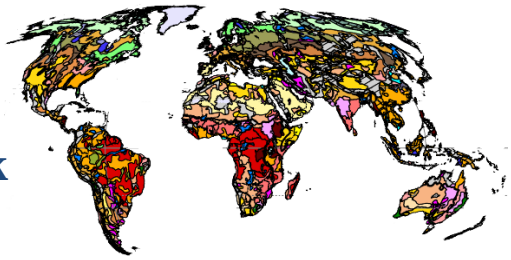


Sustainable Agriculture Support Network

Diepenveen, the Netherlands
www.SANETlink.nl

SANET

Report of a Soil survey / land suitability study in the area round Kassala, North Sudan, performed by Harco W.F. Jellema, Tropical Agronomist & Soil Scientist from February 10th – 18th 2013.

Invited by DAL Agricultural Company Limited – registered at Khartoum North , N- Sudan and AgroFair, Barendrecht the Netherlands.

This soil capability survey was executed solely for the cultivation of organic Bananas in the area of Kassala, N- Sudan.

The study is performed separately from the soil study performed by the Department of Soil and Environment Sciences, Faculty of Agriculture, University of Khartoum. (Further abbreviated as: "Soil Dep. Univ. of Khartoum")

Note:
The interpretation of the soil data was based on the analysis from the "Soil Dep. Univ. of Khartoum", because the analysis from the University of Wageningen, the Netherlands, were not completed at the moment of reporting.

Contents:

Chapter 1.
1.1 The Physical Environment

Over 80% of Kassala State consists of flat plains, whereas rocky outcrops and hilly terrain comprise the rest of the area. Alluvial and volcanic deposits cover the state and beneath these clays lay Basement Complex Formations that obtain poor repository properties for ground water. Water sources in the state tend to be distributed along the cracks in the geological formations and the few areas where alluvial deposits accumulate. The largest of the state's aquifers is the Gash Basin, which has an estimated storage capacity of 600 million cubic metres and runs North, from the Eritrean highlands through Kassala Town.

In contrast to the soils of the southern areas, the northern part of Kassala state is covered by lighter, highly permeable clay soils deposited by seasonal wadis. This soil base supports rain fed systems of cultivation such as the Gash Delta and provides rich seasonal pastures for livestock.

Rainfall ranges from approximately 83mm per annum in the northern part of the state to around 300mm per annum across most of the southern area. This is a typical dry to semi-dry rainfall zone. The southernmost part of the state, namely Wad Al Helew locality, receives significantly larger amounts of rainwater with an average of 608 mm per annum over the last three decades. However, the use of this rainwater is hampered by its short duration, uneven distribution and high rates of evaporation. Overall, a trend of long-term decline in rainfall has been observed in Kassala State since the 1940s and the current rate of depletion is calculated to stand at 2.6mm per annum.

The Gash River provides the state with approximately 560 million cubic meters of water per year during two to four months of increased flow rate. The River Atbara supplies the state with an additional 12 billion cubic metres water each year. This water source is used to irrigate the New Half of an agricultural scheme, which spans some 500,000 feddans*. Furthermore, it is used for fishing purposes near the Khashim el Girba dam(1964). However, silt accumulation in the dam reservoir has limited the state's capacity to manage the resources efficiently and reduced the dams' current storage capacity to only 27% of its original amount.

Kassala State is estimated to have over 7 million feddans* of natural pastureland. This area supports around 3 million animals of livestock in the state. It also supports a similar number of additional livestock that pass through the state on a seasonal basis. Forrest covers three percent of the state's total area, equivalent to approximately 300,000 feddans*. Of this amount, 21,625 feddans* have reserved for conservation. * [1 Feddan= 0.42 ha]

1.2
The N- Sudan soils in general

The soil of North Sudan can be divided geographically into different categories. These are the sandy soils of the northern and west-central areas, the clay soils of the central region and the laterite soils of the south. Less extensive and widely separated, but of major economic importance, is a fourth group which consists of alluvial soils found along the lower regions of the White Nile and Blue Nile rivers, along the main Nile towards lake Nubia, in the delta of the Qash River (? Gash) in the Kassala area, and in the Baraka Delta in the area of Tawkar near the red Sea in Ash Sharqi State.

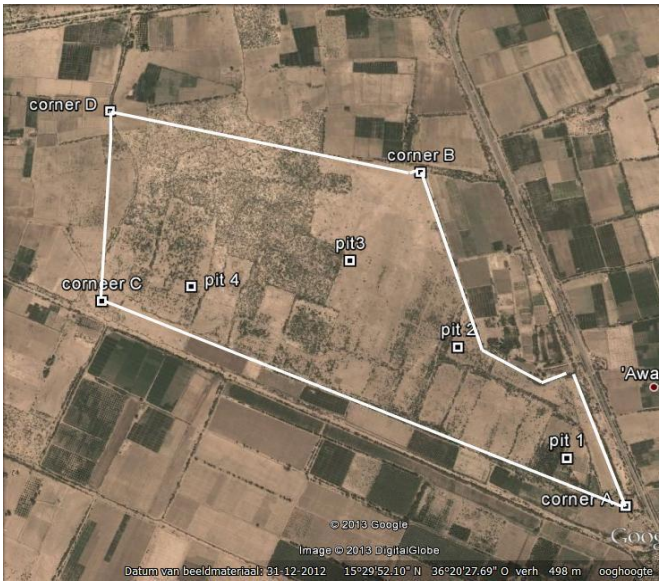
1.3

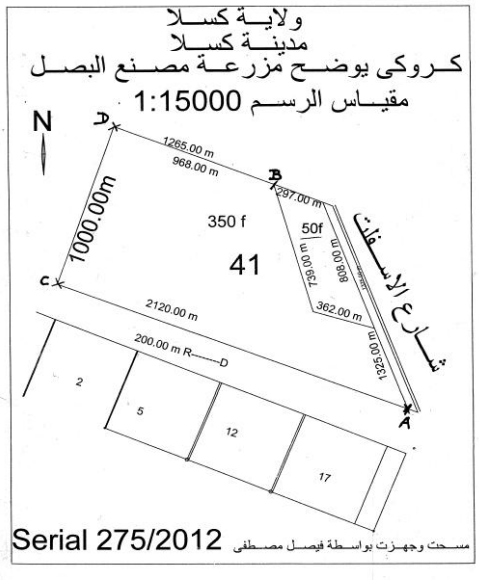
Localization of the Banana Farm property of DAL Agricultural Company Limited.
The farm is situated north-west of Kassala city

The geographic coordinates of the border corners are: (Default WGS 84)

Corner	Latitude	Longitude	Altitude (metres) ±
A	15°29’ 25.259 N	36 °21’1.7660 E	495
C	15°29’ 49.415 N	36°19’ 53.760 E	504
D	15°30’ 14.653 N	36°19’ 52.428 E	505
B	15°30’ 8.1367 N	36°20’ 33.682 E	507

table 1





1.4

Climate conditions Kassala

As mentioned previously in the soil study performed by the “Soil Dep. Univ. of Khartoum”, the farm of the DAL-group lays in the semi arid region.
The rainy season starts between May and June and ends in October, with highest rainfall averages in August.
The humidity differs largely between the rain and dry season, with respectively 54 – 60% and 27 – 45%.
The wind could be very strong in the raining season mostly South from 9 – 14 km/h, but in the dry season mostly North from 9 – 11 km/h.
The temperature is high the whole year from about 33 – 47 ° C with a maximum in April till June from 44- 47° Celsius and in October between 38 - 42° C.
The minimum temperatures are measured between November and April, namely 35 - 38° C.
This means that the climate conditions for the Banana cultivation in N-Sudan are extreme.
Bananas plants are originally found in humid lowlands and mostly grown between 30° North and South of the Equator. The average temperatures of 27° are measured, with a minimum of 11° C, and a precipitation ranges between 1500 and 2500 mm, well distributed over the year.
High temperatures could cause sun-scorch, which in combination with low humidity, could cause physiological drought.

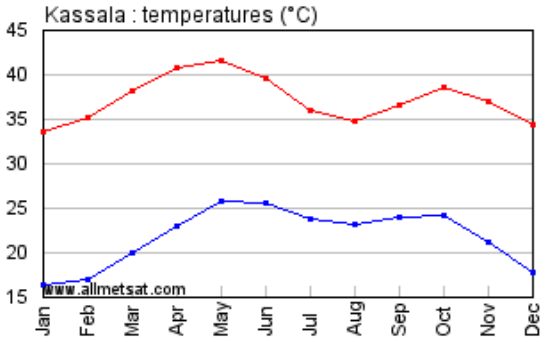
The strong winds during the year will cause damaged banana leaves a yield reduction of approximately 5 – 10%.
Weather conditions, properties of the soil and the vegetation determine **evaporation** from a land surface. Soil and vegetation properties are directly influenced by man in the case of irrigation. Evaporation from a land surface covered with vegetation and with sufficient soil water is called **potential evaporation * (p.e.)** type and condition of the vegetation are among the many factors influencing p.e. However, the available soil water content should be such as to prevent a decline of leaf evaporation by stomatal reaction.
*The term '**evapotranspiration**' is widely used in agriculture denoting the sum of water physically evaporating from the soil and physiologically evaporated (transpired) by the plant. It is mentioned in the study of "Soil Dep. Univ. of Khartoum" (page 5, and table 2.1), that the evapotranspiration exceeds rainfall the whole year around. (except in August).

To cultivate Bananas in the area of Kassala with export quality, extra preventive measures should be taken.
For protecting climate measures see chapter 3.

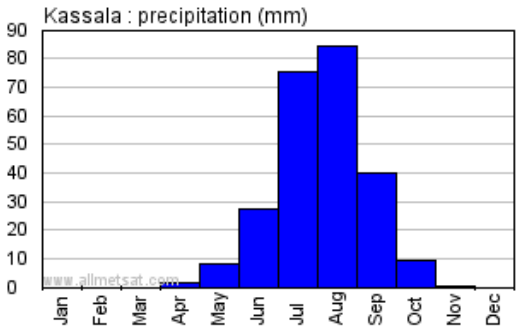
See Appendix : table 1 , 2 Sudan Meteorological Authority, station Kassala (climatological normal's 1981- 2010.

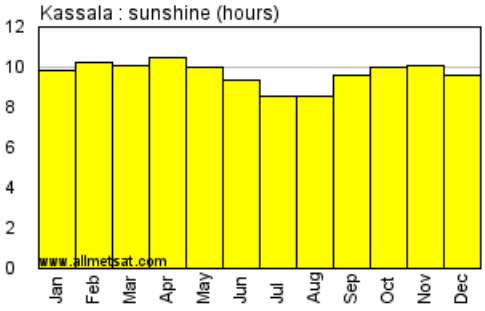
Kassala, Sudan, Africa Annual Yearly Climate Averages
Mean Temperatures, Precipitation and Sunshine Hours

Kassala, Sudan, Average Annual Temperatures

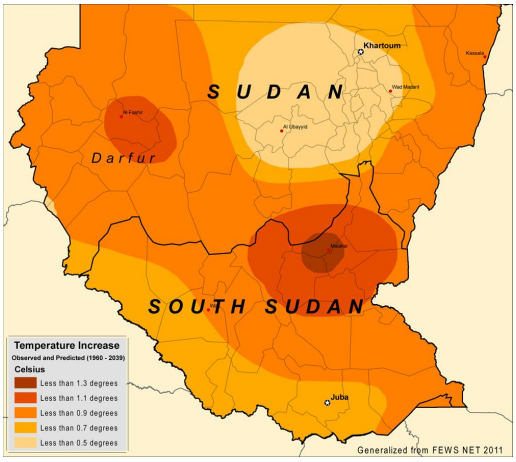


Kassala, Average Yearly Precipitation





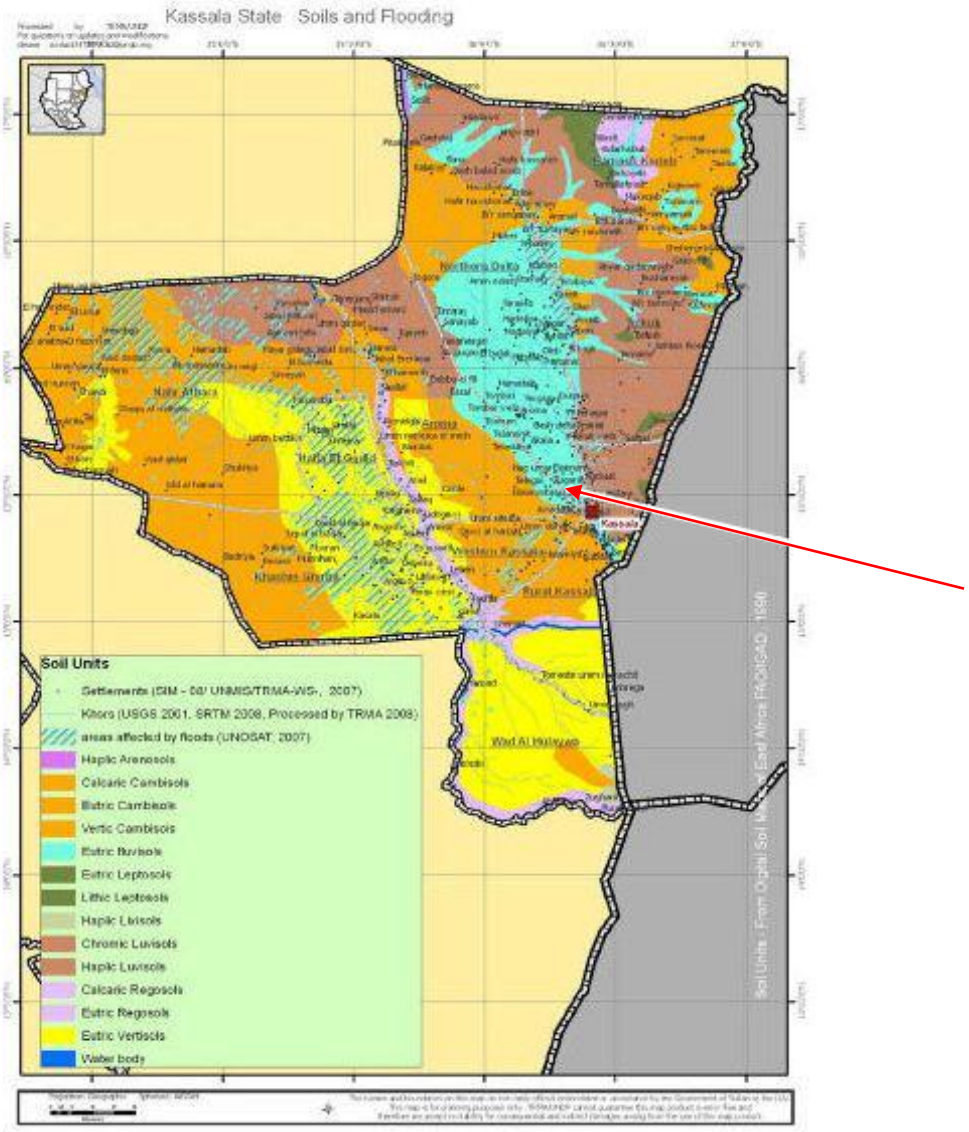
Kassala, Sudan, Average Monthly Sunshine Hours



Temperatrue Increase (observed and predicted) 1960 – 2039 , for Kassala : less than 0.9 ° C FEWS NET 2011

Chapter 2.
Soils & soil fertility and its relationship to the culture of Organic Bananas

Map (1) Kassala State Soil Types and Areas of Flooding



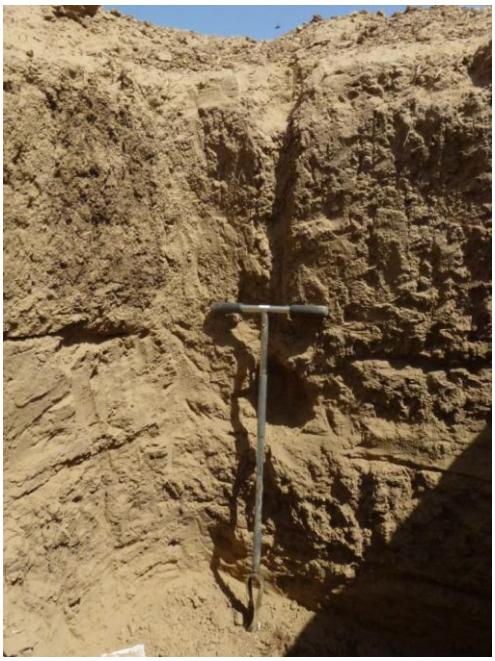
The farm is situated in the flooded area indicated on this map. (TRMA/UNDP**)**

On this map classified as Eutric Fluvisol (World Soil Resources Reports 103, Rome 2006) Classified as**: Typic Ustifluvent**, according to Soil Taxonomy, Keys to the Soil Taxonomy, 2010) ["Soil Dep. Univ. of Khartoum"].

2.1 Properties

As described by "Soil Dep. Univ. of Khartoum", in the profile description, this soil is a very young soil, which covers the whole area. These azonal soils consisting alluvial deposits, caused by periodically flooding rivers. Therefore the soils does not demonstrate a profile development, and is still very compact. The first 2 metres of the profile consist of only some small fine root in the top, from the fragile vegetation in this climate zone. (content organic matter ± 1,1 % in the topsoil).
Most of these soils, in other areas, will be very fertile, but it depends of the mother material.

In this case the soil is poor, silty loam, imperfectly drained, but does not demonstrate saline or sodic affection.
There was no evident difference between the pits 1, 2, 3 and 4 in profile development, physical and chemical properties. (Soil Dep. Univ. of Khartoum, page 22 + 23 and Appendix 2, soil profile description page 36 – 47).
The pH is approximately 7.8. (Bananas prefer 4.5– 8.2 with an optimum between pH 5.6–7.5). Remarkable is that the Cation Exchange Capacity (CEC) is very high, about 40 mmol+ /100g, this is an indication of the clay mineral and it's adsorption capacity for some nutrients. Although the adsorption capacity is high, in this case the adsorption in reality of important (cation) nutrients, like K, Ca and Mg is very low.(page 22 and 23 "Soil Dep. Univ. of Khartoum"). Also the amount of available phosphorus in the soil for the Bananas is very low. (2.1 mg/kg)


pit 1


area around pit 1


pit 4


around pit 4

2.2 Soil fertility

Talking about **soil fertility** in its relationship with the culture of Bananas and organic Bananas (without the use of chemical fertilizers) we must know the nutrient demand / - uptake / - removal of nutrients by the bananas at a certain production level.

Bananas are grown on many soil types; physical qualities are more important than the chemical composition, because the roots are very fragile with a low penetrating power and a great need of oxygen. Preferred pH about 6.0, but successful crops may be obtained down to pH 4.0 without liming, where exchangeable Al is low (e.g. peat soils) , or up to pH 8.5 where potential metal deficiencies are well controlled or non-existent. On this soil the pH is ± 7.8. Water requirements are high (150 mm/ month) and water absorption capacity is low, so irrigation should maintain soil moisture within 60 – 100% of the range between permanent wilting point and field capacity.

For Kassala is recommended the Banana variety Cavendish, with a plant density of about 1800 – 2000 plants / ha.

When the production level will be 30 ton bunches / ha / year:

Nutrient	**nutrient uptake by the plantation kg / ha / year**	**needed application of nutrients kg / ha / year**	**Efficiency %**
Nitrogen N	116	350	33
Phosphorus P_2O_5	32	35	92
Potassium K_2O	413	600	69
Calcium CaO	11		
Magnesium MgO	30		
Sulphur S	14		

table 2

Source: reference nr 10: Manual del Manejo de Banano Organic en Piura, Carlos Enrique Ojeda Riofrio, 2012, Peru

The needed nutrient applications as mentioned in table above, are normal applications when the soil fertility of the soil has a “normal” level. In case of the soils at the Kassala farm we must conclude that the situation is quite different, because all the levels of nutrients are very low. That implicates that there is no buffer capacity in the soil itself and there must be an application of nutrients on a high level (by the expected production of 30 ton / ha / year).

Recommended application of nutrients are:

	kg / ha /year
Nitrogen N	350 – 400
Phosphorus P_2O_5	100
Potassium K_2O	700
Magnesium MgO	150

table 3

Source: ***reference nr 10:*** Manual del Manejo de Banano Organico en Piura, Carlos Enrique Ojeda Riofrio, 2012 Peru

In combination with:
Source: ***reference nr 7***: World Fertilizer Use Manual, IFA, 1992;
Information from Centre Africain de Recherche sur Bananiers et Plantains, Douala Cameroon.

2.3
Application of nutrients by compost

For the production of Organic Bananas for export no chemical fertilizers are allowed, That means that only organic fertilizers can be used.
Compost is the end product after mineralizing of the differed components and it is a slow release fertilizer. (it doesn't work quick as chemical fertilizers) but improves the soil quality: increased the water holding capacity, suppression of diseases and improved soil structure.
Many organic components can be used to make compost: e.g. banana leaves or other leaves, or plant residues, straw , farm yard manure from cows , chicken manure, fibers from differed plants / fruits, cottonseed hull, Date-palm.

A good mixture will be in general: 40 % leaves ("green ingredients")
40 % fibers ("brown ingredients")
20 % manure

Other components can be used like: **Guano** : "the droppings of seabirds"
(content ± 3-12 % N, ± 7–23% P_2O_5, ± 1-4 % K_2O, ±0.05% MgO)
Or **Rock Phosphate** (18-34% P_2O_5, 25-30%CaO , however slowly available).

Compost is a organic stabilized soil improver, free of pathogens and weed seeds, it does not attract insects. It can be stored , will be (more or less) odourless and improves the soil structure (with organic matter) and stimulates the growth of plants with nutrients.
Composting is a controlled aerobic process, under thermophile circumstances (50 – 60 °C), to have a good degradation and stabilsation of the organic matter, caused by micro bacterial activities.
If the composting technique is according to the international standards and methods, there is an opportunity that it will result in **Carbon Credits.**

Important requirements:
- The optimum temperature is 45 - 55° C, (killing of pathogens and weeds > 50° C)
- The carbon/nitrogen-ratio (C/N ratio) has an optimum 20 – 30 ; > 30 decomposition too slow; < 20 emission of NH_3.
- The humidity of the waste 20 – 60 %; too dry (< 20 % humidity no micro bacterial activity) too wet (> 60 % humidity; too little O_2 exchange)

2.4
A proposal of some fertilizer applications in different combinations for Bananas in Kassala.

Case:
When the production level will be 30 ton bunches / ha / year, and considering the poor soil, the recommended application of nutrients is mentioned already in table 3.
An example of an elaboration and the calculating outline will be found in appendix 2.

Some nutrient contents: dry- matter basis % (approximately)

	% N	**% P_2O_5**	**%K_2O**	**% MgO**
Straw (in general)	<0.5	1.2	1.5	1.3
Groundnut meal	7.0	1.5	1.5	0.5
Cotton seed hull ,ash	<0.5	5.5	27	5
Cottonseed meal	7	3.0	2.0	0.5
Cow manure	2.0	1.5	2.0	1
Poultry manure	5.0	3.0	1.5	1.0
Date-palm tree mulch	1.8	1.2	1.7	

table 4

A needed quantity of (good quality) compost is about 10-20 ton /ha / year. A good quality depends of the available components in the area of Kassala, such as farm yard manure from cows and chicken manure, straw and other green components.
A search for the good components, in according to the right mix as mentioned above are essential. A processing unit – plant – has to setup with all the equipment that is needed.

2.5
Needed investments to make compost: (most simple way)

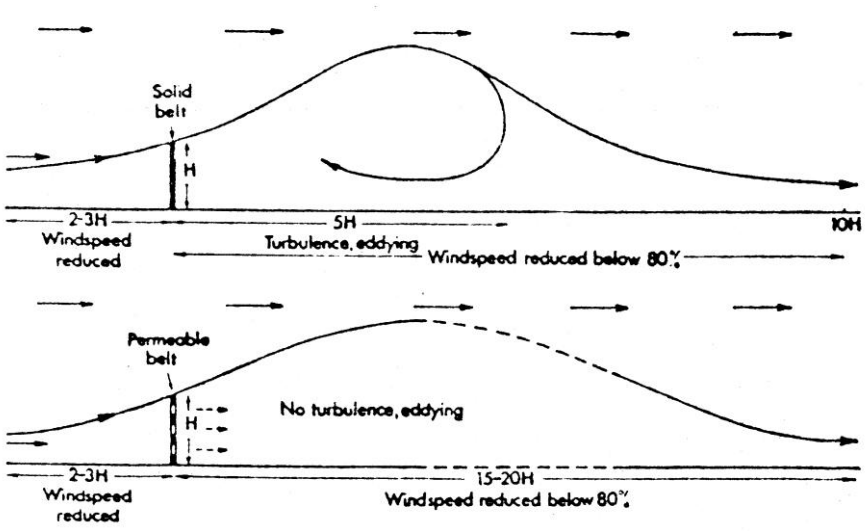
0.5 ha to prepare 2.500 ton compost (0.5 ha ground with roof)
1 tractor with turner
1 shovel

Chapter 3.
Protecting climate measures

3.1 Wind speed protection:

To be effective, windbreaks must be semi-permeable, ideally filtering 50-60 percent of the wind to reduce its strength. Solid barriers are unsuitable, leading to damaging eddies of wind on each side.
Windbreaks can be living or artificial. Living windbreaks of planted trees and shrubs are most attractive and long-lasting but artificial screens give immediate protection. Artificial screens can be used alone or in conjunction with living windbreaks to provide shelter while they establish

The effect of the windbreak depends on its height and on the distance behind this barrier. Some parts of the profile show an increase, other parts a decrease of wind velocity. For belts with a height *H* of less than some 10m , a velocity reduction of more than 20 % can be obtained up to heights of 0-5 *H* and up to a distance of 15*H* . Higher
belts have relatively less effect. A porous belt has much more effect than a very dense one. The best effect is obtained with a belt of medium density and a dynamic porosity of about 40 – 60 %. Wind protection at the leeward side of a forest is less than at the same side of a porous shelter belt. Only at a very short distance up to some 2-3 *H* is the dense belt more effective. The effect of a second belt gives less protection than a first
most windward one.



During the whole year there is a wind mostly coming from the South and the North in Kassala, so the best way to protect the farm is to set up a wind shelter on both wind sides.

Recommended trees for wind protecting: Eucalyptus camaldulensis (River Redgum) .

Or the Eucalyptus tereticonis, (well known in the area of Kassala)

wind protection

3.2
Shade trees

To prevent too strong radiation by the sun in combination with the high temperature and the low humidity it is recommended to have shade trees in-between the Banana plantation.
It was observed in some plantations in the area around Kassala that 10 % of the banana-bunches were burned on the top, due to influences of the sun radiation low humidity and high temperatures. This will reduce the quality and yields of bananas.

When the tree is well developed with a good canopy it can reduce the extreme climate stress but also reduce the loss of water.
Shading may result in a wide range of diverse intentional or unintentional effects. These include decrease of evaporation as well as matching growth and available nutrients, preventing serious water and nutrient stress respectively. A decrease in plant and soil temperature during day-time (think about the high temperature of ± 40° C) may be achieved as well as an increase of these temperature at night. Shading may provide protection against heavy rainfall and wind impact and consequent damage, as well as lead to a decrease of air flow, influencing water vapour-, heat- and CO_2 – transport from or to the surface concerned.

The species of Acacia is also a Leguminosae. That means that if the roots have the right nodules containing bacteria (Rhizobium spp) which have the power of fixing atmospheric nitrogen, some of which is then available to the host plant and the soil nitrogen is increased by sloughed, disintegrating nodules; in return the bacteria are supplied with carbohydrates by the host. Also the leaves of the trees can contribute to the organic matter content (after decay and decomposition). Together with the leaves and stems and other rest products of the banana trees it will contribute to a good organic matter content of the top soil in the plantation. (again after decay and decomposition) .

Recommended shade trees for the area near Kassala: Acacis tortilis or Acacia Nilotica or Eucalyptus Camaldulensis (River Redgum), and the Acacia seyal. These are well known trees in the area of Kassala.


Acacia tortilis


Acacia nilotica


Eucalyptus camaldulensis (20 -50 m H)


Acacia seyal

3.3
Agroforestry

It is recommended to setup a small (about 10 ha) experimental area in the banana plantation to investigate the influence of Agroforestry under the climatological circumstances around the Kassala area, to see the effect of better cultivation conditions of Bananas in terms of quality and yields.

In general all soil management activities, like ploughing, cultivating, are directed at minimizing all physical factors that impair soil productivity, maintaining or improving the nutrient status of the soil and protecting the soil from erosion, and radiation. In agroforstery these aspects need more than usual attention, because it is often claimed that one of the major advantages of agroforstery over other cropping systems is related to the superior characteristics of agroforstery systems in respect to soil management.

Indeed, agroforstery is often advocated especially for:

- Fragile areas which are subject to adverse physical factors (drought, leaching hazard) and man's neglect;
- Degraded areas, where agroforstery is suggested to contribute to improving and rehabilitating land;

On these marginal lands, it is expected that the inclusion of trees in cropping systems will result in sustainable forms of land –use, in which soil conditions are improved or at least maintained.
Trees exert several positive influences on both chemical and physical soil properties. These influences are well-displayed in natural forests, where optimal soil conditions are built – up and maintained by several processes:

- the more or less closed canopies protect the soil against radiation and creates favourable microclimate conditions (e.g. lower temperature, higher humidity) for various organisms that affect soil processes, such as decomposition and humification, nutrient transfer by mycorrhiza and N-fixing organisms, improving soil physical conditions;
- A dense network of roots near the surface coupled with deep roots which may take up nutrients from the weathering zone at the base of the soil profile;
- Symbiotic relation with mycorrhiza which facilitate nutrient absorbtion (especially P and / or with N-fixing organisms;
- Promoting of "biological" weathering of primary minerals as a result of greater solubilisation activity in the rhizosphere;
- An effective nutrient – cycling system through rapid mineralization of litter from Banana leaves / stems and rest material of the Bananas, and a rapid uptake of nutrient fall on the forest floor by a dense rootsystem and the associated mycorrhiza;
- A good maintenance of optimal soil structure as a result of high humus content provided by continuous litterfall and high biological soil activity. Among others this provides for a good water infiltration, retention and detention capacity and as a result a better water holding capacity of the soil.

It has been tried to mitigate the negative effects of cropping on soil properties by various management practices such as mulching, fertilizing, use of cover crops, zero-tillage, etc. Agroforestry has been advocated as an sustainable form of land-use under marginal conditions, like the poor soils of the farm in Kassala with very less organic matter and nutrients in the top soil.
However, in the case of high producing Bananas it is necessary an additional input of nutrients, specially Phosphate and Potassium by extra compost (in the case of cultivation organic Bananas for export quality).

It is said that there is kind of concurrence on water and nutrients between the trees in the agroforest system and the crops in-between these trees. But the trees have mostly a deep rooting system and – in this case – the Bananas, have there rooting system in the topsoil just below the surface of the profile.

It is recommended to invite a tropical forestry specialist to work out the setup of the wind, shade and agroforstery system.

Chapter 4.
Water sources / water supply for irrigation

4.1
Water sources – water quality
The Gash river is a typical seasonal rainy river, which implies that only during the raining season 3 - 4 months there is enough water for irrigation by that river.
All the farmers in the neighbourhood of the farm, have therefore a well of about 30 m deep.


pump


new well

It is recommended for the Banana –farm to use **drip-irrigation**.
Drip-irrigation saves water up to 40- 60 % comparing with open furrow- / or flood- irrigation under the semi-arid climate conditions in the area around Kassala.

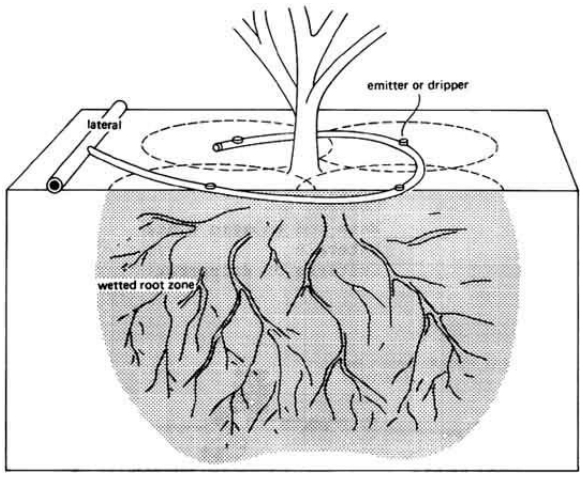
The quality of the water used for irrigation on the farm itself (From the DAL-group) , but also by the farmers in the neighbourghood is very good:

Electrical Conductivity (EC) and a indication for salts : 600 $\mu S/cm^{-1}$, pH ± 7.8
(This is drinking water quality in Europe).

That means that there is no salt at all in the water from the well, and it is therefore very useful for drip-irrigation.
A calculation has to be made how many water is needed for drip-irrigation on the Banana-farm, and how many wells have to be made to meet the demand of water (m^3/ h).

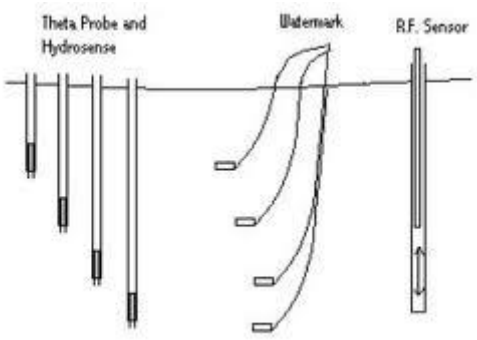
4.2
An example of drip irrigation in the Banana farm:

head tube for the supply of water between the rows in the Banana farm



a flexible small tube from the head tube around the Banana tree with the drip system

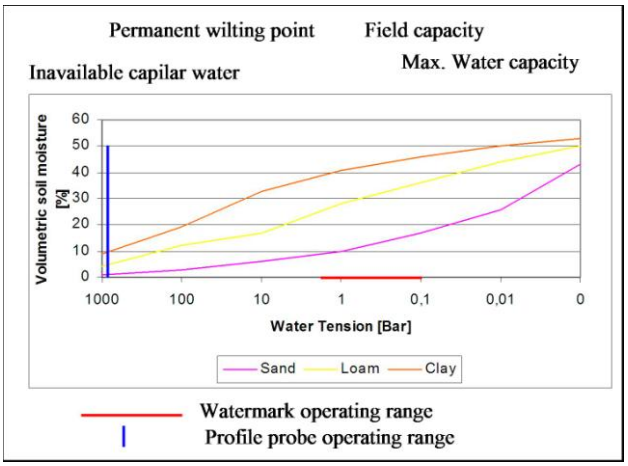
To control and to monitor the amount of water needed for irrigation, it is recommended to install a system of soil moisture meters in the soil of the farm.
With this system of soil moister meters you are able to control the amount of water needed in the soil for the Bananas. As a consequence it would be possible to use the irrigation drip system on demand, for example once every two days for a limited time, so you don't waste too much water and the Bananas will receive the right amount of water to grow.
On this way you can produce Bananas for export on a sustainable way and save water.

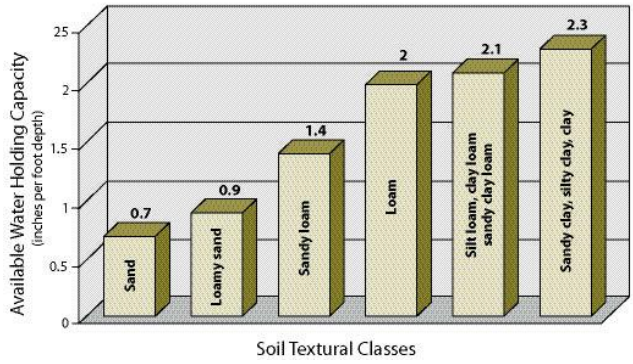


Sensors on a different dept in the soil

sensor before putting into the soil

sensors and monitor





silty loam soil: ± 2 Inches / foot depth
Available water holding capacity.

According to the analyses done by "Soil Dep. Univ. of Khartoum", the soil in the farm has a texture called: silty loam. That means the there is an available water capacity of about 20-25vol%. = 20 – 25 mm /10 cm profile. (between field capacity and permanent wilting point [0.1 bar – 15 bar]

In combination with good irrigation management, the physical soil properties are suitable for the cultivation of Bananas in the farm near Kassala.

It is recommended to invite an irrigation specialist to work out the irrigation scheme in combination with the control and monitor system of moisture meters.

Chapter 5.

Conclusions and recommendations

- **The climatologically conditions to culture Bananas with export quality are heavy; low amount of water available (dry), low humidity, dust storms and high temperatures (hot).**
  This means that protective measures must be taken for the cultivation of the Bananas in the area of Kassala for export quality, such as:
    - **Wind speed protection**
    - **Shade trees**
    - **Agroforestry**

It is recommended to setup a small (about 10 ha) experimental area in the banana plantation to carry out the influence of **Agroforestry** under the climatological circumstances around the Kassala area, to see the effect of better cultivation conditions of Bananas in terms of quality and yields, also for that it is recommended to invite a tropical forestry specialist to work out the setup of the wind, shade and agroforstery system.
(*This would be a very innovative cultivation plan for Bananas in the area of Kassala*)

- **The quality of the water from wells near and on the farm is very excellent.**
  It is recommended to setup a drip irrigation system in the farm, for that it is recommended to invite an irrigation specialist to work out the irrigation scheme in combination with the control and monitor system of moisture meters.
- **In combination with good irrigation management, the physical soil properties are suitable for the cultivation of Bananas in the farm near Kassala**.
- **For the production of Organic Bananas for export no chemical fertilizers are allowed,**
  That means that only organic fertilizers can be used.
- **For Kassala is recommended the Banana variety Cavendish, with a plant density of about 1800 – 2000 plants / ha.**
  Whit a production level of 30 ton bunches / ha / year .
  Recommended application of Nutrients are (under the percent conditions):

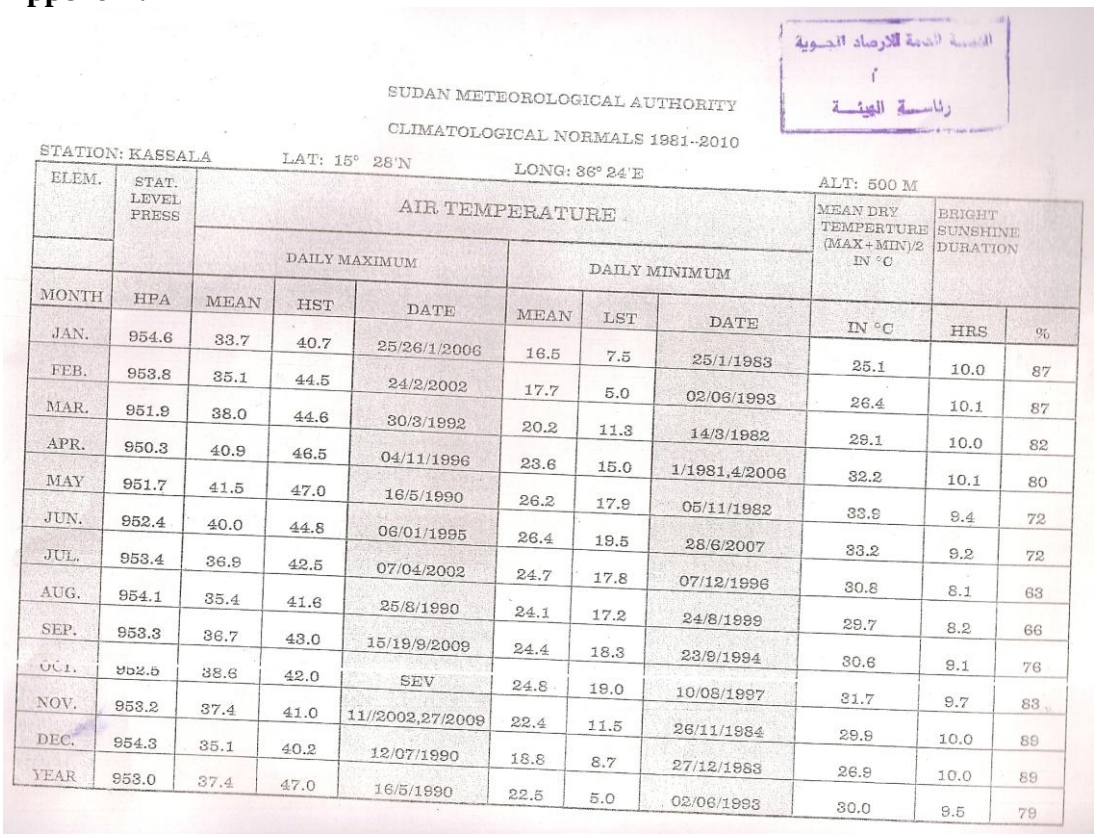
Nitrogen	N	350 – 400	kg / ha /year
Phosphorus	P_2O_5	100	
Potassium	K_2O	700	
Magnesium	MgO	150	

- **All the needed nutrients for the Banana farm has to apply in the form of compost or other organic fertilizers.**
  It is recommended to invite a specialist or company to setup the compost plant.
- A processing unit – plant – has to setup with all the equipment that is needed.
  The needed investments to setup a compost plant: (most simple way)
  0.5 ha to prepare 2.500 ton compost (0.5 ha ground with roof)
  1 tractor with turner + shovel

References

1) World reference base for soil resources 2006, Introduction – Deckers, J.A.; Nachtergaele, F.O.; , Spaargaren, O.C.;
2) World reference base for soil resources 2006, World soil resources reports No 103, FAO, Rome
3) Soil Survey Staff (2006). Keys to Soil Taxonomy, United States Department of Agriculture, Natural Resources Conservation Service, Ninth Edition, 2006, Washington D.C., USA.
4) Klute, A. (1986). Methods of Soil Analysis Part I: Physical and Mineralogical Methods (2nd edition) American Society of Agronomy, Inc., Soil Science Society of America, Inc., Madison, Wisconsin, USA.
5) Page, A. L.; Miller, R. H. and Ceaney, D. R. (1982). Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties, 2nd edition, American Society of Agronomy, Inc., Soil Science Society of America, Inc., Madison, Wisconsin, USA.
6) Interpreting soil test results, Pam Hazelton and Brian Murphy; CSIRO Publishing Australia , 2007
7) World Fertilizer Use Manual, IFA, 1992
8) Hartemink, A.F. (ISRIC) : Soil Fertlity Decline in the Tropics with Case Studies on Plantations. CABI Publishing . 2003
9) Tropical Crops , Monocotyledons, Purseglove, J.W. 1985
10) Manual del Manejo de Banano Organico en Piura, Carlos Enrique Ojeda Riofrio, Grupo Hualtaco, Solidaridad, Peru 2012.
11) The soil maps of AFRICA, European Digital Archive of Soil Maps – EuDASM 2005
12) Irrigation: Theory and Practice, A.M. Michael, Vikas Publishing House Private, Limited,2009

Appendix:



الهيئة العامة للارصاد الجوية
رئاسة الهيئة

SUDAN METEOROLOGICAL AUTHORITY

CLIMATOLOGICAL NORMALS 1981--2010

STATION: KASSALA LAT: 15° 28'N LONG: 36° 24'E ALT: 500 M

ELEM.	STAT. LEVEL PRESS	AIR TEMPERATURE						MEAN DRY TEMPERTURE (MAX+MIN)/2 IN °C	BRIGHT SUNSHINE DURATION	
		DAILY MAXIMUM			DAILY MINIMUM					
MONTH	HPA	MEAN	HST	DATE	MEAN	LST	DATE	IN °C	HRS	%
JAN.	954.6	33.7	40.7	25/26/1/2006	16.5	7.5	25/1/1983	25.1	10.0	87
FEB.	953.8	35.1	44.5	24/2/2002	17.7	5.0	02/06/1993	26.4	10.1	87
MAR.	951.9	38.0	44.6	30/3/1992	20.2	11.3	14/3/1982	29.1	10.0	82
APR.	950.3	40.9	46.5	04/11/1996	23.6	15.0	1/1981,4/2006	32.2	10.1	80
MAY	951.7	41.5	47.0	16/5/1990	26.2	17.9	05/11/1982	33.9	8.4	72
JUN.	952.4	40.0	44.8	06/01/1995	26.4	19.5	28/6/2007	33.2	9.2	72
JUL.	953.4	36.9	42.5	07/04/2002	24.7	17.8	07/12/1996	30.8	8.1	63
AUG.	954.1	35.4	41.6	25/8/1990	24.1	17.2	24/8/1999	29.7	8.2	66
SEP.	953.3	36.7	43.0	15/19/9/2009	24.4	18.3	23/9/1994	30.6	9.1	76
OCT.	952.5	38.6	42.0	SEV	24.8	19.0	10/08/1997	31.7	9.7	83
NOV.	953.2	37.4	41.0	11//2002,27/2009	22.4	11.5	26/11/1984	29.9	10.0	89
DEC.	954.3	35.1	40.2	12/07/1990	18.8	8.7	27/12/1983	26.9	10.0	89
YEAR	953.0	37.4	47.0	16/5/1990	22.5	5.0	02/06/1993	30.0	9.5	79

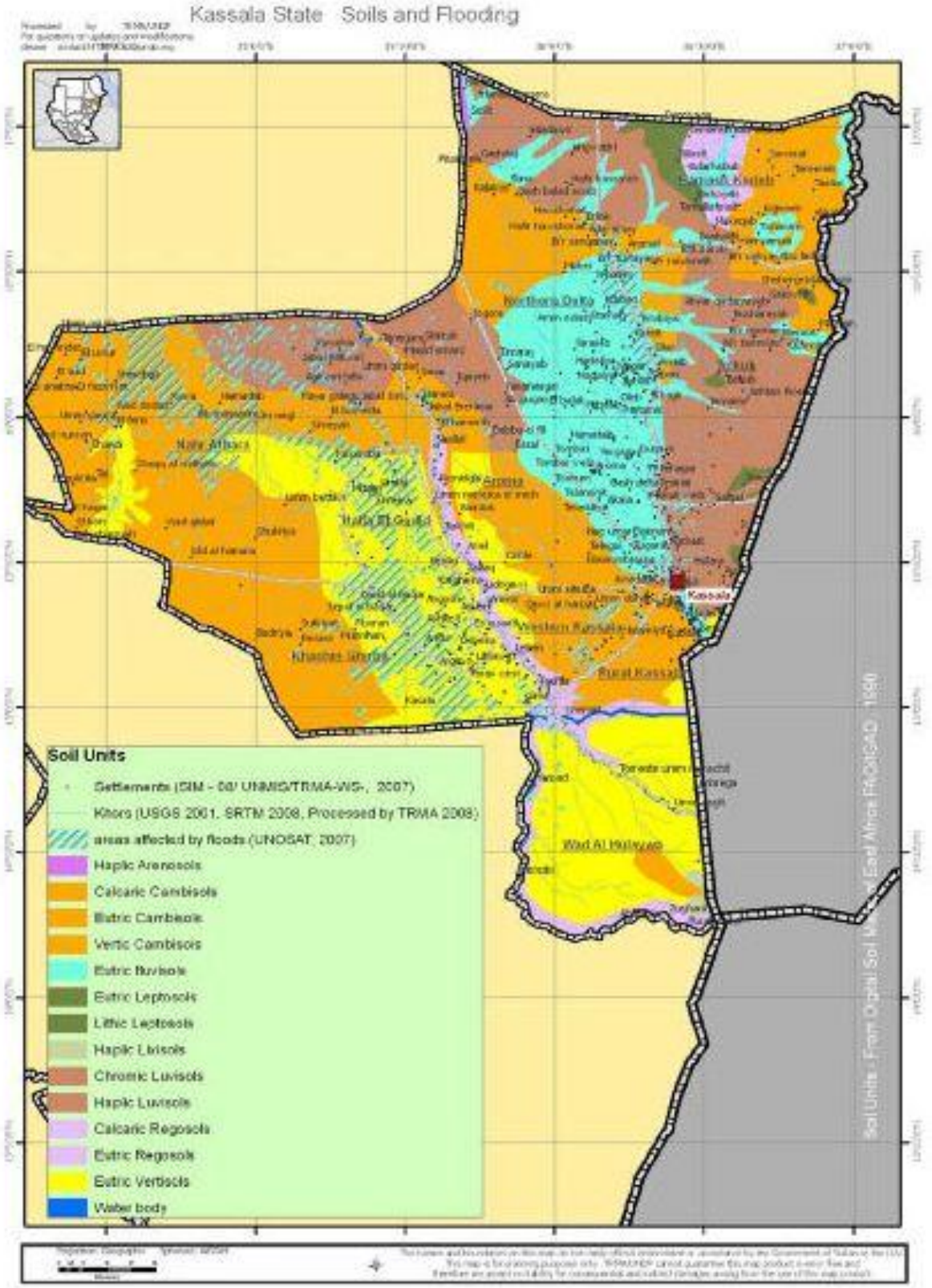
CLIMATOLOGICAL NORMALS 1981--2010

STATION: KASSALA LAT: 15° 28'N LONG: 36° 24'E ALT: 500 M

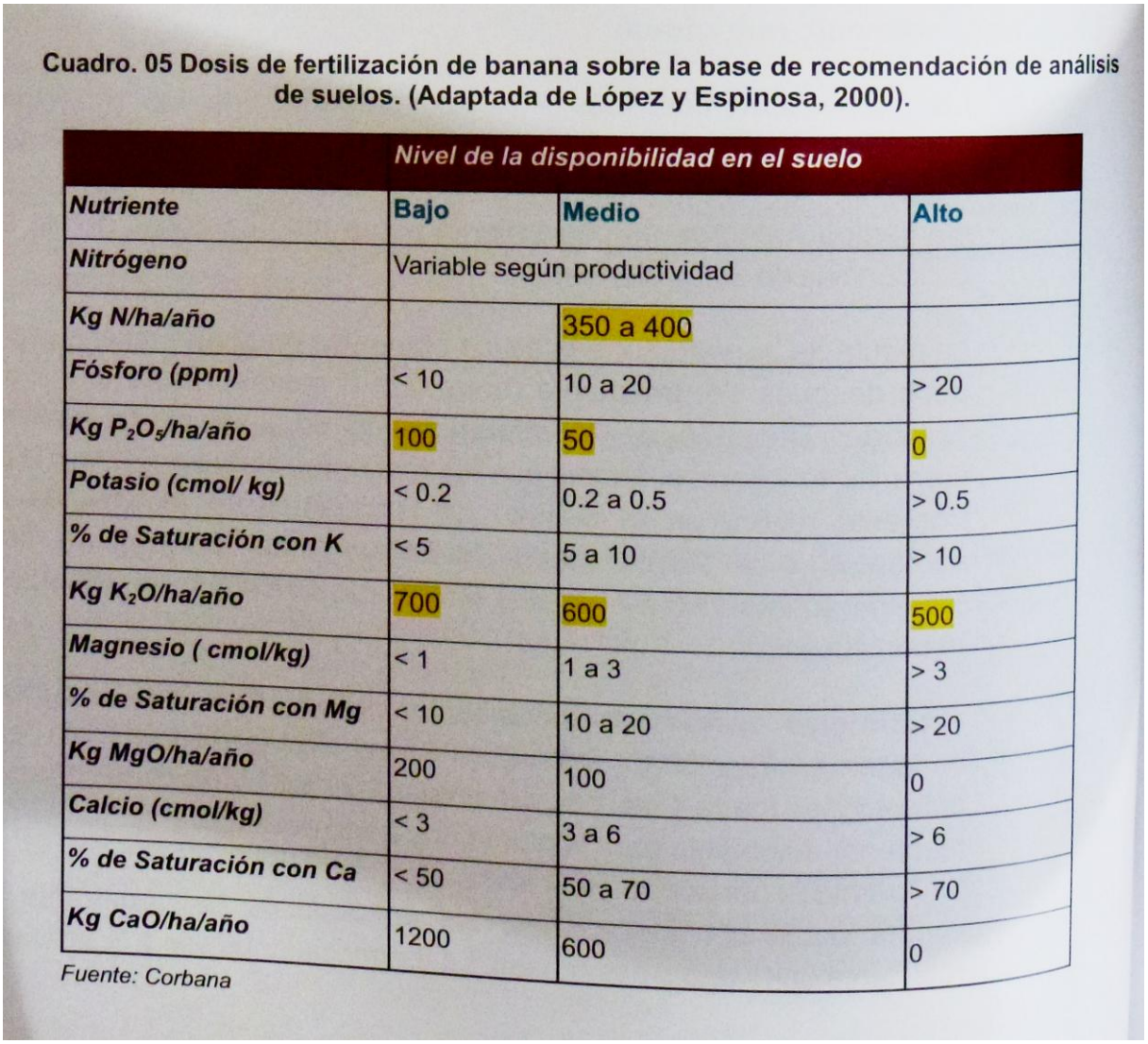
ELEM.	RELATIVE HUMIDITY R.H %	RAINFALL IN MMS						EVAP. PICHE (MM)	WIND	
		TOTAL IN MMS	NO. OF RAINY DAYS WHEN DAILY RAINFALL >=			MAXIMUM RAINFALL IN ONE DAY			PREV. DIR	MEAN SPEED KM.P.H Knot (1.85 K/h)
MONTH	MEAN		0.1 MM	1.0 MM	10.0 MMS	TOTAL	DATE			
JAN.	45	0.0	0.0	0.0	0.0	0.0	—	10.8	N	9
FEB.	39	0.0	0.0	0.0	0.0	0.0	—	12.9	N	10
MAR.	31	0.0	0.1	0.0	0.0	0.3	25/3/1995	16.3	N	10
APR.	27	2.1	0.9	0.7	0.0	6.6	14/4/2000	18.2	N	9
MAY	30	11.0	2.3	2.1	0.2	50.5	05/04/1995	17.1	N	9
JUN.	38	24.4	2.3	2.0	0.5	145.4	27/6/2007	15.5	S	12
JUL.	54	67.6	6.6	5.5	2.0	83.2	17/7/2007	11.5	S	14
AUG.	60	81.9	7.8	6.7	2.6	90.0	24/8/1987	9.0	S	13
SEP.	53	39.2	3.8	3.2	1.2	57.0	09/05/1992	9.6	S	10
OCT.	40	8.6	1.4	1.1	0.2	52.0	10/01/1986	12.8	S	9
NOV.	39	0.2	0.1	0.1	0.0	5.6	11/01/1992	13.0	N	10
DEC.	45	0.0	0.0	0.0	0.0	0.0	—	13.1	N	11
YEAR	42	235.0	25.2	21.3	6.7	145.4	27/6/2007	13.1	—	10

الهيئة العامة للارصاد الجوية
رئاسة الهيئة

Map (1) Kassala State Soil Types and Areas of Flooding



Source: TRMA / UNDP

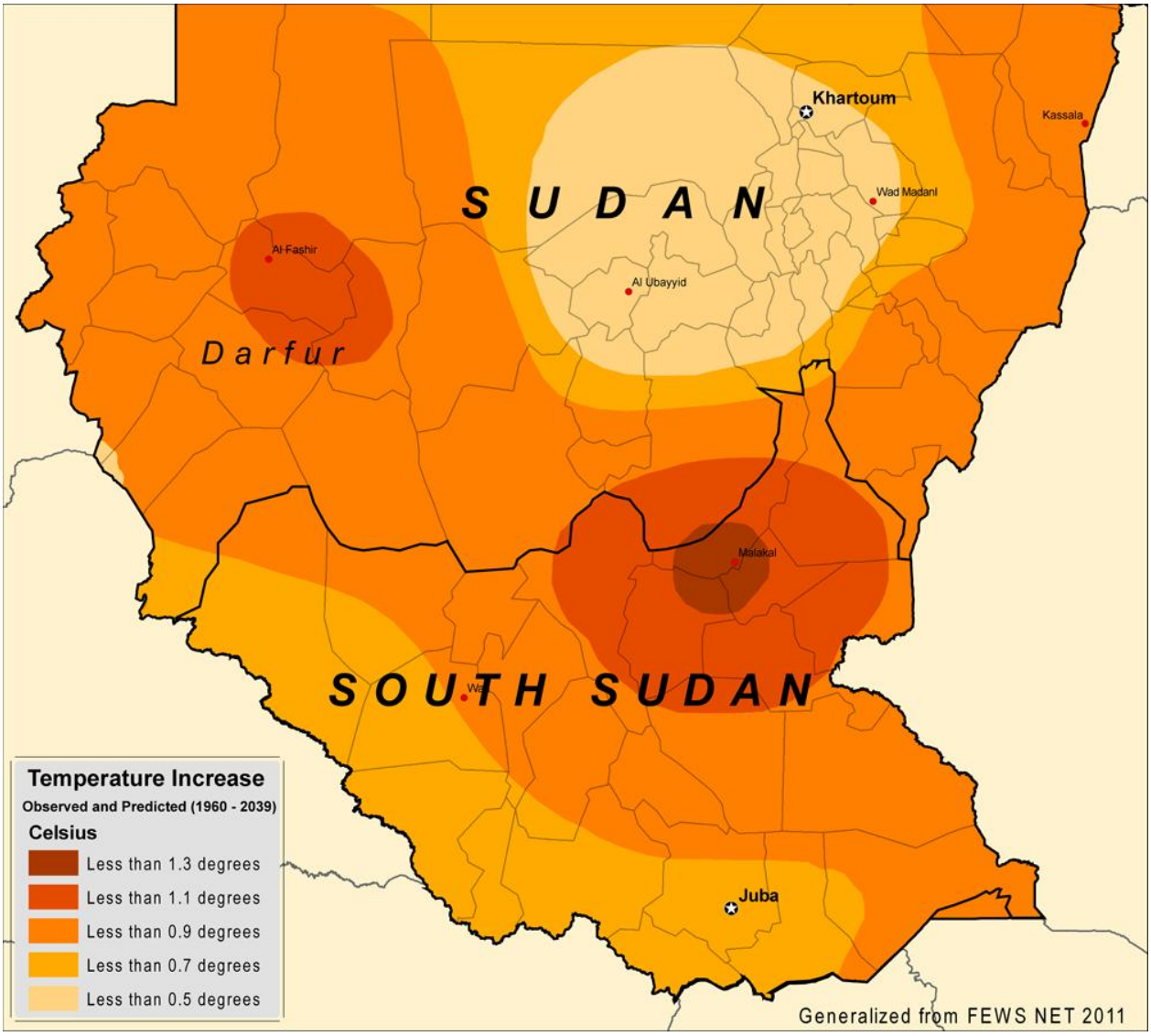


Cuadro. 05 Dosis de fertilización de banana sobre la base de recomendación de análisis de suelos. (Adaptada de López y Espinosa, 2000).

	Nivel de la disponibilidad en el suelo		
Nutriente	**Bajo**	**Medio**	**Alto**
Nitrógeno	Variable según productividad		
Kg N/ha/año		350 a 400	
Fósforo (ppm)	< 10	10 a 20	> 20
Kg P_2O_5/ha/año	100	50	0
Potasio (cmol/ kg)	< 0.2	0.2 a 0.5	> 0.5
% de Saturación con K	< 5	5 a 10	> 10
Kg K_2O/ha/año	700	600	500
Magnesio (cmol/kg)	< 1	1 a 3	> 3
% de Saturación con Mg	< 10	10 a 20	> 20
Kg MgO/ha/año	200	100	0
Calcio (cmol/kg)	< 3	3 a 6	> 6
% de Saturación con Ca	< 50	50 a 70	> 70
Kg CaO/ha/año	1200	600	0

Fuente: Corbana

Source: page 58, reference nr 10



Appendix 2

Case:
When the production level will be 30 ton bunches / ha / year and considering the poor soil, the recommended application of nutrients is mentioned already in table 3.

	Kg / ha /year
Nitrogen N	350 – 400
Phosphorus P_2O_5	100
Potassium K_2O	700
Magnesium MgO	150

Table 3

An example of an elaboration and the calculating outline:

Making compost: an example

	%	%	kg	Kg N/ kg10^4	KgP_2O_5/ kg 10^4	kgK_2O/ kg 10^4
		N - P_2O_5- K_2O				
straw	20	0.5--1.2--1.5	2000	10	24	30
Date-palm mulch	20	1.8—1.2—1.7	2000	36	24	34
banana leaves	20	2.5—0.35—3,5	2000	50	7	70
Cow manure	20	2.0—1.5—2.0	2000	40	30	40
Cotton seed ash	20	0.5-5.5-21-0.5	2000	10	110	420
total	100		10.000	146	195	594
				1.46%*	**1.9%***	**5.9%***

It's depends of the used ingredients, what will be the nutrient % after mixing and composting. However after composting the % of the nutrients will change* and depend of the process **requirements as mentioned in 2.3. (So, sampling is needed during composting).**

Proposal 1: organic fertilizers:

	Kg/ha	%	Kg N/ ha	KgP_2O_5/ ha	kgK_2O/ ha	kgMgO / ha	Kg S/ ha
		N- P_2O_5- K_2O-MgO-S					
compost*	5000	1,5-0,4-2.2 *	75	20	110		
guano	2500	12-7-4-0,05	300	175	100	12	
Sulphomag	800	0-0-22-18-22			176	144	176
Sulfato de potasio	400	0-0-50-0-18			200		72
total			360	195	586	156	248

Sulphomag and Sulpato de Potasio are organic fertilizers used in Latin America

Proposal 2: chemical fertilizers:

		%	kgN/ha	KgP_2O_5 /ha	kgK_2O/ ha	kg MgO/ ha	Kg S/ ha
		N - P_2O_5- K_2O-MgO-S					
guano	2500		300	175	100	12	
Patent-potasium	2000	0-0-26-9			520	180	
Ammonium sulphate	400	20.5-0-0-0-59	82				295
Total			402.5	175	620	192	236