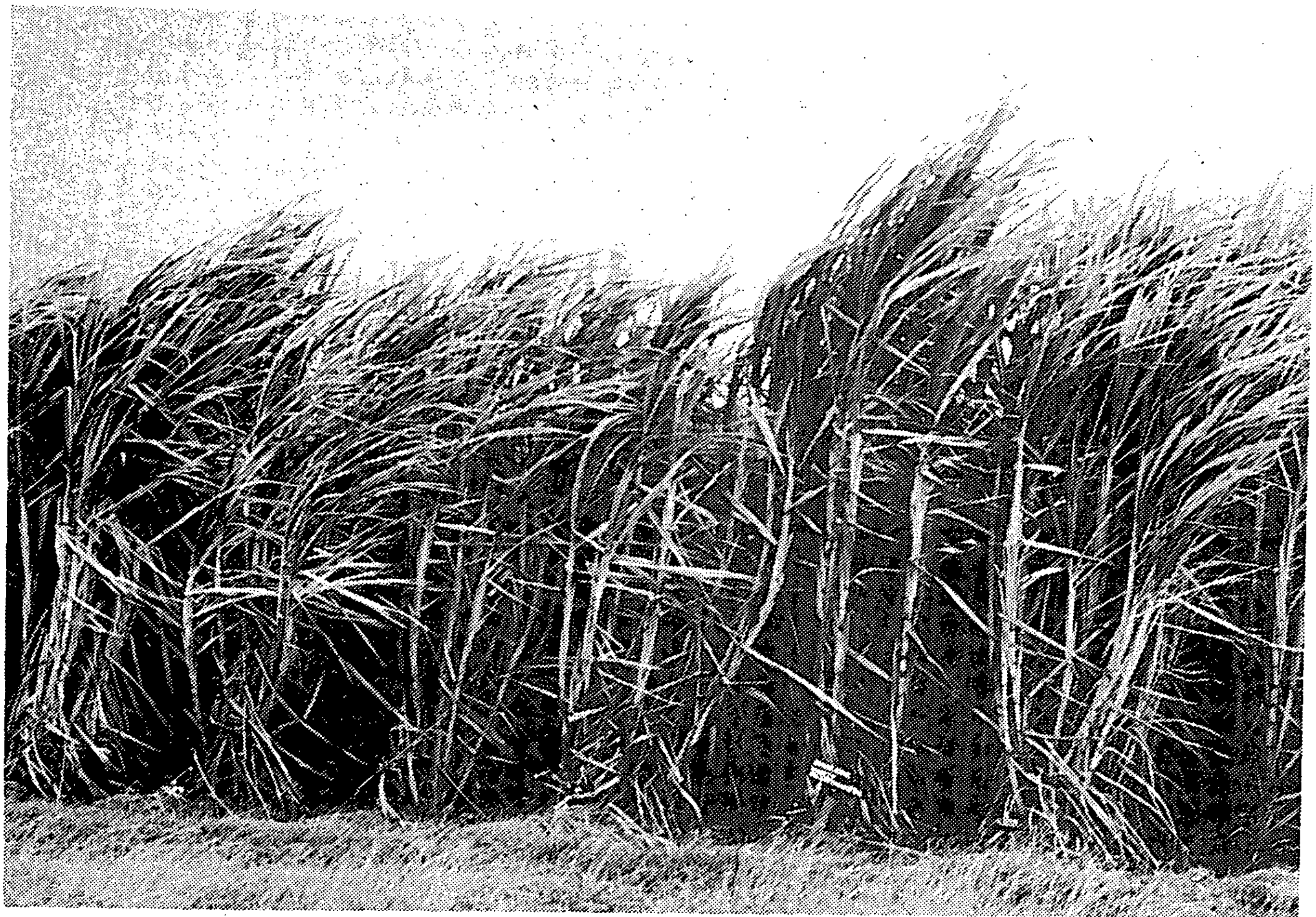
TRAINING PROJECT IN PEDOLOGY
KISII KENYA



Wateravailability for sugar-cane in South-Nyanza

PRELIMINARY REPORT NO 29

GRICULTURAL UNIVERSITY
AGENINGEN - THE NETHERLANDS

Wateravailability for sugar-cane in South - Nyanza

A study

by

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Training Project in Pedology, Kisii, Kenya
Agricultural University, Wageningen, The Netherlands

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Preface

This report of the Training Project in Pedology at Kisii of the section on Tropical Soil Science of the Agricultural University at Wageningen, the Netherlands is the twenty nineth one of a series to be presented by Kenyan officials.

The project started in November 1973 after assent had been granted by the Office of the President of Kenya. It is meant for training of postgraduate students of the Agricultural University at Wageningen and for furnishing research opportunities to the staff. The activities of student and staff are dissected to obtaining a better knowledge of the soils and the Agricultural conditions of the project area to provide a basis for the further agricultural development of the area.

The project in Kisii is conducted by:
Ir.W.G. Wielemaker, teaching and research
Ing. H.W. Boxem, management.
Visiting specialists from the Agricultural University at Wageningen help to resolve special problems.

This report is the result of an intensive special study on the water-availability for sugar cane carried out by Mr. H.Kluyfhout, who also wrote the report. Mr. H.W. Boxem edited the text and compiled it into this presentation.

We hope to pay back with these reports a small part of the great debt we owe to Kenya in general and to many Kenyans in particular for their valuable contributions to the good functioning of the project.

The supervisor of the project
J.Bennema, Professor of Tropical Soil Science

Summary

Ranges of available water and moisture content have been determined by means of pF-rings and a Wallingford neutron probe respectively. The measurements occured of different depths oh well drained permeable dark reddish brown to gray porous crumby clay, shallow and deep profiles from July 1977 till December 1977, of different sugar-cane trial fields in South-Nyanza district, South-West Kenya. With these results and collected data on climate the water availability and water balance for sugarcane is calculated from which interpretations for estimated yields are given. Conclusions:

Conclusions on climate:
The reliability of rainfall figures on monthly basis are just a rough indication for the climate and for the watervailability according to the precipitation. Knowledge about the ten-day rainfall estimation will give more information.

Conclusion on soil:
The data on readily available water (pF 2.0 - 3.6) are relevant for sugar-cane growing; water at higher tension is difficult to extract. The productive readily available water is estimated by the effectiveness in wateruptake at different depths: 100% in the top 30 cm, 25-50% for the 30-90 cm layer. No measurements were taken deeper but effectiveness was not of higher importance than 0-25%, during the period of measurements.

Conclusions on wateravailability:
The estimated average Ea/Ep ratio on monthly basis shows a critical period for sugarcane growing in both agroclimatical zones (IIb and IIc) where sugarcane can be grown namely in the dry spell of December, January, February and for zone II an additional one in July, Aughust and September. In three resp. one year is out of ten this drought will become worse and serious respectively.
In the period of measurements no effect of soildepth on water availability was detected.
The estimated yield for both zones is calculated on 700 kg sugar/ha/month assuming no other yield reducing factors than a moisture shortage.

1. Introduction

The Training Project in Pedology, Kisii, Kenya from the Agricultural University of Wageningen the Netherlands, has carried out a reconaissance soil survey (1:100.00) and a landevaluation of map-sheet 130 Kisii.

The landevaluation required knowledge about moisture availability. O'Herne studied this for maize (P.R 30), the presented report deals with sugar-cane. The moisture-content was measured by means of a Wallingford neutron probe.

The aim of the study:

- To determine the water availability for sugar cane on soils in South Nyanza district.
- To give an estimation of the Ea/Ep ratio for sugar cane in this area.

2. Climate

2.1. Temperature

Mean minimum and maximum montly figures are collected for three wheather-stations of different altitudes in Western Kenya, and found in appendix I (Table 5, p. 25) mean annual air temperature is about 21°C for this area but varies considerably with altitude.

2.2. Precipitation

Daily precipitation has been recorded at or near the different sugar-cane trial-fields during the period of measuring the water-availability. These data do not seem to be very accurate, moreover the rainfall figures are almost twice as high as the expected rainfall in the same period.
Mean Monthly rainfall data are taken from the EAMD (East African Meteorological Department) for three wheather-stations of South Nyanza in agroclimatic zone IIb,IIc which are respectively for the potential sugar-cane area. According to V. Mourik et. al, rainfall has a skew-distribution in this area. The procedure followed here, to give rainfall-probability is given by Boyer. Distribution pattern is written in the formular.

$$\hat{y} = \mu y + k\sigma y$$

Where y=Log x and x is rainfall (mm), μy and σy are the mean and standard-deviation of the transferred variates. For South Nyanza-area the k-factor depends on the skewness of rainfall-distribution and is calculated at k=-0.52 and k=-1.28 for the two probability levels given: the 30% resp. 10% non-exceedence level. This means in three resp. one year(s) out of ten a lower monthly / 3 monthly precipitation than the given data is to be expected (Table 6, p.26). Those data differ considerably from those given by V.Mourik (1974) in a reconaissance climate study for this area.

Mean annual precipitation figures can be found in the same table. The distribution is bimodal: There is surplus from March to May and a dry spell from December to February and one in July and August.

2.3. Evapotranspiration.

Definitions:

E_o =(potential) evaporation of an open water surface

Ep(Et)=(potential) evapotranspiration with optimal water availability.

Ea = actual evapotranspiration.

assumptions and remarks on definitions.

Eo Penmann estimates of Eo give a good description of the local climate (Daggs, 1965), and have been found usefull particularly with perennial crops such as sugar-cane. Furthermore no lack of accuracy will result from analysing the date on a monthly basis (Woodhead, 1968), while evaporation has a rather conservative distribution. An A-pan class evaporation as used in Ep/Eo ratios, data are comparable with the lower Penman estimates, which are used for calculations.
Mean Monthly Eo data (Penmann) are mapped by Woodhead, 1968, and are expected to be like these in four years out of five. Besides this measured Eo data (A-pan class) are listed in table 1.

Table 1. Mean monthly (potential) evaporation, Eo (mm)

Month	J	F	M	A	M	J	J	A	S	O	N	D	Years
Uriri	175	150	150	150	125	125	150	150	175	175	150	150	1800
Kamagambo (4850 ft)	200	175	175	175	150	150	175	175	200	200	175	175	2000
Koru Station (5000 ft)	187	199	159	137	131	132	129	128	195	155	151	175	1773

Ep(Et) Daily values vary drastically. This obvious variation, will be obscured when using mean climatic data to obtain Ep. Monthly figures show a rather big variation of 50% or more especially in the transitional months between dry and wet season depending on rains occuring early or late (Woodhead, 1970). Annual Ep data have a low variability.
Ep/Eo ratio's or cropcoefficients are estimated at various stages of growth (Hagan et al., 1967). This report deals with the local climatic difference with subject the common Co 421 plantcrop. Other variables than soils with be ignored. Table 2 gives a view.

Table 2. Various Ep/Eo ratios for estimating evapotraspiration at various stages of growth in the crop cycle of sugar cane

Period in crop cycle	crop age (Months)	Ep/Eo(A-pan class) Rel. Hum>70% mod.wind
Partial canopy.		
planting to ¼ full canopy	0 - 2	0.55
¼ to ½ full canopy	2 - 3	0.8
½ to ¾ full canopy	3 - 4	0.9
¾ to full canopy	4 - 5	1.0
peak use	5 - 14	1.05
? early senescence	14 - 18	0.8
ripening	18 - 20	0.6

Source: FAO, irrigation and drainage paper no.24, revised 1977. The average consumptive use of sugar cane is 4 - 5 mm/day, peak use about 6mm/day, a reasonable estimation according to data cited in Anonymous 1972. On the contrary the average Ep/Eo 0.88 is higher than the average crop factor for Kisii area Ep/Eo = 0.82 (Wielemaker 1974) and even more than the total average for Kenya Ep/Eo = 0.76 (Obasi), due to the use of the lower evapotranspiration estimate given by Woodhead.

Ea The Ea is greatly depending on available water in the soil. The accurancy of functions based on the assumptions Ea/Ep is a simple function of the soil water status and as such can be computed without reference to the particular evaporative demand existing at that time (Johns and Smith, 1975).

Figures 2b, 2c, and 2d. (appendix I, p.27 and 28) give a summary vieuw of the two representative wheather stations in agroclimatic zone IIb and IIc. Also the monthly P/Eo ratio is given.

3. Soil

3.1. Soil-description.

Soil unit:

For general information about soils and soil-units in this area see reconaissance report on map-sheet 130, Kisii, (preparation) soil survey. This research deals with the most common soil unit a Typic Argiudoll and its associations (35.000 ha; and with comparable soils even more), occurring in the potential sugar cane growing area (60.000 ha). A well drained, permeable dark reddish brown to gray porous and crumby clay with a humus rich top soil (Soil Taxonomy) and clay skins in the subsoil.

Profile description and analytical results are recorded in appendix II (p.29), For Vertisols the other common soil unit for sugar cane growing is refered to E.Bellis 1961.

3.2. Soil measurements

pF

To determine the specific readily- and total- available water at each profile, pF is measured at 2.0, 3.6 and 4.2 resp. Only the results of Kamagambo are recorded in this report (appendix II, p.31)

Moisture content.

Moisture content is determined by means of neutron- probe method which is an indirect one to measure the moisture content. Principle is the dispersion of slow neutrons mainly occuring on H-nuclei (in soil mostly in H_2O) what is forming a measure of the moisture content. Sharari and Isobe (1975) found a linear relation-ship of relative counts versus volumetric water content within a moisture range of 0 - 60 volume%. They found an increase of counts with increasing clay contents. Holmes (1966) a reported a steeper slope of the calibration curve for loam. Besides in water H-nuclei are also present in other forms what makes it necessary to make a specific calibration of each measurement series. The advantages of this non-destructive method especially with long term measurement periods is an easy moisture determination at an undisturbed profile after calibration.

Procedure of calibration(Snedecor and Cochran, 1972).

$$Y = \bar{Y} + b\ (X - \bar{X})$$

Where Y is the moisture-content (volume%), b the regression coefficient and X the counts of the neutron probe.

$$b = \frac{\sum XY}{\sum X^2}$$

b is tested with a t-distribution at (n-1) degrees of freedom and are found signifioant at 1%, on the examined profiles.

Water-balance

For large catchment areas the waterbalance is calculated with the formule:

$p - r = Ea + d + \Delta Sc.$

Remarks on the symbols for this specific area:

r: For this area run-off (r) = 0. Hennemann and Kauffman 1975 found an infiltration capacity of 250 mm/hour on the red soils. These rainfall intensities are not common but mostly considerably lower in this area. d: Amounts of waterloss in deep profiles can become important (v.Bavel et. al, 1968). Drainage (=d) in the subsoil has not been measured explicitely but approximated as shown in the example of calculation (p. 10)

ΔSc: The calculated change in storage of productive available water is determined according to v.d. Molen, 1972; The water extraction from the soil is depending on the water storage in the profile, and the root profile.

$$Sc = So \cdot e^{-Ep \cdot t/So} \qquad \text{.....................(a)}$$

Where Sc = calculated productive moisture storage in the soil (mm)

So = productive moisture storage at the beginning (mm) ?

Ep = potential evapotranspiration (mm)

t = time (days / months)

$\Delta Sc = So - Sc$

Other definitions (Obasi and Kiongi):

Productive available water is available water in the whole profile corrected on the efficiency of wateruptake by roots at different depths. This depends on the growth-stage of sugarcane, and rainfall amount and frequency.

Watersurplus is the excess of rainfall over the potential evapotranspiration when soil storage is at field capacity, expressed as d.

Watershortage is the difference between the potential - and actual evapotranspiration expressed as an Ea/Ep ratio.

Example of calculation as used in appendix III (p. 34)

Kamagambo, inside rows of sugarcane.

	(t-1)	(t)
date of measurement	19/7	26/7
productive available water, S(mm)	30.5	55.6
evapotranspiration, Ep (t) (mm)	56.3	26.3

Ep (t) is Ep between (t-1) and (t)
Ep is obtained from monthly Eo
with reference to growth stage Eoxf = Ep)

Precipitation, Pt	13.0	84.0

Measured total change in storage by evapotranspiration and precipitation:

$$\Delta S = S(t) - S(t-1) = +25.1 \text{ mm}$$

Calculate change in storage by evapotranspiration:

$$\Delta Sc = Sc(t) - S(t-1)$$

with formule (a):

$$= S(t-1).e^{-Ep.t/S(t-1)} - S(t-1) =$$

$$= 30.5.e^{-26.3/30.5} - 30.5$$

$$= -17.6.$$

Used for restorage of the soil:

$$\Delta S - \Delta Sc = 43.7 \text{ mm}$$

Left for evapotranspiration or drainage:

$$P(t) - (\Delta S - \Delta Sc) = 40.3 \text{ mm.} \quad \ldots\ldots\ldots\ldots\ldots\ldots (b)$$

. Left for evapotranspiration (x):

$$x = Ea + \Delta Sc \qquad Ea\ (max) = Ep$$

$$= 8.7 \text{ mm.,} \qquad X \leqslant (b)$$

. Left for drainage:

$$d = (b) - x$$

$$= 31.6 \text{ mm}$$

The set up of the experiment.

- The relative changes of the data within the two pF range will show a typical reaction of the sugarcane roots in wateruptake of available water, distinguished in:

readily available water (pF 2.0 - 3.6)

total available water (pF 2.0 - 4.2)

- To give an estimation of the effectiveness of wateruptake per depth, firstly the moisture content has been measured 10,20,40,60 and 80 cm but later on, a more relevant measurement at 10,15,20 ,25,30,40,60, and 80 cm depth or till the depth of the rotten-rock took place. According to literature reference: Purseglove stated that the majority of the fibrous roots of the plant, which are most active in a absorption are in the 25-30 cm of soil, and Humbert found that 80% of the total roots exist on the upper 60 cm and about 70% of the root hair surface within the first 30 cm of the soil. Performed root - countings show a similar pattern.

The standard deviation (s.d) of the data on wateravailability per depth are taken as a linear relationship for the relative waterextraction with depth, These results have been used to determine the productive available water.

- To find the best place for wateruptake measurements tubes were placed inside and between the rows of sugarcane. Results are expressed in Ea/Ep ratio after the calculation of the water balance with productive available water.

- To determine the iportance of depth of rotten rock the measurement have been done on profiles of different depths (table 3). Besides this, all fields have similar profiles.

Table 3. Depth of rotten rock at different trial fields.

trial-field	depth of rotten rock (cm)	number of profiles
Kamagambo	80 cm	2
Ranen	120 cm	1
	25 cm	2
Pe-hill	100 cm	1
	30 cm	2

Results on wateravailability are also examined on the Ea/Ep ratio.

3.3. Results and Discussion

Firstly the results and discussion are presented in the order as used in the set up of the experiment for each trial field (3 in total) then a summary given.

results per trial field:

Kamagambo (Table 8.1)

-No difference in Ea/Ep ratio based on either readily- or total available water. Due to the high rainfall and therefore high amount of available water.

-The effective wateruptake is difficult to estimate because of a considerable watermovement downwards in the profile.

-No significant difference is found between the two series of depth measurements.

-There seems to be no difference in wateruptake between and in rows of sugarcane during the period of measurement.

Not much information can be released from this trial- field, because the period is not representative for rainfall and moreover some rainfall-records are not reliable.

Ranen(Table 8.2)

-Ea/Ep ratio could not be calculated for all dates. The calculated change in moisture storage overestimated extremely the measured change in moisture content in the dry period especially for pF range 2.0 - 4.2.

-The effective wateruptake shows an unexpected picture:
only 50% of the total water is extracted from the top 40 cm.
The calibration curves at 60 and 80 cm depth show a bigger variation in moisture content than other tubes at the same depths. Although these calibrations are also significant on 1%, this results in a bigger share in water extraction from the deeper layers than, the expected amount.
On shallow profiles no difference in different depth measurements was found.

-Not enough results are available to give a definitive conclusion on the difference in measurements between and in the rows of sugarcane.

-A shallow profile shows a rapid decrease in Ea/Ep ratio.

A comparison between different profile depths is not possible due to the few results of the deep profile.
An accurate calibration of the neutron-probe results is important for the calculation of productive available water in a waterbalance.
A shallow profile is strongly depending on frequent rainfall.

Pe-hill (Table 8.3)

- A clear picture of the difficulty to extract water from the soil at a tension above pF 3.6: calculating the Ea/Ep ratio for pF-range 2.0 - 3.6 gives reliable figures but for pF range 2.0 - 4.2 the calculated moisture extraction is much higher than the measured one in periods without rainfall. Lower leaves became yellow in that period.
- An effective wateruptake per depth shows average share of 75% in the top 30 cm and 25% of the total from 30-80 cm layer over a measurement period of 6 weeks. On the shallow profile no distinction is made in effectiveness of wateruptake per depth. More accurate information is gathered from the more relevant depths of measurements, l.c. (see p page 11) which is proved by the Ea/Ep ratio which is zero when the productive available water S= 0 mm.
- Again no significant difference is found in measurements between and in rows of sugarcane expressed as the Ea/Ep ratio.
- The difference in soildepths for wateruptake is not clear in the first period of measurements. In average there seemed to be enough available water during that period but in the later period of measurements both profiles were exhausted. Probably a very intensive period of measurements without rainfall and after a wet period could show the difference and measurements deeper that 80 cm will provide relevant information. This trial field shows the far most interesting results because rainfall measurements seem to be accurate and the measuring period coincides with a dry spell, interesting for this kind of experiments.

Summary.

Measurements will become more reliable when prolonged periods of drought can be included, but anyhow some conclusions can be drawn:
The sugarcane plant extracts water only slowly from the soil above a tension of pF 3.6, which is temporary nor sufficient for an optimal evapotransipration and in extreme situations no water at all will be extracted.

- The effective wateruptake from soils under normal conditions shows a similar picture in waterextraction as stated in literature (Anonymous 1977, v. Nugteren et. al. 1970)

40%	of total water uptake comes from the	first fourth of the profile
30%	"	second
20%	"	third
10%	"	fourth

Movement of soil water will take place inside and into the rootzone when portions of the rootzone become dry. Probably the importance of the top layers are even more important.

- A calculation of the waterbalance and the expression of the Ea/Ep ratio does not show an difference for measurements in and between the rows of sugarcane in the first part of the measuring program (see p.11). The moisture content will still show some difference.
- It is clear that a deep profile can always provide more water, that is evident, but no classification on reliable suitability for water-availability can be given for the different profile depths, while only in a program with frequent measurement and in a period with a prolonged drought especially the reliability of the rainfall frequency on a ten-day basis will provide statisticall accurate information about the importance of the soil-depth in relation with water availability.

4. Interpretation of wateravailability in relation to soil suitability

4.1. Climate

The ideal climate for growing sugarcane is one with a long warm summer growing season and a fairly dry, sunny and cool but frost-free ripening and harvesting season (Purseglove, 1972.) The average temperature during growth should be higher than 25°C. The annual precipitation should exceed 1500 mm (Anonymus, Fieldbook for land- and watermanagement experts, 1972).

According to this literature the South Nyanza area does not have the optimal favourable temperature and precipitation conditions for sugarcane growing.

The upper ultimate altitude is given by the minimum night temperature lower than 12°C and / or the average temperature lower than 18-20°C. Besides this, germination is ceased or is very slow at temperatures below 21°C. The upper boundary is 5500 ft, growing season of a plant crop will take then about 22 mounths.

The lower ultimate altitude is given by the level and distribution of the actual - and potential evapotranspiration ratio, Ea/Ep, or in other words the deficiency for optimal evapotranspiration throughout the year.

When Ea/Ep ratio is below 0.5 during three consecutive months sugarcane growing is possible but yields will decrease considerably. This occurs at about 4000 ft. Where rainfall does not exceed 1200 mm /year and evaporation reaches over 2000 mm/year.

Because of these reasons sugar cane growing will be possible in agro-climatic zone IIb and IIc (see reconnaissance soil report on the Kisii area).

An approximation of the Ea/Ep ratio on a monthly, and three monthly (dry spell) basis is given in appendix IV, P.55. for three weather stations in these zones. Calculations have been done with a maximum consumptive use Ep=Eo, For an estimation of the effective precipitation reference is made to table 4., in which general data are recorded, It is based on an approximation of the drainage losses in the highly permeable soils.

Table 4. <u>The relationship between average monthly effective rainfall and mean monthly rainfall for different values of Ep.</u>

Monthly mean rainfall(mm)		50	62.5	75	82.5	100	112.5	125	137.5	150	162.5	175	187.5	200
		average monthly effective rainfall (mm)												
average monthly	125	37	46	54	62	70	76	85	92	98	107	116	120	
Ep (mm)	150	39	49	57	66	74	81	89	97	104	112	119	127	103
	175	42	52	61	69	78	86	95	103	111	118	126	134	141

Source :FAO, irrigation and drainage paper No. 24, revised 1977

Results as shown in appendix IV give a yearly average Ea/Ep = 0.6, while a more detailed vieuw gives a critical period in wateravailability in the dry spell "December, January" for both stations. In agroclimatic zone IIb it will become worse three years out of ten and seriously one year out of ten for agro-climatic zone IIb. For IIb/IIc an additional critical period of three months happens in July, August en September three years out of ten. Zone IIc shows a much more prolonged drought period three years out of ten and even any precipitation at all during two months once in ten year.

Remark : This monthly approximation gives an average of real figures. As stated before a considerable daily variation in rainfall and evapotranspiration exists. Therefore it is suggested to study the variation in these quantities in order to obtain a more accurate estimation, especially about the risks taken in this area in growing sugarcane.

4.2. Soil

The ideal sugarcane soil should have a deep profile, a considerable capacity for moisture storage, a friable consistence, a well developed structure enabling roots to penetrate several feet and an excees water to drain away, a nearly neutral reaction, abundant humus and a good supply of plant nutrients. (E.Bellis, 1961)
Well drained loams or clay loams and fairly heavy alluvial soils, average pH. 6.1 - 7.7 (Anonymus 1972, Fieldbook for land-and watermanagement experts). Heavy soils with high natural fertility (Purseglove 1972).

Besides the fertility aspects, that is outside the scope of this subject the examined soil-unit, a typic argiudoll (luvic phaeozem) has good properties for growing sugarcane. However it is good to realise that:

- Sugarcane extracts water easily to pF 3.6 above this value water is hardly available
- The productive available water with depths is

0 - 30 cm - 100%
60- 90 cm - 25 - 50%
90-180 cm - 0 - 25%

These are average ranges and depend strongly on the frequency of rainfall showers: less frequent rain will result in a higher water extraction of deeper soil layers.

- Depth of profile, up till rotten rock only becomes of high importance when the profile dries out due to a dry period lasting longer than one week, with sufficient rain for providing water for evapotranspiration.

In appendix IV where an approximation is given for the monthly Ea/Ep ratio a soildepth of 90 cm is chosen That means a standard profile with 10% readily available water and a productive water amount of 100% in the first 30 cm resp 50% from 30-90 an amount of 60 mm productive readily available water. It makes no sense to give other soildepths in such an approximation because differences in Ea/Ep ratios are not significant.

4.3. Conclusion

Wateravailability expressed as Ea/Ep ratio hounded by climate and soil conditions are listed in Table 9.p.55

Anonymus 1977 gives the Ea/Ep ratio as a precentage of yield during maximum growth.

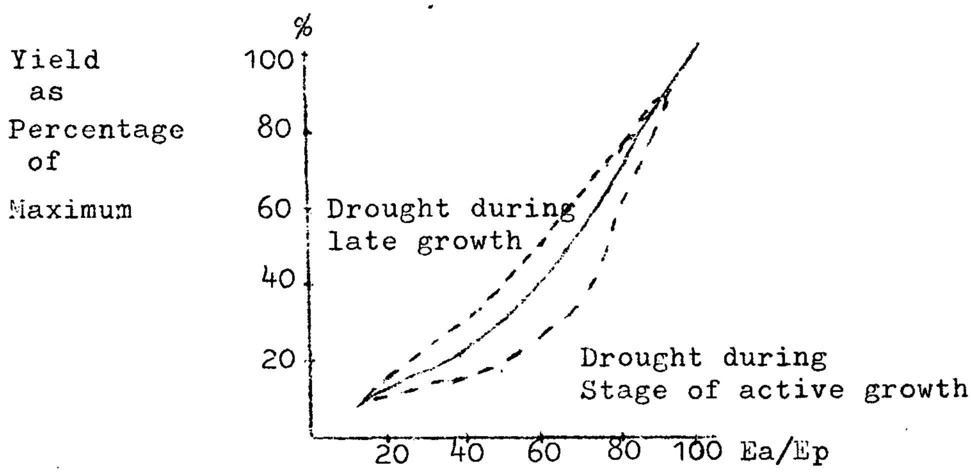

fig.a <u>Relationship between relative yield and relative Ep for non-forage crops (Downey 1972, Chap 1963).</u>

Prolonged reduction in Ea(sugarcane) during the period of active growth has a much greater negative effect on yield than when experienced during late growth. Sensitive stages for sugarcane are in the period of maximum growth out the drought resistance varies considerably with the different varieties. The variety Co 421 is known to have a high drought resistance. The estimated average yields on basis of water availability, for both agro-climatic zones are 700 kg sugar/ha/month or 135 tons cane/ha for a plant crop (20 month growthperiod) assuming no other yield reducing factors. This is calculated with

- cane/water ratio =1:80 (Barmes 1964; Hagan 1967)
- Ep =f.Eo or 1650 = 0.9X1800 is the average yearly consumptive use under optimal wateravailability.
- Ea/Ep =0.6 or 40% of maximum yield (Fig a)
- percenatage sugar is 10%

Expected yield for first and second ratoon: 110 resp. 60 tons/ha

All yields are expected to be lower three years out of ten and even more down one year out of ten, for zone IIb. In zone IIc even much more risks are taken, when growing sugarcane, in three years respectively once in ten years. Then the prolonged drought will be so severe, in this area that a considerable yield reduction is to be expected.

5. Literature

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6. LIST OF TABLES.

List of tables (cont.)

APPENDIX I

Climate

Contents

Table 5. Mean minimum-and maximum monthly temperatures (^{o}C) for three wheather stations

	Year:	J	F	M	A	M	J	J	A	S	O	N	D
minimum temperature													
Ahero(4000 feet.)	15.9	15.3	15.9	16.9	16.8	16.8	15.6	15.7	15.4	15.3	15.7	15.6	15.3
Koru(5120 ft.)	13.5	13.2	13.9	13.9	14.6	14.1	13.5	13.3	13.0	13.0	13.3	13.5	13.1
Kisii (5600ft.)	12.5	11.7	12.9	12.4	13.2	13.4	12.5	12.0	12.3	12.3	12.4	12.1	12.2
maximum temperature													
Ahero(4000 ft.)	30.0	31.3	30.7	29.1	28.8	29.0	28.9	29.2	30.6	30.7	30.5	31.4	30.3
Koru (5120 ft.)	28.1	29.5	29.6	28.9	27.4	26.9	26.8	27.0	27.0	27.9	28.5	28.3	29.0
Kisii(5600 ft.)	26.0	26.9	27.3	26.6	25.8	25.7	25.3	25.0	25.2	26.0	26.5	25.5	25.9

Table 6. Mean Monthly - and Yearly rainfall (mm) and two probability levels of non-exceedence for three wheather stations representative for agroclimatic zone IIb and IIc

Kamagambo nr 9034005 (Agroclimatic zone IIb)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
av.P	50	66	136	236	194	112	79	119	127	106	140	107	1517
P 30% non-exc.	18	15	78	193	141	84	35	72	90	73	75	43	1344
P 10% non-exc.	8	5	45	152	101	62	15	44	63	49	44	19	

Uriri nr 9034047 (Agroclimatic zone IIb & IIc)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
av. P	76	93	153	215	143	88	58	73	104	126	151	92	1335
P 30% non-exc.	23	32	106	156	106	36	20	50	69	72	93	58	1232
P 10% non-exc.	7	13	73	111	77	16	4	34	45	41	58	37	-

Oyugis nr 9034023 (Agroclimatic zone IIc)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
av. P.	28	49	110	190	213	100	99	127	109	104	109	73	1310
P 30% non-exc.	8	16	53			63	67		70	66	46	35	
P 10% non-exc.	3	6	26			41	62		43	43	20	19	

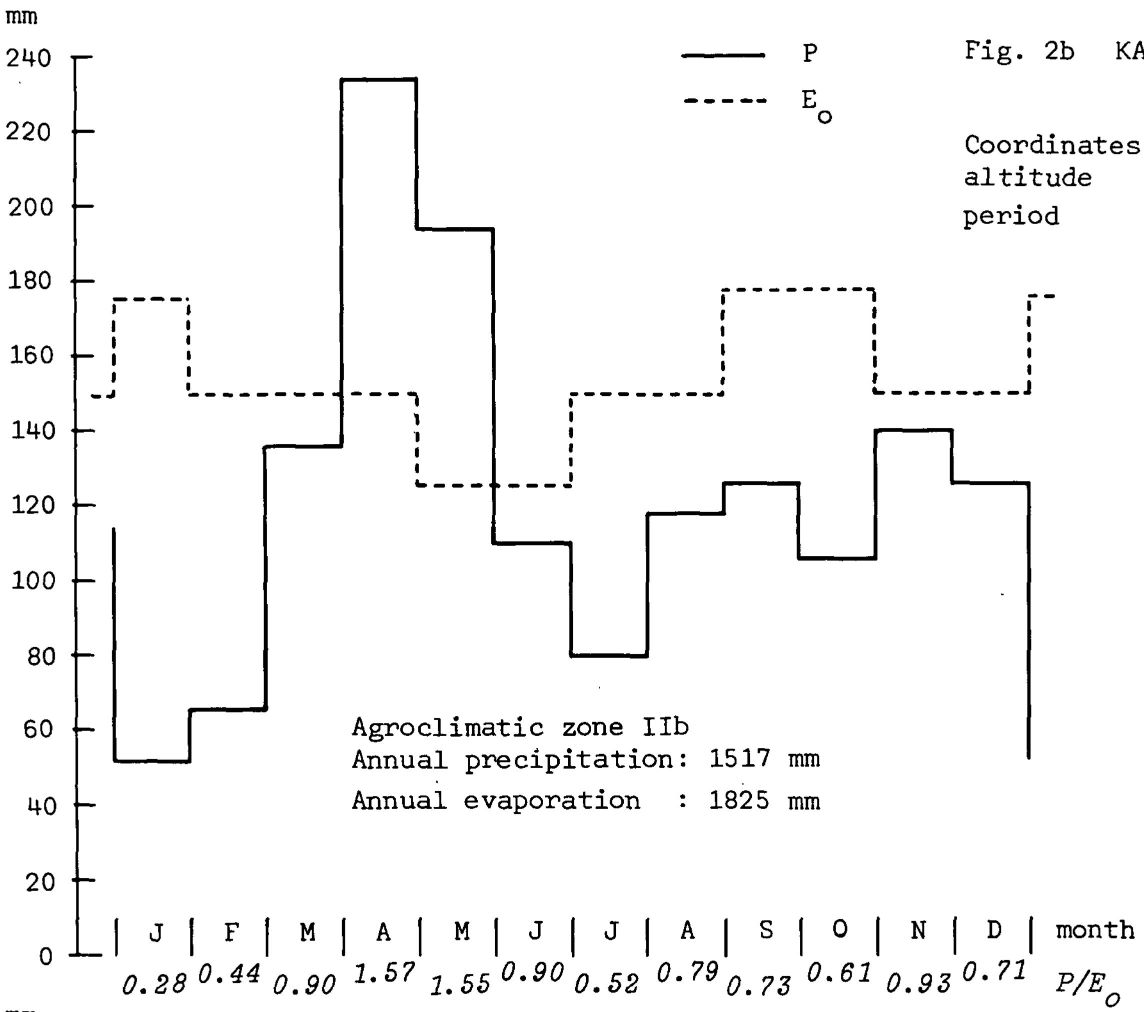


Fig. 2b KAMAGAMBO 9034-005

Coordinates: 0°45′S, 34°38′E
altitude : 5000 ft
period : 20 years

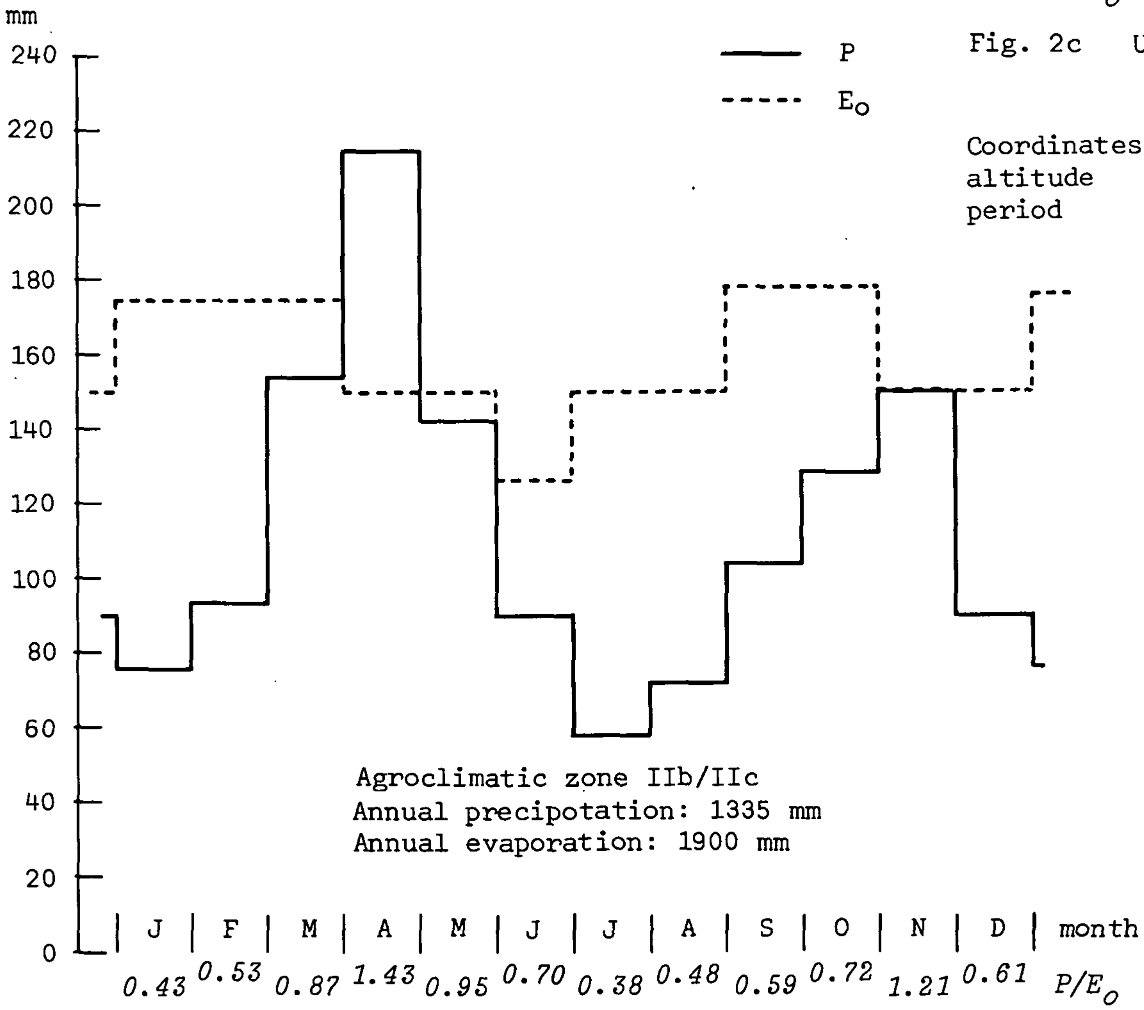
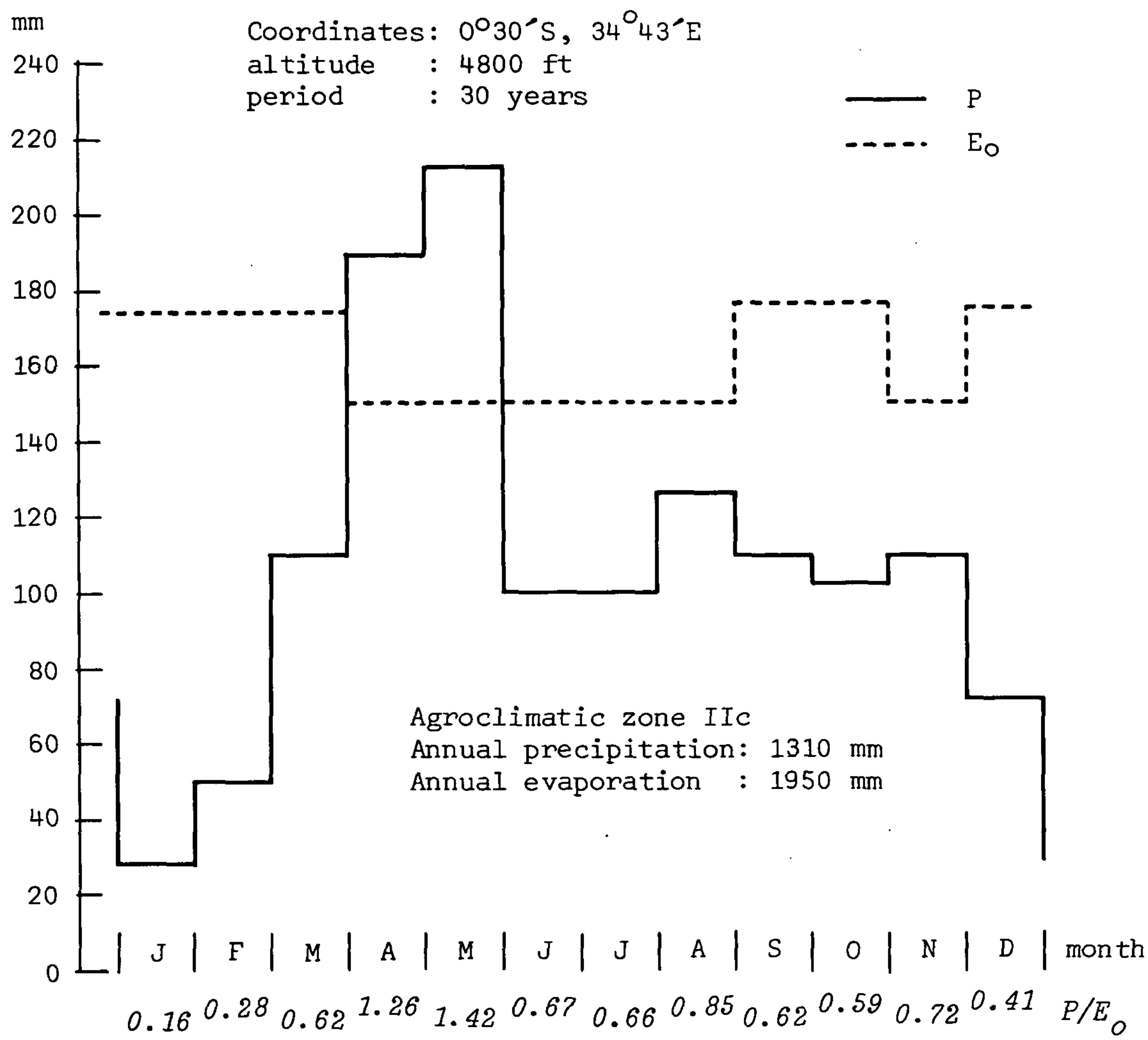


Fig. 2c URIRI 9034-047

Coordinates: 0°58′S, 34°31′E
altitude : 4900 ft
period : 20 years

Fig. 2d OYUGIS 9034-023



Figures 2b, -c and -d: Average monthly precipitation P (mm) and monthly evaporation E_o (mm) and P/E_o ratio.

APPENDIX II

Soil

Contents. page no

Profile description

Information on the Site Sampled

Profile : Kamagambo

mapping unit : U4 Yhp.;(BC, slope class)

soil classification : Soil Taxonomy : Typic Argiudoll

FAO : Luvic Phaeozem

date of examination : 23/9/77

authors of description : Kluyfhout and O'Herne

location : Coordinates : AQ 9919 S, 680 E; 0°. 45'S, 34° 37'E Opposite of the village Kamagambo at the road Kisii to Rongo., South Nyanza district, Kenya

elevation: 4850 ft.

landform : very gently undulating

Physiographic position of the site : linear single slope

microtopography : non to very slight

slope : gently sloping 2%

landuse : maize arable land.

climate : 1200 - 1400 mm, annual precipitation three out of four years.

av.t =23°C, isothermic temperature regime

General Information on the soil

parent material : Rhyolites and Rhylitic tuffs

drainage : well drained

rock outcrop or surface stoniness : nil

erosion : nil

salt or alkali : nil

human influences : fertilizers : ploughing.

Brief General Description of the Profile

Deep, well drained, dark reddish gray porous and crumby clay with humus coatings in the top layer and clay skins in the B - horizon.

Description of Individual Soil Horizons

Ap 0 - 20 cm (0 - 8 inch)	Dark reddish gray (5 YR 4/2,dry) dark reddish brown (5 YR 3/3,moist); clay; strong medium subangular blocky to strong very fine crumbly;hard; friable, sticky and plastic; abundant moderate humus coatings; many very fine, few fine and few medium pores; common fine, few medium roots; clear and wavy boundary ....
B22 20-75 8-30 inch)	Dark reddish gray (5 YR 4/2,moist); clay; strong medium angular blocky to strong fine crumbly; friable, sticky and plastic; abundant moderate clay skins; many very fine, few fine and few medium pores; few fine few medium and very coarse roots; gradual and smooth boundary ....
B23 75 -90cm (30-36inch)	Dark red (2,5 YR 3/6,moist); clay to clay-loam; moderate fine subangular blocky to strong very fine crumbly; very friable, slightly sticky and plastic; common weak clay skins; many very fine, few fine pores; very few roots, clear and wavy boundary.
C 90 + cm (36 + inch).	Rotten rock

Remark :

At 90 -cm(36 inch) depth!one very coarse rounded stone (10x10x5 cm) was found.

Table 7. Analytical results of profile Kamagambo

Laboratory : TPIP, Kisii

depth (cm)	hor.	text. class	sand 2.00-1.00	1.00-0.50	0.50-0.25	0.25-0.10	0.10-0.05	sand total sand.	silt 0.05-0.002	clay less 0.002
			size class and particle diameter (mm)							
0 - 10	Ap	c	1.0	2.0	2.4	3.5	2.3	11.2	30.5	58.4
10- 20	Ap	c	1.2	1.8	2.3	2.4	2.0	9.7	29.3	61.0
20- 40	B22	c	0.2	1.2	1.4	2.0	1.3	6.1	25.1	68.8
40- 60	B22	c	0.7	1.7	1.7	2.2	2.2	7.4		

Remark :no gravel (particles larger than 2 mm) is present in the profile

water content (vol.%)

depth (cm)	bulk dens.	sat.	pF 0.4	1	1.5	2	2.3	2.8	3	3.6	4.2
10	1.29	51.0	50.7	47.7	43.3	40.7	37.6	36.8	35.0	29.0	25.1
20	1.24	49.3	48.7	46.3	43.6	41.2	40.0	39.3	33.9	29.8	27.0
40	1.23	50.2	49.8	47.7	46.2	43.6	40.4	39.5	38.7	31.6	28.2
	1.19	51.8	51.2	49.1	45.6	40.5	37.3	36.4	34.5	32.3	27.7

depth (cm)	10	20	40	60	80
org. C*	2.2	2.1	n.d.	1.4	1.1

*Acid-dichromate digestion, walkley and Black method.

A P P E N D I X   III

Waterbalance (measured)

Contents

Table 8. 1.a. Readily-(PF 2.0 - 3.6) and Total - (pF 2.0 - 4.2 available (mm)

waterbalance with productive available water

depth (cm)	calibration $\bar{Y}+b(X-\bar{X})$	date (1977) 4/7	19/7	26/7	2/8	9/8	18/8	23/8	30/8	20/9
0-10	38.4+0.06(X-382)	15.3^{+}	8.5	17.8	9.8	10.3	11.8^{+}	11.4	19.4^{+}	12.5^{+}
	s.d.=5.9(n=10)	19.2	12.4	21.7	13.7	14.2	17.7	15.3	23.4	16.4
10-15	38.4+0.08(X-452)									
	s.d.=3.5(n=10)									
15-20	38.8+0.07(X-473)	14.3^{+}	6.9	15.0^{+}	7.8	10.0	14.0^{+}	9.9	16.9^{+}	10.2
	s.d.=2.8(n=10)	17.1	9.7	17.8	10.6	12.8	16.8	12.7	19.7	13.0
20-25	38.6+0.09(X-518)									
	s.d.=3.4(n=10)									
25-30	40.0+0.09(X-510)									
	s.d.=3.4(n=10)									
30-40	39.5+0.08(X-518)	26.3^{+}	15.1	26.2^{+}	12.2	15.4	27.4^{+}	19.0	27.6^{+}	24.1^{+}
	s.d.=5.3(n=10)	29.7	18.5	29.6	15.6	18.8	30.8	22.4	31.0	27.5
	70%. S(0-40)	39.1	21.4	41.3	20.9	25.0	38.6	28.2	44.7	32.8
		46.2	28.4	48.4	27.9	32.1	45.7	35.3	51.8	39.8
40-60	38.5+0.05(X-499)	19.0^{+}	17.3^{+}	26.0^{+}	11.6	11.4	14.6	15.1	25.1^{+}	23.4^{+}
	s.d.=8.9(n=10)	20.6	18.4	29.2	11.0	10.6	15.0	15.6	28.8	26.6
60-80	38.5+0.05(X-479)	15.2	13.0	21.5^{+}	7.6	8.4	6.5	7.5^{+}	17.5^{+}	12.3
	s.d.=4.3(n=10)	22.0	19.8	28.3	14.4	15.2	13.3	14.3	24.3	18.8
	30%. S (40-80)	10.3	9.1	14.3	5.8	5.9	6.3	6.8	12.8	13.1
		14.3	13.2	18.3	9.8	10.0	10.4	10.9	16.9	17.1
	S (mm)	49.4	30.5	55.6	26.7	30.9	44.9	35.0	57.5	45.9
		60.5	41.6	66.7	37.7	42.1	56.1	46.2	68.7	57.0
	Ep(t)(mm)		56.3	26.3	30.6	35.0	45.0	25.0	35.0	116.8
	P (t)(mm)		13.0?	84.0	25.4	0.0?	66.3	30.0	79.8	15.0?
	Ea/Ep			1.0	1.0		1.0	1.0	1.0	
				1.0	1.0		1.0	1.0	1.0	
	d			31.6	23.7		7.3	14.9	22.3	
				32.6	23.8		7.3	14.9	22.3	

Kamagambo, inside rows of sugarcane plantcrop april 1977

duplicate measurement.

$^+$=water bounded at a lower tension than pF = 2.0

?=unreliable

depth (cm)	date (1977) 3/10	6/10	11/10	14/10	14/10	19/10	24/10	27/10	2/11	8/11	12/11	pF-range
0-10	3.3	2.2	3.4	7.7	7.5	14.5$^+$	13.5$^+$	15.9$^+$	15.9$^+$	16.1$^+$	16.0$^+$	2.0-3.6
	7.2	6.1	7.3	11.6	11.4	18.4	17.4	19.8	20.0	20.6	19.9	2.0-4.2
10-15	0.4		-0.3	1,7	1.8	6.8$^+$	6.6$^+$	7.9$^+$	7.5$^+$	8.0$^+$	8.0$^+$	2.0-3.6
	1.8		1.1	3.1	3.2	8.2	8.0	9.3	8.9	9.4	9.4	2.0-4.2
15-20	1.8	3.2	1.4	2.2	2.2	6.6$^+$	7.3$^+$	7.7$^+$	7.5$^+$	7.8$^+$	7.2$^+$	2.0-3.6
	3.2	5.0	2.8	3.6	3.6	8.0	8.7	9.1	8.9	9.2	8.6	2.0-4.2
20-25	-0.8		-1.0	-1.0	-0.9	5.0	5.9$^+$	5.9$^+$	5.6$^+$	5.7$^+$	5.5$^+$	2.0-3.6
	0.9		0.7	0.7	0.8	6.7	7.3	7.3	7.3	7.4	7.2	2.0-4.2
25-30	1.4		0.9	1.1	0.6	6.8$^+$	7.9$^+$	7.7$^+$	7.0$^+$	7.2$^+$	6.8$^+$	2.0-3.6
	3.1		2.6	2.8	2.3	8.5	9.6	9.4	8.7	8.9	8.5	2.0-4.2
30-40	4.4	8.2	3.2	3.3	3.4	12.2$^+$	14.3$^+$	14.9$^+$	14.2$^+$	13.8$^+$	12.5$^+$	2.0-3.6
	7.8	15.0	6.6	6.7	6.8	15.6	17.7	18.3	17.6	17.2	15.9	2.0-4.2
	8.3	9.5	5.7	11.2	10.9	36.3	38.3	42.0	40.5	41.4	39.2	2.0-3.6
	16.8	18.3	14.8	20.0	19.7	45.8	48.1	51.2	50.0	50.9	48.7	2.0-4.2
40-60	12.0	9.8	7.0	6.0	5.8	22.4$^+$	23.8$^+$	27.8$^+$	24.2	25.0$^+$	23.0$^+$	2.0-3.6
	18.8	16.6	13.8	12.8	12.6	29.2	30.6	34.6	31.0	31.8	29.8	2.0-4.2
60-80	12.0	11.6	10.2	10.6	9.4	16.2	16.0	21.0$^+$	19.6$^+$	19.2$^+$	18.2$^+$	2.0-3.6
	18.8	18.4	17.0	17.4	16.2	23.0	22.8	27.8	26.4	26.0	25.0	2.0-4.2
	7.2	6.4	5.2	5.0	4.6	11.6	11.9	14.6	18.1	13.3	13.3	2.0-3.6
	11.3	10.5	9.2	9.1	8.6	15.7	16.0	18.7	17.2	17.3	16.4	2.0-4.2
	15.7	15.9	10.9	16.2	15.5	47.9	50.2	56.6	53.6	54.7	51.6	2.0-3.6
	28.1	28.8	24.0	29.1	28.3	61.5	64.1	69.9	67.2	68.2	65.1	2.0-4.2
	73.5	18.4	30.6	18.4	30.6	30.6	18.4	30.6	18.4	18.4	24.5	
	30.0	0.0?	0.0?	21.0	33.0	36.0?	31.5	40.2	33.0	69.0	66.0	
	0.8			0.9	1.0		1.0	1.0	1.0	1.0	1.0	2.0-3.6
	0.8			0.9	1.0		1.0	1.0	1.0	1.0	1.0	2,0-4.2
	0			0	3.1		10.8	3.2	17.6	49.5	44.6	2.0-3.6
	0			0	3.2		10.5	3.8	17.3	49.6	44.7	2.0-4.2

Table 8.1.b. Readily - (pF 2.0 - 3.6) and Total - (pF 2.0 - 4.2) available water (mm)
Water balance with productive available water

depth (cm)	calibration $\bar{Y}+b(X-\bar{X}$	4/7	19/7	26/7	2/8	9/8	18/8	23/8	30/8	20/9	3/10	6/10
0-10	39.1+0.06(X-403)	15.1+	7.1	22.0+	8.8	10.3	11.4	12.9+	20.7+	13.6+	-3.9	4.5
	s.d.=5.2(n=10)	19.0	11.0	25.9	12.7	14.2	15.3	16.8	24.6	17.5	7.8	8.4
10-15	39.6+0.10(X-452)										0.7	
	s.d.=3.6(n=10)										2.7	
15-20	37.0+0.08(X-460)	9.2	3.7	19.5+	4.8	7.8	11.2	8.8	16.9+	14.5+	2.0	3.8
	s.d.=2.8(n=10)	12.0	6.5	22.3	7.6	10.6	14.6	11.6	19.7	18.2	3.9	6.6
20-25	39.6+0.10(X-502)										2.4	
	s.d.=3.2(n=10)										4.3	
25-30	40.4+0.10(X-518)										3.3	
	s.d.=3.0(n=10)										5.2	
30-40	39.7+0.12(X-500)	13.1	9.3	14.7	7.5	9.3	20.1	19.4	25.7+	25.2+	6.7	11.6
	s.d.=6.0(n=10)	19.9	16.1	21.5	14.3	16.1	26.9	26.2	32.5	32.3	13.5	18.4
	70%.S(0-40)	26.2	14.0	39.3	14.8	19.1	29.0	28.7	44.3	37.5	13.3	13.0
		35.6	23.7	48.8	24.2	28.6	39.5	38.2	52.4	47.0	22.8	23.4
40-60	38.5+0.06(X-495)	13.0	9.7	28.6+	7.3	8.9	7.5	11.0	21.6+	19.7+	11.9	9.7
	s.d.=6.0(n=10)	22.2	18.9	37.8	16.5	18.1	16.7	20.2	20.8	28.9	21.1	18.7
60-80	38.6+0.03(X-486)	15.2	11.7	22.2+	10.0	10.7	9.4	8.7	16.8+	18.8+	15.0	14.5
	s.d.=3.5(n=10)	24.4	20.9	31.4	19.2	19.9	18.6	17.9	26.0	28.0	24.2	23.7
	30%.S(40-80)	8.5	6.4	15.2	5.2	5.9	5.1	5.9	11.5	11.6	8.1	9.3
		14.0	11.9	20.8	10.7	11.4	11.6	11.4	17.6	17.1	13.6	12.8
	S(mm)	34.7	20.4	54.5	20.0	25.0	34.1	34.6	55.8	49.1	21.4	20.3
		49.6	35.7	69.6	34.9	40.0	49.9	49.7	70.0	64.0	36.3	36.2
	Ep(t)(mm)		56.3	26.3	30.6	35.0	45.0	25.0	35.0	116.8	73.5	18.4
	P(t)(mm)		13.0?	84.0	25.4	0.0?	66.3	30.0	79.8	15.0?	30.0	0.0?
	Ea/Ep			1.0	1.0		1.0	1.0	1.0		0.8	
				1.0	1.0		1.0	1.0	1.0		0.8	
	d			23.6	30.8		17.2	4.5	23.6		0	
				23.8	30.5		11.4	4.8	24.5		0	

Kamagambo, between rows of sugarcane
plantcrop april 1977
duplicate measurement.

$^{+}$=water bounded at a lower tension than pF 2.0
?=unreliable

depth (cm)	date (1977) 11/10	14/10	19/10	24/10	27/10	2/11	5/11	8/11	12/11	pF-range
0-10	3.4	5.9	7.0	14.0^{+}	13.4^{+}	15.5^{+}	15.5^{+}	16.0^{+}	15.1^{+}	2.0-3.6
	7.3	9.8	10.9	17.9	17.3	19.4	19.4	19.9	18.0	2.0-4.2
10-15	0.1	1.1	1.7	7.8^{+}	8.6^{+}	8.9^{+}	7.7^{+}	7.9^{+}	8.1^{+}	2.0-3.6
	2.1	3.1	3.7	10.0	10.6	10.9	9.7	9.7	10.1	2.0-4.2
15-20	1.0	1.6	1.4	6.4^{+}	6.2^{+}	7.3	7.1^{+}	7.1^{+}	6.9^{+}	2.0-3.6
	2.9	3.5	3.3	8.3	8.1	9.2	9.0	8.9	8.8	2.0-4.2
20-25	1.1	1.4	1.6	7.3^{+}	7.0^{+}	8.3^{+}	8.1^{+}	8.3^{+}	7.6^{+}	2.0-3.6
	3.0	3.3	3.5	9.2	8.9	10.2	10.0	10.2	9.5	2.0-4.2
25-30	1.9	2.0	2.0	7.3^{+}	7.1^{+}	8.6^{+}	7.8^{+}	8.4^{+}	7.6^{+}	2.0-3.6
	3.8	3.9	3.9	9.2	9.0	10.5	9.7	10.3	9.5	2.0-4.2
30-40	5.2	4.0	2.5	14.5^{+}	8.8^{+}	18.0^{+}	16.9^{+}	16.6^{+}	15.8^{+}	2.0-3.6
	8.6	7.4	5.9	17.9	12.2	21.4	20.3	20.0	19.2	2.0-4.2
	8.9	11.2	11.3	40.1	35.8	46.7	44.1	45.0	42.7	2.0-3.6
	18.3	20.7	21.8	49.6	45.2	56.1	53.6	54.5	52.2	2.0-4.2
40-60	7.3	6.8	6.6	15.1	14.4	22.1^{+}	20.0^{+}	20.7^{+}	18.8^{+}	2.0-3.6
	16.5	16.0	15.8	24.3	23.6	31.3	29.2	29.9	28.0	2.0-4.2
60-80	13.1	12.2	11.7	11.6	17.0^{+}	19.6^{+}	19.5^{+}	20.7^{+}	18.3^{+}	2.0-3.6
	22.3	21.4	20.9	20.8	26.2	28.8	28.7	29.9	24.1	2.0-4.2
	6.1	5.7	5.5	8.0	9.4	12.5	11.9	12.4	10.1	2.0-3.6
	11.6	11.2	11.0	13.5	14.9	18.0	17.4	17.9	15.6	2.0-4.2
	15.0	16.9	16.8	48.1	45.2	59.2	56.0	57.4	52.9	2.0-3.6
	30.0	31.9	32.8	63.1	60.2	74.1	71.0	72.4	67.9	2.0-4.2
	30.6	18.4	30.6	30.6	18.4	30.6	18.4	18.4	24.5	2.0-3.6
	0.0?	21.0	33.0	36.0?	31.5	40.2	33.0	69.0	66.0	2.0-4.2
		1.0	1.0		1.0	0.9	1.0	1.0	1.0	2.0-3.6
		1.0	1.0		1.0	0.9	1.0	1.0	1.0	2.0-4.2
		0.7	2.5		17.0	0	17.8	49.2	46.0	2.0-3.6
		0.7	1.5		16.0	0	17.7	42.2	46.0	2.0-4.2

Table 8.2.a. Readily -(pF 2.0 - 3.6) and Total -(pF 2.0 - 4.2) available water (mm)
Waterbalance with productive available water

depth (cm)	calibration $\bar{Y}+b\ (X-\bar{X})$	date(1977) 3/10	5/10	10/10	13/10	17/10	21/10	27/10	28/10	1/11
0-10	33.4+0.06(X-443) s.d.=4.3(n=11)	9.6 13.2	3.2 6.8	2.1 5.7	1.7 5.3	3.5 7.1	6.8 10.4	11.0 14.6	8.4 12.0	12.4 16.0
10-15	35.9+0.05(X-475) s.d.=1.7(n=11)	3.6 6.6	3.2 6.2	2.4 5.4	2.2 5.2	2.5 5.5	3.4 6.4	4.9 7.9	4.3 7.3	7.0^{+} 10.0
15-20	37.3+0.07(X-500) s.d.=1.8(n=11)	4.8 6.8	4.6 6.6	3.5 5.5	2.9 4.9	2.7 4.7	3.2 5.2	2.7 7.7	5.5 7.5	7.6 9.6
20-25	38.4+0.09(X-520) s.d.=2.1(n=11)	4.5 5.8	4.2 5.5	2.6 3.9	2.6 3.9	1.7 3.0	2.4 3.7	5.0 6.3	7.2 8.5	7.4^{+} 10.7
25-30	37.8+0.09(X-525) s.d.=2.1(n=11)	4.0 4.9	3.6 4.5	2.6 3.5	2.1 3.0	1.4 2.3	1.0 1.9	4.4 5.3	4.3 5.2	7.3^{+} 8.2
30-40	37.0+0.10(X-512) s.d.=4.5(n=11)	6.9 9.2	5.8 8.1	3.6 5.9	2.9 5.2	1.8 4.1	0.2 2.4	4.0 6.3	4.5 6.8	12.6^{+} 14.9
	50%.S (0-40)	16.6 23.3	12.8 22.1	7.9 15.0	7.1 13.8	8.1 13.4	8.4 14.8	17.3 23.7	15.8 23.7	30.1 34.8
40-60	34.0+0.09(X-494) s.d.=8.3(n=11)	8.7 18.5	9.2 19.0	5.3 15.1	3.7 13.5	2.4 12.2	0.6 10.4	0.6 10.4	1.7 11.5	19.7^{+} 29.5
60-80	35.4+0.20(X-457) s.d.=13.4(n=11)	15.0 26.8	12.6 24.4	7.4 19.2	5.4 17.2	-1.4 10.4	1.4 10.4	-0.2 11.6	2.6 9.2	9.8 21.6
	50%.S(40-80)	11.8 22.7	10.8 21.7	6.2 17.2	4.5 15.4	1.2 11.3	0.3 10.5	0.3 11.0	0.8 10.4	11.8 32.1
	S (mm)	$\overline{28.4}$ 46.0	$\overline{25.6}$ 21.7	$\overline{14.1}$ 32.2	$\overline{11.6}$ 29.2	$\overline{9.3}$ 24.7	$\overline{8.7}$ 25.3	$\overline{17.6}$ 34.7	$\overline{16.6}$ 34.1	$\overline{41.9}$ 60.3
	Ep(t)(mm)		12.3	30.2	18.4	24.5	24.5	36.8	6.1	18.4
	P (t)(mm)		0.0	2.0	0.0	14.5	4.0?	53.0	2.0	25.0
	Ea/Ep					0.7 0.8		1.0 1.0		
	d					0 0		7.3 6.8		

Ranen, inside rows of sugarcane
2e ratoon nov. 1976.
singular measurement.

+=water bounded at a lower tension than pF.=2.0
?=unreliable

depth (cm)	date 4/11	8/11	pF-range
0-10	11.3	12.8+	2.0-3.6
	14.9	16.4	2.0-4.2
10-15	5.8	6.3+	2.0-3.6
	8.8	9.3	2.0-4.2
15-20	7.0	7.1	2.0-3.6
	9.0	9.1	2.0-4.2
20-25	6.8	6.6	2.0-3.6
	8.1	7.9	2.0-4.2
25-30	6.7+	5.9+	2.0-3.6
	7.6	6.8	2.0-4.2
30-40	12.4+	12.5+	2.0-3.6
	14.7	14.8	2.0-4.2
	25.0	25.6	2.0-3.6
	31.6	32.2	2.0-4.2
40-60	20.0+	22.4+	2.0-3.6
	29.8	31.2	2.0-4.2
60-80	32.6+	36.6+	2.0-3.6
	34.4	48.4	2.0-4.2
	26.3	29.5	2.0-3.6
	32.1	39.8	2.0-4.2
	51.3	55.1	2.0-3.6
	63.7	72.0	2.0-4.2
	15.8	21.0	
	61.5	38.5	
	1.0	1.0	2.0-3.6
	1.0	1.0	2.0-4.2
	36.8	13.2	2.0-3.6
	42.3	9.2	2.0-4.2

Table 8.2.b. <u>Readily-(pF 2.0 -3.6) and Total - (pF2.0 -4.2) available water (mm)</u>
<u>Waterbalance with productive available water</u>

depth	calibration	date (1977)									
(cm)	$\bar{Y}+b(X-\bar{X})$	3/10	5/10	10/10	13/10	17/10	21/10	27/10	28/10	1/11	4/11
0-10	34.4+0.06(X-436)	7.0	7.0	4.3	3.5	5.7	10.1	10.6	10.0	13.6$^+$	13.2$^+$
	s.d.=3.7(n=11)	10.6	10.6	7.9	7.1	9.3	13.7	14.2	13.6	17.2	16.8
10-15	37.0+0.09(X-488)	3.8	3.7	1.5	1.9	2.5	4.1	5.8	5.2	7.5$^+$	6.7$^+$
	s.d.=2.2(n=11)	6.7	6.6	4.4	4.8	5.4	7.0	8.7	8.1	10.4	9.6
15-20	38.1+0.09(X-509)	5.2	5.2	3.4	3.3	2.8	3.5	5.9	5.5	8.3	7.4
	s.d.=2.0(n=11)	7.2	7.2	5.4	5.3	4.8	5.5	7.9	7.5	10.3	9.4
20-25	38.5+0.09(X-515)	5.4	4.3	3.1	2.8	2.2	2.4	4.7	5.0	7.3	6.4
	s.d.=1.9(n=11)	6.6	5.5	4.3	4.0	3.4	3.6	5.9	6.2	8.5	7.6
25-30	37.5+0.08(X-516)	5.0	4.2	3.1	2.5	1.9	1.9	4.3	3.8	7.0$^+$	6.5$^+$
	s.d.=1.8(n=11)	5.9	5.1	4.0	3.4	2.8	2.9	5.2	4.7	7.9	7.4
30-40	37.0+0.10(X-512)	8.6	7.1	3.4	2.8	3.4	1.4	3.5	3.7	13.2$^+$	12.2$^+$
	s.d.=4.4(n=11)	10.9	9.4	5.7	5.1	5.7	3.7	5.8	6.0	15.5	14.5
	50%.S(0-40)	17.5	15.7	9.4	8.4	8.6	11.6	17.4	16.6	28.5	26.2
		27.0	17.3	15.9	14.9	15.7	18.1	23.9	23.1	39.7	33.0
40-60	33.2+0.08(X-474)	11.4	9.6	5.6	5.4	2.9	0.3	1.1	2.2	10.2	20.3$^+$
	s.d.=7.2(n=11)	25.4	23.6	19.6	19.4	16.9	14.3	15.1	16.2	24.2	34.3
60-80	32.4+0.14(X-452)	8.5	9.9	4.6	1.5	0.1	0.1	-2.2	-2.2	2.3	31.7$^+$
	s.d.=12.9(n=11)	24.1	25.5	20.2	17.1	15.7	15.7	13.4	13.4	13.3	47.3
	50%.S(40-80)	10.0	9.8	5.2	3.5	1.5	0.2	0.6	1.1	6.3	26.0
		24.8	24.6	19.9	18.3	16.3	15.1	14.3	14.8	18.8	40.5
	S (mm)	27.5	25.5	14.6	11.9	10.1	11.8	18.0	17.7	34.8	52.2
		51.8	41.9	35.8	33.2	32.0	33.2	38.2	37.9	58.5	73.8
	Ep(t)(mm)		12.3	30.7	18.4	24.5	24.5	36.8	6.1	18.4	15.8
	P (t)(mm)		0.0	2.0	0.0	14.5	4.0?	53.0	2.0	25.0	61.5
	Ea/Ep				0.6			1.0			1.0
					0.7			1.0			1.0
	d				0			10.1			28.3
					0			11.2			30.7

Ranen, between rows of sugarcane
2e ratoon nov. 1976
singular measurement.

$^{+}$=water bounded at a lower tension than pF 2.0
?=unreliable

depth (cm)	date 8/11	pF-range
0-10	13.8^{+}	2.0-3.6
	17.4	2.0-4.2
10-15	8.1^{+}	2.0-3.6
	11.0	2.0-4.2
15-20	8.5	2.0-3.6
	10.5	2.0-4.2
20-25	7.4^{+}	2.0-3.6
	8.6	2.0-4.2
25-30	6.3^{+}	2.0-3.6
	7.4	2.0-4.2
30-40	12.2^{+}	2.0-3.6
	14.5	2.0-4.2
	28.1	2.0-3.6
	34.6	2.0-4.2
40-60	21.1^{+}	2.0-3.6
	35.1	2.0-4.2
60-80	34.2^{+}	2.0-3.6
	49.8	2.0-4.2
	27.7	2.0-3.6
	42.5	2.0-4.2
	55.8	2.0-3.6
	77.1	2.0-4.2
	21.0	
	38.5	
	1.0	2.0-3.6
	1.0	2.0-4.2
	13.9	2.0-3.6
	13.9	2.0-4.2

Table 8.2.c. Readily-(pF 2.0-3.6) and Total-(pF 2.0-4.2) available water (mm)
Water balance with productive available water

depth (cm)	calibration $\bar{Y}+b(X-\bar{X})$	date (1977) 4/7	12/7	19/7	26/7	2/8	9/8	18/8	30/8	22/9	27/9	3/10
0-10	26.1+0.07(X-344)	8.5	1.6	-1.8	-3.8	-0.3	4.8	0.3	2.5	2.0	5.8	1.9
	s.d.=5.8(n=10)	11.2	4.3	0.9	-1.1	2.4	7.5	3.0	6.2	4.7	8.5	4.6
10-15	30.6+0.07(X-424)											0.2
	s.d.=2.8(n=10)											2.1
15-20	32.5+0.08(X-438)	13.2	7.3	1.7	-8.6	0.8	10.4	1.4	1.0	5.7	11.7	3.8
	s.d.=2.8(n=10)	14.8	8.9	3.3	-7.0	2.4	12.0	3.0	2.6	7.3	13.3	4.6
20-25	32.7+0.09(X-457)	6.6	3.7	0.9	-4.3	0.4	5.2	0.7	0.5	2.9	5.9	3.9
	s.d.=2.8(n=10)	7.4	4.3	1.7	-3.5	1.2	6.0	1.5	1.3	3.7	6.7	4.7
	S (mm)	$\overline{28.3}$	$\overline{12.6}$	$\overline{2.6}$	$\overline{0.0}$	$\overline{1.2}$	$\overline{20.4}$	$\overline{2.4}$	$\overline{4.0}$	$\overline{10.6}$	$\overline{23.4}$	$\overline{9.8}$
		33.4	17.7	5.9	0.0	6.0	25.5	7.5	9.1	15.7	28.5	16.0
	Ep(t)(mm)		42.0	36.8	36.8	36.8	36.8	47.3	63.0	141.0	30.6	36.8
	P (t)(mm)		10.0	0.0	0.0	16.5	0.0?	0.0	59.0	154.4	0.0?	0.0
	Ea/Ep		0.7	0.3	0.1	0.4		0.4	0.9	1.0		0.5
			0.8	0.4	0.2	0.3		0.5	0.9	1.0		0.6
	d		0	0	0	0		0	0	6.8		0
			0	0	0	0		0	0	6.4		0

Ranen, inside rows of sugarcane
2e ratoon nov. 1976
duplicate measurement.

+=water bounded at a lower tension than pF 2.0
?=unreliable

depth (cm)	date (1977) 5/10	10/10	14/10	17/10	21/10	27/10	28/10	1/11	4/11	8/11	pF-range
0-10	0.2	-2.3	-3.1	-0.2	4.9	7.2	6.5	10.6	11.0	12.5	2.0-3.6
	4.7	0.4	-0.4	2.5	7.6	9.9	9.2	13.3	13.7	15.2	2.0-4.2
10-15	-0.7	-1.9	-2.6	-1.2	1.5	2.7		4.2	4.5	5.1	2.0-3.6
	1.2	0.0	-0.7	0.7	3.4	4.6		6.1	6.4	7.0	2.0-4.2
15-20	3.3	1.6	1.2	1.6	4.3	5.6	8.1^+	7.8^+	7.6^+	6.9	2.0-3.6
	4.1	2.4	2.0	2.4	5.1	6.4	8.9	8.6	8.4	7.7	2.0-4.2
20-25	3.0	1.3	0.7	0.9	4.1	5.1		7.3^+	7.4^+	6.1	2.0-3.6
	3.8	2.1	1.5	1.7	4.9	5.9		8.1	8.4	6.9	2.0-4.2
	$\overline{6.5}$	$\overline{2.9}$	$\overline{1.9}$	$\overline{2.5}$	$\overline{14.8}$	$\overline{20.6}$	$\overline{19.0}$	$\overline{29.6}$	$\overline{30.5}$	$\overline{30.6}$	2.0-3.6
	13.8	4.9	3.5	7.3	21.0	26.8	25.0	36.8	36.7	36.8	2.0-4.2
	12.3	30.7	18.4	24.5	24.5	36.8	6.1	18.4	15.8	21.0	
	0.0	2.0	0.0	14.5	-4.0?	53.0	2.0	25.0	61.5	38.5	
		0.2				1.0		0.8	1.0	1.0	2.0-3.6
						1.0		0.8	1.0	1.0	2.0-4.2
		0				10.1		0	42.8	17.4	2.0-3.6
						10.4		0	43.9	17.4	2.0-4.2

Table 8.2.d. Readily -(pF2.0 - 3.6) and Total -(pF 2.0 - 4.2) available water (mm)
Water balance with productive available water

depth (cm)	calibration $\bar{Y}+b(X-\bar{X})$	date (1977) 4/7	12/7	19/7	26/7	2/8	9/8	18/8	30/8	22/9	27/9	3/10
0-10	24.9+0.09(X-372)	8.4	-2.1	-4.9	-3.4	-4.3	6.4	-2.6	-2.3	-4.9	8.2	-1.0
	s.d.=6.6(n=10)	11.4	0.9	-1.9	-1.4	-1.3	9.4	0.4	0.7	-1.9	11.2	2.0
10-15	29.4+0.08(X-412)											0.7
	s.d.=2.9(n=10)											2.6
15-20	31.7+0.09(X-406)	9.6	4.9	0.5	-2.8	-0.8	8.2	1.2	1.2	1.0	3.5	3.3
	s.d.=2.6(n=10)	11.2	6.5	2.1	-1.2	0.8	9.8	2.8	2.6	5.1	12.2	4.1
20-25	33.4+0.08(X-437)	4.8	2.5	0.3	-1.4	-0.4	4.1	0.6	0.5	1.8	5.3	3.5
	s.d.=1.5(n=10)	5.6	3.3	1.1	-0.6	0.4	4.9	1.6	1.3	2.6	6.1	4.3
	S(mm)	22.8	7.4	0.8	0.0	0.0	18.7	1.8	1.5	5.3	24.0	7.5
		28.2	10.7	3.2	0.0	1.2	24.1	5.0	4.6	7.1	29.3	12.9
	Ep(t)(mm)		42.0	36.8	36.8	36.8	36.8	47.3	63.0	141.0	30.6	36.8
	P (t)(mm)		10.0	0.0	0.0	16.5	0.0?	0.0	59.0	154.4	0.0?	0.0
	Ea/Ep		0.6	0.2	0.0	0.5		0.4	0.9	1.0		0.5
			0.7	0.3	0.1	0.4		0.4	0.9	1.0		0.6
	d		0	0	0	0		0	0	9.6		0
			0	0	0	0		0	0	10.3		0

Ranen, between rows of sugarcane
2e ratoon nov. 1976
duplicate measurement.

+=water bounded at a lower tension than pF 2.0
?=unreliable

depth (cm)	date (1977) 5/10	10/10	14/10	17/10	21/10	27/10	1/11	4/11	8/11	pF-range
0-10	-1.3	-4.7	-5.0	-2.5	3.5	6.5	11.2	10.5	11.0	2.0-3.6
	1.7	-1.7	-2.0	0.5	6.5	9.5	14.5	13.5	14.0	2.0-4.2
10-15	0.5	-0.8	-1.2	-0.9	1.4	3.0	5.0	4.6	4.9	2.0-3.6
	2.4	1.1	0.7	1.0	3.3	4.9	6.9	6.5	6.8	2.0-4.2
15-20	2.7	1.6	1.4	1.4	2.7	4.9	7.4+	7.1	8.0+	2.0-3.6
	3.5	2.4	2.2	2.2	3.5	5.7	8.2	7.9	8.8	2.0-4.2
20-25	3.0	1.6	1.9	1.6	2.0	4.3	6.6	6.3	7.7+	2.0-3.6
	3.8	2.4	2.7	2.4	2.8	6.1	7.4	7.1	8.5	2.0-4.2
	6.2	3.2	3.3	3.0	9.6	18.7	30.2	28.5	31.6	2.0-3.6
	11.4	5.9	5.6	6.1	16.1	25.2	36.7	35.0	38.1	2.0-4.2
	12.3	30.7	18.4	24.5	24.5	36.8	24.5	15.8	21.0	
	0.0	2.0	0.0	14.5	4.0?	53.0	27.0	61.5	38.5	
				0.6		1.0	0.6	1.0	1.0	2.0-3.6
				0.6		1.0	0.6	1.0	1.0	2.0-4.2
				0		7.2	0	47.4	14.1	2.0-3.6
				0		7.1	0	44.0	15.4	2.0-4.2

Table 8.3.a. Readily -(pF2.0- 3.6) and Total-(pF 2.0-4.2) available water (mm)
Water balance with productive available water

depth (cm)	calibration $\bar{Y}+b(X-\bar{X})$	date (1977) 4/7	12/7	19/7	26/7	2/8	9/8	18/8	22/9	28/9	30/9	5/10
0-10	27.5+0.07(X-328)	12.4+	8.7	2.7	-0.8	3.3	8.3	0.8	5.5	6.2	3.4	-3.1
	s.d.=7.3(n=11)	15.0	11.3	5.3	1.8	5.9	10.9	3.4	8.1	8.8	6.0	-0.5
10-15	25.9+0.08(X-361)									0.1	-0.7	-3.4
	s.d.=4.0(n=11)									2.3	1.5	-1.2
15-20	27.1+0.06(X-389)	8.0	6.3	1.8	-1.4	0.7	5.8	0.0	1.6	0.4	0.0	-1.3
	s.d.=2.5(n=11)	12.9	11.2	6.7	3.5	5.6	10.7	4.9	6.5	2.9	2.5	1.2
20-25	27.8+0.07(X-390)									1.1	0.8	-0.3
	s.d.=2.5(n=11)									2.6	3.3	2.2
25-30	24.9+0.07(X-373)									2.8	2.2	1.3
	s.d.=2.3(n=11)									4.8	4.2	3.3
30-40	27.7+0.07(X-395)	19.6+	15.3	11.1	4.3	7.1	16.9+	8.5	11.5	3.0	1.9	-0.1
	s.d.=3.9(n=11)	26.2	21.9	17.7	10.9	13.7	23.5	15.1	18.1	6.3	5.2	3.2
	80%. S(0-40)	32.0	24.2	12.5	3.4	8.9	24.8	7.4	14.9	10.9	12.4	1.0
		43.3	35.5	23.8	13.0	20.2	36.1	18.7	26.2	22.2	18.2	7.9
40-60	28.4+0.06(X-406)	22.7	20.0	17.5	12.1	11.9	18.2	12.8	15.4	9.6	9.0	7.1
	s.d.=4.3(n=11)	31.5	28.8	26.3	20.9	20.7	27.0	21.6	24.2	18.4	17.8	15.9
60-80	27.3+0.04(X-423)	12.3	11.5	10.2	8.3	6.2	5.7	5.8	6.8	4.0	3.3	2.4
	s.d.=1.7(n=11)	24.7	23.9	22.6	20.7	18.6	18.1	18.2	19.2	16.4	15.7	14.8
	20%.S(40-80)	7.0	6.3	5.5	4.1	3.6	4.8	3.7	4.4	2.7	2.5	1.9
		11.2	10.5	9.8	8.3	7.9	9.0	8.0	8.7	7.0	6.7	6.1
	S'(mm)	39.0	30.5	18.0	7.5	12.5	29.6	11.2	19.3	13.6	14.9	2.9
		54.5	46.1	33.5	21.3	28.0	47.1	26.7	34.8	29.2	24.9	14.0
	Ep(t)(mm)		35.2	30.8	30.8	30.8	35.0	45.0	182.0	36.6	12.0	30.0
	P (t)(mm)		62.0	0.0	0.0	39.4	64.9	5.5	304.7	14.8	0.0	0.0
	Ea/Ep		1.0	.	.	1.0	1.0	0.5	1.0	0.7		0.4
			1.0			1.0	1.0		1.0			
	d		35.3			3.6	5.3	0	113.6	0		0
			35.2			1.9	2.8		114.6			

Pe-hill, inside rows of sugarcane
2[e] ratoon nov. 1976
singular measurement.

+=water bounded at a lower tension than pF= 2.0
?=unreliable

depth (cm)	date (1977) 7/10	10/10	14/10	17/10	28/10	1/11	4/10	7/10	pF-range
0-10	-5.9	-4.6	-5.3	-3.4	4.4	12.1+	11.8+	12.4+	2.0-3.6
	-3.3	-2.0	-2.7	-0.8	7.0	14.7	14.4	15.0	2.0-4.2
10-15	-4.4	-4.3	-4.5	-3.9	0.7	4.5+	4.3+	4.6+	2.0-3.6
	-2.2	-2.1	-2.3	-1.7	2.9	6.7	6.5	6.8	2.0-4.2
15-20	-2.9	-1.9	-2.3	-2.2	0.5	3.7	3.3	3.4	2.0-3.6
	-0.4	0.6	0.2	0.3	3.0	6.2	5.8	5.9	2.0-4.2
20-25	-1.5	-1.5	-1.5	-1.5	0.5	4.6+	4.5+	4.5+	2.0-3.6
	1.0	1.0	1.0	1.0	3.0	7.1	7.0	7.0	2.0-4.2
25-30	0.7	0.6	0.1	0.1	0.6	5.6+	5.8+	5.7+	2.0-3.6
	2.7	2.6	2.1	2.1	2.6	7.6	7.8	7.7	2.0-4.2
30-40	0.2	-1.7	-1.9	-2.0	-1.5	5.0	8.6+	8.1+	2.0-3.6
	3.5	1.6	1.4	1.3	1.8	8.3	11.9	11.4	2.0-4.2
	0.7	0.5	0.1	0.1	5.4	28.4	30.6	31.0	2.0-3.6
	5.8	4.2	1.8	2.5	15.6	40.5	42.7	42.2	2.0-4.2
40-60	3.7	4.3	3.7	3.1	3.6	4.0	15.4	13.3	2.0-3.6
	12.5	13.1	12.5	11.9	12.4	12.8	24.2	22.1	2.0-4.2
60-80	-0.8	0.8	-0.4	0.3	0.2	1.2	0.8	4.4	2.0-3.6
	11.6	13.2	12.0	12.7	12.6	13.6	13.2	16.8	2.0-4.2
	0.7	1.0	0.7	0.7	0.8	1.0	3.2	3.5	2.0-3.6
	4.8	5.3	4.9	4.9	5.0	5.3	7.5	7.8	2.0-4.2
	1.4	1.5	0.8	0.8	6.2	29.4	33.8	34.5	2.0-3.6
	10.6	9.5	6.7	7.4	20.6	45.8	50.2	50.0	2.0-4.2
	12.1	18.0	24.0	18.0	66.0	18.0	15.0	15.0	
	0.0	0.0	0.0	0.0	33.4	91.8	47.3	27.9	
	0.2	0.1	0.1	0.0	0.4	1.0	1.0	1.0	2.0-3.6
					0.3	1.0	1.0	1.0	2.0-4.2
	0	0	0	0	0	50.6	27.9	12.2	2.0-3.6
					0	48.6	27.9	13.1	2.0-4.2

Table 8.3.b. Readily-(pF 2.0 - 3.6) and Total-(pF 2.0 - 4.2) available water (mm)
Waterbalance with productive available water

depth (cm)	calibration $\bar{Y}+b(X-\bar{X})$	date (1977) 4/7	12/7	19/7	26/7	2/8	9/8	18/8	30/8	22/9	28/9
0-10	24.4+0.09(X-272)	7.2	5.2	-1.2	-4.6	-1.8	11.4	-0.1	2.4	1.1	5.3
	s.d.=8.9(n=11)	9.8	7.8	1.4	2.0	0.8	14.0	2.5	4.8	3.7	7.9
10-15	24.8+0.07(X-329)										-1.0
	s.d.=2.9(n=11)										1.2
15-20	24.5+0.10(X-332)	1.7	1.9	-1.0	-3.5	-2.7	4.7	-2.0	-1.0	2.1	-0.4
	s.d.=3.1(n=11)	6.6	6.8	3.9	1.4	2.2	9.6	2.9	3.9	7.0	2.1
20-25	26.8+0.11(X-347)										1.3
	s.d.=2.6(n=10)										3.8
25-30	24.6+0.07(X-350)										0.0
	s.d.=2.2(n=11)										2.0
30-40	25.3+0.07(X-368)	6.1	7.0	5.6	2.9	2.2	2.9	1.8	1.4	2.5	1.8
	s.d.=1.4(n=11)	12.7	13.6	12.2	9.5	8.8	9.5	8.4	8.0	9.1	5.1
	88%.S(0-40)	13.2	12.4	5.2	2.5	1.9	16.7	1.5	3.4	3.8	7.3
		25.6	24.8	15.5	11.3	10.6	29.2	12.2	14.7	17.5	19.5
40-60	24.6+0.05(X-355)	8.5	10.1	8.1	7.1	6.0	6.2	5.9	5.7	5.5	5.1
	s.d.=1.7(n=11)	17.7	18.9	16.9	15.9	14.8	15.0	14.7	14.5	14.3	13.9
60-80	25.0+0.03(X-375)	3.4	4.3	2.8	1.5	1.3	1.8	3.3	1.3	1.0	0.5
	s.d.=1.1(n=11)	15.8	16.7	15.2	13.9	13.7	14.2	13.7	13.7	13.4	12.9
	12%.S (40-80)	1.4	1.7	1.3	1.0	0.9	1.0	1.1	0.8	0.8	0.7
		4.0	4.3	3.8	3.6	3.4	3.5	3.6	3.4	3.3	3.2
	S (mm)	14.6	14.1	6.5	3.5	2.8	17.7	2.6	4.2	4.6	8.0
		29.6	29.1	19.3	14.9	14.0	32.5	15.8	18.1	20.8	22.7
	Ep(t)(mm)		35.0	30.8	30.8	30.8	35.0	45.0	60.0	132.0	36.0
	P (t)(mm)		62.0	0.0	0.0	39.4	64.9	5.5	80.5	224.2	14.8
	Ea/Ep		1.0	.	.	1.0	1.0	0.5	1.0	1.0	0.4
			1.0			1.0	1.0		1.0	1.0	
	d		27.3			9.2	15.3	0	18.9	91.8	0
			27.3			9.4	11.4		18.2	89.5	

Pe-hill, between rows of sugarcane
2e ratoon nov. 1976
singular measurement.

+=water bounded at a lower tension than pF- 2.0
?=unreliable

depth	date (1977)										pF-range
(cm)	30/9	5/10	7/10	10/10	14/10	17/10	28/10	1/11	4/11	7/11	
0-10	-0.6	-3.2	-3.6	-7.6	-7.0	-6.4	3.9	13.3+	14.3+	15.7+	2.0-3.6
	2.0	-0.6	-1.0	-5.0	-4.4	-3.8	6.5	15.9	16.9	17.3	2.0-4.2
10-15	-3.2	-3.0	-2.9	-4.0	-4.5	-4.0	-1.0	2.1	3.2	3.0	2.0-3.6
	-1.0	-0.8	-0.7	-1.8	-2.3	-1.8	3.2	4.3	5.4	3.2	2.0-4.2
15-20	-1.0	-2.1	-2.0	-3.9	-3.9	-4.2	-1.8	1.9	4.6+	4.1+	2.0-3.6
	1.5	-0.4	0.5	-1.4	-1.4	-1.7	0.7	4.4	7.1	6.6	2.0-4.2
20-25	0.6	-0.7	-0.2		-2.8	-2.7	-1.6	0.5	4.1	4.2	2.0-3.6
	3.5	1.8	2.3		-0.3	-0.2	0.9	3.0	6.6	6.7	2.0-4.2
25-30	-0.2	-1.0	-1.0	-4.5	-1.9	-1.9	-1.8	-1.2	0.8	3.9	2.0-3.6
	1.8	1.0	1.0	0.0	0.1	0.1	0.2	0.8	2.8	2.9	2.0-4.2
30-40	0.5	-0.7	-1.4	-1.6	-2.3	-2.4	-2.5	-2.3	-2.1	1.4	2.0-3.6
	3.8	2.3	1.9	1.7	1.0	0.9	0.8	1.0	1.2	1.9	2.0-4.2
	1.0	0.0	0.0	0.0	0.0	0.0	3.4	15.7	23.8	28.4	2.0-3.6
	4.7	4.5	5.0	2.8	0.1	0.5	10.8	26.4	32.9	38.3	2.0-4.2
40-60	4.2	3.0	4.0	1.5	0.7	0.6	0.4	0.4	1.7	0.7	2.0-3.6
	13.0	11.8	12.8	10.3	9.5	9.4	9.2	9.2	10.5	9.5	2.0-4.2
60-80	0.2	-0.6	0.7	-1.7	-2.0	-2.3	-2.0	-2.0	-1.6	-1.5	2.0-3.6
	12.6	11.8	13.1	10.7	10.4	10.1	10.4	10.4	10.8	10.9	2.0-4.2
	0.5	0.4	0.6	0.2	0.1	0.1	0.0	0.0	0.2	0.1	2.0-3.6
	3.1	2.8	3.1	2.5	2.4	2.4	2.4	2.4	2.6	3.7	2.0-4.2
	1.5	0.4	0.6	0.2	0.1	0.1	3.4	15.7	24.0	28.5	2.0-3.6
	7.8	7.3	8.1	5.3	2.5	2.9	13.2	28.8	35.5	42.0	2.0-4.2
	12.0	30.0	12.0	18.0	24.0	18.0	66.0	18.0	15.0	15.0	
	0.0	0.0	0.0	0.0	0.0	0.0	33.4	91.8	47.3	27.9	
	0.7	0.1	0.0	0.0	0.0	0.0	0.5	1.0	1.0	1.0	2.0-3.6
							0.3	1.0	1.0	1.0	2.0-4.2
	0	0	0	0	0	0	0	63.5	24.0	9.4	2.0-3.6
							0	58.2	25.6	9.4	2.0-4.2

Table 8.3.c. Readily-(pF 2.0-3.6) and Total -(pF 2.0-4.2) available water (mm)
Water balance with productive available water.

depth	calibration	date (1977)										
(cm)	$\bar{Y}+b(-\bar{X})$	4/7	12/7	19/7	26/7	2/8	9/8	18/8	30/8	22/9	28/9	30/9
0-10	27.1+0.06(X-348)	10.1	7.9	4.0	-0.0	2.8	7.5	1.6	-0.3	3.8	1.8	0.0
	s.d.=6.1(n=13)	13.9	11.7	7.8	2.8	6.6	11.3	5.4	3.5	7.6	5.6	3.8
10-15	26.3+0.07(X-357)										2.6	1.1
	s.d.=3.1(n=13)										4.8	3.3
15-20	29.9+0.07(X-370)	11.7	7.8	5.1	0.6	1.3	6.6	1.4	-1.1	5.5	5.5	1.8
	s.d.=2.8(n=13)	16.3	12.4	9.7	5.2	5.9	9.2	6.0	3.5	10.1	7.8	4.1
20-25	26.1+0.09(X-366)										1.5	-0.2
	s.d.=2.7(n=13)										4.3	2.6
25-30	27.1+0.07(X-363)	2.9	0.9	-0.4	-2.6	-2.3	-0.7	-2.3	-3.5	-0.1	2.1	0.5
	s.d.=1.9(n=13)	8.2	6.2	4.9	0.6	3.0	4.6	3.0	1.8	5.2	4.8	3.2
	S (mm)	24.7	16.6	9.1	0.6	4.1	12.1	3.0	0.0	9.3	13.5	3.4
		38.4	30.4	22.4	10.6	15.5	25.1	14.4	8.8	22.9	27.3	17.0
	Ep(t)(mm)		35.2	30.8	30.8	30.8	35.0	45.0	60.0	132.0	36.0	12.0
	P(t) (mm)		62.0	0.0	0.0	39.4	64.9	5.5	80.5	224.5	19.8	0.0
	Ea/Ep		1.0	.	0.3	1.0	1.0	0.3	1.0	1.0	0.3	0.8
			1.0			1.0	1.0		1.0	1.0		0.9
	d		34.9		0	5.1	23.9	0	23.5	82.9	0	0
			34.9			4.0	20.4		26.1	78.1		0

Pe-hill, inside rows of sugarcane
2e ratoon nov. 1976
duplicate measurement.

+=water bounded at a lower tension than pF 2.0
?=unreliable

depth (cm)	5/10	7/10	10/10	14/10	17/10	21/10	25/10	28/10	1/11	4/11	7/11	pF-range
0-10	-4.0	-5.1	-5.8	-6.1	-8.3	-4.9	4.3	3.0	7.9	7.2	8.8	2.0-3.6
	0.2	-1.3	-2.0	-2.3	-4.5	-1.1	8.1	6.8	11.7	11.0	12.6	2.0-4.2
10-15	-0.6	-0.2	-1.6	-1.9	1.3	-1.4	2.9	2.3	5.5+	5.3+	5.8+	2.0-3.6
	1.6	1.0	0.6	0.3	0.9	-0.8	5.1	4.5	7.7	7.5	8.0	2.0-4.2
15-20	0.6	-0.2	-0.1	0.3	0.1	-2.5	2.7	2.7	5.9+	5.5	6.1	2.0-3.6
	2.9	2.0	2.2	2.0	2.4	-0.2	5.0	5.0	8.2	7.8	8.4	2.0-4.2
20-25	-1.5	-1.6	-2.1	-2.3	-1.7	-1.6	0.6	0.0	4.5+	3.9+	4.9+	2.0-3.6
	1.3	1.2	0.7	0.5	1.1	-0.1	3.4	2.8	7.3	6.7	7.7	2.0-4.2
25-30	0.2	-0.4	-0.6	-1.0	-0.6	-0.9	8.6+	0.4	3.9	3.6	4.4	2.0-3.6
	2.5	2.3	2.1	1.7	2.1	1.8	3.3	3.1	6.6	6.3	7.1	2.0-4.2
	0.6	0.0	0.0	0.3	1.4	0.0	11.1	8.4	27.7	25.5	30.0	2.0-3.6
	8.3	6.6	5.6	4.5	6.5	1.8	24.9	22.2	41.5	39.3	43.8	2.0-4.2
	30.0	12.0	18.0	24.0	18.0	24.0	24.0	18.0	18.0	15.0	15.0	
	0.0	0.0	0.0	0.0	0.0	20.3	0.0?	13.1	91.8	47.3	27.9	
	0.1	0.0	0.0	0.0	0.0	0.9		0.9	1.0	1.0	1.0	2.0-3.6
						1.0		0.8	1.0	1.0	1.0	2.0-4.2
	0	0	0	0	0	1.0		0	54.5	34.5	8.4	2.0-3.6
						1.0		0	57.5	28.5	8.4	2.0-4.2

depth date (1977)

Table 8.3.d. Readily-(pF 2.0-3.6) and Total -(pF 2.0-4.2) available water (mm)
Water balance with productive available water.

depth (cm)	calibration $\bar{Y}+b(X-\bar{X})$	date (1977) 4/7	12/7	19/7	26/7	2/8	9/8	18/8	30/8	22/9	28/9	30/9
0-10	26.3+0.06(-300)	10.4+	8.9+	0.5	-0.7	2.0	6.4	0.6	0.2	-1.1	3.1	0.8
	s.d.=5.5(n=12)	14.2	12.7	4.3	3.1	5.8	10.2	4.4	4.0	2.7	6.9	4.6
10-15	25.1+0.07(X-341)											0.7
	s.d.=3.1(n=12)											2.9
15-20	30.1+0.08(X-349)	16.6+	14.4+	8.0	4.1	8.6	12.9	7.6	1.3	11.4+		2.5
	s.d.=2.8(n=12)	21.2	19.0	12.6	8.7	13.2	17.5	12.2	5.9	16.0		4.8
20-25	25.4+0.10(X-364)											0.5
	s.d.=3.2(n=12)											3.3
25-30	26.6+0.08(X-369)											1.1
	s.d.=2.3(n=12)											3.8
30-40	25.4+0.09(X-403)	33.4+	29.0+	19.4	6.2	17.2	29.0+	12.6	3.8	30.8+	35.9+	1.8
	s.d.=4.5(n=12)	42.8	38.4	28.8	15.6	26.6	38.4	22.0	13.2	40.2	43.8	6.5
	S (mm)	$\overline{60.4}$	$\overline{52.3}$	$\overline{27.3}$	$\overline{10.3}$	$\overline{27.8}$	$\overline{48.3}$	$\overline{20.8}$	$\overline{5.3}$	$\overline{42.7}$	$\overline{39.0}$	$\overline{7.4}$
		78.2	70.1	45.7	27.4	45.6	66.1	38.6	23.1	58.9	52.2	25.9
	Ep(t)(mm)		35.2	30.8	30.8	30.8	35.0	45.0	60.0	132.0	36.0	12.0
	P (t) (mm)		62.0	0.0	0.0	39.4	64.9	5.5	80.5	224.2	14.8	0.0
	Ea/Ep		1.0	0.8	0.6	0.7	1.0	0.7	1.0	1.0		0.2
			1.0	0.8		0.7	1.0	0.7	1.0	1.0		
	d		35.2	0	0	0	9.4	0	36.0	54.8		0
			34.9	0		0	10.0	0	36.0	56.9		

Pe-hill, between rows of sugarcane
2^{e} ratoon nov. 1976
duplicate measurement.

$^{+}$=water bounded at a lower tension pF 2.0
?=unreliable

depth (cm)	date (1977) 5/10	7/10	10/10	14/10	17/10	21/10	25/10	28/10	1/11	4/11	7/11	pF-range
0-10	-1.6	-3.7	-4.3	-4.8	-3.0	-0.9	3.8	3.0	8.9^{+}	9.6^{+}	9.6^{+}	2.0-3.6
	2.2	0.1	-0.5	1.0	-0.8	2.9	7.6	6.8	12.7	13.4	13.4	2.0-4.2
10-15	-1.0	-1.2	-2.3	-1.9	-1.9	-1.0	0.3	0.9	4.3	5.5^{+}	5.1^{+}	2.0-3.6
	1.2	1.0	-0.1	0.3	0.3	1.2	2.5	3.1	6.5	7.7	7.3	2.0-4.2
15-20	1.6	1.4	0.4	0.0	0.0	0.9	1.6	2.3	6.0^{+}	8.0^{+}	7.2^{+}	2.0-3.6
	3.9	3.7	2.7	2.3	2.3	3.2	3.9	4.6	8.3	10.3	9.5	2.0-4.2
20-25	-1.0	-1.7	-2.5	-2.4	-2.8	-2.3	-1.3	-1.3	3.6	5.7^{+}	5.6^{+}	2.0-3.6
	1.8	1.1	0.3	0.4	0.0	0.5	1.5	1.5	6.4	8.5	8.4	2.0-4.2
25-30	0.2	-0.5	-0.6	-1.1	-0.9	-1.9	-0.7	-0.6	2.9	4.6	5.3^{+}	2.0-3.6
	2.9	2.2	2.1	1.6	1.8	0.9	2.0	2.1	5.6	7.3	8.0	2.0-4.2
30-40	-0.6	-1.6	-2.4	-3.2	-3.2	-0.1	-1.4	-2.3	3.0	8.5	10.8	2.0-3.6
	4.1	3.1	2.3	1.5	1.5	4.6	6.1	2.4	7.7	13.2	15.5	2.0-4.2
	1.8	1.4	0.4	0.0	0.0	0.9	7.1	6.2	28.7	41.9	43.6	2.0-3.6
	16.1	11.2	7.4	6.1	5.9	13.3	23.6	20.5	47.2	60.4	62.1	2.0-4.2
	30.0	12.0	18.0	24.0	18.0	24.0	24.0	18.0	18.0	15.0	15.0	
	0.0	0.0	0.0	0.0	0.0	23.3	0.0?	13.1	91.8	47.3	27.9	
	0.2	0.2	0.1	0.0	0.0	0.8		0.8	1.0	1.0	1.0	2.0-3.6
						0.9		0.7	1.0	1.0	1.0	2.0-4.2
	0.	0	0	0	0	0		0	51.3	19.1	11.2	2.0-3.6
						0		0	47.6	19.1	11.2	2.0-4.2

APPENDIX IV

monthly Ea/Ep (approximated).

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Table 9. Approximated Monthly/three Monthly Ea/Ep ratio at different probability levels of precipitation for agroclimatic zone IIb IIc.

Kamagambo nr 9034005 (Climatic zone IIb)

	J	F	M	A	M	J	J	A	S	O	N	D
av.P(mm)	50	66	136	236	194	112	79	119	127	106	140	107
Eo=Ep(mm)	175	150	150	150	125	125	150	150	175	175	150	150
av P/Eo	0.28	0.44	0.90	1.57	1.55	0.90	0.52	0.79	0.73	0.61	0.93	0.71
eff.P.	45	50	95	155	125	75	60	85	95	90	100	80
Ea/Ep.	0.3	0.3	0.6	1.0	1.0	0.9	0.5	0.6	0.6	0.5	0.7	0.5
Ea/Ep(P30% N.E.)	-0.2-						0.2			0.4		-
Ea/Ep(P10%N.E.)	-0.1-						0.1			0.3		-

Uriri nr 9034047 (Climatic zone IIb/IIc

	J	F	M	A	M	J	J	A	S	O	N	D
av.P (mm)	76	93	153	215	143	88	58	73	104	126	151	92
Eo=Ep(mm)	175	175	175	150	150	125	150	150	175	175	150	150
av.P/Eo	0.43	0.53	0.87	1.43	0.95	0.70	0.38	0.48	0.59	0.72	1.21	0.61
eff.P.	60	70	110	140	100	65	45	65	80	95	105	70
Ea/Ep	0.3	0.4	0.6	1.0	0.9	0.6	0.4	0.5	0.5	0.5	0.7	0.5
Ea/Ep (P 30% N.E.)	-0.4-							-0.4-				-
"/"(P10% N.E.)	-0.3-							-0.3-				-

Oyugis nr 9034023 (Climatic zone IIc)

	J	F	M	A	M	J	J	A	S	O	N	D
av. P(mm)	28	49	110	190	213	100	99	127	109	104	109	73
Eo≠Ep(mm)	175	175	175	150	150	150	150	150	175	175	150	175
av.P/Eo	0.16	0.28	0.62	0.26	0.42	0.67	0.66	0.85	0.62	0.59	0.72	0.41
eff. P.	25	42	85	1.30	140	74	74	90	84	80	78	60
Ea/Ep	0.2	0.3	0.5	1.0	1.0	0.8	0.6	0.7	0.5	0.5	0.6	0.4
Ea/Ep(P30% N.E.)	0.1	0.1	0.3			0.5	0.5		0.4	0.4	0.3	0.2
Ea/Ep (P10%- N.E.)	0.0	0.0	0.2			0.3	0.5		0.3	0.3	0.2	0.1