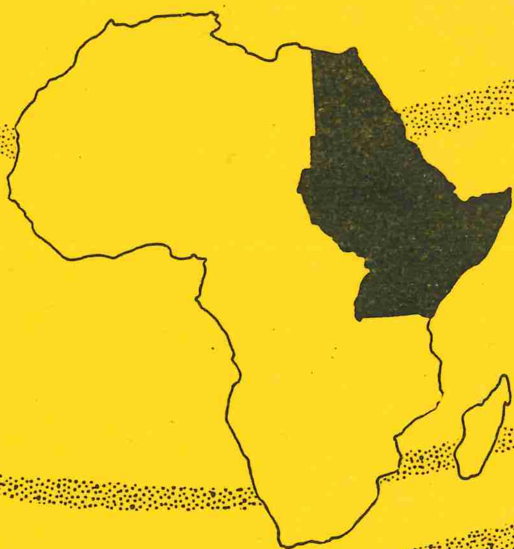
Consultancy/Mission Report

No. 88/1

SOILS OF EASTERN AND NORTHEASTERN AFRICA AT 1:1 MILLION SCALE AND THEIR IRRIGATION SUITABILITY

(draft report)



INTERNATIONAL SOIL REFERENCE AND INFORMATION CENTRE

Consultancy/Mission Report No. 88/1

SOILS OF EASTERN AND NORTHEASTERN AFRICA AT 1:1 MILLION SCALE AND THEIR IRRIGATION SUITABILITY

A preliminary compilation of data for input in FAO's digital geographic information system

Prepared by the
International Soil Reference and Information Centre (ISRIC),
Wageningen, The Netherlands,
on assignment of FAO, Rome, Italy
(contracts 2111.310.02 and 211.410.01)

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INTRODUCTION

Between january 1987 and january 1988, the International Soil Reference and Information Centre (ISRIC), compiled a draft 1:1 million scale soil map for North East Africa. Countries concerned are Egypt, Sudan, Ethiopia, Djibouti, Somalia, Uganda, Kenya, Rwanda, Burundi, and Northern Tanzania. Together, these countries cover about a fifth of the African continent. The map consists of 12 sheets of 90 cm by 130 cm.

The project, codename SMEA, was carried out by Messrs. R.T.A. Hakkeling (Msc. graduate Amsterdam University) and D.M. Endale (Msc. graduate Wageningen University), under supervision of Dr. W.G. Sombroek, Director of ISRIC.

The basic purposes were: 1. to test the validity at 1:1 million level of the 1987 revision of the FAO/Unesco legend for the Soil Map of the World, 2. to provide an estimate of the acreage, at regional level, that may have a potential for irrigation development.
The product is to be entered, in digital form, into FAO's geographical information system as it is in development for internal use at its headquarters. For ISRIC, it is a first tryout at the effectuation of a digital soil and terrain database at 1:1 million scale (SOTER) as being promoted by an ISSS Working Group for the purpose.

A wide variety in sources of information (from recent, highly reliable maps to satellite image interpretations) resulted in considerable differences in reliability of the data. this will be elaborated in paragraph 1.3

For each mapping unit of the soil map, a suitability classification for irrigated upland crops and for paddy rice was estimated. For estimation, a methodology was developed that uses site and soil properties available in the mapping unit descriptions. The methodology is dealt with in part 2 of this report. Results are added to the mapping unit descriptions and listed in a separate set of annexes.

The Mapping Unit Descriptions also form a separate set of annexes.

PART 1. THE SOIL MAP

1. MAP COMPILATION

1.1 The base map

As base map, the 1:1 million scale Operational Navigation Charts (ONC) were chosen. Figure 1 shows the distribution of the map sheets.

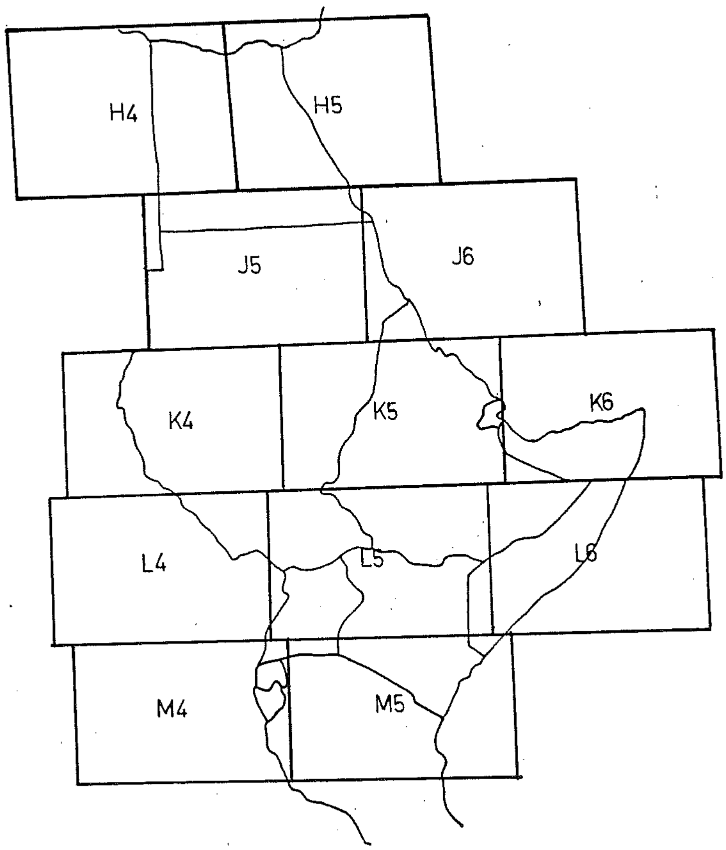


FIGURE 1.
DISTRIBUTION OF THE BASE MAP SHEETS

ONC maps have several advantages over regular topographic maps:
- A world wide coverage
- World wide obtainable
- Showing geomorphological information
- Good detail
- As an average highly reliable.

The draft version of the soil map is drawn on full-transparent foil. In this way, nearly all geomorphological information is visible on the soil map, thus enabling easy understanding of the major soil differences, especially when related to mountains, scarps, plains, and floodplains.

1.2 Data transfer

As every source map uses a different base map, many topographic features would be out of place when copied without sufficient attention being to topography. To prevent this, main topographical features, like mountains, major rivers, major towns, lakes and coastlines, were copied from the base map to the transparent foil and used as points of reference when copying the source maps.
Even when satellite images proved that the ONC base map was not correct, base map location was used as reference. This was done to prevent confusion.

1.3 Sources of information used

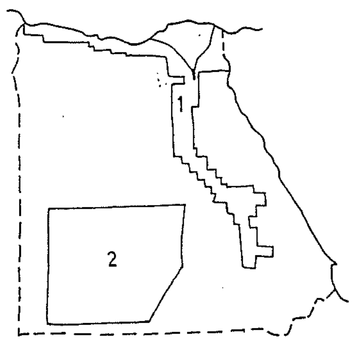
As mentioned before, considerable differences in reliability of the sources of information occur. For all source maps listed below, reliabilities are given.

Definition of reliability classes:

- High :Recent 1:1 million scale soil surveys. Unit descriptions must contain unit components with area percentages, landscape, geology, slope classes, phases and soil textures. Soils must be classified with the FAO/ Unesco system or with the US Soil Taxonomy system.
- Medium :Reconnaissance soil surveys with moderately good unit descriptions, not meeting all demands for High reliability.
- Low :Soil surveys with poor unit descriptions and lacking classification of the soils.

Where necessary, main limitations of the source maps are given.

FIGURE 2
EGYPT
source map
location



1. - Land Master Plan. Soil-, Land Capability and Land Management Category Maps. By Euroconsult-Pacer, 1987. Arnhem, The Netherlands.
   - Scale 1:1 Million, reliability low
   - Main limitations: no slope class, no classification, no profile descriptions.
2. - Soil Associations Map of the Western Desert of Egypt. By Alaily F. and Blume H.P., 1986. Fachhochschule Berlin.
   - Scale 1:1 Million, reliability medium
   - Main limitations: no slope class, textures too general

Additional information

- Soil Associations Map of Egypt. By Hammad M.A., 1975. Soil Survey Institute, Wageningen, The Netherlands. Scale 1:4 Million
- High Dam Soil Survey, United Arab Republic. By FAO, 1966. Scale 1:1 Million

- Geological Map of Egypt. By the Egyptian Geological Survey and Mining Authority, 1981.
  Scale 1:2 Million
- Soil Types and Associations of South West Egypt. By Blume H.P. et al, 1984. Berliner Geowiss. Abh. 50. 293-302.

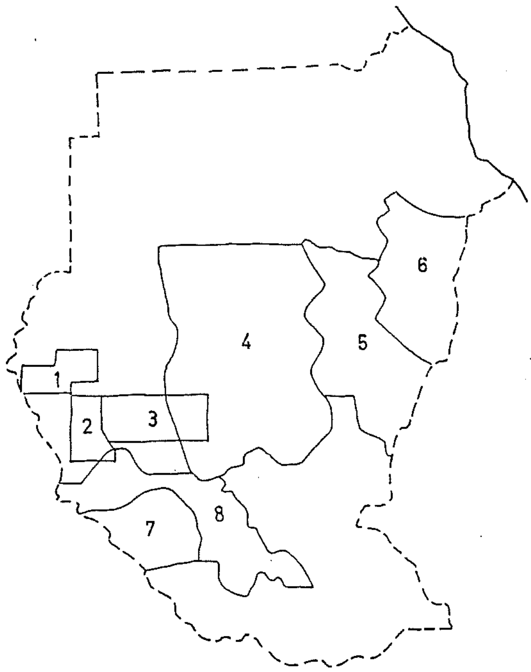


FIGURE 3
SUDAN
source maps location

1. - Land and Water Resources Survey in the Jebel Marra Area. By FAO, 1968. (FAO/SF:48/SUD-17)
   - Scale 1:250,000, reliability low
   - Main limitations: no classifications, no slope classes.
2. - Southern Darfur Land Use Planning Survey. By Hunting Technical Services Ltd, 1974. Herts, England.
   - Scale 1:250,000, reliability medium
   - Main limitation: no slope classes
3. - Preliminary Report on ERTS-1 Imagery in the Sudan. By Eggeling M.D. and Gaddas R.R., 1973. FAO, Khartoum.
   - Scale 1:250,000, reliability low
   - Main limitations: no classifications, no slope classes
4. - Exploratory Soil Survey of North and South Kordofan. By Pachego R. and Dawoud H., 1976. FAO, Soil Survey Report no.81.
   - Scale 1:1 Million, reliability medium
5. - Soil Resources Regions of the Blue Nile, White Nile, Gezira, and Khartoum Provinces of the Sudan. By Purnell M. et al, 1976. FAO, Soil Survey Report no.80.
   - Scale 1:1 Million, reliability medium
6. - Exploratory Soil Survey of Kassala Province. By Kevie W.vd and Burayman I.M., 1976. FAO, Soil Survey Report no.73.
   - Scale 1:1 Million, reliability medium

7. - Land Resources of Part of the Ironstone Catena of Bahr El Ghazal Province. By Venema J.L. and Klinkenberg K., 1978.
   - Scale 1:500,000, reliability medium
8. - Land Systems from ERTS, Bahr el Ghazal Province. By Hunting Technical Services Ltd, 1975. Herts, England.
   - Scale 1:1 Million, reliability low
   - Main limitations: no classifications, no slope classes

Additional information:
- Desertification in North Darfur. By Fouad N. Ibrahim, 1980. Universitat Hamburg.
  Scale 1:1 Million
- Carte Pedologique du Chad. By ORSTOM, 1970. Paris, France.
  Scale 1:1 Million
- Carte Pedologique de la Republique Central Africaine. By ORSTOM, 1983. Paris, France.
  Scale 1:1 Million
- Multitemporal Landsat Imagery Interpretation of the Flood Region Draining to the Sudd, Southern Sudan. By FAO, 1977.
  Scale 1:1 Million
- Soil Resources and Potential for Agriculture Development in Bahr el Jebel Area. By Remote Sensing Centre, Academy of Scientific Research and Technology, Cairo, 1978.
  Scale 1:1 Million
- Geological Map of the Sudan. By the Ministry of Energy and Mines, 1981. Khartoum, Sudan
  Scale 1:2 Million
- Report on the Methods, Organization and Costs of a Soil Survey and Land Classification of Equatoria Province. By Blokhuys W.A. and Ochtmans L.M.J.,1960.
  Scale 1:2 Million
- The Pedogeomorphic Map of the Central Clay Plain. (Part of Thesis). By Blokhuys W.A., in preparation.
- Scale 1:2 Million

ETHIOPIA

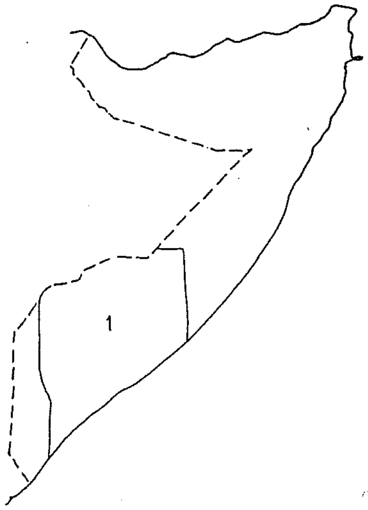
- Geomorphology and Soils, Ethiopia (8 sheets). By the Land Use Planning and Regulatory Department/ Assistance to Land Use Planning (FAO), 1984. FAO
- Scale 1:1 Million, reliability high

DJIBOUTI

No source maps

Additional information:
- Geological Map of Ethiopia and Somalia. By Consiglio Nazionale delle Richerche, 1973. Firenze, Italy
  Scale 1:2 Million

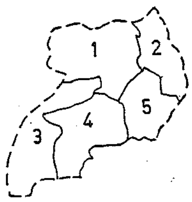
FIGURE 4
<u>SOMALIA</u>
source map
location



1. – Agricultural and Water Surveys, Somalia. By Lockwood Survey Corporation Ltd./FAO, 1968. FAO, Rome
   – Scale 1:660,000 approx., reliability medium.
   – Main limitations: No associated soils

Additional information:
   – Geological Map of Ethiopia and Somalia. By Consiglio Nazionale delle Richerche, 1973. Firenze, Italy
     Scale 1:2 Million

FIGURE 5
<u>UGANDA</u>
source maps
locations



Uganda Protectorate, Department of Agriculture, Memoirs of the Research Division, with Maps:

1. – The Soils of the Northern Province, Uganda, Excluding Karamoja. Memoir no.3. By Ollier C.D., 1959.
   – Scale 1:500,000, reliability medium
   – Main limitations: no classifications, no associated soils
2. – Soils of the Karamoja district, Northern Province of Uganda. Memoir no.5. By Wilson J.G., 1959.
   – Scale 1:250,000, reliability medium
   – Main limitations: no classification, no associated soils
3. – The Soils of the Western Province of Uganda. Memoir no.6. By Harrop J.F.,1960
   – Scale 1:500,000, reliability medium
   – Main limitations: no classifications, no associated soils

4. - Soils and Land Use of Buganda. Memoir no.4. By Radwanski S.A., 1960
   - Scale 1:500,000, reliability medium
   - Main limitations: no classification, no associated soils
5. - Soils of the Eastern Province of Uganda. Memoir no.2. By Ollier C.D. and Harrop .J.F., 1959
   - Scale 1:500,000, reliability medium
   - Main limitations: no classification, no associated soils

Additional information:
- Introduction to the Soils of the Uganda Protectorate. Memoir no.1. By Chenery E.M., 1960
- Terrain Systems of Uganda, Atlas. By Ollier C.D.et al., 1969

Report Military Engineering Experimental Establishment, no. 959. Christchurch.

Scale 1:1 Million
- Agriculture in Uganda. By Jameson J.D., 1970. Oxford, England.
  Map at scale 1:1.5 Million

KENYA

- Exploratory Soil Map and Agro-Climatic Zones Map of Kenya. By Sombroek W.G. et al.,1980. Kenya Soil Survey, Nairobi.
- Scale 1:1 Million, reliability high

Additional information:
- Descriptions and analytical data of profiles sampled for the preparation of the exploratory soil map

RWANDA/BURUNDI

- Les Sols de Rwanda et Burundi. By Wambeke A. van, 1961. Pedologie 11-2 pp 289-353
- Scale 1:1 Million, reliability low
- Main limitations: no slope classes, no indications about areas of associated soils

Additional information:
- Proceedings of the 14th International Soil Classification Workshop, Rwanda 1981. Part 2: Field and Background Soil Data. Published in 1983 by ABO-AGCD, Brussels, Belgium.

TANZANIA

- Consultants Final Report on the Soils, Physiography, and Agroecological Zones of Tanzania. By Pouw E. de, 1984. Crop Monitoring and Early Warning System Project (GCPS-URT-047-NET), Ministry of Agriculture, Dar Es Salaam, Tanzania. FAO.
- Scale 1:2,000,000, reliability medium

ADDITIONAL INFORMATION, NOT COUNTRY-CONNECTED

1. - FAO/Unesco Soil map of the World. Volume VI-AFRICA, 1977
   - Scale 1:5,000,000
2. - Soil Map of the World. By USDA/SCS, 1940-1955 approx. (only in draft). World Soil Geographic Office, Lanham, USA.
   - Scale 1:1 Million
3. - AFRIKA-KARTENWERK-bodengruppen (N-E Lake Victoria Region). By German Research Society, 1983. Berlin-Stuttgart, Germany.
   - Scale 1:1 Million

1.4 Border discrepancies - Correlation between different surveys.
As could be expected, significant differences occur when soil maps of neighboring countries are compared along their mutual border. Solutions for these problems differ from case to case and will therefore be discussed separately.

- Central Sudan / Ethiopia
  The border between these countries reflects a major geomorphological boundary (Sudan clay plain versus Ethiopian Highlands). Little correlation difficulties occur.

- Ethiopia / Kenya
  Although little differences occur in geomorphology, some major differences occur in the field of soil classification. This was dealt with by interpretation of 1:500,000 working copies of satellite images kindly provided by the Kenya Soil Survey.

- Ethiopia / Southern Somalia
  Soil descriptions on the Somali side of the border were very poor, so Ethiopian descriptions were used where necessary.

- Uganda / Kenya
  The greater part of this border is formed by the Turkana Scarp, preventing soil boundaries to cross the border. Where difficulties arose, interpretation of a landsat mosaic map of Uganda proved helpful. Because of the higher reliability, credit was given to the descriptions in the Kenya report.

- Uganda / Rwanda ; Uganda / Tanzania ; Tanzania / Rwanda ; Tanzania / Burundi
  Little differences in descriptions on both sides of the border.

- Tanzania / Kenya
  Some differences occur. Because of higher reliability and greater detail, credit was given to the data in the Kenya report.

If soil data were only available at one side of the border, these data were used as a reference for satellite image interpretation of the area at the other side of the border.

1.5 Satellite image interpretation

For all areas not covered by soil maps of scales between 1:250,000 and 1:2,000,000 and all areas covered by soil maps with a low reliability, Landsat satellite images were obtained and interpreted (see figure 6). For Egypt, MSS band 5 images were used, for Sudan and Somalia, False Colour images were obtained from the Regional Remote Sensing Facilities, Nairobi, Kenya. Wherever possible, an overlap of images into a well surveyed area was obtained as well.
In total, about 180 images were interpreted.

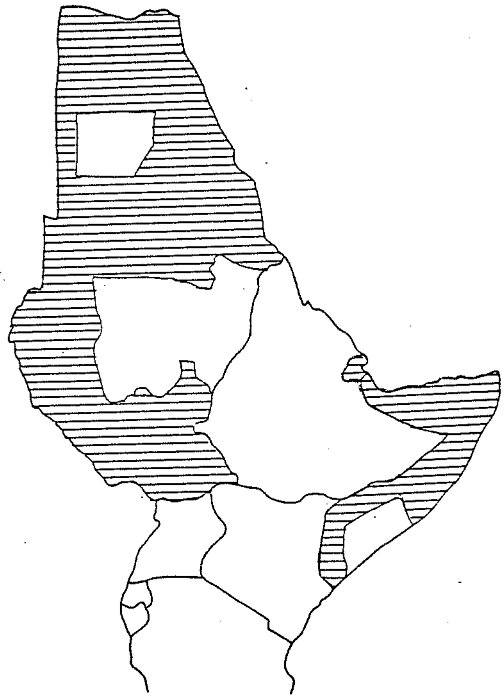


FIGURE 6
Area covered by satellite image interpretation (hatched)

All images had scales of about 1:1 million. Small differences in scale between images and the base map were dealt with by using topographic features, if visible on both the images and the base map, as a reference.
Images were covered with a transparent foil on which the interpretation lines were drawn. This to protect the images and to facilitate the transfer of lines from image to base map.

Interpretation of a set of images covering an area starts with checking the "overlap images" with the soil map and the geological map of that area, thus creating a soil/landscape/ geology model. Mapping units that continue from the well surveyed overlap area into the unsurveyed area, receive the same symbol, with the same descriptions and reliability as the original unit.
Mapping units further away, and differing from the units in the overlap area, are described with help of the soil/landscape/ geology model. Reliabilities of these newly distinguished and described units are classified as very low.

Areas covered by low reliability soil maps are also Landsat-image interpreted, with help of the model and the source map. Reliabilities of units described this way are classified as low.

Descriptions of newly distinguished mapping units must at least contain information about landscape, geology, dominant and associated soils, slope class,surface form,soil depth and texture. It will be clear that in most cases data given are no more than "educated guesses".

2. MAPPING UNIT DESCRIPTIONS

2.1 Soil classification

All soils are classified following the fourth draft of the new FAO/Unesco soil classification system. The final version of this system will be published in 1988.

Main differences between the new system and the current FAO/ Unesco classification system are the disappearance of some soil groups and the appearance of new soil groups and subgroups. Brief descriptions of the new soil groups are given in appendix I of Part 2 of the report. Also new are third level specifiers, a further specification of the soil subgroups. Brief descriptions of possible third level specifiers are listed in appendix II of Part 2 of this report.

Dunes and solid rock are not considered as miscellaneous land-forms, like in many other reports, but are classified as Haplic Arenosols and Lithic Leptosols respectively. Although this may not be correct from a classificational point of view, it is hardly possible to discriminate between dunes and Haplic Areno-sols, or between solid rock and Lithic Leptosol.

2.2 Mapping unit description sheets.

To enable an easy transfer to any digitized database, nearly all data on the Mapping Unit Description sheets are in a digitized form. This means that data in the mapping unit descriptions of the source maps had to be reworked. It is inevitable that during this process some loss of detail occurs. However, mapping unit descriptions in a digital form provide a great uniformity over the whole area, which is very important in an area so big and with so much variety is soils, landscape and climate.

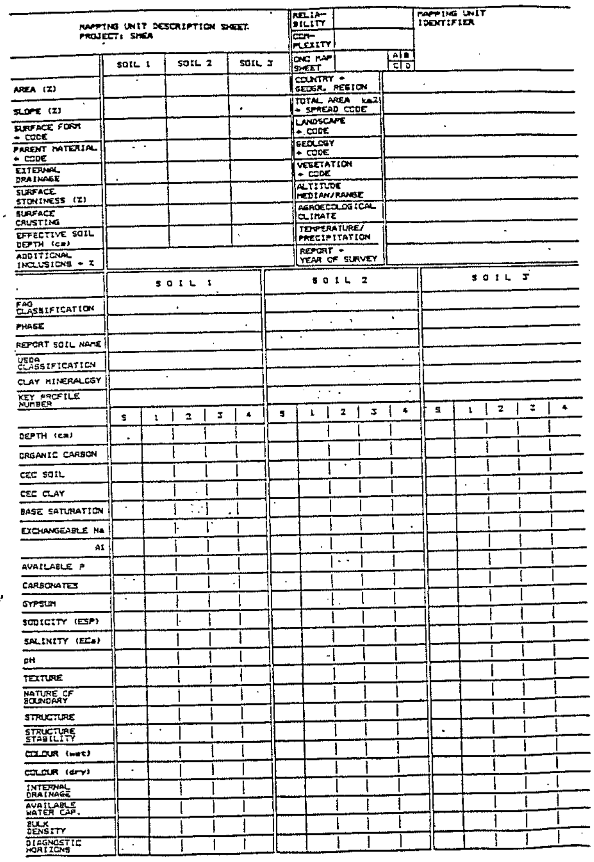
Mapping Unit Description Sheets (in short: MUDsheets) can be sub-divided into 3 sectors. (see figure 7)

Top right: Information about the mapping unit as a whole
Top left : Information about the sites of the three most important unit components
Bottom : Profile information concerning the three most important unit components. Whole profile information under "S", if representative profiles were available, information for separate horizons under "1,2,3,4".

A detailed manual for these MUDsheets is given on the next pages.

Mapping unit identifiers are reflecting dominant soil type, dominant texture and dominant slope classes, thus providing important soil information, even without further description. Two dominant soils are given in the identifier if the two most

important soils differ 10% or less in area covered within the mapping unit. If the major soil type was a Lithic Leptosol, the second soil type was given in the identifier if it covered more than 20% of the mapping unit.
If the dominant soil(s) are found on more than one slope class, lowest and highest class are given in the identifier.
Only one texture group symbol is given in the identifier. If actual textures of the dominant soil(s) cover 2 or 3 texture groups, the most representative group is given. If textures cover 4 or 5 texture groups, no texture indication is given.



MAPPING UNIT DESCRIPTION SHEET.
PROJECT: SMEA

				RELIABILITY	
				COMPLEXITY	
				ONC MAP SHEET	A B C D
	SOIL 1	SOIL 2	SOIL 3	MAPPING UNIT IDENTIFIER	
AREA (%)				COUNTRY + GEOGR. REGION	
SLOPE (%)				TOTAL AREA km2 + SPREAD CODE	
SURFACE FORM + CODE				LANDSCAPE + CODE	
PARENT MATERIAL + CODE				GEOLOGY + CODE	
EXTERNAL DRAINAGE				VEGETATION + CODE	
SURFACE STONINESS (%)				ALTITUDE MEDIAN/RANGE	
SURFACE CRUSTING				AGROECOLOGICAL CLIMATE	
EFFECTIVE SOIL DEPTH (cm)				TEMPERATURE/ PRECIPITATION	
ADDITIONAL INCLUSIONS + %				REPORT + YEAR OF SURVEY	

	SOIL 1	SOIL 2	SOIL 3
FAO CLASSIFICATION			
PHASE			
REPORT SOIL NAME			
USDA CLASSIFICATION			
CLAY MINERALOGY			
KEY PROFILE NUMBER			

	S	1	2	3	4	S	1	2	3	4	S	1	2	3	4
DEPTH (cm)															
ORGANIC CARBON															
CEC SOIL															
CEC CLAY															
BASE SATURATION															
EXCHANGEABLE Na															
Al															
AVAILABLE P															
CARBONATES															
GYPSUM															
SODICITY (ESP)															
SALINITY (ECe)															
pH															
TEXTURE															
NATURE OF BOUNDARY															
STRUCTURE															
STRUCTURE STABILITY															
COLOUR (wet)															
COLOUR (dry)															
INTERNAL DRAINAGE															
AVAILABLE WATER CAP.															
BULK DENSITY															
DIAGNOSTIC HORIZONS															

FIGURE 7
reduced example of a mapping unit description sheet (MUDsheet)

Actual profile data are supposed to be within the classes given in the bottom part of the MUDsheet. If the source data covered more classes, two or three classes are given.

For Lithic Leptosols, only slope and soil depth is given. Other characterizations are not relevant.

MANUAL FOR MAPPING UNIT DESCRIPTION SHEETS

UNIT INFORMATION

- **Mapping Unit Indentifier** (From: SMEA project meeting 1987)

  Dominant soil, sequence number - texture, slope

  - Dominant Soil: New FAO codes, to third level
  - Texture:

Texture		Slope	
1	sand	a	0-2
2	sandy loam	b	2-5
3	loam	c	5-8
4	clay loam	d	8-16
5	clay	e	16-30
(see texture triangle, fig. 8)		f	30+

  example: LVvx6 - 3b = chromi vertic Luvisol, association number 6, loamy, on 5-8% slopes

- **Reliability**
  - High : Based on recent 1:1 Million scale soil surveys and/or profile descriptions
  - Medium : Based on reconnaissance soil surveys with moderately good unit descriptions
  - Low : Based on remote sensing, soil surveys with poor unit descriptions and geological information
  - Very low: Based only on remote sensing and geological information

- **Complexity**
  - Association: Unmappable subunit differences based on landscape features
  - Complex : Subunit differences <u>not</u> based on landscape features

- **ONC MAP SHEET** + segment

- **Country + geographic region**

  example: Sudan, S-W

- **Total area** in km^2

- **Spread Code:** codes to be designed

(From: R.F. van de Weg, 1978)

- Landscape

Symbol	
M	- Mountains, Major Scarps
H	- Hills, Minor Scarps
R	- Mountain Footridges (Footslope Ridges)
F	- Footslopes
L	- Plateaus
U	- Uplands
Y	- Piedmont Plains
P	- Plains
A	- Flood Plains
B	- Bottom Lands
Z	- Coastal Ridges
S	- Swamps
La	- Recent Lava Flows
W	- Bad Lands
V	- Valleys/Minor Valleys
T	- Tidal Flats and Swamps
D	- Dunes
E	- Deltas
C	- Valley bottoms
X	- Intricate combination/Complex landforms

- Geology (From: R.F. van de Weg, 1978)

A. IGNEOUS ROCKS

Symbol	
	Acid rocks
G	examples: granite, granodiorite
Y	aplite, rhyolite
I	**Intermediate rocks**
	examples: syenite, alkalisyenite
	trachyte, alkalitrachyte, trachyandesite
	diorite
	andesite
	phonolite, "kenyte" (olivine phonolite)
	Basic rocks
	examples: basalt, alkalibasalt, nephelinite,
B	gabbro, norite
	dolerite
	Ultrabasic rocks
B	examples: hornblendite, pyroxenite, hyperstenite
	serpentinite, peridotite
V	**Undifferentiated Igneous rocks**
P	**Pyroclastic rocks**
P1	unconsolidated pyroclastics (ashes, pumices, scoriae)
P2	consolidated pyroclastics (tuffs, welded tuffs, ignimbrites)

B. METAMORPHIC ROCKS

Symbol	
L	crystalline limestones
C	calc-silicate gneisses (granulites)
Q	granitoid gneisses/quartzites
R	quartz-feldspar (quartzo-felspatic) gneisses
M	quartz-muscovite/muscovite/sillimanite gneisses
N	biotite/biotite-garnet gneisses
F	gneisses rich in Fe-Mg (ferromagnesian) minerals such as: hornblende/biotite-hornblende/amphibolite gneisses
U	undifferentiated basement system gneisses/rocks

C. SEDIMENTARY ROCKS

Symbol	
Z	conglomerates, gravels
S	(sandstones (consolidated sands)) (grits (coarse sandstones with angular grains)) (arkoses (sandstones with more than 25% feldspar) (grains, relatively rich sandstones)) (greywackes (fine to coarse, angular to sub-angular) (particles, which are mainly rock fragments))
K	siltstones (consolidated silts)
D	mudstones (consolidated clays)
W	marls (calcareous mudstones)
T	shales (consolidated clays/silts with fine stratification)
O	Plio-Pleistocene "bay" sediments ("Marafa beds")
J	Lagoonal deposits
E	Cover sands (eolian deposits, in N.E. Kenya)
A	Undifferentiated Unconsolidated sediments e.g. alluvium, colluvium, dune sands)
Ev	evaporites (e.g. gypsum, trona, etc.)
L	limestones/coral reef limestones/travertines
H	cherts/flints/chalcedonites/diatomites (rocks consisting of SiO_2)

D. UNKNOWN

Symbol	
X	If the bedrock is unknown, or various parent materials are involved

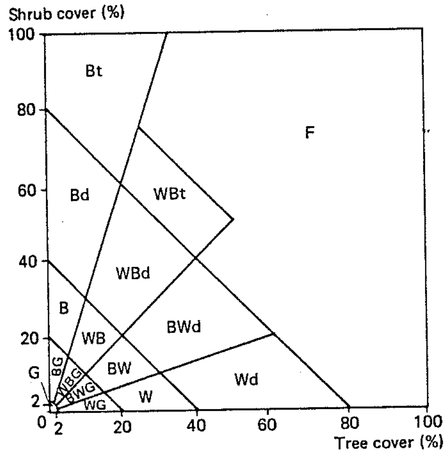
(After: Van de Weg and Mbuvi (1975)

- **Vegetation:**

F = Forest
W = Woodland
B = Bushland
G = Grassland
t = Thicket
d = dense

M = Mangrove
S = Swamp vegetation (Mainly Papyrus)
A = Alpine vegetation
X = Complex Mixture
C = Cultivation
E = Exposed Surface, Bare

Combinations of vegetation types:



- **Altitude:** in meters, if necessary estimated from base maps

- **Agroecological climate**)
- **Temperature regime**) given when available
- **Precipitation (annual)**)

- **Report + year of survey** : only soil reports given

SITE INFORMATION

- **Soil 1, 2, 3** in decreasing area percentages

- **Area percentages:** rounded off to plurals of five

- **Slope** (From: FAO, 1984)

0-2%	8-16%
2-5%	16-30%
5-8%	30+%

- **Surface Form** (From: J. Shields, June 1986)

D	Dissected
B	Depression
I	Inclined
L	Level
R	Rolling
S	Steep
U	Undulating
T	Terraced
V	Small Valley

- **Parent material** (After: E. van Waveren, 1986)

A	Alluvial
C	Colluvial
H	Ejecta Ash
L	Lacustrine
M	Marine
O	Organic
R	Solid Rock
E	Eolian Sand
U	Unconsolidated/unspecified
X	Residual

- **External Drainage** (From: W.G. Sombroek, SMEA Project meeting, 1987)

  W well

  I imperfect

  P poor

  F flooded

- **Surface stoniness (%)** (After: J. Shields, June 1986)

  0-0,1

  0,1-3,0

  3,0-15

  15-90

  90+

- **Surface crusting** (From: A.W. Vogel, 1986)

  U unslaked

  W weak

  M moderate

  S strong

- **Effective soil depth cm** (After: J. Shields, Febr. 1986)

  0-10 cm

  10-50 cm

  50-100 cm

  100-150 cm

  150+ cm

- **Additional inclusions**(with %)

  Inclusions must be significantly different from soils 1, 2, 3.

PROFILE INFORMATION

- FAO Classification: from fourth draft of new Legend, to third level (full name)
- Phase: from fourth draft, with percentage of component covered by the phase
  / : two phases covering the same part of the component (example: salic/sodic).
  ; : two phases not necessarily covering the same part of the component (example: rudic;petroferric)
- Report soil name: from report
- USDA classification: from Soil Taxonomy, Soil Survey Staff, 1975
- Clay mineralogy: if available
- Key profile number: from survey report
- S = total soil, if no horizon data are available
- If horizon data are available (From: J. Shields, Febr. 1986; SMEA Project 1987)
  1. Surface horizon
  2. Subsurface horizon/layer
  3. Subsoil horizon/layer
  4. Substrata
- Depth: of bottom boundary of horizon, in cm
- Organic Carbon: (weight %) (From: J. Shields, Febr. 1986)
  A 0 -0,6
  B 0,6-2
  C 2 -3
  D 3 -8
  E 8^+
- CEC soil (meq/100 g soil) (From: J. Shields, June 1986)
  A 0-2
  B 2-10
  C 10-30
  D 30-60
  E 60^+
- CEC clay (meq/100 g clay) (From: J. Shields, June 1986)
  A 0 -1.5
  B 1.5-6.0
  C 6.0-16
  D 16 -36
  E 36^+

- Base Saturation, related to CEC-pH_7 (%) (From: A.W. Vogel, 1986)

A	0-10
B	10-25
C	25-50
D	50-75
E	75-100

- Exchangeable Na (meq/100 g soil) (From: A.W. Vogel, 1986)

A	0-0.1
B	0.1-0.3
C	0.3-0.7
D	0.7-2.0
E	2.0^+

- Exchangeable Al (% CEC) (From: A.W. Vogel, 1986)

A	0-30
B	30-85
C	85^+

- Available Phosphorus (ppm) (From: A.W. Vogel, 1986)

A	0 -3
B	3 -6.5
C	6.5-13
D	13 -22
E	22^+

- Carbonates (weight %) (From: A.W. Vogel, 1986)

A	0-5
B	5-15
C	15-25
D	25-40
E	40^+

- Gypsum (weight %) (From: A.W. Vogel, 1986)

A	0-5
B	5-25
C	25^+

- Sodicity (ESP; %) (From: A.W. Vogel, 1986)

  A 0-6

  B 6-15

  C 15-30

  D 30-60

  E 60^+

  (From: A.W. Vogel, 1986)

- Salinity (ECe; mS/cm, saturation extract) (From: H.M.H. Braun and R.F. van de Weg, 1977)

  A 0-2

  B 2-4

  C 4-8

  D 8-15

  E 15^+

- pH (water) (From: J. Shields, Febr., 1986)

  A 0 -3.8

  B 3.8-5.4

  C 5.4-6.5

  D 6.5-8.5

  E 8.5^+

- Texture of fine earth fraction (From: FAO, Guidelines 1977)

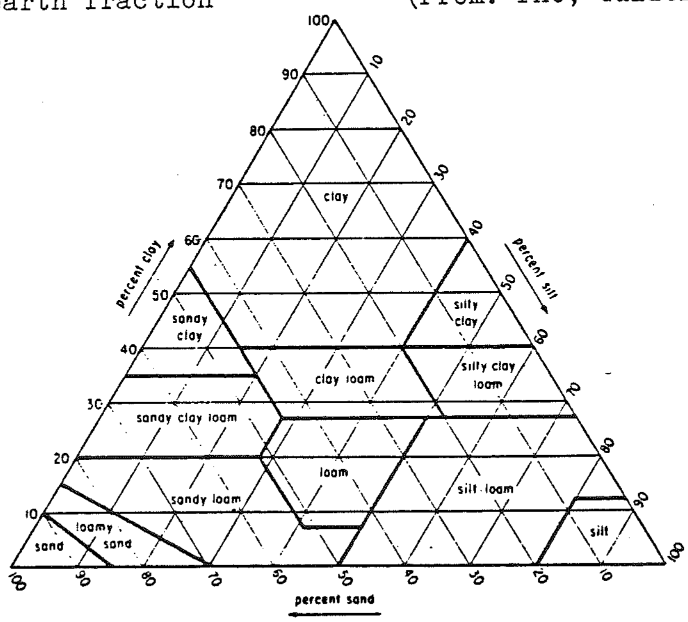


Figure 9

Texture triangle

- Nature of boundaries (From: FAO, 1977)

  A - abrupt

  B - clear

  C - gradual

  D - diffuse

- Structure (From: FAO, 1977)

  Size:

  very fine..........1

  fine...............2

  medium.............3

  coarse.............4

  Form (type):

platy..............pl	granular...............gr
prismatic..........pr	crumby.................cr
columnar...........cpr	single grain...........sg
angular blocky.....ab	massive................m
subang. blocky.....sb	

- Structure stabilities

  weak ....w

  moderate ....m

  strong ....s

- Colour wet) Munsell Color scale
- Colour dry)
- Internal drainage (From: J. Shields, Febr. 1986)

  A well

  B imperfect

  C poor

- Available Water Capacities Volume % (From: W.G. Sombroek, SMEA Project meeting, 1987)

  A 0-15

  B 5-10

  C 10-15

  D 15+

- Bulk density (g/cm^3) (From: J. Shields, Febr. 1986)

  A 0 -0.90

  B 0.90-1.2

  C 1.2 -1.5

  D 1.5+

- Diagnostic Horizons: FAO legend, latest draft

PART 2. SOIL SUITABILITY ASSESSMENTS FOR IRRIGATED UPLAND CROPS AND FOR WETLAND RICE (PADDY RICE)

1. INTRODUCTION

1.1 General

Irrigation is an expensive undertaking. The ultimate socio-economic benefit determines its viability. Interactions between soil, applied water (quantity and quality), crops and management factors need to be considered in evaluating irrigation potential. Variability of these factors from site to site makes the evaluation rather site specific. Experts agree that there are no ideal soil and land requirements for irrigation. Standardization of land evaluation for irrigation can therefore be misleading. This should be kept in mind when considering the results of this report.

1.2 Soil suitability assessment for irrigation in North Eastern Africa.

In this report, a soil suitability assessment is carried out within the context of the following assumptions:

- gravity irrigation is used (other types of irrigation can give different results)
- the costs of the realization of the necessary infrastructure is not considered.
- the investigation is to a scale of 1:1 million. This has an important influence on its applications and limitations.
- irrigability assessment is made for upland crops and paddy rice respectively. The variation in the land requirements for different upland crops is recognised, but the scale allows only a broad generalization.

These assumptions and limitations notwithstanding, the knowledge of soil and topography is useful in the initial identification of promising lands, which thereupon would justify a more detailed evaluation at any future moment.

2. SOIL IRRIGABILITY.

Characteristics of particular relevance to irrigability assessment are:

<u>Soil characteristics</u>

- effective soil depth *
- particle size distribution *
- structure stability (pre/post irrigation)
- porosity
- infiltration rate
- saturated hydraulic conductivity *
- water retention characteristics
- salinity/alkalinity *
- calcium carbonate content *
- gypsum content *

- pH *
- depth to ground water *
- salinity of groundwater
- toxic substances

Site characteristics
- topography
- surface stoniness *
- subsurface stoniness *

Characteristics marked with an asterisk can be deduced to some degree from the FAO/Unesco soil name and from phases.

Interactions between characteristics can determine land qualities which can also be used as criteria for soil irrigability assessment:
- ability for drainage and aeration
- water retention capacity
- saline groundwater table
- field layout (gilgai)
- flooding hazard
- workability
- field stability

Depending on the availability, dependability, ranking and accuracy of data on these characteristics and qualities, assessment of soil irrigability can be carried out to different sensitivities and/or scales.

3. METHODOLOGY

3.1 Background

The approach by FAO in their publication "Land Resources for Populations of the Future" (1984), was considered a fast but acceptable methodology of soil irrigability assessment at the initial state of the project, in view of the then apparent time constraint and the not too well defined requirements.
The method was therefore adopted, with modifications to meet the possibilities of the data available in the MUDsheets.

3.2 General approach.

An initial situation is created by making a suitability classification for each soil type of a mapping unit under standard curcomstances (level surface, no other textural constraints than can be deduced from the soil name, no phases). The suitabilities are derived from the soil name, using the soil and site characteristics marked above.

The initial soil suitability classification has 3 classes:
S1: very suitable, no or few slight limitations
S2: moderately and marginally suitable, slight to moderate limitations
N : not suitable, severe limitations

Also distinguished are the following intergrades:
S1/S2 : 50% of the soil type is suitable, 50% is marginal
S2/N : 50% of the soil type is marginal, 50% is not suitable
S1/S2/N: 33% of the soil type is suitable, 34% is marginal, 33% is not suitable.

It can be assumed that 30% of the soils classified as N can be made marginally suitable with considerable costs.

The initial situation is treated with a series of modifications, reflecting the influence of restraining site or soil properties. Modifications are in the form of possible downgradings:
<0> = no downgrading
<-1>= downgrade 1 class (f.e. from S1 to S2)
<N> = downgrade to not suitable
A fourth soil suitability class is created (S3), containing initially suitable soils (S1) with 2 restraining factors and initially marginal soils (S2) with 1 restraining factor. If a soil already in class S3 is downgraded again, it becomes not suitable.

Slope and texture classifications can show significant variation within a mapping unit component. This is why modifications for slope and texture have intergrades in percentages.
Example: 20% <0>; 40% <-1>; 40% <N>.
At the end of the series of modifications (after step 8, see paragraph 1.3), suitability classes S2 and S3 are combined in class S2, marginal soils. Final suitability classifications for a whole mapping unit is given as x/y/z, reflecting percentages of suitable (x), marginal (y) and not suitable (z) area.

The resulting suitability classification is a classification for soil and site properties, other factors like climate, water availability, commandability of the water and socio-economic aspects are not taken into account.
Main limitation of the map is the wide variety in reliability of the data.

3.3 Calculation model

I. ENTRY

Percentual subdivision of the mapping units in components.
(soil 1,2,3 and inclusions on description sheets)

-- results after step I = entry step II --

II. ADDING OF SUITABILITY CLASSES FOR SOIL TYPES UNDER STANDARD CIRCUMSTANCES (LEVEL SURFACE, NO TEXTURAL RESTRAINTS, NO PHASES)

Suitabilities for all 147 soil sub-units of the new FAO classification system are listed in appendix I. For explanation, see general approach.
Soil suitabilities are adopted from: Land resources for populations of the future (FAO, 1984), and modified where necessary for the new classification.

-- results after step II = entry step III --

III. MODIFICATION OF FLUVISOLS AND PLANOSOLS FOR VARIOUS DRAINAGE CLASSES (in percentages)

	Upland Crops			Paddy Rice		
	<0>	<-1>	<N>	<0>	<-1>	<N>
FLUVISOLS:						
well drained	80	20	-	25	50	25
imperfectly drained	10	80	10	50	50	-
poorly drained	-	20	80	75	25	-
PLANOSOLS:						
well drained	75	25	-	-	75	25
imperfectly drained	10	75	15	50	50	-
poorly drained	-	25	75	75	25	-

No drainage information: assume 33% well, 34% imperfect, 33% poor

-- results after step III = entry step IV --

IV. MODIFICATION FOR SLOPE

6 slope classes are distinguished, in 14 relevant combinations. Each combination has its own modification percentages, which are given in appendix III. Percentages differ for upland crops and paddy rice.
NOTE: For 4th and 5th soil (as additional inclusions on the MUDsheets), slopes, textures and phases are estimated from soils 1,2,3 and from the descriptions of resembling mapping units.

-- results after step IV = entry step V --

V. MODIFICATION FOR TEXTURE

12 texture classes are distinguished, in 5 texture groups. These groups form 15 relevant combinations. Each combination has its own modification percentages, which are listed in appendix IV. Percentages differ for upland crops and paddy rice.

NOTE: For Vertisols, Vertic subunits and verti third level specifiers, no texture modification takes place. (These soils are already in class S2 after steps 2 and 3, mainly because of texture.)
NOTE: Ferralsols are not downgraded for fine texture. (Many clayey Ferralsols show pseudosand, and therefore do not react like clays.)
NOTE: If topsoil and subsoil textures are given, the topsoil textures are used. If the topsoil is less than 30 cm thick, the subsoil is taken into account as well. If no differentiation is given, it is assumed that given texture = topsoil texture.

-- results after step V = entry step VI --

VI. MODIFICATION FOR FIRST PHASE

Each phase type has its own modification percentages, which are listed in appendix V.

NOTE: When phases are given for the whole mapping unit, it is assumed that they apply only to 75% of the area. (In many cases, f.e. the Kenya Soil Survey map, a phase is already attributed to a soil unit if it covers more than 50% of the unit area)
NOTE: Lithic phases occur mostly on the steeper slopes of a unit,and must therefore be related to the slope class combinations.
EXAMPLE: Luvisol, 75% lithic phase, on 5-16% slopes.
Suitability assessment after slope modification: -/20/80. (80% is the steeper slopes).
Without relating phase and slope, the suitability assessment after phase modification would be -/5/95 (%)
When relating phase and slope, the suitability assessment stays -/20/80 (%). (The lithic phase is included in the steeper slopes.)

-- results after step VI = entry step VII --

VII. MODIFICATION FOR SECOND PHASE

Rules are as for first phase, with the following consideration: If phases 1 and 2 together are more than 100%, the second phase is dealt with in step VII. If phases 1 and 2 together are less than 100%, phase 2 is dealt with in step VI.
EXAMPLE: phase 1 covers 75%, phase 2 50%. Area free of phases: 12.5% (50% of the area not covered by phase 1)
phase 1 covers 50%, phase 2 25%. Area free of phases:25%

-- results after step VII = entry step VIII --

VIII. MODIFICATION FOR THIRD LEVEL IDENTIFIER

Modifications are listed in appendix II.
Most third level identifiers have no effect on the suitability. Identifiers like areni and verti must not be taken into consideration, because they are already dealt with in step V (texture).

After step VIII, classes S2 and S3 are combined into class S2 (see general approach).

4. ANNEXES ON DATABASE AND RESULTS

Results of the soil irrigability assessment are given in a set of separate annexes.

4.1 Database
In order to make uniform assessments, a minimum set of necessary data was extracted from the soil mapping unit description sheets. Data extracted are: Soil name, area percentage, drainage condition, slope, texture and phases. These data are listed in the annexes.
After entering these data in the computer, calculation was carried out.

Appendix VI shows the meaning of the abbreviations used in the database.
Codes are given in the annexes, preceding the databases.

4.2 Results of calculations
Results are given in two different layouts in the annexes and, generalized two plurals of 5, on top of the MUDsheets.

The first set of results in an annex (RESULT I) gives the irrigability assessments per unit component in S1/S2/N and the final assessments for the whole mapping unit.

The second set of results in an annex (RESULT II) shows the effects of all modifications of the calculation model in S1/S2/S3/N and the final assessments for the whole mapping unit. Purpose of this layout is to guide anyone who wants to check the procedure and perhaps note anomalies and errors.

Area percentages mostly add up to hundred. If not, the most probable reason is a fifth soil in the MUDsheet, which is not taken into consideration. These inclusions cover normally only 5% of the area.

5. FINAL REMARKS

1. The accuracy of the assessment depends highly upon the accuracy of the soil data.
2. More detailed survey will most presumably bring up more restraining soil and site properties. (More phases, other soil subgroups and third level specifiers, which are usually less suitable)
3. Mapping unit component percentages, slope classes, textures and phases have a much higher impact upon the final suitability than soil type.
4. Irrigability assessments calculated as mentioned above were compared with irrigabilities given in small scale irrigation studies of Central Ethiopia (Awash Valley), Southern Somalia and Eastern Kenya (Bura Irrigation Scheme). Considering scale differences, results were very satisfying. Larger differences were always due to differences in soil data.
Details are not included in this report.

APPENDIX I

SOIL SUITABILITY UNDER IDEAL CIRCUMSTANCES FOR FAO-SOIL SUBUNITS (AMENDED IVth DRAFT, 1987)

The symbols of major soil groupings and soil units have been changed in order to avoid confusion between the 1974 Legend and the Revised one. The new symbols are listed below, brief descriptions of newly distinguished units are added.

S1 = very suitable
S2 = marginally suitable
N = not suitable

S1/S2 = 50% S1; 50% S2
S2/N = 50% S2; 50% N
S1/N = 50% S1; 50% N

Level I Major soil groupings with changes in definitions or comments	Level II Soil units	irrigation suitability: Upland crops	irrigation suitability: Paddy Rice	Changes in definitions of soil units or comments
Fluvisols (FL)	Eutric Fluvisols (Fle)	see text	see text	
	Calcaric Fluvisols (Flc)	see text	see text	
	Dystric Fluvisols (Fld)	see text	see text	
	Mollic Fluvisols (Flm)	see text	see text	- new, with mollic A horizon
	Umbric Fluvisols (Flu)	see text	see text	- new, with umbric A horizon
	Yermic Fluvisols (Fly)	N	N	- new, with yermic properties
	Thionic Fluvisols (Flt)	N	N	
Gleysols (GL)	Eutric Gleysols (GLe)	S2/N	S1/S2/N	
	Calcic Gleysols (GLk)	S2/N	S1/S2/N	
	Dystric Gleysols (GLd)	S2/N	S1/S2/N	
	Mollic Gleysols (GLm)	S2/N	S1/S2/N	
	Umbric Gleysols (GLu)	S2/N	S1/S2/N	- formerly Humic Gleysol
	Thionic Gleysols (GLt)	N	N	- new, with sulfuric horizon
	Gelic Gleysols (GLi)	N	N	
Regosols (RG)	Eutric Regosols (RGe)	S1	S1	
	Calcaric Regosols (RGc)	S1/S2	S2/N	
	Gypsic Regosols (RGj)	N	N	- new, with gypsiferous material
	Dystric Regosols (RGd)	S1	S1	
	Gelic Regosols (RGi)	N	N	
Leptosols (LP) new major grouping; groups the former Rankers, Rendzinas and Lithosols, as well as soils less than 50 cm deep and with a cambic horizon or no diagnostic horizons.	Eutric Leptosols (LPe)	N	N	- with B.S. of 50% or more
	Dystric Leptosols (LPd)	N	N	- with B.S. of 50% or less
	Rendzic Leptosols (LPk)	N	N	- formerly Rendzinas
	Mollic Leptosols (LPm)	N	N	- with mollic A horizon
	Umbric Leptosols (LPu)	N	N	- formerly Rankers
	Lithic Leptosols (LPs)	N	N	- formerly Lithosols
	Gelic Leptosols (LPi)	N	N	- with permafrost
	Yermic Leptosols (LPy)	N	N	- new, with yermic properties
Arenosols (AR)	Haplic Arenosols (ARh)	N	N	- new, with only ochric A horizon
	Cambic Arenosols (ARb)	N	N	
	Luvic Arenosols (ARl)	N	N	
	Ferralic Arenosols (ARo)	N	N	
	Albic Arenosols (ARa)	N	N	
	Calcaric Arenosols (ARc)	N	N	- new, with calcaric material
	Gleyic Arenosols (ARg)	N	N	- new, with hydromorphic properties
Andosols (AN)	Haplic Andosols (ANh)	S1	S2	- formerly Ochric Andosols
	Mollic Andosols (ANm)	S1	S2	
	Umbric Andosols (ANu)	S1	S2	- formerly Humic Andosols
	Vitric Andosols (ANz)	N	N	
	Gelic Andosols (ANi)	N	N	- new, with permafrost
Vertisols (VR)	Haplic Vertisols (VRh)	S2/N	S1	- new: former subdivisions based on chroma (Pellic and Chromic) replaced by presence/absence of calcic or gypsic horizon, hydromorphic or yermic properties.
	Calcic Vertisols (VRk)	S2/N	S1	
	Gypsic Vertisols (VRj)	N	N	
	Gleyic Vertisols (VRg)	S2/N	S1	
	Yermic Vertisols (VRy)	N	N	
Cambisols (CM)	Eutric Cambisols (CMe)	S1	S1	
	Dystric Cambisols (CMd)	S1	S1	
	Umbric Cambisols (CMu)	S1	S2	- formerly Humic Cambisols
	Gleyic Cambisols (CMg)	S2	S1	
	Calcaric Cambisols (CMc)	S1/S2	S2/N	- formerly included in Calcic Cambisols
	Chromic Cambisols (CMx)	S2	S2	
	Vertic Cambisols (CMv)	S2	S1	
	Ferralic Cambisols	S2	S2	
	Gelic Cambisols (CMi)	N	N	
	Yermic Cambisols (CMy)	N	N	- new, with yermic properties

App. I (cont.)

Calcisols (CL) new major soil grouping; soils with a calcic or gypsic horizon	Haplic Calcisols (CLh)	S1/S2	S2/N	- with calcic horizon
	Gypsic Calcisols (CLj)	N	N	- with gypsic horizon
	Arenic Calcisols (CLq)	N	N	- consisting of coarse textured material
Solonetz (SN)	Haplic Solonetz (SNh)Rc)	N	S2/N	- formerly Orthic Solonetz
	Mollic Solonetz (SNm)	N	S2/N	
	Calcic Solonetz (SNk)	N	S2/N	- new, with calcic horizon
	Gypsic Solonetz (SNj)	N	N	- new, with gypsic horizon
	Gleyic Solonetz (SNg)	N	S2/N	
Solonchaks (SC)	Haplic Solonchaks (SCh)	S2/N	S2/N	- formerly Orthic Solonchaks
	Mollic Solonchaks (SCm)	S2/N	S2/N	
	Calcic Solonchaks (SCk)	N	N	- new, with calcic horizon
	Gypsic Solonchaks (SCj)	N	N	- new, with gypsic horizon
	Sodic Solonchaks (SCn)	N	N	- new, ESP higher than 15%
	Gleyic Solonchaks (SCg)	N	N	
	Gelic Solonchaks (SCi)	N	N	- new, with permafrost
Kastanozems (KS)	Haplic Kastanozems (KSh)	S1	S2	
	Luvic Kastanozems (KSl)	S1	S2	
	Calcic Kastanozems (KSk)	S1/S2	S2/N	- soils with gypsic horizon no longer included
	Gypsic Kastanozems (KSj)	N	N	- new, with gypsic horizon
Chernozems (CH)	Haplic Chernozems (CHh)	S1	S2	
	Calcic Chernozems (CHk)	S1/S2	S2/N	
	Luvic Chernozems (CHl)	S1	S2	
	Glossic Chernozems (CHw)	S1	S2	
	Gleyic Chernozems (CHg)	S2/N	S1/S2/N	- new, with hydropmorphic properties
Phaeozems (PH)	Haplic Phaeozems (PHh)	S1	S2	
	Calcaric Phaeozems (PHc)	S1/S2	S2	
	Luvic Phaeozems (PHl)	S1	S2	
	Gleyic Phaeozems (PHg)	S2/N	S1/S2/N	
Greyzems (GR)	Haplic Greyzems (GRh)	S1	S2	- formerly Orthic Greyzems
	Gleyic Greyzems (GRg)	S1	S1/S2/N	
Luvisols (LV) addition: 'has a CEC of 16 meq or more per 100g clay' (high activity clays) soils with ferric properties or plinthite are included with Lixisols	Haplic Luvisols (LVh)	S1	S2	- formerly Orthic Luvisols
	Chromic Luvisols (LVx)	S1	S2	
	Calcic Luvisols (LVk)	S1/S2	S2/N	
	Vertic Luvisols (LVv)	S2	S1	
	Albic Luvisols (LVa)n)	S2	S2	
	Gleyic Luvisols (LVg)	S2/N	S1/S2/N	
	Yermic Luvisols (LVy)	N	N	- new, with yermic properties
Lixisols (LX) new major soil grouping (clay illuviation with high base saturation but low clay activity; less than 16 meq per 100g clay); formerly a part of the Luvisols	Haplic Lixisols (LXh)	S1	S2	- no special features
	Ferric Lixisols (LXf)l)	S2	S2	- with ferric properties
	Plinthic Lixisols (LXp)	S2	S2	- with plinthite
	Albic Lixisols (LXa)	S2	S2	- with albic E horizon
	Gleyic Lixisols (LXg)	S2/N	S1/S2/N	- with hydromorphic properties
	Yermic Lixisols (LXy)	N	N	- with yermic properties
Podzoluvisols (PL)	Eutric Podzoluvisols (PLe)	S1/S2/N	S2/N	
	Dystric Podzoluvisols (PLd)	S1/S2/N	S2/N	
	Gleyic Podzoluvisols (PLg)	S2/N	S2/N	
	Gelic Podzoluvisols (PLi)	N	N	- new, with permafrost
Podzols (PZ)	Haplic Podzols (PZh)	N	N	- formerly Orthic Podzols
	Cambic Podzols (PZb)	N	N	- formerly Leptic Podzols
	Ferric Podzols (PZf)	N	N	
	Humic Podzols (PZu)	N	N	
	Gleyic Podzols (PZg)	N	N	
	Gelic Podzols (PZi)	N	N	- new, with permafrost
Planosols (PN)	Eutric Planosols (PNe))	see text		
	Dystric Planosols (PNd))			
	Mollic Planosols (PNm))			
	Umbric Planosols (PNu))			- formerly Humic Planosols
	Gelic Planosols (PNi)	N	N	
	Yermic Planosols (PNy)	N	N	- new, with yermic properties

App. I (cont.)

Acrisols (AC) addition: B horizon which has a CEC of less than 16 meq per 100g clay' (low activity clays)	Haplic Acrisols (ACh)	S2	S2	- formerly Orthic Acrisols
	Ferric Acrisols (ACf)	S2	S2	
	Umbric Acrisols (ACu)	S2	S2	- formerly Humic Acrisols
	Plinthic Acrisols (ACp)	S2	S1/S2	
	Gleyic Acrisols (ACg)	S2/N	S1/S2/N	
Alisols (AL) new major soil grouping (former Acrisols with high activity clays, 16 meq or more per 100g clay)	Haplic Alisols (ALh)	S2	S2	- no special features
	Ferric Alisols (ALf)	S2	S2	- with ferric properties
	Umbric Alisols (ALu)	S2	S2	- with umbric horizon
	Plinthic Alisols (ALg)	S2	S1/S2	- with plinthite
	Gleyic Alisols (ALg)	S2/N	S1/S2/N	- with hydromorphic properties
Nitosols (NT) additions: further requirements on horizon boundaries, clay content and nitic properties	Haplic Nitosols (NTh)	S2	S2	- substitutes the former subdivision in Eutric Nitosols and Dystric Nitosols
	Rhodic Nitosols (NTr)	S2	S2	
	Mollic Nitosols (NTm)	S2	S2	
	Umbric Nitosols (NTu)	S1/S2	S2	- formerly Humic Nitosols
Ferralsols (FR)	Haplic Ferralsols (FRh)	S2	S2	- formerly Orthic Ferralsols
	Xanthic Ferralsols (FRx)	S2	S2	
	Rhodic Ferralsols (FRr)	S2	S2	
	Umbric Ferralsols (FRu)	S2	S2	- formerly Humic Ferralsols
	Akric Ferralsols (FRs)	N	N	
	Plinthic Ferralsols (FRp)	S2	S1/S2	
	Yermic Ferralsols (FRy)	N	N	- new, with yermic properties
Plinthosols (PL) new major soil grouping (soils previously grouped with the Ferralsols or Gleysols) soil having 25% or more plinthite within 50 cm of surface	Umbric Plinthosols (PLu)	S2	S1/S2	- with umbric A horizon
	Albic Plinthosols (PLa)	S2/N	N	- with albic E horizon
	Dystric Plinthosols (PLd)	S2	S1/S2	- with B.S. less than 50%
	Eutric Plinthosols (PLe)	S2	S1/S2	- with B.S. more than 50%
Histosols (HS)	Folic Histosols (HSl)	N	N	- new; definition of soil units based on degree of decomposition of plant materials and on drainage; substitutes the former separation Eutric and Dystric which can be taken care of at the third level
	Terric Histosols (HSs)	N	N	
	Fibric Histosols (HSf)	N	N	
	Thionic Histosols (HSt)	N	N	
	Gelic Histosols (HSi)	N	N	
Anthrosols (AT) new major soil grouping, (man-influenced soils)	Aric Anthrosols (ATa)	S2/N	S2	- with remnants of diagnostic horizons
	Cumulic Anthrosols (ATc)	S2/N	S2	- with sediment deposits caused by man
	Fimic Anthrosols (ATf)	S2	S2/N	- soils with a plaggen or an antrhopic epipedon according to the USDA Soil Taxonomy (1975)
	Urbic Anthrosols (ATu)	N	N	- with accumulation of wastes

Note

1. Major soil groupings of the 1974-Legend deleted in the Revised Legend: Lithosols, Rendzinas and Rankers now grouped within the Leptosols Xerosols, Yermosols, now incorporated in other soil groups

APPENDIX II

MODIFICATIONS Upland Crops	Paddy Rice	IRRIGATION SUITABILITY MODIFICATION for IIIrd level specifiers, with brief descriptions 0/-1 = 50% 0/50% -1 ; -1/N = 50% -1 / 50% N
-1	N	- Albi-soils having an albic E horizon.
N	N	- Ali-soils having a saturation with aluminium of more than 50 % in some part of the soil within 100 cm of the surface.
0	0	- Anthraqui-soils showing hydromorphic properties associated with surface water stagnation in long lasting irrigation.
0	0	- Calcari-soils which are calcareous within 125 cm of the surface
0/-1	-1/N	- Calci-soils having a calcic horizon or concentrations of soft powdery lime within 125 cm of the surface
0	0	- Chromi-soils exclusive of Vertisols having a strong brown to red B horizon (rubbed soil having a hue of 7,5YR and a chroma of more than 4 or a hue redder than 75YR).
0	0	- Chromi-Vertisols having a moist value of more than 3 and a chroma of more than 2 dominant in the soil matrix throughout the upper 30 cm.
0	0	- Dystri-soils having a base saturation of less than 50% (by NH_4OAc) in some part within 125 cm of the surface.
0	0	- Eutri-soils having a base saturation of 50 percent or more (by NH_4OAc) to a depth of 125 cm from the surface
-1	-1	- Ferri-soils having ferric properties within 100 cm of the surface
0	0	- Fluvi-soils developed from alluvial deposits.
0	0	- Grumi-Vertisols having a strongly developed fine structure in the upper 20 cm.
N	N	- Lepti-soils having continuous coherent and hard rock within 50 cm of the surface
N	N	- Mazi-Vertisols having a massive structure in the upper 20 cm and becoming hard when dry.
0	0	- Niti-Acrisols showing nitic properties
0	0	- Pelli-Vertisols having a moist value of 3 or less and a chroma of 2 or less dominant in the soil matrix throughout the upper 30 cm.
0	0	- Rhodi-soils having a red to dusky red B horizon (rubbed soils have hues redder than 5YR with a moist value of less than 4 and a dry value not moer than one unit higher than the moist value).
0	0	- Sombri-applies to Ferralsols showing some accumulation of dark colour organic matter in the oxic B horizon.
-1	0	- Stagni-soils having hydromorphic properties related to surface water stagnation during part of the year (at least 7 days during the growing period or longer at other times of the year); lacking a groundwater table within 100 cm of the surface.
N	N	- Takyri-soils, exclusive of Vertisols, having a heavy texture, cracking into polygonal elements when dry and forming a platy or massive surface crust.
N.	N	- Yermi-soils such as Regosols and Arenosols showing yermic properties.
		Intergrades
-1	0	- Verti - intergrade to vertisols
-1	-1	- Sali - intergrade to solonchaks
-1/N	-1/N	- Gleyi - intergrade to gleysols
N	N	- Areni - intergrade to arenosols

OTHER INTERGRADES : NO CHANGE

APPENDIX III

Modifications for slope class (in percentages)

	Slope class	modifications: upland crops O	-1	N	paddy rice O	-1	N
1.	0-2	100	-	-	100	-	-
2.	0-5	50	50	-	40	60	-
3.	0-8	30	70	-	30	40	30
4.	0-16	10	30	60	10	20	70
5.	0-30	5	20	75	-	-	100
6.	2-5	25	75	-	-	100	-
7.	2-8	15	85	-	-	50	50
8.	2-16	5	45	50	-	25	75
9.	2-30	-	25	75	-	15	85
10.	5-8	-	100	-	-	-	100
11.	5-16	-	20	80	-	-	100
12.	5-30	-	10	90	-	-	100
13.	5-30+	-	-	100	-	-	100
14.	8+	-	-	100	-	-	100

APPENDIX IV

Modifications for texture

Texture group combination		modifications					
		upland crops			paddy rice		
		0	-1	N	0	-1	N
1	S	-	25	75	-	-	100
2	S-SL	25	20	55	15	20	65
3	S-L	50	15	35	45	10	45
4	S-CL	50	25	25	55	10	35
5	S-C	40	40	20	65	10	25
6	SL	59	15	35	33	34	33
7	SL-L	75	10	15	65	20	15
8	SL-CL	65	20	15	75	15	10
9	SL-C	25	55	20	80	10	10
10	L	100	-	-	100	-	-
11	L-CL	75	25	-	100	-	-
12	L-C	50	50	-	100	-	-
13	CL	50	50	-	100	-	-
14	CL-C	25	75	-	100	-	-
15	C	-	100	-	100	-	-

APPENDIX V

Modifications for phases

Phase	Modification Upl.crops	Modification Paddy Rice
Anthraquic	N	0
Duripan	-1/N	-1
Fragipan	-1/N	-1
Gelundic	0	0
Gilgai	0	0
Inundic	0	0
Lithic	N	N
Petric	-1/N	-1/N
Petrocalcic	-1/N	-1
Petroferric	-1/N	-1
Petrogypsic	N	N
Phreatic	0	0
Placic	-1	-1
Rudic (formerly stony, rocky, gravelly)	N	N
Salic	-1	-1
Sodic	-1	0
Combined phases		
Lithic/Rudic	N	N
Salic/Sodic	N	-1

APPENDIX VI

Contents of database

Field	Field Name	Description
1	MUID	Mapping unit identifier
2	OMUI	Original mapping unit identifier
3	IDS1	Identifier - Soil 1
4	IDS2	Identifier - Soil 2
5	IDS3	Identifier - Soil 3
6	IDS4	Identifier - Soil 4
7	TLI1	3rd level identifier - Soil 1
8	TLI2	3rd level identifier - Soil 2
9	TLI3	3rd level identifier - Soil 3
10	AR1	Area % - Soil 1
11	AR2	Area % - Soil 2
12	AR3	Area % - Soil 3
13	AR4	Area % - soil 4
14	DC1	Drainage condition - Soil 1
15	DC2	Drainage condition - Soil 2
16	DC3	Drainage condition - Soil 3
17	SL1	Slope - Soil 1
18	SL2	Slope - Soil 2
19	SL3	Slope - Soil 3
20	T1	Texture - Soil 1
21	T2	Texture - Soil 2
22	T3	Texture - Soil 3
23	PA1	Phase 1 - Soil 1
24	PAP1	% Phase 1 - Soil 1
25	PB1	Phase 2 - Soil 1
26	PBP1	% Phase 2 - Soil 1
27	PA2	Phase 1 - soil 2
28	PAP2	% Phase 2 - Soil 2
29	PB2	Phase 2 - Soil 2
30	PBP2	% Phase 2 - Soil 2
31	PA3	Phase 1 - soil 3
32	PAP3	% Phase 1 - Soil 3
33	PB3	Phase 2 - Soil 3
34	PBP3	% Phase 2 - Soil 3
35	TAREA	Area - mapping unit

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