Extra Annex to:

Report of a soil survey / land suitability study in the area round Kassala, N-Sudan, performed by Harco Jellema, Soil Scientist.

Results of soil analysis by the "Soil and Biochemical Laboratory" of the University Wageningen in the Netherlands.
This lab is specialized to analyze tropical soils in relation to soil fertility.

This Laboratory has an accreditation as test laboratory according ISO-17025 by the Dutch Accreditation Board.

The Dutch Accreditation Board is member of the European co-operation for Accreditation

That implicates also that this lab is certified by:

ILAC - the International Laboratory Accreditation Cooperation and

the International Accreditation Forum

Soil Sampling

The soil samples were collected from pit 1,2,3,and 4 at the DAL- Group Banana farm in Kassala, as mentioned in chapter 1.3 of the report.

The samples were collected from 0- 20 cm depth and from 20-40 cm depth.
Every sample is a compound mixed sample from ad random different places at the same depth in the same pit.

It is not possible to compare these samples from "Wageningen NL" exactly with the samples from "Soil Dept. University Khartoum", because our duplicate collected samples were not analyzed at the soil lab in Khartoum. It is only possible to compare with their samples from the study by the Soil Department of the University of Khartoum.

Methods of soil analysis in accordance with the Dutch Accreditation Board
NEN = Netherlands Norm / Standard
EN = European Norm
ISO = International Organization of Standardization

analysis	standard	Norm number	protocol
Particle size analysis	NEN	5753	Pipette analysis for <2µ clay, <50µ, > 50µ the sand fraction by sieves
pH-H_2O	NEN-ISO	10390	1:5 soil : demiwater
Electrical Conductivity (EC)	NEN	5749	1:5 soil : demiwater [µS/cm]
Cation Exchange Capacity (CEC)	NEN-EN-ISO	11260	Determination of effective cation exchange capacity and base saturation level [Cmol(+)/kg soil]
ICP measure of B, Cu, Mn, Zn	NEN	6966/5704	ICP/Atomaire emissiespectrometrie [mg/kg]
Organic matter (105-550°C)	NEN	5754	Organic matter measure by glow loss method [%]
P-Olsen			According publication Olsen 1954 [mg/kg]

Results:

Particle size analysis

	Clay, <2µm	**Silt 2-50µm**	**<50µm**	**Sand, >50µm**
	(%)	(%)	(%)	(%)
demonstrable accuracy limit	0.3	0.3	0.3	0.3
Pit 2 0-20cm-	34.9	52.6	87.5	7.7
Pit 2 20-40cm-	19.4	73	92.4	3.2

Cation Exchange Capacity (CEC)

	CEC	**Ca^{++}**	**Mg^{++}**	**Na^{+}**	**K^{+}**	**$Fe(^{3+})$**	**$Al(^{3+})$**	**Bas.Sat**	**Ca/Mg**
	[cmol (+)/kg]	[cmol (+)/kg]	[cmol (+)/kg]	[cmol (+)/kg]	[cmol (+)/kg]	[cmol (+)/kg]	[cmol (+)/kg]	%	
(d.a.l.)	3	0.8	0.7	1	0.8	1.3	1.8		
Pit1 0-20cm-	34	26.8	7.5	0.8	0.6	0.0	0.0	105	3.57
Pit4 0-20	37	29.4	4.3	1.7	0.4	0.0	0.0	96.7	6.8
Pit4 20-40	32	27.6	4.4	1.0	1.0	0.0	-0.1	106.3	6.3

(d.a.l.) = demonstrable accuracy limit Bas.Sat= Base Saturatrion

	pH-H_2O	**EC [µS/cm]**	**P-Olsen [mg/kg]**	**Org.matter [%]**
(d.a.l.)			2	0.3
Pit1 0-20cm-	7.6	194	5.6	5.9
Pit4 0-20	7.7	110	10.6	5.7
Pit4 20-40	7.7	522	14.9	5.5

ICP measure of mico elements: B, Cu, Mn, Zn

	B [mg/kg]	**Cu [mg/kg]**	**Mn [mg/kg]**	**Zn [mg/kg]**
(d.a.l.)			0.1	0.3
Pit 4 0-20cm-	0.24	0.02	0.07	0.1

Some remarks:

The small budget for analyzing soil samples in the Netherlands makes it necessary to combine and to eliminate some analysis. The whole area of the Banana farm is nevertheless one type of soil and there is no evident difference between pit 1, 2, 3 and 4 (see also the results of "Soil Dep. Univ. of Khartoum"). Therefore the particle size diameter is analyzed from the pit more or less in the middle of the farm nr 2. The chemical analysis are from pit 1 and 4 and special from the depth 0-20 the rooting depth of bananas.

Particle size analysis: name for this type of soil : **Silty Clay Loam (FAO).**

EC = 110 – 522 µS/cm = 0.110 – 0.522 dS/m (that is drinking water quality)

P concentration analyzed by the method of Olsen.
5.6 – 14.9 mg/kg or ppm gives a real indication of a **medium P** status, that is available for Bananas.

Cation Exchange Capacity (CEC)
The CEC is the capacity of the soil to hold and to exchange Cations. (Ca,Mg, K, Na). It provides a buffer effect to changes in pH, and the soil's reaction to fertilizers and other ameliorants. A low CEC means that the soil has a low resistance to changes in soil chemistry that are caused by land use.
CEC units are usually expressed as centimoles of positive charge per kg soil [cmol(+)/kg], which is numerically equivalent to the previously used unit of [me/100g].
The five most abundant cations in soils are Ca, Mg, K, Na and in strong acid soils Al.
The cations Mn, Fe, Cu and Zn, are usually present in amounts that do not contribute significantly to the cation complement. Therefore it is common practice to measure the concentration of only the most abundant cations (Ca, Mg, K, Na and if pH<5.5 also Al)

Base saturation: (BS) is the percentage of cation exchange capacity that is saturated with Ca, Mg, Na, K ions
BS=[Ca+Mg+K+Na] x 100/CEC
It provides an indication of how closely nutrient status approaches potential fertility.

Rating:

CEC	high
Base Sat.	very high
Ca/Mg	good balanced
[Ca]	very high
[Mg]	high
[K]	moderate
[Na]	moderate
[Al]	very low *

* there is no significant Al toxicity for plants (only if pH<5.5 and high [concentration Al]).
Salinity is not evident proved.

The **micro nutrients concentration of:** B, Cu, Mn and Zn are at a low level.

General conclusions based on the results of soil testing in "Wageningen NL"

The soil fertility at the banana farm from the DAL-group in Kassala can be classified as a fertile soil. This is corresponding with the impression at the local farmers not far away from the DAL-group farm, and on the same soil profile. There was a good production level of Bananas without any use of fertilizers for several years, and no deficiency was observed of nutrients on the banana leafs .

This implicates that the needed nutrients will be less than mentioned in the report at chapter 2.2, table 3

Production level 30 ton bunches/ ha/year, the *new* recommended application of nutrients:

	NEW	**Old**
	kg/ha/year	**kg/ha/year**
Nitrogen N	350	350-400
Phosphorus P_2O_5	50	100
Potassium K_2O	500	700
Magnesium MgO	0	150

New: based on the analysis from Wageningen
Old : based on the analysis from Khartoum

Good maintenance of application is still needed during cultivation.

Some remarkable difference between analysis from Khartoum and Wageningen:

	Khartoum	**Wageningen**
P-Olsen [mg/kg]	1.89 - 2.80	5.6 - 14.9
% clay	13.0 - 28.9	19.4 - 34.9
% sand	11.9 - 20.0	3.2 - 7.7
Org Carb x 1.72 = Org matter	1.7 – 2.41	5.5 – 5.9
Ca [mmol(+)/l x 1.4 ρ_b =cmol(+)/kg	2.8 – 10.5	26.8 – 29.4
Ca/Mg	2.1 - 4	3.57 – 6.8

P_b= bulk density soil

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Diepenveen, the Netherlands