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BALE GADULA IRRIGATION PROJECT

Annex C:

Soil Suitability and Land Evaluation Report

By

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Summary and Recommendations

The area surveyed for the Bale Gadulla, phase I feasibility study, covers about 968 hectare.

Of this approximately 46 ha (or 4 3/4% of the total area) is covered by Kubsa village.

In total about 583 ha (of 60 1/2% of the total area) is moderately well suited for irrigated crop cultivation. It consists of nearly level to gently sloping (1 1/2-3% slopes), very deep (3-8m depth upto the bedrock), somewhat imperfectly drained, slowly permeable, black cracking clay (or silty clay) soils.

These lands have been somewhat downgraded because of difficult work ability for seedbed preparation and problems related to restricted subsoil drainage (suitability subclass S_2d_w)

Approximately 218 3/4 ha (or 22 1/2% of the total area) has been downgraded as only marginally suitable for irrigated crop cultivation. It consists mainly of the same black (sometimes brownish black) cracking clay soils, but either < 3m deep to the underlying bedrock and/or very sodic or with 3 1/2-4% slopes and thus more subjected to erosion hazard (see suitability subclasses: S_3d'a, S_3ad, S_3ed, S_3d'3 and S_3d'w)

The remaining 120 1/4 ha (approximately) or 12 1/4 of the total area, consists of steep rocky hills, footslopes and steep sideslopes (slopes > 4%) and is therefore not suited for irrigation development (suitability subclasses: N_2sr, N_2se)

It may further be noted that, although a very large part of the project area (about 401 1/2 ha, or 41% of the total) is covered by common to many surface stones (of vesicular basalt), their removal (by hand picking) would only take (or cost) about 13 mandays per hectare (or 40 Birr per ha) and this will amount to a stone heap of about 112m^3 stones per ha, which may be used for other purposes, such as the construction of roads or walls.

To enable the construction of the irrigation scheme, only the river terraces (T-mapping units), covering about 393 ha (or 41% of the total area) are in need of some low vegetation clearance requirements, while all the other suitable mapping units are already cultivated (rainfed).

Moreover, about 132 ha (or 13 1/2% of total area) of more or less suitable lands are in need of medium levelling/grading (with 2 1/2-3% slopes) and about 112 3/4 ha (or 11 1/2% of total area) of high levelling/grading operations.

It should finally be noted that, due to the low annual rainfall, about 583 ha (or 60½% of the survey area) will be upgraded from only marginally suited under the present rainfed conditions (class S_3) to moderably well suited (class S_2) under irrigated conditions. This may roughly indicate an expected productivity increase from below 40% to about 60% of that achieved from ideally suitable land under the same level of inputs.

1. INTRODUCTION

The report outlines the results of a feasibility soil survey of only a small part (called phase I) of the Bale Gadulla area, which had already been studied in rather detail by a Korean soil survey team together with a national counterpart staff of WRDA, in 1990, at an overall observation density of about 1 per 6 hectare.

Afterwards, however, update and improvement of the soil and landform characterizations, the soil mapping accuracy and reporting was felt to be needed.

The present study is based primarily on a detailed aerial photo-interpretation (scale 1:50,000) in combination with about 78 additional field observations and study of the previous soil survey data (about 75 observations) and maps.

The new observations included 71 auger hole observations made at regular intervals of about 200m along transects located more or less perpendicularly to the physiographic mapping units orientation, and including numerous (about 85) soil surface observations as well.

Furtheron 7 soil profile pits were dug upto 2m depth and 4 deep borehole were drilled upto the bedrock. All this amounted to an overall <u>observation density</u> of about <u>1 per 4 hectare</u>.

The soil profile pits were located on representative sites, described in detail and sampled for laboratory analysis, while infiltration and permeability tests were executed in triplicate near those pits.

Final soil boundaries were traced on 1:5,000 scale topographic field sheets, which were later reduced to 1:10,000 scale final maps.

The complete soil survey and mapping methodology is described in chapter 3.

The study was conducted in consultation with Ato Mekuria Tafesse, General Manager WRDA and National Project Coordinator ETH/88/013, Mr. S.Thirugnanasambanthar, FAO team leader, and the members of the Steering Committee for the UNDP assisted projects in the irrigation subsector.

The work was executed in the field with the assistance of WRDA technical staff, including Ato Girum Asfaw (the national soil survey counterpart) and Ato Melesse Kumsa (national soil survey assistant) and Ato Mesfin Kidane and Ato Birhane Gashu (topographic surveyors). The deep boreholes and their descriptions were made by Ato Teodros G/Egziabher (geologist) and Ato Bulcha Nigatu (driller).

The terminology used for soil description, taxonomic soil classification and irrigability evaluation in the report is explained in USDA (1951 and 1988) and FAO (1976, 1977, 1979, 1985 and 1988).

Of the 4 different soil series identified in the project area only three have been tentatively named, and described in detail in this report, since the fourth one is very limited in extent and not suited for irrigation because of steep slope and relative shallowness.

The three major soil series are very similar in most profile characteristics. They are all very deep, somewhat imperfectly drained, black to brownish black, moderately to very strongly alkaline, occasionally sodic, medium to highly calcareous, non-saline, cracking clays (vertisols).

Their names (see below) are derived from the Kubsa village located in the phase I area, the Weib and the Asendabo rivers, respectively.

Their differing characteristics and taxonomic classification are:

1. Kubsa soil series (Chromo-Hypo-Calcic Vertisols; FAO, 1988/91) Brownish black clay (with 15-32% silt and 65-85% clay), and a calcic horizon of soft powdery lime in between 60-110cm of the surface.

   These soils have both a rudic (=surface stones) - and a sodic (ESP upto 28) phase.

2. Asendabo soil series (Pelli-Hypo-Calcic Vertisols; FAO 1988/91) Black silty clay (with 30-55% silt and 45-65% clay) and a calcic horizon of soft powdery lime in between 60-120 cm of the surface.

3. Weib soil series (Pelli-Eutric Vertisols; FAO, 1988/91) Black clays (with 9-37% silt and 60-90% clay) and a very deep (below 125cm) or no calcic horizon.

They mostly have a rudic (= surface stones) and rarely a sodic phase.

Complete description of these soil series (and their phases) is given in appendix I, together with the analytical results of the soil samples taken and of the infiltration and permeability tests. Determinations of intake family is given in appendix II. Total depth of the (sub) soils, until the bedrock and brief descriptions is given in appendix III.

2. THE ENVIRONMENT

2.1 Location, access and extent of the project area

a. Location

The project area lies in a valley on the left bank of the Weib river in Gadulla awraja, about 30km from Goro, at an altitude of around 1900m. (see figures 1 and 2).

- Its location is roughly in between 07° 06' and 07° 09' Northern Latitudes and 40° 22' and 40° 24' Eastern longitudes, or according to the Universal Transverse Mercator Grid Designation (Zone 37, clarke 1880 spheroid) in between 16,000 and 19,500m North and 652,500 and 657,500, East.

The area can be found on 1991 aerial photograph no 0034, run B2 (contract ET 1:10, scale 1;50:000). and on 250,000 scale toposheet.

b. Access

The project area is about 30 km from Goro, and about 80 km from Robe. Between Robe and Goro there is a good all-weather dirt road. From Goro the road deteriorates and for the last 18km it is no more than a track to Kubsa village located in the project area.

c. Extent

The area surveyed for the phase I project covers about 968 ha, of which about 60 1/2% (583 hectare) are moderately suitable for irrigation development.

2.2 Climate

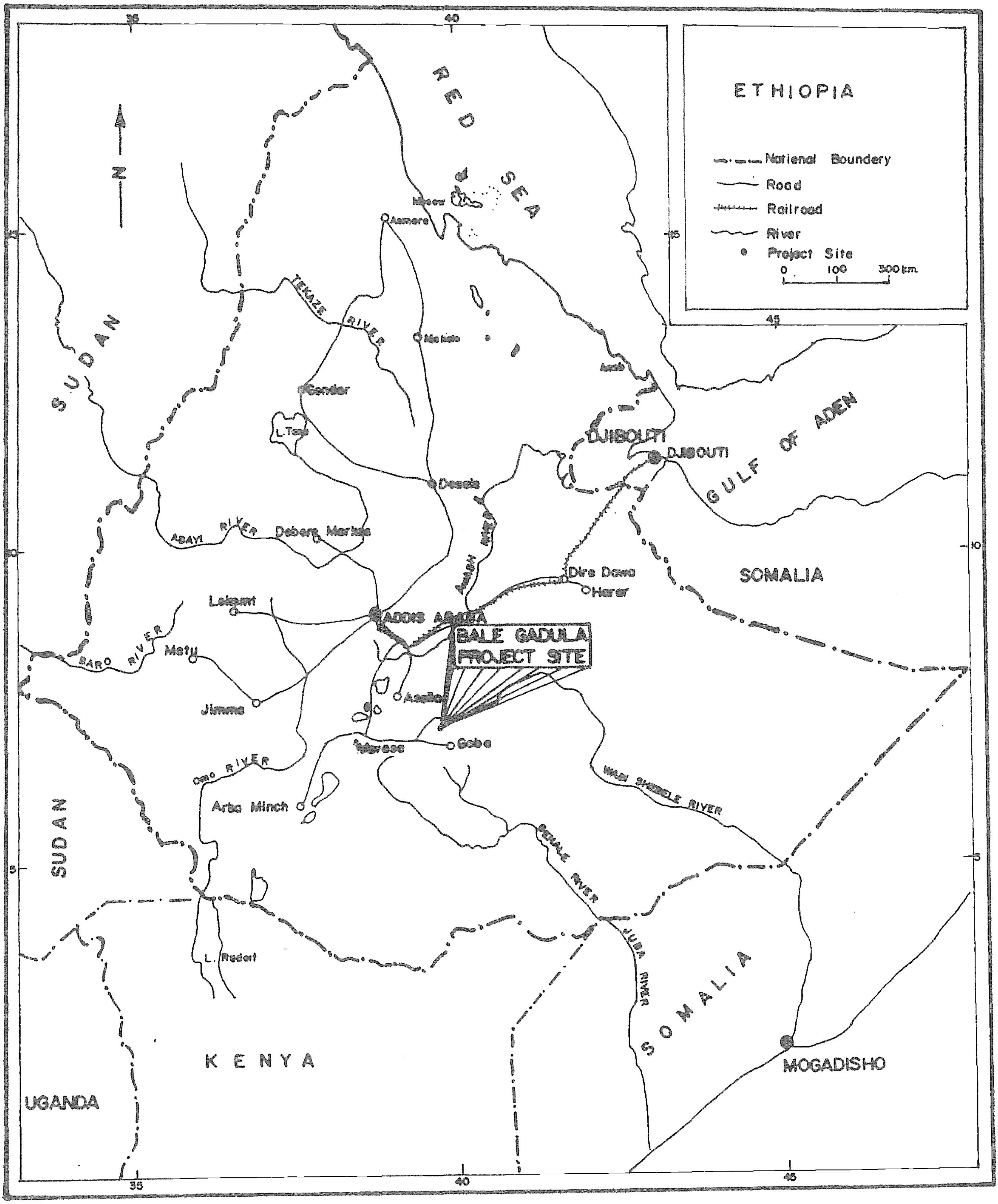
a. General Characteristics

Meteorological data for the project area are not available. The nearest meteorological station is at Goro; monthly rainfall and temperature data for this station are given in Tables 1 and 2 and in Figs. 2 and 3.

Rainfall is eratic at Goro. In the 11-year period for which records are available, the maximum annual rainfall was 1,383 mm and the minimum 351 mm.

The mean annual rainfall is about 723.9 mm; about 50% of it is received during March, April and May (Belg) and more than 25% in September and October (Mehr), while the other 7 months are relatively dry, having only 20% of the total annual rainfall.

FIGURE 1 PROJECT LOCATION



The survey area has an elevation ranging from 1790 to 1915m.

Air temperatures at Goro (which is located at an elevation of about 2,000m.) are very uniform throughout the year. On the basis of the three years of available data, mean monthly temperatures vary between 17.3°c (June) and 19.6°c (January). Mean monthly minima vary between 7.4°C (October) and 11.6°C (January), while maximum vary between 24.4°C (June) and 28.2°C (February).

The mean monthly pan evaporation varies from 128 mm (September) to 180 mm (March) with a mean annual of 1732 mm.

The mean daily wind velocity varies between 1.5 m/sec. to 4.0m/sec. with the high wind speeds occurring from June till August.

b. Soil moisture regime

No exact data on soil moisture are available in the Bale-Gadulla area. It has thus to be estimated from the rainfall data.

The somewhat imperfectly drained and nearly local to gently undulating upland Vertisols are considered to have an Ustic soil moisture regime, which means a dry upper subsoil for at least 90 days (cumulative) and at least moist in some parts for at least 90 consecutive days.

c. Soil Temperature regime

This has also to be estimated from the climatic (air temperature) data.

The mean annual soil temperature at a depth of 50cm is most probably higher than 15°C and lower than 22°C, and the difference between mean summer and mean winter soil temperature is less than 5°C, and thus it is classified as Isothermic.

2.3 Natural vegetation and present Land use

The nearly level terrace landforms (see T - Mapping units) along the Asendabo river are not cultivated and covered by a medium dense bush forest of Acacia and often short and tall trees. These areas are presently used for grazing. The more undulating landforms (see V-mapping units) are almost entirely cultivated.

Table 1. Rainfall, Gorro

Mean monthly rainfall (mm) based on 11 years' data, 1976-86

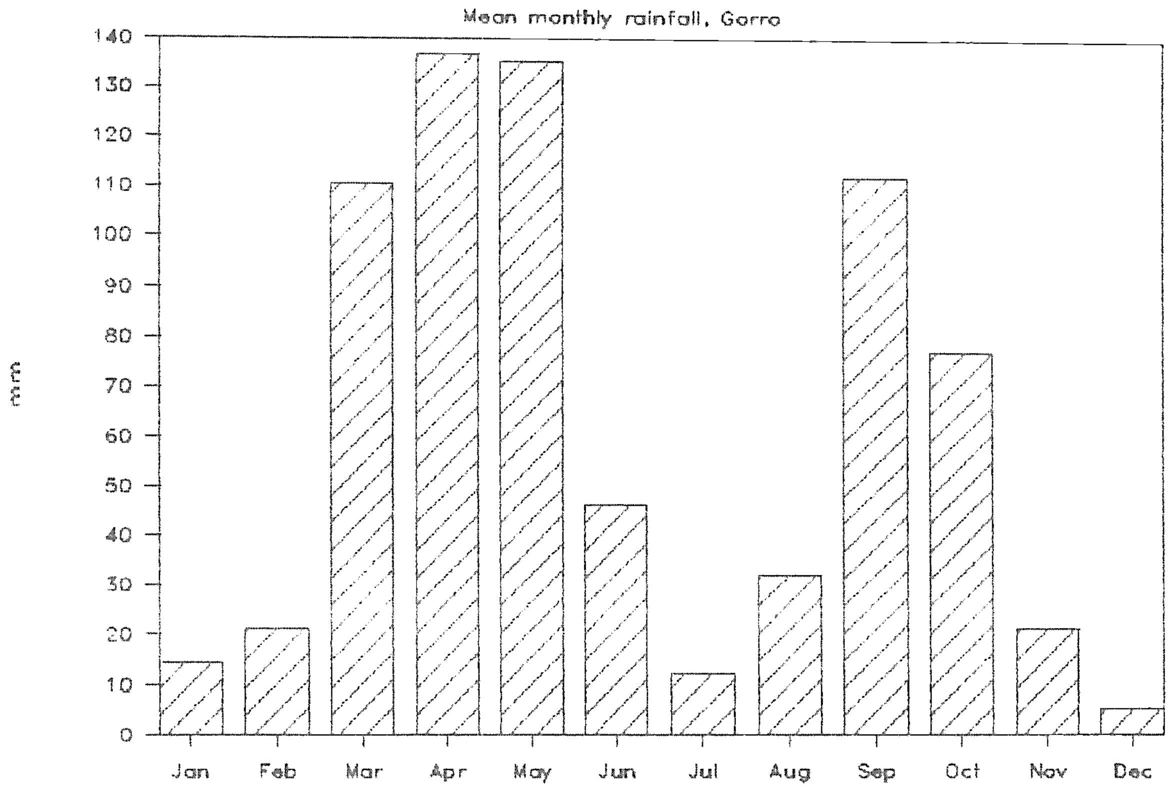
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
14.5	21.2	110.6	136.6	135.3	46.2	12.1	32.0	111.9	77.1	21.3	5.1	723.9

Table 2. Air temperature, Gorro

Mean monthly air temperatures (deg.C) based on 3 years' data, 1982, 1984, 1985

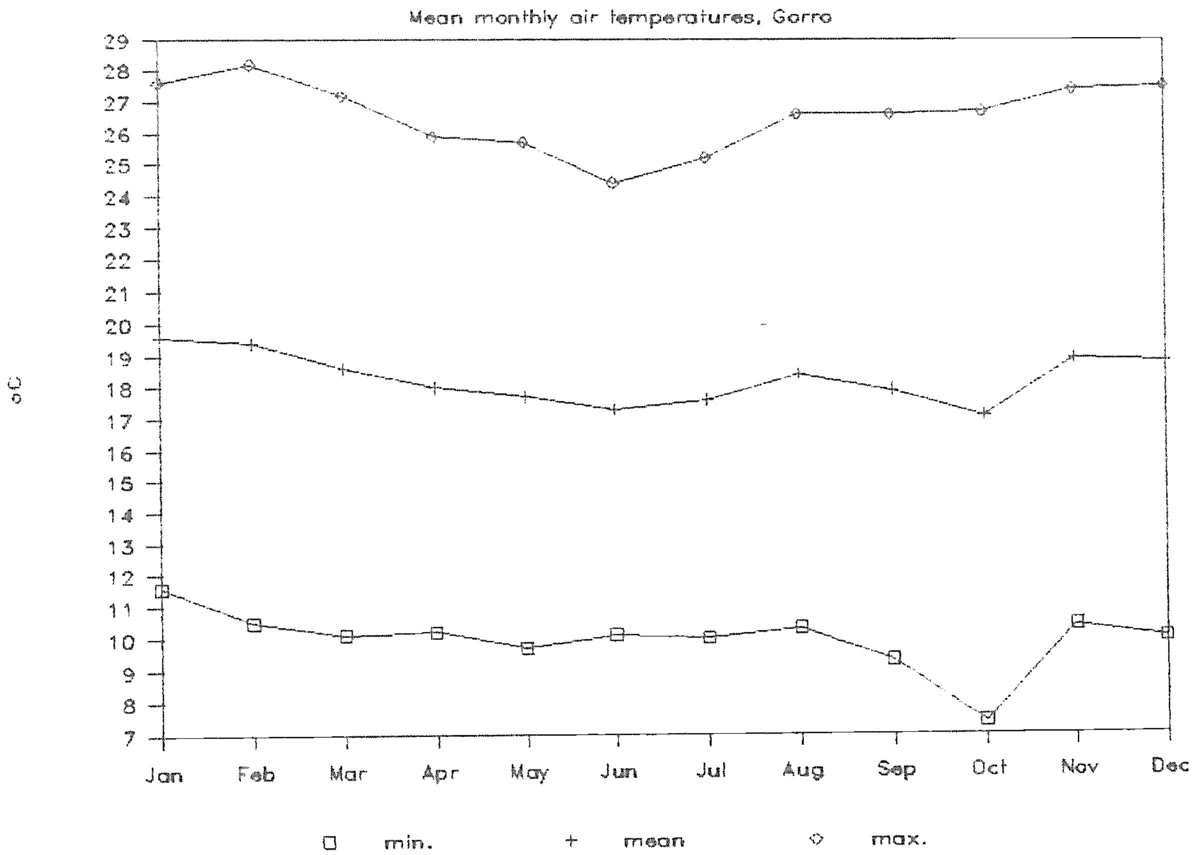
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Min	11.6	10.5	10.1	10.2	9.7	10.1	10.0	10.3	9.3	7.4	10.4	10.0	10.0
Mean	19.6	19.4	18.6	18.0	17.7	17.3	17.6	18.4	17.9	17.1	18.9	18.8	18.3
Max	27.6	28.2	27.2	25.7	24.4	24.4	25.2	26.6	26.6	26.7	27.4	27.5	26.6

Fig. 2



Mean monthly rainfall, Gorro
mm
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Fig. 3



Mean monthly air temperatures, Gorro
oC
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
min.
mean
max.

Farming practices are traditional ploughing by ox. The main rainfed crops are maize, barley, wheat, oats, sorghum and different spices. (cumin, fenugreek and coriander). In terms of land area, barley is the most important crop. Barley, Wheat and Oats are all grown in both seasons and so are the spices, but maize seems to be usually grown in the Belg only.

2.4 Physiography, Geology and Drainage

As can be seen on the 1:50,000 scale Aerial Photo-Interpretation map (Fig. 4) and the schematic cross-section (Fig.5) of the Bale Gadulla (phase I) area three (or four) major landforms have been distinguished. They are:

P= The Plateau with undulating summit (P_1) above 2300m elevation (often with large State Farms) very, steep escarpments (P_2) and steep lower foothills(=H on the final soil map).

All these units, except H, are located outside the area surveyed.

V= The undulating Older Valley Bottom, which is predominantly cultivated and mostly covered by common to many basaltic surface stones. Within the phase I area, its elevation ranges from 1825-1900m.

This unit has been subdivided mainly on the basis of slope (degree and form) into:

V1 - undulating or convex upper part
V2 - gently undulating lower part
V3 - level to gentle concave drainage ways and depressions

T= Nearly level River Terraces along the Asendabo river. They are covered by medium dense Acacia bushes and with few or no surface stones. Their elevation ranges from 1785-1840m. Three different Terraces have been distinguished T1, T_2 and T_3 (upper-, middle-, and lower terrace respectively).

A= Alluvial valleys of the Asendabo dry river bed (A,) and the Weib river (partly a deep canyon)

The plateau and foothills, as well as the valley bottom and terraces are underlain by vesicular basalts (similar to the surface stones) of the lower Tertiary (Paleocene - Oligocene- Miocene) Trap series (Ashangi group), according to the Geological Map of Ethiopia (Scale 1:2 million), compiled by V.Kazmin (United Nation, 1972).

Both rivers, the Asendabo and Weyib, are draining the area to the Southeast into the Wabi Shebelle river system.

Aerial Photo-Interpretation Map of the Bale-Gadula area (Phase I) and Surroundings

Approximate Scale - 1:50.000

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22 February 1992

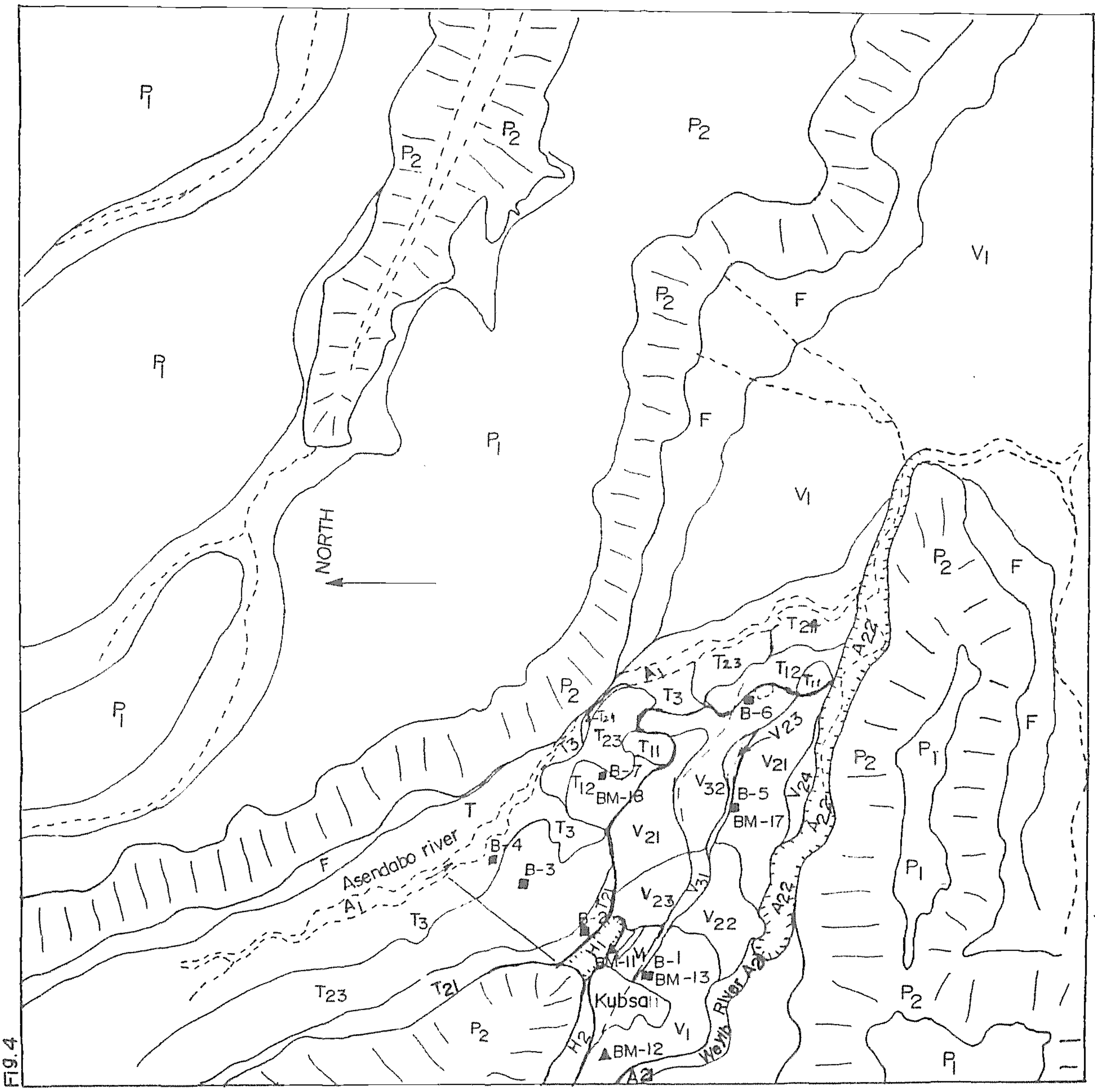
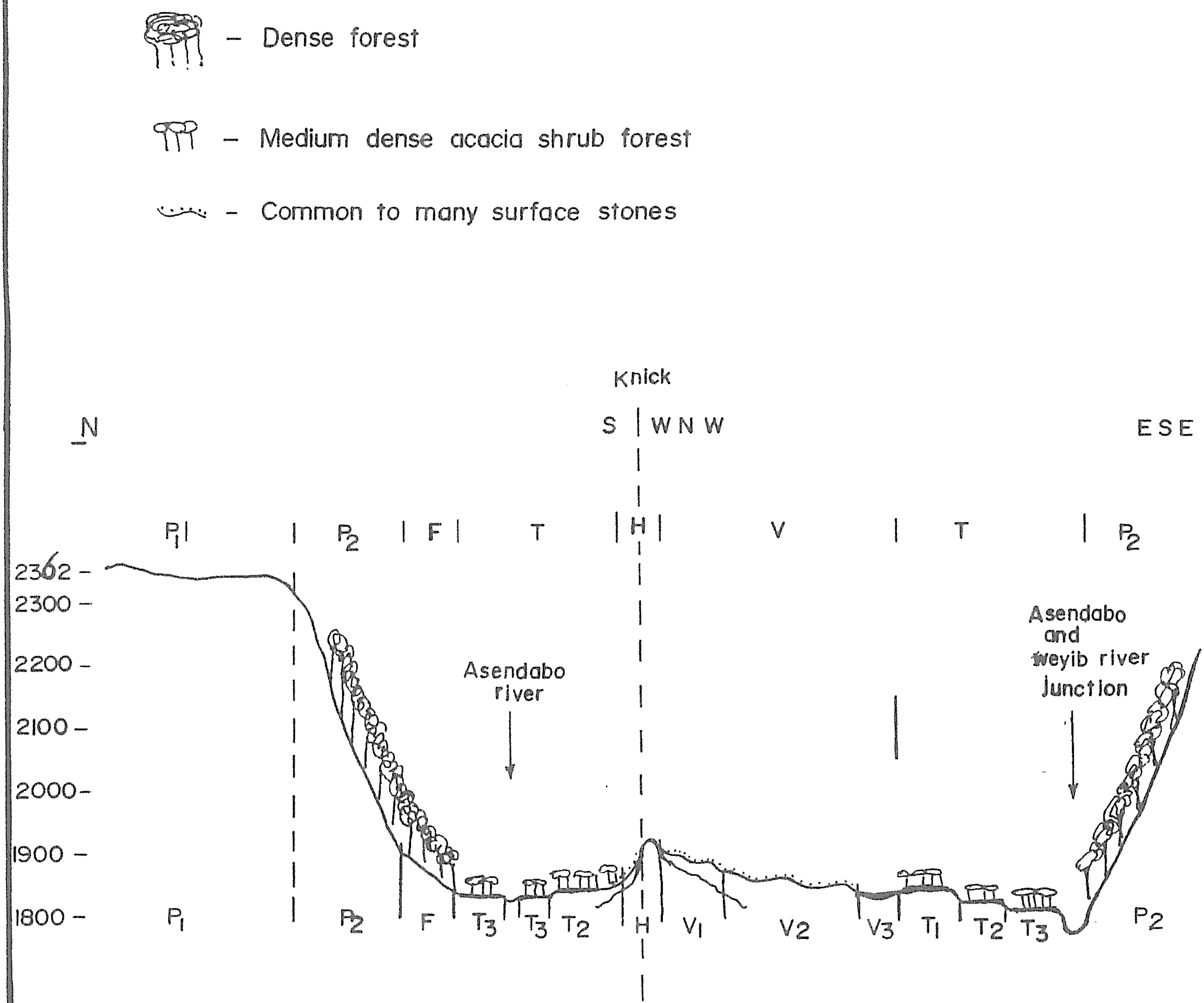


Fig.5: Schematic cross-section of the Bale - Gadula (Phase I)area



3. SOIL SURVEY METHODS

3.1 pre-survey activities

Maps and reports of the 1990 Korean soil survey were collected and studied as well as the 1991 (scale 1:50,000) aerial photographs, which were interpreted in detail.

A preliminary physiographic legend for soil survey purposes was established and on the basis of photo-interpretation mapping units, transects for highly intensive soil survey observations and representative sites for soil profile pits and deep borehole drillings (upto the bedrock) were located.

All this was then transferred to 1:5,000 scale topo-sheets, with 1m. contour intervals to be used in the field.

3.2 Field Operations

Systematic soil survey work for the feasibility study of the Bale Gadulla (phase I) area started on 23 January and was completed by the end of February 1992.

The soil survey fieldwork involved.

- Systematic auger hole observations upto 200cm depth were made along the transects at intervals of 200m, over a total length of about 14km. In total 71 auger holes were made.

- In between these auger hole observations, continuous so-called, (shallow) soil surface observations were made with special attention for changes in soil surface colour, stoniness, slope and vegetation cover etc. In total at least 85 of such observations were recorded by a brief code and/or boundary line plotted on the map.

- Detailed soil profile descriptions were made on representative sites, including soil sampling for laboratory analysis. In total 7 soil profile pits were made upto 2m. depth.

- Near 4 of the above mentioned soil profile pits a deep borehole was drilled upto the bedrock.

  Thus in total 71+85+7=163 new observations were made. This together with the approx 75 old observations over an area of about 968 ha, resulted in an average observation density of 1 per 4ha.

- Besides Infiltration-and permeability tests were executed in triplicate on all 7 soil profiles sites.

3.3 Post Fieldwork activities

After completion of fieldwork, all data had to be interpreted, including the laboratory results, which were received from WRDA's laboratory on 24 and 26 March 1992.

PF values and bulk densities to be determined by the national Soils Laboratory, however, where only received on 17 April 1992, and the calculated results of the infiltration and permeability tests were also handed over by the national counterpart on 17 April 1992.

Correction and update of the final (1:10,000 scale) draft soil map and legend, was completed on 10 April 1992, while the final (draft) Irrigability Map was completed on 21 April 1992, after receipt of all the data.

The feasibility draft report (including the drawing of schematic cross-sections and graphs and small maps) started in early april and was completed on 4 May 1992, when it was handed over to the project staff of WRDA for final checking, typing and drawing.

4. SOILS AND DESCRIPTION OF SOIL MAPPING UNITS

4.1 The soils and their Taxonomic classification

Inspite of the 18 physiographic soil mapping units delineated, soils within the phase I project area are very uniform and similar in profile characteristics.

Apart from one unnamed soil series occurring on the alluvial-colluvial footslope (H_2) below the steep rocky hill (H_1)and which is very limited in extent (15 1/4 Ha only) and not suitable for irrigation development because of steep slopes (8-9%) and not very deep soils ($\leq$ 1 1/2m to the bedrock) all other (three) soil series differ only from each other in soil colour (very slightly: Pellic or just chromic), depth (or presence)of a calcic horizon (within or below 125 cm of the surface) and soil texture: being either silty clay (with 31-53% silt) or clay (with < 32% silt) and slightly in soil reaction (pH) being either strongly to extremely or moderately alkaline.

Otherwise these three soil series (collectively covering about 938 ha(or 97% of the project area), are all very deep, somewhat imperfectly drained, black to brownish black, moderately to very strongly alkaline (occasionally sodic), medium to highly calcareous, non-saline, cracking clays (= Vertisols).

Their tentative names (see below) are derived from the Kubsa Village located in the phase I area, the Weyib river, forming the southern boundary of the phase I area and the Asendabo river, forming the north and eastern boundary, respectively.

These three soil series are described in detail under appendix I, together with their laboratory analytical data. Their main characteristics and diagnostic criteria are as follows:

1- Kubsa Soil Series: They are the dominant soils of the undulating or convex upper part of the Older Valley Bottom (V_1), partly dissected and with 2 1/2-7% slopes and predominantly cultivated and/or covered by Kubsa village, and with common to many surface stones of vesicular basalt.

They are very deep (3-4m deep to bedrock), somewhat imperfectly drained, very slowly permeable, slightly to highly calcareous (9-25% $CaCO_3$) with a calcic horizon within 125 cm depth, moderately alkaline in the topsoil and very strongly alkaline below (PH(H_2O) 8.0-9.4), sodic below 20cm depth (ESP 9-30% of CEC), brownish black, cracking clays (65-84% clay in the fine earth fraction).

Representative profile: BAG001

These soils generally occur on the undulating or convex upper part of the Older Valley Bottom in association with the Weyib soil series having a deeper calcic Horizon (=below 115cm depth or more).

According to the revised (1988) legend and the (June 1991) annex 1 of the FAO/UNESCO/ISRIC Soil Map of the World, these soils with fine, cracking clays and intersecting slickensides within 100cm of the surface, have been classified in the soil group of Vertisols and in the soil unit Calcic Vertisols (VRK), (=having a calcic horizon within 125cm of the surface) and soil subunits Hypo-Calcic Vertisols (= the calcic horizon consists of concentration of soft powdery lime). And because they have chromas, moist of 1.5 or more, they may receive the prefix chromi, thus Chromo-Hypo-Calcic Vertisols.

Similarly to the above, these soils have been classified in the order of Vertisols in the U.S.Soil Taxonomy System (Key, 1988), and suborder Usterts (==ustic soil moisture regime) and great group Chromusterts (= having chromas moist, of 1.5 or more) and subgroup Udic Chromusterts (=having cracks that remain open from 90 to 150 cumulative days in most years).

2- Weyib soil series: They are the dominant soils of the phase I project area, covering the gently undulating lower part with many surface stones) and/nearly level to gently concave depressions and drainage ways (with few surface stones) of the predominantly cultivated older Valley Bottom, as well as the Upper and Lower River Terraces without(or few) surface stones.

They are also very deep (mostly 3-8 1/2m deep to bedrock), somewhat imperfectly drained, very slowly permeable, slightly to moderately calcareous (8-15%Ca Co_3), with no calcic horizon within 125cm of the surface, strongly alkaline (PH (H_2O) 8.2 - 8.6), only occasionally sodic (ESP of 36-39% below 40cm depth), black, cracking clays (60-90% clay in the fine earth fraction).

Representative Profiles: BAG004, BAG005, BAG006, BAG007.

Similar to the Kubsa soil series, these soils have been classified in the subgroup of Vertisols, according to the FAO/UNESCO/ ISRIC(1988) revised legend and in the soil unit Eutric Vertisols (=not having a gypic or calcic horizon within 125 cm of the surface but with a base saturation of more than 50% throughout the profile). Because of their chromas, moist of 1, they have given the prefix Pelli. Thus Pelli-Eutric Vertisols.

In the US Soil Taxonomy System (Key, 1988) they are also Vertisols (=order) and Usterts (suborder) because of ustic soil moisture regime and great group Pellusterts (because of chromas 1), and subgroup Udic Pellusterts (=having cracks that remain open from 90 to 150 cumulative days in most years.

3- Asendabo soil series; They are the dominant soils of the non cultivated Middle River Terrace, predominantly with no (or few) surface stones and medium dense Acacia shrub land.

They are similar in all aspects to the Kubsa soil series, but always black in colour and with a higher percentage of silt (31-53% silt in the fine earth fraction) and thus silty clays. They have a calcic horizon usually between 63-117cm of the surface and they are moderately alkaline.

Representative profiles: BAG002 and BAG003

Similarly to the Kubsa soil series they have been classified in the soil subunit of Hypo-Calcic Vertisols (FAO/UNESCO/ISRIC legend, 1988/91), but with a prefix Pelli, because of their chromas, moist of 1, thus Pelli-Hypo-Calcic Vertisols.

Likewise, in the US Soil Taxonomy System (key 1988) they are classified in the subgroup of Udic Pellusterts.

4.2 Detailed Physiographic soil map legend

On the basis of physiographic landform, slopes, surface stoniness and land use and vegetation cover types and soil taxonomic characteristics, the following physiographic soil mapping units were delineated within the phase I Bale-Gadulla project site.

Physiographic Soil Map Legend of the Bale-Gadulla Area

Mapping Unit Symbols	Physiographic Description, including vegetation cover type, slope classes and depth to bedrock	Soil series name (Soil Taxonomy, FAO 1988 variants, phases) and major soil profile characteristics	Irrigation Suitability subclasses
P	Plateau, outside project area	not surveyed	not relevant
H	Steep Hills and footslopes; pred. under grassland and many surface stones		
H1	Very Steep and Rocky Summits and upper slopes	Rockland (vesicular basalt)	N2sr
H2	Steep footslopes (8-9% slopes: < 1½m deep to bedrock	Not named (Mollic Fluvisols, rudic phases). Moderately deep, well drained, brownish black, silty loam over gravels	N2s
V	Pred. Cultivated, Undulating Older Valley Bottom		
V1	Undulating or Convex Upper Part: pred: 3-4m deep to bedrock: Common to many surface stones (vesicular basalt)		
V11	Strongly sloping (4-7%) slopes) upper slopes; more dissected	Kubsa soil series (Chromi-Hypo-Calcic Vertisols; sodic, rudic phases (see V12 unit)	N1ed
V12	Gently Convex Lower Slopes (2½-3% slopes)	Kubsa soil series (Chromi-Hypo Calcic Vertisols, sodic, rudic phase). Very deep somewhat imperfectly drained, brownish black, cracking clays with a calcic horizon within 125cm depth (Repr. profile B-1)	S3d'a
V2	Gently Undulating Lower Part; pred. 5-8½m. deep to bedrock; Common to many surface stones (vesicular basalt)		
V21	Nearly level to very gently undulating summits (1½-2% slopes	Weyib soil series (Pelli-Eutric Vertisols, rudic phase). Very deep, somewhat imperfectly drained, black, cracking clays (Repr. profile: B-5)	S2dw
V22	Gentle convex (2½-4% slopes)	Weyib soil series: rudic phase as above	S2dw
V23	Convex (3½-4%) slopes	Weyib soil series: Rudic phase as above	S3ed
V24	Deep (4-7%) Sideslopes to Weyib	Weyib soil series : Rudic Phase	N1ed

Physiographic Soil Map Legend of the Bale-Gadulla Area

Mapping Unit Symbols	Physiographic Description, including vegetation cover type. slope classes and depth to bedrock	Soil series name (Soil Taxonomy, FAO 1988 variants, phases) and major soil profile characteristics	Irrigation Suitability subclasses
	River valley.	as above	
V3	Nearly Level to Gentle Concave Drainage Ways and Depressions; Pred. 3-5m. deep to bedrock; mostly none or few surface stones		
V31	Narrow, Concave drainage ways: (3½-4% slopes)	Weyib soil series: as above, but non rudic	S3ed
V32	Broad depression without surface stones	Weyib soil series, non rudic	S2dw
V33	Broad depression with many surface stones.	Weyib soil series (Pelli-Eutric Vertisols, sodic, rudic phase) Very deep, somewhat imperfectly drained, sodic cracking clays (Repr. profile: B-6)	S3ad
T	Nearly level River Terraces With Scattered Bush Vegetation		
T1	Upper Terrace		
T11	Slightly convex Summits: upto 2½% slopes; few rock outcrops, pred, <3m deep to bedrock	Weyib soil series (Pelli-Eutric Vertisols) (See T12 unit)	S3d'w
T12	Nearly level summits; 1-1½% Slopes; pred. 3-4m. deep to bedrock	Weyib soil series (Pelli-Eutric Vertisols, non-rudic phase) (Repr. profile: B-7)	S2dw
T2	Middle Terrace		
T21	Transitional footslopes below H: 6-7% slopes; many surface stones: pred>-2m, deep to bedrock	Asendabo soil series (Pelli-Hypo-Calcic Vertisols, rudic phase). Very deep, somewhat imperfectly drained, black to brownish black cracking, silty clays, with a calcic horizon within 125cm depth (Repr. profile: B-2)	Nled
T22	Very gently sloping (2% slopes); Common to many surface stones: pred >5m. deep to bedrock	Asendabo soil series (Pelli-Hypo Calcic Vertisols, rudic phase);	S2dw
T23	Nearly level summits: 1-1½% Slopes pred. >5m. Deep to bedrock	Asendabo soil series (Pelli-Hypo Calcic Vertisols, non-rudic but sodic phase) Very deep, somewhat imperfectly	S2dw

Physiographic Soil Map Legend of the Bale-Gadulla Area

Mapping Unit Symbols	Physiographic Description, including vegetation cover type, slope classes and depth to bedrock	Soil series name (Soil Taxonomy, FAO 1988 variants, phases) and major soil profile characteristics	Irrigation Suitability subclasses
		drained, black, cracking, sodic silty clays, with a calcic horizon within 125 depth (Repr. profile: B-3)	
T24	Sideslopes (3½-4% slopes) with few rock outcrops; pred. <3m deep to bedrock	Asendabo Soil series as above: slightly rocky phase	S3d'e
T3	Lower Terrace Nearly level (< 1% slopes): pred. 3-5m deep to bedrock	Weyib soil series (Pelli-Eutric Vertisols). Very deep, somewhat imperfectly drained, black, cracking clays (Repr. profile: B-4).	S2dw
A	Alluvial valleys, outside project area	Not surveyed	Not relevant
A1	Asendabo dry valley, with basaltic		
A2	Weyib valley		

4.3 Description of physiographic soil mapping units

In this section the 18 mapping units shown on the physiographic soil map (scale 1:10,000), are described in more detail and their hectarages (and percentage of total area) are given.

Mapping Unit H_1: Steep, Rocky Hills 14¾ ha(1½% of total area)

This unit is too elevated (above command elevation), too steep and too rocky for any irrigation development. It is covered by grassland and many rock outcrops and surface stones of vesicular basalt. Irrigation suitability subclass: N_2sr.

Mapping unit H_2: Steep Footslopes: 8-9% slopes: 15¼ ha (or 1½% of total area).

Moderately deep, well drained, good permeable, yellowish brown to brownish black, silt loam over gravels. It occurs on the steep alluvial-colluvial footslopes below the steep rocky hills.

Brief Profile Description

0- 35cm Brownish black, strongly calcareous, silt loam
35- 75cm. Dark yellowish brown, strongly calcareous silt loam
75-140cm. Dark yellowish brown, strongly calcareous gravelly silt loam.
140cm. Rock (vesicular basalt).

The natural vegetation consists of grassland
soil reaction (pH) is strongly alkaline.
This unit is too steep for irrigation development.
Irrigation suitability subclass: N_{2s}

Mapping Unit V_{II}: Kubsa soil series, strongly (4-7%) sloping, Rudic phase.
Approx. 39½ ha (or 4% of total area)

Very deep, somewhat imperfectly drained, very slowly permeable, slightly to highly calcareous, moderate (topsoil) to extremely (subsoil) alkaline, sodic (subsoil), brownish black, cracking clays.

It occurs on the moderately dissected, undulating upper part of the older valley bottom. This unit is partly covered by Kubsa village, some grassland and some cultivated lands and all of it has common to many surface stones of vesicular basalt.

Brief Profile Description

A_1 0-20cm. Brownish black; well developed, very fine and fine subangular blocky. strongly calcareous, clay. pH8.0

A_B 20-63cm. Brownish black; moderately development, medium to coarse, angular blocky including wedgeshaped; strongly calcareous, cracking clay. pH 8.4 (9% exchangeable sodium percentage).

B_k 63-110cm. Brownish black; moderately developed, medium to coarse, angular blocky including wedgeshaped; extremely calcareous, with concentrations of soft lime concretions or pseudomycelium; cracking clay. pH 9.4 (27% ESP).

B_u 110-170$^+$cm Brownish black; moderately developed, medium to coarse, angular blocky including wedgeshaped; extremely calcareous, cracking clay. pH 9.2 (29% E.S.P.)

This soil is in general only marginally suited to most (climatically adapted) crops. Its suitability is mainly downgraded because of its extreme sodicity in combination with restricted subsoil drainage,and also to some extent because of its difficult workablity for seedbed preparation. This particular mapping unit, however, is considered as not suitable at all, because of its steep slopes (and erosion hazard).

Irrigation suitability subclass: N1se
Land development requirements of this unit have been rated as high because of its severe topographic limitations.

Mapping Unit V_{12}: Kubsa soil series, gently (2½-3%) sloping, uidic Rudic phase.
approx. 68 ha (or 7% of total area).

Similar to V_{11} above, but only gently sloping and thus less subjected to erosion hazard.

This unit occurs on the gentle convex lower slopes of the upper part of the older valley bottom

Its suitability for irrigation development has been downgraded because of restricted subsoil drainage in combination with high sodicity and limited subsoil depth (3-4m) upto the bedrock, as only marginally suitable. A further limitation is its difficult workability, as mentioned above. Irrigation suitability subclass: $S_{3d'a}$. Land development requirements of this unit are medium because of moderate topographic limitations.

Mapping Unit V_{21}: Weyib soil series, nearly level to very gently (1 1/2-2%) slopes, Rudic phase Approx. 166 3/4 ha (or 17¼% of total area).

Very deep, somewhat imperfectly drained, very slowly permeable, slightly to moderately calcareous, strongly alkaline, black, cracking clays.

It occurs on the nearly level to very gently undulating summits of the lower part of the older valley bottom. This whole unit is cultivated and with common to many surface stones (of vesicular basalt).

Brief Profile Description

A_1 0-20cm Black; well developed, fine and medium, subangular blocky; strongly calcareous silty clay. PH 8.6.

A_3 20-57cm Black; well developed, coarse, angular blocky including wedgeshaped; strongly calcareous, cracking clay, PH 8.0.

B_u 57-122cm Brownish black; well developed, coarse, angular blocky including wedgeshaped; strongly calcareous cracking clay. PH 8.4.

B_k 122-160cm Black with grayish brown concentrations of soft lime concretions; extremely calcareous, cracking clay, PH 8.4

This soil is in general moderately well suited to most (climatically adapted) crops. Its suitability is somewhat downgraded because of its difficult workability for seedbed preparation and problems related to restricted subsoil drainage. Irrigation suitability subclass: S_{2dw}

Land development requirements are low, except for the possible need to construct a drainage system of about 1meter deep ditches at regular intervals. Depth to bedrock of this unit is about 5 to 8½ meter.

Mapping Unit V_{22}: Weyib soil series, gently (2½-3%) sloping, Rudic phase

Approx. 47 ha (or 4 3/4% of total area).

Similar to V21 above, but it occurs on the gentle convex slopes of the lower part of the lower valley bottom and is slightly more subjected to sheet erosion.

Irrigation suitability subclass: S_{2dw}
Land development requirements are low because of light topographic limitations only.

Mapping Unit V_{23}: <u>Weyib soil series, (3½-4%) sloping, rudic phase</u>
Approx. 36¼ha (or 3½% of total area)

Similar to V_{21} (and V_{22}) above, but it occurs on the somewhat steeper convex slopes of the lower part of the older valley bottom, and is thus more subjected to erosion hazard, for which reason it has been down graded as only <u>marginally</u> suitable for irrigation development.

Irrigation suitability subclass: S_{3ed}. Land development requirements of this unit are medium due to moderate topographic limitations.

Mapping Unit V_{24}: <u>Weyib soil series, strongly (4-7%) sloping, rudic phase</u>

Approx 44 ha (or 4¼% of total area).

Similar to V_{21} (and V_{22} and V_{23}) above, but occurring on the steep sideslopes of the lower part of the older valley bottom and severely subjected to erosion hazard. This unit is too steep for gravity irrigation development. Irrigation suitability subclass: N_{2se}. Land development requirements of their unit would be very high, due to very severe topographic limitations.

<u>Mapping Unit</u> V_{31}: <u>Weyib soil series (3½-4%) sloping</u>

Approx. 19 ha (or 2% of total area.)

Similar to V_{23}, but it occurs on the narrow slightly concave, narrow drainage ways, traversing mainly the upper part of the older valley bottom. Mostly there are only few or no surface stones on this unit.

Irrigation suitability subclass: S_{3ed}

<u>Mapping Unit</u> V_{32}: <u>Weyib soil series, nearly level (<1%) slopes.</u>

Approx. 57 ha (or 6% of total area).

Similar to V_{21}, but occurring in the nearly level broad depression and mostly without (or few) surface stones.

Irrigation suitability subclass: S_{2dw}

Mapping Unit V_{33}: Weyib soil series, nearly level (<1% slopes), rudic, sodic phase

Approx. 21 ha (or 2¼% of the total area).

Similar to V_{32} above and also occurring in the nearly level, broad depression, but with common to many surface stones and with sodic phase.

Brief Profile Description

A_1	0-15cm	Black; well developed, very fine, subangular blocky; strongly calcareous, clay PH 8.2
A_B	15-40cm	Black; moderately developed, coarse, angular blocky including wedgeshaped; strongly calcareous, cracking clay. PH 8.0. (9% exchangeable sodium percentage, ESP).
B_u	40-115cm	Black; strongly developed, coarse, angular blocky including wedgeshaped; strongly calcareous, cracking clay. PH 8.6 (36%ESP).
B_k	115-160cm	Black, with grayish brown concentrations of soft lime concretions, extremely calcareous, cracking clay. PH 8.4 (39% ESP).

This unit is marginally suited to most (climatically adapted) crops. Its suitability is mainly downgraded because of its extreme sodicity in combination with restricted subsoil drainage, and also to some extent because of its difficult workability for seedbed preparation.

Irrigation suitatility subclass: S_{3sd}

Mapping Unit T_{11}: Weyib soil series, slightly convex (upto 2½% slopes) with few rock outcrops.

Approx. 17 ha(or 1¾% of total area)

Similar to V_{22}, etc, but it occurs on the slightly convex part, with few rock outcrops, of the upper river terrace. This unit is uncultivated and covered by medium dense Acacia shrubland and with few or no surface stones. Subsoil depth to the bedrock is generally in between 2-3m only. This unit has been downgraded as only marginally suitable for irrigation development because of restricted subsoil drainage in combination with limited subsoil depth.

Irrigation suitability subclass: $S_{3d \cdot w}$

Mapping Unit T_{12}: Weyib soil series, nearly level (1-1½ slopes)
Approx. 89½ ha (or 9¼% of total area)

Similar to T_{11} above, but occurring on the nearly level upper river terrace summit and with 3-4m deep (sub)soil upto the bedrock.

Brief Profile Description

A_1	0-23cm	Black; moderately developed, very fine and fine, subangular blocky; strongly calcareous, clay. PH 8.4.
AB	23-70cm	Black; moderately developed, coarse, angular blocky including wedgeshaped; strongly calcareous, cracking clay. PH 8.6.
B_u	70-150cm	Black; moderately developed, coarse, angular blocky including wedgeshaped; strongly calcareous, cracking clay.PH 8.2
B_k	150-160cm	Black, with bright brown concentration of soft lime concretions; extremely calcareous, cracking clay, pH 8.4

This unit is moderately well suited for most (climatically adopted) crops. It is only somewhat downgraded because of difficult workability and restricted subsoil drainage. Irrigation suitability subclass: S_{2dw}.

Mapping Unit T_{21}: Asendabo soil series, strongly (6-7%) sloping, rudic phase
Approx. 6¾ ha(or ¾% of table area).

Very deep, somewhat imperfectly drained, slowly permeable, slightly to highly calcareous, moderately alkaline, black, cracking silty clay.

It occurs on the transitional footslopes below H, sloping to the middle river terrace summit. It is covered by dense Acacia shrub vegetation and many surface stones of vesicular basalt.

Brief Profile Description

A_1	0 - 20cm	Black; moderately developed, fine and medium, subangular blocky; slightly calcareous, silty clay. PH 8.0.
AB	20 -63cm	Black; moderately developed, coarse, subangular blocky; moderately calcareous, cracking silty clay, PH 8.2.

B_k 63-108cm Black; moderately developed coarse, (sub) angular blocky including wedgeshaped; strongly calcareous (many lime pseudomycelia, cracking (silty) clay, PH 8.0.

B_u 108-165cm Black; moderately developed, medium and coarse, angular blocky, including wedgeshaped, strongly calcareous, cracking(silty) clay. PH 8.2

B_{u2} 165-190cm Black; as above, (silty)clay PH 8.4

These soils are generally moderately well suited for irrigation development; only downgraded because of difficult workability and restricted subsoil drainage. This mapping unit however, is not suitable because of steep slopes and erosion hazard.

Irrigation suitability subclass N_{2se}

Mapping Unit T_{22}: Asendabo soil series very gently (2%) sloping, rudic phase

Approx. 10 ha (or 1¼% of total area).

Similar to T_{21} above, but occurring at its foot and very gently sloping.

This unit is therefore moderately well suited for irrigation development as discussed under T_{22}. Irrigation suitability subclass: S_{2dw}

Mapping Unit T_{23}: Asendabo soil series, nearly level (1-1½% slopes). Approx. 142½ha (or 14½% of total area)

Similar to T_{22} above, occurring on the nearly level middle terrace summit, but with no (or very few) surface stones.

Brief Profile description

A_1 0-15cm Black; well developed, fine, subangular blocky; moderately calcareous; silty clay. PH 8.0.

AB 15-73cm Black; moderately developed, coarse, angular blocky including wedgeshaped; strongly calcareous cracking silty clay. PH 8.2

B_k 73-117cm Brownish black; moderately developed, coarse angular blacky including wedgeshaped; strongly calcareous; cracking (silty) clay, PH 8.4.

B_u 117-210cm Black; strongly developed, coarse, angular blocky including wedgeshaped; strongly calcareous, cracking (silty)clay, . PH 9.2.

Likewise to the T_{22} unit, this unit is moderately well suited for irrigation development.

Irrigation suitability subangular: S_{2dw}

Mapping Unit T_{24}: Asendabo soil series, (3-4%) sloping, somewhat rocky phase
Approx. 57½ ha (or 6% of total area).

Similar to T_{23} above, but occurring on rather steep sideslopes of the middle terrace with a few rock outcrops. Depth to bedrock varies generally between 2-3m only.

This unit is only marginally suitable for irrigation development because of restricted subsoil drainage in combination with limited (sub) soil depth. And erosion hazard.
Irrigation suitability subclass $S_{3d'e}$

Mapping Unit T_3: Weyib soil series, nearly level(<1% slopes)
Approx. 70¼ha (or 7½% of total area)

Similar to T_{12}, but occurring on the lower terrace summit and with 3 to 5m. (sub)soil depth to the bedrock.

Brief Profile Description

A_1 0-17cm Black; well developed, very fine, and fine subangular blocky; strongly calcareous, clay. PH 8.2.

AB 17-65cm Black; moderately developed, coarse, angular blocky including wedgeshaped; strongly calcareous, cracking clay, PH 8.4.

B_u 65-117cm Black; strongly developed, coarse, angular blocky including wedgeshaped; strongly calcareous, cracking clay, PH 8.2.

B_k 117-182cm Brownish black; strongly developed, medium, angular blocky including wedgeshaped; strongly calcareous, with many soft lime concretions, cracking clay, PH 8.2.

B_u 182-195cm Brownish black; moderately developed, medium, subangular blocky, clay, PH 8.2.

This unit has been somewhat downgraded because of difficult workability and problems related to restricted subsoil drainage as moderately suitable for most (climatically adapted) crops.

Irrigation suitability subclass: S2dw

This remaining 46 hectare (or 4.75% of total area) are covered by Kubsa village, which is located on 15.5ha of V11 and 28ha of V12 and 2.5ha of V13 soil mapping units.

Table 3: Showing hectarages (and % total area of all mapping Units occuring in the phase I, Bale Gadulla Area

Kubsa Village:	Hectares	% of total area
including V11	15.50	
V12	28.00	
V13	2.50	
Subtotal Kubsa Village	46.00	4.75
H1	14.75	1.50
H2	15.25	1.50
Subtotal H land type	30ha	3.00%
V11	39.50	4.00
V12	68.00	7.00
Subtotal V1 subland type	107.50	11.00
V21	166.75	17.25
V22	47.00	43.75
V23	36.25	3.50
V24	44.00	4.50
Subtotal V2 subland type	294.00	30.00
V31	19.00	2.00
V32	57.00	6.00
V33	21.00	2.50
Subsoil V3 subland type	97.00	10.25
total V-land type	948.50	51.25
T11	17.00	1.75
T12	89.50	9.25
Subtotal T1-sub land type	106.50	11.00
T21	6.75	0.75
T22	10.00	1.50
T23	142.50	14.50
T24	57.50	6.00
Subtotal T2-subland type	216.75	22.50
T3-subland type	70.50	7.50
Total T-land type	393.50	41.50
Total area	968ha	100.00%

5. IRRIGATION WATER QUALITY

The study area is to be developed by using the water of the Weyib river.

The quality of this water seems to be highly suitable for irrigation and no hazardous effects on soils are expected over its long-term use. As can be seen in Table 2, the Weyib river has low soluble salts and therefore no salinity problem and pH reading falls in the normal range.

Toxic elements like sodium, chloride and boron are too small and will cause no problem for irrigated crops.

Table 2, shows the chemical analysis of the Weyib river water. It was copied from the Korean report.

Table 4: Chemical analysis of the Weyib river irrigation water

Chemical Conductivity (ΣC_w)	0.08 dSm^{-1}
PH	7,11
Cations (in meq/l)	
Sodium (Na^+)	0.24
Potassium (K^+)	0.04
Calcium (Ca^{++})	0.36
Magnesium (Mg^{++})	0.16
Anions (in meq/l)	
Chloride (Cl-)	0.08
Floride (F-)	
Bicarbonate (HC^-_3	0.56
Carbonate (CO_3--)	
Sulfate (SO_4--)	nill
Phosphate (PO_4--)	
Nitrate(NO_3-)	
Boron (mg/l)	-

Water analysis were carried out at WRDA's water laboratory services.

6. LAND EVALUATION FOR IRRIGATED AND RAINFED AGRICULTURE

Some factors that effect land suitability for surface irrigation are permanent and others are changeable at a cost.

Typical examples of permanent factors are climate, macrotopography, soil depth to bedrock and soil texture.

Changeable characteristics which may be altered, may typically include micro-relief, vegetation, stoniness, salinity, depth of groundwater and some social and economic conditions(e.g. land tenure, accessibility).

The costs of necessary land improvements have to be estimated so that economic and environmental consequences of development can be predicted.

In section 6.1 Land development requirements and limitations for surface irrigation are discussed and categories or degree classes defined such as for bush clearance, land levelling and removal of surface stones on the basis of an estimation of the costs for improvement. Table 6 summarizes the land development limitations, requirements and classes of all the soil mapping units shown on the soil map.

In section 6.2 the physical and chemical properties of the three identified soil series (Kubsa-, Weyib and Asendabo) are discussed and evaluated.

In section 6.3 the potential (post development) suitability of the soil units delineated, has been worked out for a wide range of climatically suitable crops, both for irrigated and rainfed cultivation (see table 7 and 8 respectively).

Then on the basis of these two aspects (land development classes and potential crop suitability) a general land evaluation for both irrigated and rainfed crop cultivation was made for all the soil mapping units (see table 9).

6.1 Land Development Requirements and Limitations for Surface Irrigation

Permanent limiting factors for irrigation development in the Bale-Gadulla (phase I), scheme, consists of steep, rocky hills and steep footslopes only, while the surrounding high plateaus with steep escarpments confine the project to the old river valley bottom with river terraces, only.

Changeable Limiting factors for irrigation development in the Bale-Gadulla scheme include:

a) medium dense vegetation cover, comprising mainly Acacia bushes and thornscrubs, on the river terraces only (=T-landtypes).

b) Common to many surface stones of vesicular basalt, covering most of the older valley bottom (landtype V).

c) Slopes and other topographic limitations

ad a- Vegetation clearance

In order to be able to construct the irrigation scheme, the area will have to be cleared of existing trees, bushes and shrubs. In the phase I area, only the river terraces of the T-landtype are covered by medium dense low Acacia shrub vegetation with scattered trees. This area comprises about 393 ha (or 41% of the total phase I area) and the clearing requirements of these T-mapping units are considered as low.

Mapping units of the older valley bottom (V-landtype) are all cultivated and do not need any bush clearance.

ad b- Removal of surface stones

All the mapping units of the (gently) undulating or convex upper and lower part of the older valley bottom (V_1 and V_2 mapping units) are covered by common to many surface stones (mostly 10-30cm in diameter). These stones, however, do not occur within the soil profile, but they make the use of mechanized agricultural equipment impracticable and will thus have to be removed.

Manual picking of these surface stones, to clear an area of 10X10meters, resulted in a stone heap of about 1.125m^3 and was completed by 2 man in 30 minutes. Thus about 112m^3 stones per ha, may be cleared in 20x30x100 minutes = 100 manhours, or 13 mandays. At a labour cost of 3 Birr per day, this will be about 40 Birr per ha, which is a negligeable amount.

It may further be noted, that clearing the topsoil upto about 20 cm depth, resulted in an additional stone heap of only 0.15 m^3 per 100m^2 (= 15m^3 per hectare).

Moreover, these topsoil stones, are generally smaller in size, with diameters ranging from 5-10cm. Therefore, these few, and small topsoil stones may be left in the soil without causing any problem.

To conclude, stone removal requirements are nil to very low. (even in the most dense stone cover units) and do not have any influence in the irrigability evaluation of the phase I project lands.

ad c- <u>Land levelling</u>

After construction of the irrigation and drainage system, land levelling will be necessary for the furrow irrigation to ensure a proper water flow in the furrows and homogeneous moistening of the soil profile.

To enable the irrigation engineer to calculate an accurate estimate of levelling requirements and costs, representative sample fields should be selected and measured in detail. In this report however, only very general qualitative classes of levelling requirements have been distinguished mainly on the basis of slopes (classes).

Table 5: Preliminart land levelling classes, and related mapping units and their extent

Land levelling catagories	Slope Classes %	Soil Mapping Units	Area Total ha	% of Total
Low grading/levelling requirements	< 2%	V21	166.75	17.25
		V32	57.00	6.00
		V33	21.00	2.25
		T12	89.50	9.25
		T22	10.00	1.25
		T23	142.50	14.50
		T3	70.25	7.50
		Subtotal	557.00	58.00%
Medium grading	2.5 - 3%	T11	17.00	1.75
		T12	68.00	7.00
		V22	47.00	4.75
		Subtotal	132.00	13.50%
High grading	3.5 - 4%	V31	36.50	3.50
		V23	19.00	2.00
			57.50	6.00
		Subtotal	112.75	11.50%
Excluded: too steep or rocky, or otherwise not suitable	> 4%	H1	14.75	1.50
		H2	15.25	1.50
		V11	39.50	4.00
		V24	44.00	4.50
		T21	6.75	0.75
		Kubsa Village	46.00	4.75
		Subtotal	166.25	17.00%
		Grand Total	968.00	100%

d. Land Development classes

In summary of the above, it may be noted, that the medium dense vegetation cover of Acacia shrubs (on the river terraces) as well as the common to many surfaces stones on most of the cultivated older valley bottom surfaces, both require only low development efforts (and costs) and are therefore allowed in land development classes D1.

Thus the only remaining factor of importance for the land development classes in this phase I project area, is formed by the different slope classes.

Of this latter, the low grading category has been allowed for in land development class 1, and medium grading in land development class 2, while high grading will come into land development class 3 and the remaining units will be excluded of any irrigation development.

In 6 table below, the type of limitation and their development requirements as well as the land development classes have been summarized for all the soil mapping units.

6.2 Evaluation of the soils (soil fertility)

About 938 hectare (or 97% of the total phase I area) is covered by very deep, somewhat imperfectly drained, black to brownish black, moderately to (very) strongly alkaline, medium to highly calcareous, non-saline, (occasionally sodic), cracking clay soils.

On the basis of only minor variations in soil colour (either black or brownish black), presence or absence of a calcic horizon within 125 cm of the surface, soil texture (being either silty clay with 31-53% silt or clay with less than 32% silt), or soil reaction (PH of the upper and lower subsoil varying either in between 8.0-8.6 which is moderately alkaline, or in between 8.4 - 9.4 which is strongly to very strongly alkaline), three different soil series have been tentatively distinguished. They are named Kubsa, Asendabo and Weyib soil series and respectively classified as Chromi-Hypo-calcic-, Pelli-Hypo-Calcic, and pelli-Eutric Vertisols.

The physical properties of these dark-coloured, cracking clay soils are moderately good.

They are difficult to work for seedbed preparation and somewhat imperfectly drained with (most probably) slow to very slow permeablities although the values obtained from the field tests are somewhat higher than expected. These values vary in between 0.24-0.73 meter per day, which is moderately slow to moderately rapid. These relatively high values may be the result of insufficient pre-wetting and thus not closing all the shrinkage cracks.

Table 6: Land Development Limitations, requirements and Classes, of all soil Mapping units in the Phase I, Bale-Gadulla area

Soil Mapping Units	Type of Degree of Limitations			Development Requirements			Land Development Classes	Area	
	Topography Slopes	Vegetation	Surface Stones	Levelling Removal	Bush Clearance	Stone Clearance		Ha	%
V12	2.5-3	Cultivated	Many	Medium	None	Low	D2L	68.00	7.00
V21	1.5-2	Cultivated	Many	Low	None	Low	D1	166.75	17.25
V22	2.5-3	Cultivated	Many	Medium	None	Low	D2L	47.00	4.75
V23	3.5-4	Cultivated	Many	High	None	Low	D3L	36.25	3.50
V31	3.5-4	Cultivated	few-none	High	None	None	D3L	19.00	2.00
V32	<2	Cultivated	few-none	Low	None	None	D1	57.00	6.00
V33	<2	Cultivated	Many	Low	None	Low	D1	21.00	2.25
T11	2.5	Acacia Shrub	Few	Medium	Low	Low	D2L	17.00	1.75
T12	1-1.5	Acacia Shrub	None	Low	Low	None	D1	89.50	9.25
T22	2	Acacia Shrub	Many	Low	Low	Low	D1	10.00	1.25
T23	1-1.5	Acacia Shrub	None	Low	Low	None	D1	142.50	14.50
T24	3.5-4	Acacia Shrub	V.few r.0	High	Low	Low	D3L	57.50	6.00
T3	<1	Acacia Shrub	None	Low	Low	None	D1	70.25	7.50
Total area to be developed								801.75	83%
Excluded, because not suitable for irrigation development: H1, H2, V11, V24 T21 and Kubsa Village								166.25	17%
Grand Total								968	100

The same can be said of the relatively high basic infiltration rates measured in the field, varying mostly in between 5.8-7.3cm per hour. These values indicate moderate to marginal suitability for gravity irrigation.

Total available moisture measured on undisturbed core samples of 4 different soil profiles vary in between 183-350mm over 1 meter which is rather high. (silty clay to clay textures usually show values of available moisture in between 180-250mm only).

Top soil structure of these soils, however, are generally very good, fine to medium size, subangular blocky and friable when moist.

The chemical properties of these soils are generally good except for their soil reaction (pH) which is moderate to (very) strongly alkaline (pH 8.0-9.4) causing limited availability of micro-nutrients and occasionally sodicity problems, which will require addition of gypsum. At higher pH (>8.5) values, availability of phosphorus also decreases in the presence of calcium and boron toxicity is common in sodic soils (pH>9.0).

Cation Exchange capacity (CEC) is high to extremely high (62-81 meq/100gr soil) and exchangeable bases of Ca and Mg are very high and of K high to very high and base saturation % is very high.

Exchangeable sodium percentage (ESP) is mostly below 15% but occasionally 27-39%, which may cause future physical problems through clay deflocculation. These high ESP levels may have deterious effects on the structural stability of these soils and their physical response when water is applied, especially since they contain expending type of clay minerals. The presence of excessive amounts of exchangeable sodium promotes the dispersion and swelling of clay minerals. The soil becomes impermeable to both air and water. these soils will thus require gypsum application without which 50% yield reduction may occur.

Organic carbon content is high in the topsoil (2.4-3.3%) and medium in the subsoil (0.7-2.0%). Nitrogen is high to very high in the topsoil (0.15-0.86%) and medium to very high in the subsoil (0.10-0.98%). Available phosphorus varies between 76-925 ppm (or 11.4 to 138.7 kg per ha) which is slight to high.

6.3 Crop Requirements and Crop Suitability of the soils and the soil mapping Units

6.3.1 General Description of suitability classes and subclasses

Most crops are tolerant of a wide range of soil conditions. Varieties of some crops can be bred, to suit (or tolerate) particular soil environmental conditions. Crop yields also depend greatly on management: by good management or use of special techniques, a skilled farmer may be able to produce satisfactory yields from a soil relatively unsuited to the crop. Good crops can sometimes be obtained from 'poor' soils too, in years with favourable weather. Besides, the suitability of soils for irrigated crops intends to be independent of rainfall characteristics.

The crops for which the suitability of the soils has been rated here, are those adapted to the climatic environmental (altitude) conditions (see figure 7).

The land suitability classes quoted in table 7 (for irrigated) and table 8 (for rainfed) are defined as follows:

S1 = Highly suitable
S2 = Moderately suitable
S3 = Marginally suitable
N1 = Presently not suitable
N2 = Permanently not suitable

The subclasses are indicated by using lower case latter suffixes for the major limitations: the first suffix being the most important limitation.

They are:

c = climatic conditions not well suited to the crop (temperatures too low)

r = restricted rootability - limited depth to bedrock rock outcrops.

s = Very steep slopes

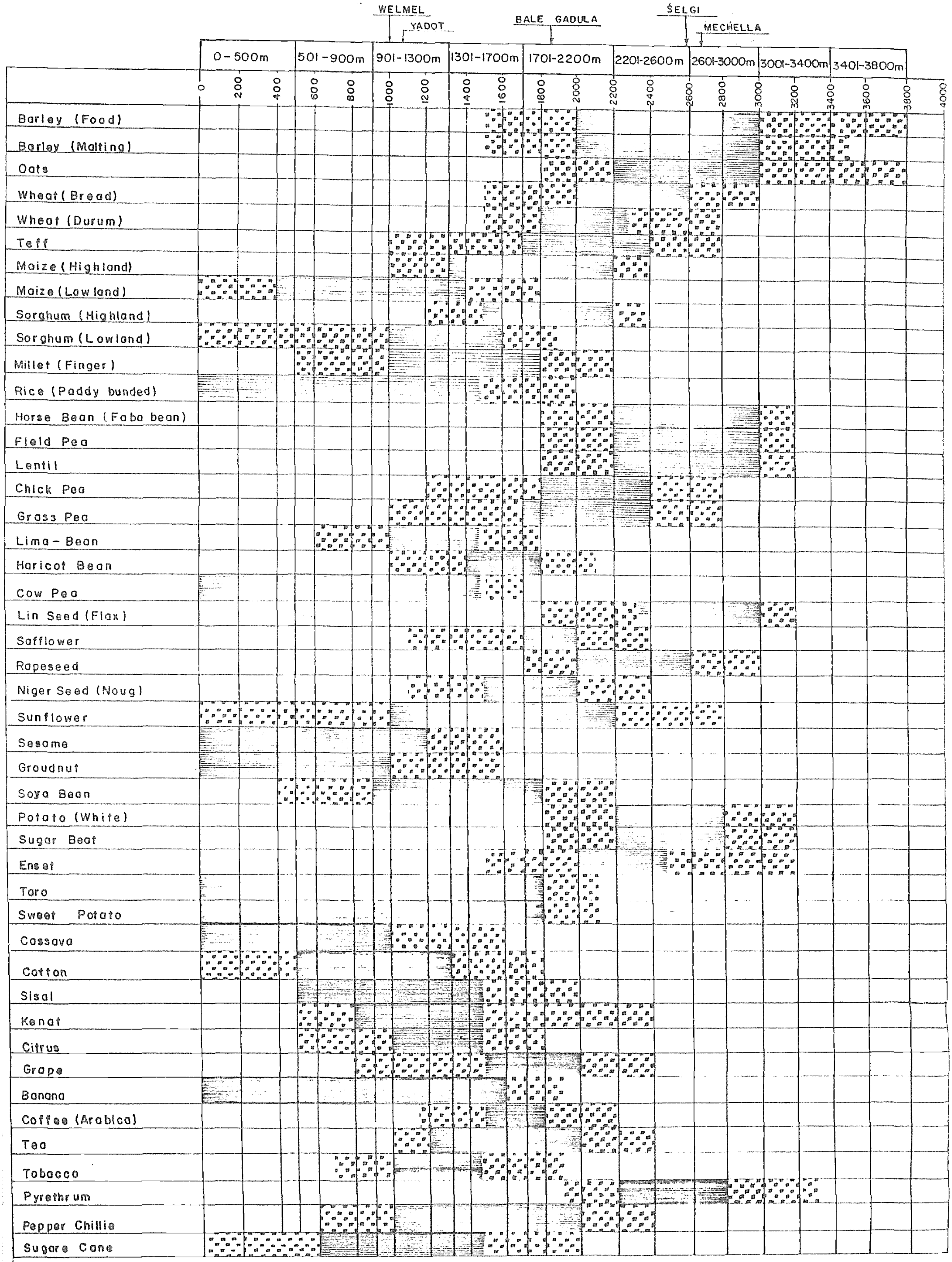
e = (sheet) erosion hazard (moderate steep slopes)

w = difficult workability for seedbed preparation and/or too heavy topsoil causing poor aeration or prevailing peg penetration (groundnuts) and/or causing losse at harvesting.

d = problems due to restricted subsoil drainage or poor aeration, but at least 3m deep upto the bedrock. These soils may be artificially improved for instance by ditches of 1 m. or more deep at frequent intervals.

OPTIMUM ALTITUDES FOR MAJOR CROPS IN ETHIOPIA

FIG 1



d' = restricted subsoil drainage as above and in combination with limited soil depth (e.g 2-3m depth only) as a result of which the groundwater table will build up rapidly under irrigation, to reach within the rootzone.

p = only for rainfed: rainfall restricted or too erratic; hazard of perodic drought (800-1000mm annual rainfall).

a = Soil reaction (pH) too high (=alkaline) and/or even sodic.

In table 9 the dominant suitability for most of the climatically adapted crops is given for all the soil mapping units; both for irrigated agriculture as well as for rainfed. Also the extent (and % of the total area) is given for all the suitability subclasses.

6.3.2 Major requirements of the crops shown in the crop suitability tables

Maize has relatively high moisture and nitrogen requirements and a shallow rooting system (mainly within 40cm). It is killed if the rootstone is waterlogged for more than about a day. It tolerates a wide range of soil reaction. With rainfall less than 800mm, in the Bale Gadulla area, the dark coloured cracking clay soils of this area should not be placed higher than suitability class 3 because of drought hazard during the growing season. Thus suitability subclass S_{3p}: (P for low rainfall), provided that no other limitations are present which require them to be placed in a lower class. For irrigated conditions these soils should not be rated higher than class 2, because of difficult workability and restricted subsoil drainage: suitability subclass S_{2dw} and whenever the subsoil (upto the bedrock) is less than 3m. deep, they should not be rated higher than class 3: suitability subclass $S_{3d'w}$ (d' = risque of rapid build-up of ground water table within the root zone).

Wherever these soils are sodic they should also be rated as class 3: suitability subclass S_{3ad}.

Wheat is deep-rooting, has only a moderate moisture requirement, is tolerant of short period wetness in the rootzone (but not sustained water logging) and tolerates a wide range in pH.

Wheat grown in the rainy season is susceptible to disease and difficult to weed and is not recommended, at present. Therefore suitability subclass (for rainfed): N_{1c}. For commercial production, however, it requires to be grown with irrigation in the dry season.

The dark-coloured, cracking clay soils of this area can be included in class 2, where they can be artificially drained, provided there are no other limitations, requiring them to be placed in a lower class. Thus suitability subclass (for irrigated conditions): $\underline{S}_{2dw}$

For <u>Sorghum</u>, any soil receiving less than 800mm, annual rainfall, should not be placed higher than class 2, because of <u>drought hazard</u> during the growing season, under <u>rainfed</u> cultivation. Thus suitability subclass: $\underline{S}_{2p}$.

Under irrigated conditions, the dark-coloured. Cracking clay soils, can be placed in class 1, where there are no other limitations, such as wetness or depth. But because of their somewhat imperfect interal drainage, they are rated in suitability subclass S_{2d}.

Rainfall is too low in this area, to provide adequate moisture for <u>rice</u> during the growing period and these soils are thus rated as not suited for rice under <u>rainfed</u>. Suitability subclass: $\underline{N}_{2p}$. But under irrigated conditions they may be well suited.

For <u>groundnuts</u> temperature conditions are rather too low, and with annual rainfall below 800mm, these soils should not be placed higher than class 3. Besides, the heavy topsoil textures of these cracking clay soils are preventing the pegs from penetrating while clay topsoils are also unsuitable since this increases losses during harvesting. Therefore the suitability subclass under rainfed will be $\underline{S}_{3pw}$, provided there are no other limiting factors to put them in a lower class. Under irrigated conditions they may be placed in class 2 or suitability subclass $\underline{S}_{2cw}$.

Yields of <u>beans</u> are reduced by short-periods of water logging. Therefore, these somewhat inperfectly drained, cracking clay soils should not be rated higher than class 2; or suitability subclass S_{2dw}, for both, rainfed and irrigated cultivation.

Likewise for <u>Soyabeans</u>, can these dark-coloured cracking clay soils be placed in suitability subclass '$\underline{S}_{2dw}$ for irrigated conditions. And because of low rainfall in suitability subclass $\underline{S}_{3pd}$, under <u>rainfed</u>.

<u>Safflower</u> and <u>sunflower</u> are also very sensitive to water logging and impeded drainage and are therefore likewise placed in suitability subclass $\underline{S}_{2dw}$ under rainfed conditions, and because of the low annual rainfall of less than 800mm, in suitability subclass S_{3pd} under rainfed conditions.

Potatoes are best grown on an acid soil, while the somewhat imperfectly drained cracking clay soils should not be placed higher than class 2, since potatoes are very sensitive to waterlogging for more than 1-3 days in the surface layer.

Without irrigation potatoes can only be grown in the rainy season, but since annual rainfall is less than 800mm, they should not be rated higher than class 3, or suitability subclass S_{3pd}.

With irrigation available, it is possible to grow three crops in the year (although preferably not on the same land, because of disease build up) and these strongly alkaline clay soils can thus be placed in suitability subclass: S_{2da}.

Tomatoes do not well under alkaline conditions and the plant is not frost tolerant.

With less than 800mm annual rainfall, these somewhat imperfectly drained clay soils should not be rated higher than class 3, or rainfed suitability subclass: S_{3pd} while under irrigation they may be rated as suitability subclass S_{3da}.

Kenaf is sensitive to water logging and to ensure even fibre quality, irrigation is necessary in this area with less than 800mm annual rainfall. For under rainfed conditions these soils are thus rated as not suitable for Kenaf or suitability subclass N_{2p}.

But for irrigated conditions these somewhat imperfectly drained clay soils may be rated not higher than suitability subclass S_{2d}.

Dark-coloured cracking clay soils can generally be placed in class 2 for citrus, if artificially drained to 1 meter depth and irrigated. However the high altitude (above 1800m) is another limitation downgrading these soils as class 3, or suitability subclass S_{3cd}, provided there are no their limitations. Under rainfed these soils are not suitable because of low rainfall, or suitability subclass N_{2cp}.

For Bananas, these clay soils can be placed in class 2, if they are drained to at least 60cm, but temperatures are rather too low, for which reason they have been downgraded as class 3, or suitability subclass S_{3cd}. And under rainfed as suitability subclass S_{3cp}.

For Coffee and Tea, these heavy clay soils would not be placed higher than class 3, because of restricted permeability and aeration.

Also the calcareousness and higher pH (even sodicity) is another limiting factor, and rainfall is too low (should be above 1300mm). So they are not suited for rainfed cultivation, or suitability subclass: $\underline{N}_{2pda}$. But assuming irrigated conditions, suitability subclass may be $\underline{S}_{3da}$, provide there are no other limitations.

For Tobacco temperatures are also rather too low and so is the rainfall. therefore rainfed suitability subclass $\underline{N}_{2pc}$. But for irrigated conditions these some what imperfectly drained clay soils may be rated not higher than suitability subclass $\underline{S}_{3dc}$, since it is very intolerant to water logging.

Cotton is tolerant of moderate to strong alkalinity (so long as this is not accompanied by impeded drainage which is the case with the dark clay soils). It requires higher temperatures. With rainfall of less than 800mm annually, these cracking clay soils can not be placed higher than suitability subclass $\underline{S}_{3cp}$.

Under irrigated conditions these somewhat imperfectly drained clay soils should also not be rated higher than class 3, or suitability subclass $\underline{S}_{3cd}$.

Because of sunshine and hot temperature requirements, and of not being tolerant to water logging, these black cracking clay soil should not be rated higher than class 2 for Sugarcane. And because of annual rainfall being less than 800mm, these clay soils are rated for under rainfed conditions in suitability subclass $\underline{S}_{3pd}$ only.

Under irrigated conditions these clay soils are suitable for sugar cane cultivation, if they are adequately drained, by means, of ditches 1 meter or more deep at frequent intervals or cultivation of the crop on cambered beds. Irrigation suitability subclass: $\underline{S}_{2cd}$.

Table 7: Irrigated Crop Suitability of the Bale-Gadulla (Phase I) area

Crops	Soil Mapping Units: Soil series, variants and phases																
	H1	H2	V11	V12	V21	V22	V23	V24	V31	V32	V33	T11	T12	T21	T22	T23	T24	T3
Maize	N2rs	N2s	Nled	S3ad	S2dw	S2dw	S3ed	Nled	S3ed	S2dw	S3ad	S3d'w	S2dw	Nled	S2dw	S2dw	S3d'e	S2dw
Wheat	N2rs	N2s	Nled	S3d'a	S2dw	S2dw	S3ed	Nled	S3ed	S2dw	S3da	S3d'w	S2dw	Nled	S2dw	S2dw	S3d'e	S2dw
Barely	N2rs	N2s	Nled	S3d'w	S2dw	S2dw	S3ed	Nled	S3ed	S2dw	S2dw	S3d'	S2dw	Nled	S2dw	S2dw	S3d'e	S2dw
Sorghum	N2rs	N2s	Nled	S3d'w	S2dw	S2dw	S3ed	Nled	S3ed	S2dw	S2dw	S3d'	S2dw	Nled	S2dw	S2dw	S3d'e	S2dw
Rice	N2rs	N2s	Nle	S2e	S1	S2e	S3e	Nle	S3e	S1	S1	S2r	S1	Nle	S1	S1	S3re	S1
Groundnuts	N2rs	N2s	S3ew	S2cw	S2cw	S2cw	S2cw	S3cw	S2cw	S2cw	S2cw	S32w	S2cw	S3ew	S2cw	S2cw	S32w	S2cw
Beans	N2rs	N2s	S3ed	S2dw	S2dw	S2dw	S3ed	S3ed	S3ed	S2dw	S2dw	S2dw	S2dw	S3ed	S2dw	S2dw	S3ed	S2dw
Soya Beans	N2rs	N2s	S3ed	S2dw	S2dw	S2dw	S3ed	S3ed	S3ed	S2dw	S2dw	S2dw	S2dw	S2dw	S2dw	S2dw	S3ed	S2dw
Safflower	N2rs	N2s	S3ed	S2dw	S2dw	S2dw	S3ed	S3ed	S3ed	S2dw	S2dw	S2dw	S2dw	S2dw	S2dw	S2dw	S3ed	S2dw
Sunflower	N2rs	N2s	S3ed	S2dw	S2dw	S2dw	S3ed	S3ed	S3ed	S2dw	S2dw	S2dw	S2dw	S2dw	S2dw	S2dw	S3ed'	S2dw
Potatoes	N2rs	N2s	S3ed	S3d'a	S2da	S2da	S2ed	S3ed	S2ed	S2da	S2da	S3d'a	S2da	S3ed	S2da	S2da	S3ed'	S2da
Tomatoes	N2rs	N2s	S3ed	S3d'a	S3da	S3da	S3da	S3ed	S3da	S3da	S3da	S3d'a	S3da	S3ed	S3da	S3da	S3d'a	S3da
Lenaf	N2rs	N2s	S3ed	S2d	S2d	S2d	S3ad	S3ed	S3ed	S2d	S2d	S2d	S2d	S3ed	S2d	S2d	S3ed	S2d
Citrus	N2rs	N2s	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd
Bananas	N2rs	N2s	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd	S3cd
Coffee	N2rs	N2s	N1da	N1d'a	S3da	S3da	S3da	S3de	S3da	S3da	N1da	N1d'a	S3da	S3de	S3da	N1da	N1d'a	S3da
Tea	N2rs	N2s	N1da	N1d'a	S3da	S3da	S3da	S3de	S3da	S3da	N1da	N1d'a	S3da	S3de	S3da	N1da	N1d'a	S3da
Tobacco	N2rs	N2s	N2s	S2dc	S3dc	S3dc	S3dc	N2s	S3dc	S3dc	S3dc	S3dc	S3dc	N2s	S3dc	S3dc	S3dc	S3dc
Cotton	N2rs	N2s	S3ed	S3cd	S3cd	S3cd	S3cd	S3ed	S3cd	S3cd	S3cd	S3cd	S3cd	S3ed	S3cd	S3cd	S3cd	S3cd
Sugar Cane	N2rs	N2s	S3ed	N2d'	S2cd	S2cd	S2cd	S3ec	S2cd	S2cd	S3d'	N2d'	S2cd	S3ed	S2cd	S2cd	N2d'	S2cd

Table 8: Rainfed Crop Suitability of the Bale-Gadulla (Phase I) area

Crops	Soil Mapping Units: Soil series, variants and phases																
	H1	H2	V11	V12	V21	V22	V23	V24	V31	V32	V33	T11	T12	T21	T22	T23	T24	T3
Maize	N2rs	N2s	N1Se	S3pe	S3p	S3p	S3pe	S3pe	S3pe	S3p	S3pe	S3p	S3p	S3pe	S3p	S3p	S3pe	S3p
Wheat	N2rs	N2s	N1c	N1c	N1c	N1c	N1c	N1c	N1c	N1c	N1c	N1c	N1c	N1c	N1c	N1c	N1c	N1c
Barely	N2rs	N2s	S3pe	S2pe	S2p	S2p	S2pe	S2pe	S2pe	S2p	S2pe	S3d'	S2p	S3pe	S2p	S2p	S2pe	S2p
Sorghum	N2rs	N2s	S3pe	S2pe	S2p	S2p	S2pe	S2pe	S2pe	S2p	S2pe	S3d'	S2p	S3pe	S2p	S2p	S2pe	S2p
Rice	N2rs	N2s	N2pe	N2p	N2p	N2p	N2pe	N2pe	N2pe	N2p	N2pe	N2p	N2p	N2pe	N2p	N2p	N2pe	N2p
Groundnuts	N2rs	N2s	N1sw	S3pw	S3pw	S3pw	S3pw	N1sw	S3pw	S3pw	S3pw	S3pw	S3pw	N1sw	S3pw	S3pw	S3pw	S3pw
Beans	N2rs	N2s	S3sd	S2dw	S2dw	S2dw	S3ed	S3ed	S3ed	S2dw	S2dw	S2dw	S2dw	S3sd	S2dw	S2dw	S3ed	S2dw
Soya Beans	N2rs	N2s	N2ps	S3pd	S3pd	S3pd	S3ps	N2ps	S3ps	S3pd	S3pd	S3pd	S3pd	N2ps	S3pd	S3pd	S3ps	S3pd
Safflower	N2rs	N2s	S3sp	S3pd	S3pd	S3pd	S3pe	S3ps	S3pe	S3pd	S3pd	S3pd	Sepd	S3sp	S3pd	S3pd	S3pe	S3pd
Sunflower	N2rs	N2s	S3sp	S3pd	S3pd	S3pd	S3pe	S3sp	S3pe	Sepd	S3pd	S3pd	S3pd	S3sp	Sepd	S3pd	s3pe	S3pd
Potatoes	N2rs	N2s	S3ps	S3pd	S3pd	S3pd	S3pe	S3ps	S3pe	S3pd	S3pd	S3pd	S3pd	S3ps	S3pd	S3pd	S3pe	S3pd
Tomatoes	N2rs	N2s	S3ps	S3pd	S3pd	S3pd	S3pe	S3ps	S3pe	S3pd	S3pd	S3pd	S3pd	S3ps	S3pd	S3pd	S3pe	Sepd
Kenaf	N2rs	N2s	N2ps	N2p	N2p	N2p	N2p	N2ps	N2p	N2p	N2p	N2p	N2ps	N2p	N2p	N2p	N2p	N2p
Citrus	N2rs	N2s	N2cp	N2cp	N2cp	N2cp	N2cp	N2cp	N2cp	N2cp	N2cp	N2cp	N2cp	N2cp	N2cp	N2cp	N2cp	N2cp
Bananas	N2rs	N2s	S3cp	S3cp	S3cp	S3cp	S3cp	S3cp	S3cp	S3cp	S3cp	S3cp	S3cp	S3cp	S3cp	S3cp	S3cp	S3cp
Coffee	N2rs	N2s	N2pa	N2pa	N2pda	N2pda	N2pda	N2pda	N2pda	N2pda	N2pda	N2pda	N2pda	N2pda	N2pda	N2pda	N2pda	N2pda
Tea	N2rs	N2s	N2pa	N2pa	N2pda	N2pda	N2pda	N2pda	N2pda	N2pda	N2pda	N2pda	N2pda	N2pda	N2pda	N2pda	N2pda	N2pda
Tobacco	N2rs	N2s	N2ps	N2pc	N2pc	N2pc	N2pc	N2ps	N2pc	N2pc	N2pc	N2pc	N2pc	N2ps	N2pc	N2pc	N2pc	N2pc
Cotton	N2rs	N2s	S3sc	S3cp	S3cp	S3cp	S3cp	S3sc	S3cp	S3cp	S3cp	S3cp	S3cp	S3sc	S3cp	S3cp	S3cp	S3cp
Suagr Cane	N2rs	N2s	S3sd	S3pd	S3pd	S3pd	S3pd	S3sd	S3pd	S3pd	S3pd	S3pd	S3pd	S3sd	S3pd	S3pd	S3pd	S3pd

6.3.3 Major Differences in Land Evaluation for irrigated and rainfed agriculture

As can be seen in table 9 below, all class 2 land for under irrigated conditions have been downgraded to class 2 to 3, mainly because of low annual rainfall, especially for as far as the non-cereal crops are concerned, but also for wheat (see table 8, above).

On the other hand, somewhat steeper sloping mapping units, which were considered not suitable for gravity irrigation development have been classified as marginally suitable for under rainfed conditions.

Thus as a whole about 92.25% of the total area is mostly only marginally suitable for rainfed, while introducing irrigation would classify about 60.5% of the survey area as moderablely suitable for crop cultivation.

Table 9: Comparing general land evaluation for irrigated and rainfed cultivation of the Bale-Gadulla, Phase I, areaa

Irrigated Agriculture				Rainfed Agriculture			
Irrigated Suitability Subclasses	Soil Mapping Units	Extent Ha	% of Total area	Rainfed Suitability Subclasses	Soil Mapping Units	Extent Ha	% of Total area
S2dw	V21	166.75	17.25	S2-3pd	V21	166.75	17.25
S2dw	V22	47.00	4.75	S2-3pd	V22	47.00	4.75
S2dw	V32	57.00	6.00	S2-3pd	V32	57.00	6.00
S2dw	T12	89.50	9.25	S2-3pd	T12	89.50	9.25
S2dw	T22	10.00	1.25	S2-3pd	T22	10.00	1.25
S2dw	T23	142.50	14.50	S2-3pd	T23	142.50	14.50
S2dw	T3	70.25	7.50	S2-3pd	T3	70.50	7.50
Subtotal	S2	583.00	60.50%	Subtotal S2-3		583.00	60.50%
S3d'a	V12	68.00	7.00	S3pe	V12	68.00	7.00
S3da	V33	21.00	2.25	S3pe	V23	36.25	3.50
S3ed	V23	36.25	3.50	S3pe	V31	19.00	2.00
S3ed	V31	19.00	2.00	S3pe	T24	57.50	6.00
S3d'e	T24	57.50	6.00	S3pe	V11	39.50	4.00
S3d'w	T11	17.00	1.75	S3pd'	T11	17.00	1.75
Subtotal	S3	218.75	22.5%	S3pd	V33	21.00	2.25
N2Sr	H1	14.75	1.50	S3ps	V24	44.00	4.50
N2s	H2	15.25	1.50	S3ps	T21	6.75	0.75
Nled	V24	44.00	4.50				
Nled	T21	6.75	0.75	Subtotal	S3	309.00	31.75%
Nled	V11	39.50	4.00				
				N2sr	H1	14.75	1.50
				N2s	H2	15.25	1.50
Subtotal	N	120.25	12.25	Subtotal	N	30.00	3%
Kubsa Village		46	4.75	Kubsa Village		46.00	4.75%
Grand Total		968 Ha	100.00%			968 Ha	100%

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Appendix I

Detailed Soil Profile DEscriptions

and Analytical Data

SOIL PROFILE DESCRIPTION Profile: BAG001 Unit: V-12 Status:

Sheet/Grid: /1800N 5345E
Location : Near Bench mark -13.
Survey Area : Bale Gadulla
Author(s) : Lucas Van Sleen Girum Asfaw Melese Kumsa

Coord : N 7 -06-45 E 40 -22-10
Elevation: 1892 m
Date : 11/02/92

Classification FAO: Calcic Vertisol(1988) Chromic Vertisol (1974) - sodic phase
ST : Udic Chromustert, clayey, montmorrilonitic(calc.),, Local Series : Kubsa Soil series
Soil Climate: ustic isothermic
Topography : gently undulating
Element/Pos.: interfluve- upper slope
Flooding : nil
Land Use : Urban
Vegetation : short grassland
Species :

Land Form: valley
Slope : 2 - 8% convex
Micro Top: even
Grasscover: >70%

Parent Material: in situ weathered over volcanic ash - derived from basalt
Rock Outcrops : very few - Surface Stones : common stones
Erosion: nil and nil
Sealing/Crusting: nil

Drainage : imperfect, internal drainage: very slow, external drainage: rapid
Watertable: not observed
Moist Cond: dry 0 - 170cm
Eff. Soil Depth: > 150cm
Human Infl: fertilizer application
Remarks:

Samples: A: 0- 20 B: 20- 63 C: 63-110 D: 110-170

A1 0 - 20 cm 10YR 2/2 (moist) and 7.5YR 2/2 Mixed, clay, strong very fine subangular blocky structure, very hard (dry), sticky (wet), plastic (wet), common very fine pores, strongly calcareous, many very fine and fine roots, field pH: 8.0, clear smooth boundary.

AB 20 - 63 cm 10YR 2/2 (moist), clay, moderate coarse wedge shaped angular blocky structure, extremely hard (dry), very sticky (wet), very plastic (wet), many distinct intersecting slickensides on pedfaces, common very fine pores, strongly calcareous, common very fine and fine roots, field pH: 8.4, clear smooth boundary.

Bk 63 - 110 cm 10YR 2/2 (moist) and 10YR 2/3 Mixed, clay, moderate medium and coarse wedge shaped angular blocky structure, extremely hard (dry), very sticky (wet), very plastic (wet), many distinct intersecting slickensides on pedfaces, common very fine pores, many fine irregular soft calcareous white concretions, extremely calcareous, few very fine and fine roots, field pH: 9.0, clear smooth boundary.

Bu 110 - 170 cm 10YR 2/2 (moist), clay, moderate medium and coarse wedge shaped angular blocky structure, very hard (dry), very sticky (wet), very plastic (wet), many distinct intersecting slickensides on pedfaces, few very fine pores, few fine irregular soft calcareous white concretions, extremely calcareous, few very fine roots, field pH: 9.0,

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Print Date: 03/07/9:

S O I L A N A L Y S E S R E S U L T S

PROFILE: BAG001

	DEPTH		pH H2O	pH X	EC mS/cm	P ppm	C weight %	N weight %	CaCO3 Total %	CaCO3 Act. %	CaSO4 %	CEC meq/100gr soil	Ca meq/100gr soil	Mg meq/100gr soil	K meq/100gr soil	Na meq/100gr soil	PBS %	K fixed
A	0	20	8.0	0.0	0.1	0	3.34	0.28	0.0	10.1	0.0	71.6	62.5	4.5	1.7	1.6	98	0.0
B	20	63	8.4	0.0	0.1	0	1.92	0.43	0.0	9.2	0.0	70.0	63.0	5.2	0.9	6.5	100	0.0
C	63	110	9.4	0.0	0.8	0	1.19	0.09	0.0	24.6	0.0	79.8	57.4	6.3	1.5	22.0	100	0.0
D	110	170	9.2	0.0	1.1	0	0.86	0.35	0.0	18.9	0.0	73.0	60.1	7.2	1.6	21.6	100	0.0

	Particle size (weight %) vcS	cS	mS	fS	vfS	cSi	fSi	Clay	CECclay meq/100gr	METHODS 123456789
A	0	0	3	0	0	0	32	65	0	
B	0	0	2	0	0	0	20	78	0	
C	0	0	1	0	0	0	15	84	0	
D	0	0	1	0	0	0	17	82	0	

Print date: 03/07/92

SOIL PHYSICAL PROPERTIES

PROFILE: BAG001

INFILTRATION (cm/hr) METHOD:

1	0.0
2	0.0
3	0.0

SURFACE STRUCTURE STABILITY INDEX: 0.00

DEPTH (cm)	BULK DENSITY (g/cc)	WATER CONTENT (weight %) 0.03bar	0.05bar	0.1bar	0.3bar	1.0bar	3.0bar	5.0bar	15.0bar	METHOD
A 0 20	1.21				57.72	49.3	43.9		42.8	
B 20 63	1.55				65.35	62.2	57.0		42.3	
C 63 110	1.31				77.12	60.0	47.2		44.0	
D 110 170	1.32				73.62	56.3	52.4		39.5	

Print date: 03/07/92

BAG001

Available Moisture

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 0 -  20cm = (Fc-pwp) x 20 x BD  =   2.61cm
20 -  63cm = (Fc-pwp) x 43 x BD  =  15.36cm
63 - 100cm = (Fc-pwp) x 37 x BD  =  16.05cm
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                                    35.02cm over 100cm depth
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SOIL PROFILE DESCRIPTION

Profile: BAG002 Unit: T-21 Status:

Sheet/Grid: /1850N 5400E
Location : 300 meters,NE of Bench mark-11.
Survey Area : Bale Gadulla
Author(s) : Lucas Van Sleen Girum Asfaw Melese Kumsa

Coord : N 7 -07-00 E 40 -22-30
Elevation: 1841 m
Date : 12/02/92

Classification FAO: Calcic Vertisol(1988) Pellic Vertisol (1974) - Rudic phase
ST : Udic Pellustert, clayey, montmorrilonitic(calc.),, Local Series : Asendabo Soil Series
Soil Climate: ustic isothermic
Topography : gently undulating
Element/Pos.: Alluvial Colluvial footslope- middle slope
Flooding : rare
Land Use : traditional grazing
Vegetation : semi-deciduous shrub
Species : Acacia

Land Form: valley
Slope : 2 - 8% concave
Micro Top: even
Grasscover: 10-30%

Parent Material: colluvium over in situ weathered derived from basalt
Rock Outcrops : nil - Surface Stones : many stones
Erosion: slight sheet erosion and slight deposition by water Sealing/Crusting: nil

Drainage : moderately well, internal drainage: slow, external drainage: rapid
Watertable: not observed
Moist Cond: moist 0 - 20 , dry 20 - 63 , moist 63 - 190cm Eff. Soil Depth: > 150cm
Human Infl:
Remarks: Asendabo soil series,Calcareous pseudo-mycelio in between 20-63cm few and many in between 63-108cm depth.Crac
cm wide at 50cm depth.

Samples: A: 0- 20 B: 20- 63 C: 63-108 D: 108-165 E: 165-190

A1 0 - 20 cm 9YR 2/1 (moist).and 10YR 2/1 Mixed, silty clay, moderate to strong fine and medium subangular blocky structure, friable (moist), very sticky (wet), very plastic (wet), many very fine pores, few medium subrounded basalt rock fragments, slightly calcareous, many very fine and fine roots, field pH: 7.8, clear smooth boundary.

AB 20 - 63 cm 9YR 2/1 (moist) and 7.5YR 2/1.5 Mixed, silty clay, moderate coarse subangular blocky structure, extremely hard (dry), friable (moist), very sticky (wet), very plastic (wet), few very fine pores, common medium subrounded basalt rock fragments, few fine irregular soft calcareous white soft segregation, moderately calcareous, common very fine and fine roots, field pH: 7.8, clear smooth boundary.

Bk 63 - 108 cm 10YR 1.7/1 (moist), clay, moderate coarse subangular blocky structure, extremely hard (dry), friable (moist), very sticky (wet), very plastic (wet), common distinct intersecting slickensides on pedfaces, common very fine pores, few medium subrounded basalt rock fragments, many fine irregular soft calcareous white soft segregation, extremely calcareous, common very fine and fine roots, field pH: 7.6, . gradual wavy boundary.

Bu1 108 - 165 cm 10YR 2/1 (moist), clay, moderate medium and coarse wedge shaped angular blocky structure, many prominent intersecting slickensides on pedfaces, common very fine pores, few fine subrounded basalt rock fragments, common fine irregular soft calcareous white soft segregation, extremely calcareous, few very fine roots, field pH: 7.8, clear smooth boundary.

Bu2 165 - 190 cm 7.5YR 2/1 (moist), clay, moderate coarse wedge shaped angular blocky structure, friable (moist), very sticky (wet), very plastic (wet), common distinct partly intersecting slickensides on pedfaces, common very fine pores, few calcareous white soft segregation, extremely calcareous, nil roots, field pH: 7.8,

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Print Date: 03/07/9

S O I L   A N A L Y S E S   R E S U L T S

PROFILE: BAG002

	DEPTH		pH H2O	X	EC mS/cm	P ppm	C weight %	N weight %	CaCO3 Total %	CaCO3 Act. %	CaSO4 %	CEC meq/100gr soil	Ca meq/100gr soil	Mg meq/100gr soil	K meq/100gr soil	Na meq/100gr soil	PBS %	K fixed
A	0	20	8.0	0.0	0.4	0	2.85	0.21	0.0	0.4	0.0	65.0	57.5	7.5	1.5	0.4	100	0.0
B	20	63	8.2	0.0	0.1	0	1.79	0.57	0.0	7.7	0.0	69.4	60.5	7.0	2.9	0.5	100	0.0
C	63	108	8.0	0.0	0.8	0	1.09	0.10	0.0	6.1	0.0	71.2	67.0	6.0	7.0	1.0	100	0.0
D	108	165	8.2	0.0	0.3	0	0.80	0.40	0.0	11.9	0.0	65.2	60.5	4.5	2.2	1.5	100	0.0
E	165	190	8.4	0.0	0.5	0	0.80	0.03	0.0	13.2	0.0	63.6	60.5	4.5	1.0	2.0	100	0.0

	Particle size (weight %) vcS	cS	mS	fS	vfS	cSi	fSi	Clay	CECclay meq/100gr	METHODS 123456789
A	0	0	1	0	0	0	46	53	0	
B	0	0	1	0	0	0	44	55	0	
C	0	0	3	0	0	0	38	59	0	
D	0	0	1	0	0	0	31	68	0	
E	0	0	2	0	0	0	33	65	0	

Print date: 03/07/92

SOIL PHYSICAL PROPERTIES

PROFILE: BAG002

INFILTRATION (cm/hr) METHOD:

1	8.9
2	27.8
3	0.0

SURFACE STRUCTURE STABILITY INDEX: 0.00

DEPTH (cm)	BULK DENSITY (g/cc)	WATER CONTENT (weight %) 0.03bar	0.05bar	0.1bar	0.3bar	1.0bar	3.0bar	5.0bar	15.0bar	METHOD
A 0 20	1.21				57.72	49.3	43.9		42.8	
B 20 63	1.22				53.86	46.3	44.3		37.5	
C 63 108	1.25				51.44	48.0	44.1		37.3	
D 108 165	1.24				55.09	48.8	42.5		33.1	
E 165 190	1.24				56.07	47.9	44.0		37.7	

Print date: 03/07/92

BAG 002

Available Moisture

0 - 20cm = (Fc-pwp) x 20 x BD = 3.20cm
20 - 63cm = (Fc-pwp) x 43 x BD = 8.51cm
63 -100cm = (Fc-pwp) x 37 x BD = 6.54cm

18.25cm over 100cm depth

SOIL PROFILE DESCRIPTION Profile: BAG003 Unit: T-23 Status:

Sheet/Grid: /1920N 5460E Coord : N 7 -07-10 E 40 -22-45
Location : 550m,SW of Asendabo river or 1.1km NE of BM-11.
Survey Area : Bale Gadulla Elevation: 1833 m
Author(s) : Lucas Van Sleen Girum Asfaw Melese Kumsa Date : 12/02/92

Classification FAO: Vertisols(1988) Pellic Vertisol (1974) - sodic phase
ST : Udic Pellustert, clayey, montmorrilonitic(calc.),, Local Series : Asendabo Soil Series
Soil Climate: ustic isothermic
Topography : flat Land Form: valley
Element/Pos.: terrace- middle slope Slope : 0.7 - 2% straight
Flooding : nil Micro Top: even
Land Use : traditional grazing
Vegetation : semi-deciduous shrub Grasscover: >70%
Species : Acacia

Parent Material: fluvial deposits over in situ weathered - derived from basalt
Rock Outcrops : nil - Surface Stones : few stones
Erosion: slight sheet erosion Sealing/Crusting: nil

Drainage : moderately well, internal drainage: very slow, external drainage: slow
Watertable: not observed
Moist Cond: moist 0 - 15 , dry 15 - 200cm Eff. Soil Depth: > 150cm
Human Infl:
Remarks: Asendabo soil series.Cracks at 50cm depth.

Samples: A: 0- 15 B: 15- 73 C: 73-117 D: 117-210

A1 0 - 15 cm 10YR 2/1 (moist), silty clay, strong fine subangular blocky structure, very hard (dry), friable (moist), very sticky (wet), very plastic (wet), many very fine pores, extremely calcareous, many very fine and fine roots, field pH: 8.2, gradual smooth boundary.

AB 15 - 73 cm 10YR 2/1 (moist), silty clay, moderate coarse wedge shaped angular blocky structure, extremely hard (dry), very sticky (wet), very plastic (wet), many distinct intersecting slickensides on pedfaces, many very fine pores, extremely calcareous, many very fine and common fine roots, field pH: 8.0, gradual wavy boundary.

Bk 73 - 117 cm 10YR 2/2 (moist), silty clay, moderate coarse wedge shaped angular blocky structure, extremely hard (dry), very sticky (wet), very plastic (wet), many distinct intersecting slickensides on pedfaces, common very fine pores, many medium spherical soft calcareous white soft segregation, extremely calcareous, common very fine roots, field pH: 8.0, clear irregular boundary.

Bu 117 - 210 cm 10YR 2/1 (moist), silty clay, strong coarse wedge shaped angular blocky structure, extremely hard (dry), very sticky (wet), very plastic (wet), many prominent intersecting slickensides on pedfaces, few very fine pores, common medium spherical soft calcareous white soft segregation, strongly calcareous, nil roots, field pH: 7.8,

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Print Date: 04/07/92

S O I L A N A L Y S E S R E S U L T S

PROFILE: BAG003

	DEPTH		pH H2O	pH X	EC mS/cm	P ppm	C weight %	N weight %	CaCO3 Total %	CaCO3 Act. %	CaSO4 %	CEC meq/100gr soil	Ca meq/100gr soil	Mg meq/100gr soil	K meq/100gr soil	Na meq/100gr soil	PBS %	K fixed
A	0	15	8.0	0.0	0.1	0	2.40	0.86	0.0	6.6	0.0	70.6	65.0	10.2	1.7	0.3	100	0.0
B	15	73	8.2	0.0	0.3	0	1.89	0.27	0.0	11.3	0.0	79.0	65.0	14.5	1.2	0.5	100	0.0
C	73	117	8.4	0.0	0.3	0	1.03	0.74	0.0	21.9	0.0	78.5	60.0	13.5	0.9	6.1	100	0.0
D	117	210	9.2	0.0	0.4	0	0.67	0.49	0.0	13.8	0.0	77.2	64.5	15.0	1.4	6.3	100	0.0

Particle size (weight %) CECclay METHODS

	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	CECclay meq/100gr	METHODS 123456789
A	0	0	2	0	0	0	53	45	0	
B	0	0	2	0	0	0	43	55	0	
C	0	0	2	0	0	0	35	63	0	
D	0	0	2	0	0	0	46	52	0	

Print date: 03/07/92

Sheet/Grid: /1940N 5480E
Location : 145m SW of Asendabo river or 1.5km NE of BM-11.
Survey Area : Bale Gadulla
Author(s) : Lucas Van Sleen Girum Asfaw Melese Kumsa

Coord : N 7 -07-15 E 40 -23-00
Elevation: 1829 m
Date : 12/02/92

Classification FAO: Vertisols(1988) Pellic Vertisol (1974)
ST : Udic Pellustert, clayey, montmorrilonitic(calc.),,
Local Series : Weieb Soil Series
Soil Climate: ustic isothermic
Topography : flat
Element/Pos.: terrace- middle slope
Flooding : rare
Land Use : traditional grazing
Vegetation : semi-deciduous shrub
Species : Acacia

Land Form: valley
Slope : 0.3 - 0.7% straight
Micro Top: even

Grasscover: >70%

Parent Material: fluvial deposits over in situ weathered derived from basalt
Rock Outcrops : nil - Surface Stones : very few stones
Erosion: slight sheet erosion and slight deposition by water
Sealing/Crusting: nil

Drainage : moderately well, internal drainage: very slow, external drainage: slow
Watertable: not observed
Moist Cond: moist 0 - 17 , dry 17 - 117, moist 117 - 195cm
Eff. Soil Depth: > 150cm
Human Infl:
Remarks: Weyib soil series.Cracks 1cm wide at 65cm.

Samples: A: 0- 17 B: 17- 65 C: 65-117 D: 117-182 E: 182-195

A1 0 - 17 cm 10YR 2/1 (moist), clay, strong very fine subangular blocky structure, friable (moist), very sticky (wet), very plastic (wet), many very fine pores, very few medium subrounded basalt rock fragments, extremely calcareous, many very fine and fine roots, field pH: 8.2, clear smooth boundary.

AB 17 - 65 cm 10YR 2/1 (moist), clay, moderate coarse wedge shaped angular blocky structure, extremely hard (dry), very sticky (wet), very plastic (wet), many distinct intersecting slickensides on pedfaces, many very fine pores, extremely calcareous, common very fine and fine roots, field pH: 8.0, diffuse boundary.

Bu 65 - 117 cm 10YR 2/1 (moist), clay, strong coarse wedge shaped angular blocky structure, extremely hard (dry), very sticky (wet), very plastic (wet), many prominent intersecting slickensides on pedfaces, many very fine pores, extremely calcareous, few very fine and fine roots, field pH: 8.0, gradual wavy boundary.

Bk 117 - 182 cm 10YR 2/1 (moist), clay, strong medium wedge shaped angular blocky structure, extremely hard (dry), friable (moist), very sticky (wet), very plastic (wet), many prominent intersecting slickensides on pedfaces, many fine irregular soft calcareous white soft segregation, extremely calcareous, few very fine roots, field pH: 8.0, clear smooth boundary.

Bu 182 - 195 cm 7.5YR 2/2 (moist), clay, moderate medium subangular blocky structure, friable (moist), very sticky (wet), very plastic (wet), common distinct intersecting slickensides on pedfaces, few very fine pores, extremely calcareous, nil roots, field pH: 8.2,

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Print Date: 04/07/92

S O I L   A N A L Y S E S   R E S U L T S

PROFILE: BAG004

	DEPTH		pH H2O	pH X	EC mS/cm	P ppm	C weight %	N weight %	CaCO3 Total %	CaCO3 Act. %	CaSO4 %	CEC meq/100gr soil	Ca meq/100gr soil	Mg meq/100gr soil	K meq/100gr soil	Na meq/100gr soil	PBS %	K fixed
A	0	17	8.2	0.0	0.5	0	3.16	0.19	0.0	1.0	0.0	76.6	65.0	12.0	2.2	0.3	100	0.0
B	17	65	8.4	0.0	0.3	0	2.00	0.75	0.0	9.1	0.0	74.0	60.5	11.5	1.4	0.3	99	0.0
C	65	117	8.2	0.0	0.1	0	1.36	0.07	0.0	7.6	0.0	76.0	65.0	15.0	1.0	0.7	100	0.0
D	117	182	8.2	0.0	0.1	0	0.81	0.08	0.0	7.8	0.0	76.0	64.0	13.5	0.8	0.8	97	0.0
E	182	195	8.2	0.0	0.2	0	0.67	0.06	0.0	10.9	0.0	70.2	64.5	13.5	0.9	0.8	100	0.0

	Particle size (weight %) vcS	cS	mS	fS	vfS	cSi	fSi	Clay	CECclay meq/100gr	METHODS 123456789
A	0	0	2	0	0	0	36	62	0	
B	0	0	2	0	0	0	35	63	0	
C	0	0	2	0	0	0	19	79	0	
D	0	0	2	0	0	0	19	79	0	
E	0	0	3	0	0	0	17	80	0	

Print date: 03/07/92

S O I L   P H Y S I C A L   P R O P E R T I E S

PROFILE: BAG004

INFILTRATION (cm/hr)   METHOD:

1	5.9
2	5.8
3	0.0

SURFACE STRUCTURE STABILITY INDEX: 0.00

DEPTH (cm)	BULK DENSITY (g/cc)	WATER CONTENT (weight %) 0.03bar	0.05bar	0.1bar	0.3bar	1.0bar	3.0bar	5.0bar	15.0bar	METHOD
A 0 0	0.00									

Print date: 04/07/92

SOIL PROFILE DESCRIPTION Profile: BAG005 Unit: V21 Status:

Sheet/Grid: /1725N 5540E
Location : BM-17.
Survey Area : Bale Gadulla
Author(s) : Lucas Van Sleen Girum Asfaw Melese Kumsa

Coord : N 7 -06-30 E 40 -23-00
Elevation: 1838 m
Date : 13/02/92

Classification FAO: Vertisols(1988) Pellic Vertisol (1974) - Rudic phase
ST : Udic Pellustert, clayey, montmorrilonitic(calc.),, Local Series : Weieb Soil Series
Soil Climate: ustic isothermic
Topography : gently undulating
Element/Pos.: interfluve- lower slope
Flooding : nil
Land Use : traditional dryland farming- crops: wheat
Vegetation :
Species :

Land Form: valley
Slope : 2 - 8% convex
Micro Top: low gilgai
Grasscover:

Parent Material: in situ weathered over volcanic ash - derived from basalt
Rock Outcrops : nil - Surface Stones : many stones
Erosion: nil
Sealing/Crusting: nil

Drainage : moderately well, internal drainage: very slow, external drainage: slow
Watertable: not observed
Moist Cond: moist 0 - 20 , dry 20 - 57 , moist 57 - 122cm
Eff. Soil Depth: > 150cm
Human Infl: ploughing
Remarks: Cracks 2cm wide at 50cm depth and deeper.

Samples: A: 0- 20 B: 20- 57 C: 57-122 D: 122-160

A1 0 - 20 cm 9YR 2/1 (moist), clay, strong fine and medium subangular blocky structure, very hard (dry), friable (moist), very sticky (wet), very plastic (wet), many very fine pores, very few medium subrounded basalt rock fragments, extremely calcareous, many very fine roots, field pH: 8.2, clear smooth boundary.

AB 20 - 57 cm 10YR 2/1 (moist), clay, strong coarse wedge shaped angular blocky structure, extremely hard (dry), very sticky (wet), very plastic (wet), many distinct intersecting slickensides on pedfaces, common very fine pores, extremely calcareous, common very fine roots, field pH: 8.0, diffuse boundary.

Bu 57 - 122 cm 10YR 2/2 (moist), clay, strong coarse wedge shaped angular blocky structure, extremely hard (dry), friable (moist), very sticky (wet), very plastic (wet), many prominent intersecting slickensides on pedfaces, common very fine pores, extremely calcareous, few very fine roots, field pH: 8.2, gradual irregular boundary.

Bk 122 - 160 cm 10YR 2/2 (moist), clay, strong coarse wedge shaped angular blocky structure, extremely hard (dry), friable (moist), very sticky (wet), very plastic (wet), many prominent intersecting slickensides on pedfaces, common very fine pores, common fine irregular soft calcareous white soft segregation, extremely calcareous, nil roots, field pH: 8.0,

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Print Date: 11/05/92

SOIL ANALYSES RESULTS

PROFILE: BAG005

	DEPTH		pH H2O	pH X	EC mS/cm	P ppm	C weight %	N weight %	CaCO3 Total %	CaCO3 Act. %	CaSO4 %	CEC meq/100gr soil	Ca meq/100gr soil	Mg meq/100gr soil	K meq/100gr soil	Na meq/100gr soil	PBS %	K fixed
A	0	20	8.6	0.0	0.3	0	2.70	0.22	0.0	10.3	0.0	65.4	52.5	10.5	1.5	0.3	99	0.0
B	20	57	8.0	0.0	0.2	0	1.81	0.98	0.0	12.6	0.0	66.0	56.0	14.2	0.7	0.5	100	0.0
C	57	122	8.4	0.0	0.1	0	1.34	0.22	0.0	12.4	0.0	63.8	58.0	14.9	1.3	0.8	100	0.0
D	122	160	8.4	0.0	0.1	0	0.81	0.81	0.0	15.3	0.0	65.4	54.0	13.5	1.1	2.8	100	0.0

	Particle size (weight %) vcS	cS	mS	fS	vfS	cSi	fSi	Clay	CECclay meq/100gr	METHODS 123456789
A	0	0	2	0	0	0	46	52	0	
B	0	0	2	0	0	0	35	63	0	
C	0	0	2	0	0	0	22	76	0	
D	0	0	2	0	0	0	21	77	0	

Print date: 11/05/92

SOIL PROFILE DESCRIPTION Profile: BAG006 Unit: V-33 Status:

Sheet/Grid: /17100N 5640E Coord : N 7 -06-00 E 40 -23-30
Location : 75m NW of pond or 1075m ESE of BM-17.
Survey Area : Bale Gadulla Elevation: 1810 m
Author(s) : Lucas Van Sleen Girum Asfaw Melese Kumsa Date : 13/02/92

Classification FAO: Vertisols(1988) Pellic Vertisol (1974) - sodic phase
ST : Udic Pellustert, clayey, montmorrilonitic(calc.),, Local Series : Weieb Soil Series
Soil Climate: ustic isothermic
Topography : almost flat Land Form: valley
Element/Pos.: depression- lower slope Slope : 0.7 - 2% concave
Flooding : rare Micro Top: even
Land Use : traditional dryland farming- crops: wheat
Vegetation : Grasscover:
Species :

Parent Material: in situ weathered over volcanic ash derived from basalt
Rock Outcrops : nil - Surface Stones : many stones
Erosion: nil and slight deposition by water Sealing/Crusting: nil

Drainage : moderately well, internal drainage: very slow, external drainage: slow
Watertable: not observed
Moist Cond: moist 0 - 15 , dry 15 - 115, moist 115 - 160cm Eff. Soil Depth: > 150cm
Human Infl: ploughing
Remarks: Weyib soil series,sodic phase.Cracks 2cm wide at 50cm depth and deeper.

Samples: A: 0- 15 B: 15- 40 C: 40-115 D: 115-160

A1 0 - 15 cm 10YR 2/1 (moist), clay, strong very fine subangular blocky structure, very hard (dry), friable (moist), very sticky (wet), very plastic (wet), many very fine pores, very few medium subrounded basalt rock fragments, extremely calcareous, many very fine and fine roots, field pH: 7.8, gradual smooth boundary.

AB 15 - 40 cm 10YR 2/1 (moist), clay, moderate coarse wedge shaped angular blocky structure, extremely hard (dry), very sticky (wet), very plastic (wet), many distinct intersecting slickensides on pedfaces, common very fine pores, very few medium subrounded basalt rock fragments, extremely calcareous, common very fine and fine roots, field pH: 8.0, diffuse boundary.

Bu 40 - 115 cm 10YR 2/1 (moist), clay, strong coarse wedge shaped angular blocky structure, extremely hard (dry), very sticky (wet), very plastic (wet), many prominent intersecting slickensides on pedfaces, common very fine pores, extremely calcareous, common very fine roots, field pH: 8.2, clear wavy boundary.

Bk 115 - 160 cm 10YR 2/1 (moist) and 10YR 2/2 Mixed, clay, moderate coarse wedge shaped angular blocky structure, friable (moist), very sticky (wet), very plastic (wet), many prominent intersecting slickensides on pedfaces, common very fine pores, very few medium subrounded basalt rock fragments, common medium irregular soft calcareous white concretions, extremely calcareous, few very fine roots, field pH: 8.0,

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Print Date: 11/05/92

PROFILE: BAG006

	DEPTH		pH		EC	P	C	N	CaCO3		CaSO4	CEC	Ca	Mg	K	Na	PBS	K fixed
									Total	Act.								
			H2O	X	mS/cm	ppm	weight %		------ % -------			------ meq/100gr soil ---%						
A	0	15	8.2	0.0	0.1	0	3.00	0.27	0.0	7.6	0.0	71.4	60.0	12.0	1.1	0.8	100	0.0
B	15	40	8.0	0.0	0.1	0	2.00	0.13	0.0	12.2	0.0	69.0	57.5	10.6	0.9	6.2	100	0.0
C	40	115	8.6	0.0	0.5	0	0.90	0.13	0.0	14.6	0.0	66.8	52.5	12.5	0.7	24.2	100	0.0
D	115	160	8.4	0.0	1.2	0	0.72	0.34	0.0	15.0	0.0	73.4	57.5	12.5	1.1	28.6	100	0.0

	Particle size (weight %)								CECclay	METHODS
	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr	123456789
A	0	0	2	0	0	0	37	61	0	
B	0	0	2	0	0	0	18	80	0	
C	0	0	2	0	0	0	18	80	0	
D	0	0	2	0	0	0	9	89	0	

Print date: 11/05/92

SOIL PHYSICAL PROPERTIES

PROFILE: BAG006

INFILTRATION (cm/hr) METHOD:

1 7.3
2 7.2
3 11.2

SURFACE STRUCTURE STABILITY INDEX: 0.00

DEPTH (cm)	BULK DENSITY (g/cc)	WATER CONTENT (weight %) 0.03bar	0.05bar	0.1bar	0.3bar	1.0bar	3.0bar	5.0bar	15.0bar	METHOD
A 0 0	0.00									

Print date: 11/05/92

SOIL PROFILE DESCRIPTION Profile: BAG007 Unit: T-12 Status:

Sheet/Grid: /1840N 5540E
Location : 120m NE of BM-18..
Survey Area : Bale Gadulla
Author(s) : Lucas Van Sleen Girum Asfaw Melese Kumsa

Coord : N 7 -06-40 E 40 -23-10
Elevation: 1834 m
Date : 13/02/92

Classification FAO: Vertisols(1988) Pellic Vertisol (1974)
ST : Udic Pellustert, clayey, montmorrilonitic(calc.),,
Local Series : Weieb Soil Series
Soil Climate: ustic isothermic
Topography : flat
Element/Pos.: terrace- lower slope
Flooding : rare
Land Use : traditional grazing
Vegetation : semi-deciduous shrub
Species : Acacia

Land Form: valley
Slope : 0.7 - 2% straight
Micro Top: even
Grasscover: >70%

Parent Material: fluvial deposits over in situ weathered - derived from basalt
Rock Outcrops : very few - Surface Stones : very few stones
Erosion: slight sheet erosion
Sealing/Crusting: nil

Drainage : moderately well, internal drainage: very slow, external drainage: slow
Watertable: not observed
Moist Cond: moist 0 - 23 , dry 23 - 150, moist 150 - 160cm
Eff. Soil Depth: > 150cm
Human Infl:
Remarks: Weyib soil series,cracks 1.5cm wide at70cm.

Samples: A: 0- 23 B: 23- 70 C: 70-150 D: 150-160

A1 0 - 23 cm 10YR 2/1 (moist), clay, moderate very fine subangular blocky structure, friable (moist), very sticky (wet), very plastic (wet), many very fine pores, many very fine and fine roots, field pH: 8.4, clear smooth boundary.

AB 23 - 70 cm 10YR 2/1 (moist), clay, moderate coarse wedge shaped angular blocky structure, extremely hard (dry), very sticky (wet), very plastic (wet), many distinct intersecting slickensides on pedfaces, many very fine pores, very few medium subrounded basalt rock fragments, common very fine roots, field pH: 8.2, diffuse boundary.

Bu 70 - 150 cm 9YR 2/1.5 (moist), clay, moderate coarse wedge shaped angular blocky structure, extremely hard (dry), very sticky (wet), very plastic (wet), many prominent intersecting slickensides on pedfaces, common very fine pores, few very fine roots, field pH: 8.2, clear smooth boundary.

Bk 150 - 160 cm 10YR 2/1 (moist) and 10YR 2/2 Mixed, clay, moderate coarse wedge shaped angular blocky structure, friable (moist), very sticky (wet), very plastic (wet), common prominent intersecting slickensides, common very fine pores, many medium irregular soft calcareous white soft segregation, nil roots, field pH: 8.2,

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Print Date: 11/05/92

S O I L   A N A L Y S E S   R E S U L T S

PROFILE: BAG007

	DEPTH		pH		EC	P	C	N	CaCO3		CaSO4	CEC	Ca	Mg	K	Na	PBS	K fixed
									Total	Act.								
			H2O	X	mS/cm	ppm	weight %		------ % -------			------ meq/100gr soil ---%						
A	0	23	8.4	0.0	0.1	0	2.50	0.15	0.0	8.4	0.0	71.0	56.0	12.5	0.7	0.6	98	0.0
B	23	70	8.6	0.0	0.1	0	1.89	0.30	0.0	10.5	0.0	71.0	55.5	12.5	1.2	0.7	98	0.0
C	70	150	8.2	0.0	0.1	0	0.99	0.04	0.0	15.4	0.0	63.4	59.5	15.5	1.4	1.4	100	0.0
D	150	160	8.4	0.0	0.1	0	0.81	0.50	0.0	11.2	0.0	62.4	50.5	15.0	1.4	4.0	0	0.0

	Particle size (weight %)								CECclay	METHODS
	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr	123456789
A	0	0	2	0	0	0	32	66	0	
B	0	0	2	0	0	0	24	74	0	
C	0	0	2	0	0	0	14	84	0	
D	0	0	3	0	0	0	12	85	0	

Print date: 11/05/92

S O I L   P H Y S I C A L   P R O P E R T I E S

PROFILE: BAG007

INFILTRATION (cm/hr)　　　　　METHOD:

1　6.0
2　6.8
3　0.0

SURFACE STRUCTURE STABILITY INDEX: 0.00

DEPTH (cm)	BULK DENSITY (g/cc)	WATER CONTENT (weight %) 0.03bar	0.05bar	0.1bar	0.3bar	1.0bar	3.0bar	5.0bar	15.0bar	METHOD
A 0 23	1.17				58.53	51.6	45.4		43.0	
B 23 70	1.46				53.22	48.3	37.3		36.8	
C 70 150	1.37				51.07	46.7	39.7		36.8	
D 150 160	1.34				55.69	50.8	42.7		37.4	

Print date: 11/05/92

BAG 007

Available moisture

0-23 cm = (Fc-pwp) x 23 x BD = 4.18cm
23-70cm = (Fc-Pwp) x 47 x BD = 11.27cm
70 - 100cm = (Fc-Pwp) x 30 x BD = 5.86cm

21.31cm over 100 cm depth

Appendix II

Hydraulic Conductivity and Infiltration Rate

Hydraulic Conductivity

Introduction

To determine the hydraulic Conductivity, permeability tests were performed in most of the distinguished soil units. The test were executed according to the inversed auger hole method as described in "Drainage principle and applications Volume III, Surveys and Investigations". The principle is similar to the auger hole method with this difference that in the inversed auger hole method the Rate of fall of the water level in the hole is measured instead of the rise.

Procedures

Test locations were situated near the representative soil pits. This gave the advantage that the locations and consequently the soil units and the textural sequence of the soils to be tested were known. Three augerings were made near the representative profile pits up to one meter depth. After augering the holes were filled with water and the profile described. The first filling was done to reach a wet condition in the profile as under irrigation. The water filling was done from a jerican so carefully inorder not to disturb the wall of the hole by a flow of water. After the water of the first fill drained away the actual width and depth of the auger hole were measured. In some profiles it was observed that during the first fill the wall of the auger hole collapsed causing a wider and less deep auger hole.

For measuring the rate of fall of the water level a float and a measuring tape installed an a standard were used. After installation of this equipment the hole was filled for the second time. The rate of fall was measured after 0.00 sec, 15 sec, 30 sec, 60 sec, 120 sec 180 sec, 240 sec, 360 sec and 540 sec.

Result

At the time of Survey work it was observed that the cracking clay soils and cavities in the surface and sub soils, which are visible during augering, were impossible to examine because of the water flowing away through the cracks and cavities. The procedure used for the execution of permeability test can be limited or influenced by the presence of soil cracks, holes created by roots, worms or larger animals and the presence of thin sand lenses may give unreliable figures. The test results are presented in M/day for auger holes upto one meter depth. The classification of the Hydraulic conductivity is based on the following description:-

Very slow	< 0.03 m/day
Slow	0.03 - 0.12 m/day
Moderately slow	0.12 - 0.49 m/day
Moderate	0.49 - 1.55 m/day
Moderately rapid	1.55 - 3.05 m/day
Rapid	3.05 - 4.58 m/day
Very rapid	> 4.58 m/day

Source:- Soil Conservation Service, USDA Dec. 1948

Results of Hydraulic Conductivity tests

Soil Mapping Unit	Near Soil	Tests result M/day	Classification	Remark
	B-2-1	0.55	Moderate	
	b-2-2	0.66	"	
	B-2-3	0.73	"	
	B-4-1	-	-	Due to crack
	B-4-2	-	-	and clay
	B-4-3	-	-	clogging
	B-6-1	0.32	Moderately Slow	
	B-6-2	0.24	Moderately Slow	
	B-6-3	0.28	Moderately Slow	
	B-7-1	0.55	Moderate	
	B-7-2	0.40	Moderately Slow	
	B-7-3	0.30	Moderately Slow	

Infiltration Measurements

The infiltration capacity refers to the vertical entry of water into the soil surface, for these measurements the doube Ring in filtrometer has been used. In here the initial intake rate and the equilibrium of the basic intake rate has become constant after several hours are the two interest figures.

The rate of infiltration is measured by observing the fall of water within two concentric cylinders driven into the soil surface. The use of a double ring with measurement confined to the inner ring, minimizes errors due to flow divergence in direction other than the vertical. To avoid unreliable results, water of the same quality as will be used for irrigation should preferably be used for six hours. It does not work very well on cracked clays as the water disappears too fast and results are too variable but they indicate important aspects of soil physical properties.

Evaporation rates are usually too low to be significant, but if the infiltration rate is very low and the weather is hot and dry it is necessary to correct for evaporation. It is after convenient to carry out the test close to a sampled profile so that the complete description on the soil is obtained.

Procedure

Near the representative soil profile the pairs of cylinders should be installed 3-10 meters apart. Drive the cylinders in to the soil to a depth of approximately 10-15 centimeters. Place plastic or your hand over the soil to dissipate the force of the water inorder to reduce turbidity. Prepare every thing ready for all replicates before starting the test. Fill both cylinders to a depth of about 10 cm and record the time and the height of the water in the inner cylinder using a ruler or a hook gauge. Do the same for the replicates and repeat the measurement after 15 min, 30 min, 45 min, 60 min, 90 min, and 120 min, and each hour for the remainder of the test.

The infiltration rate can be measured either by measuring the distance of the water surface from the top of the cylinder before, and after topping up or by measuring the amount of water (using a graduate cylinder) required for topping upto a fixed hook gauge. The former method is simpler when different diameter cylinders are used. The outer cylinder should be kept at approximately the same level as the inner one.

It is important that it should never be filled up higher than the inner cylinder or the measured water level may rise instead of fall. The recordings should be entered on a form and the average hourly rates calculated. The curves of infiltrations versus time should be plotted on graph paper and the cumulative amount of water infiltrated also plotted as a check. If one cylinder gives different rate from the others it should be rejected and taking the averages.

Soil Mapping Unit	Infiltration Measurement results		
	Near Soil pit	Test result Cm/h	Remark
	1-2-1	8.9	
	B-2-2	27.8	
	B-2-3	-	Impossible to insert the ring due to burried stones.
	B-4-1	5.9	
	B-4-2	5.8	
	B-4-3	-	Due to crack
	B-5-1	7.0	
	B-5-2	9.3	
	B-5-3	26.5	Due to crack
	B-6-1	7.3	
	B-6-2	7.2	
	B-6-3	11.2	
	B-7-1	6.0	
	B-7-2	6.8	
	B-7-3	-	Due to crack

For interpretation of the obtained data, references can be made to FAO soils bulletin 42. In this Publication, the following figures are mentioned.

- If the infiltration rate after six hours remains in excess of 12.5cm/hr, gravity irrigation may not be practicable, because of difficulties with water distribution and excessive percolation losses.

- With rate in the order of magnitude of 0.1 - 0.2cm/hr surface waste of water may be excessive.

Optimal infiltration rates are considered to be between 0.7cm/hr and 3.5cm/hr

Looking to the figures of the results they show 7 - 11.2 and same funny results are also obtained due to the cracks and cavities in the subsoils.

Appendix III

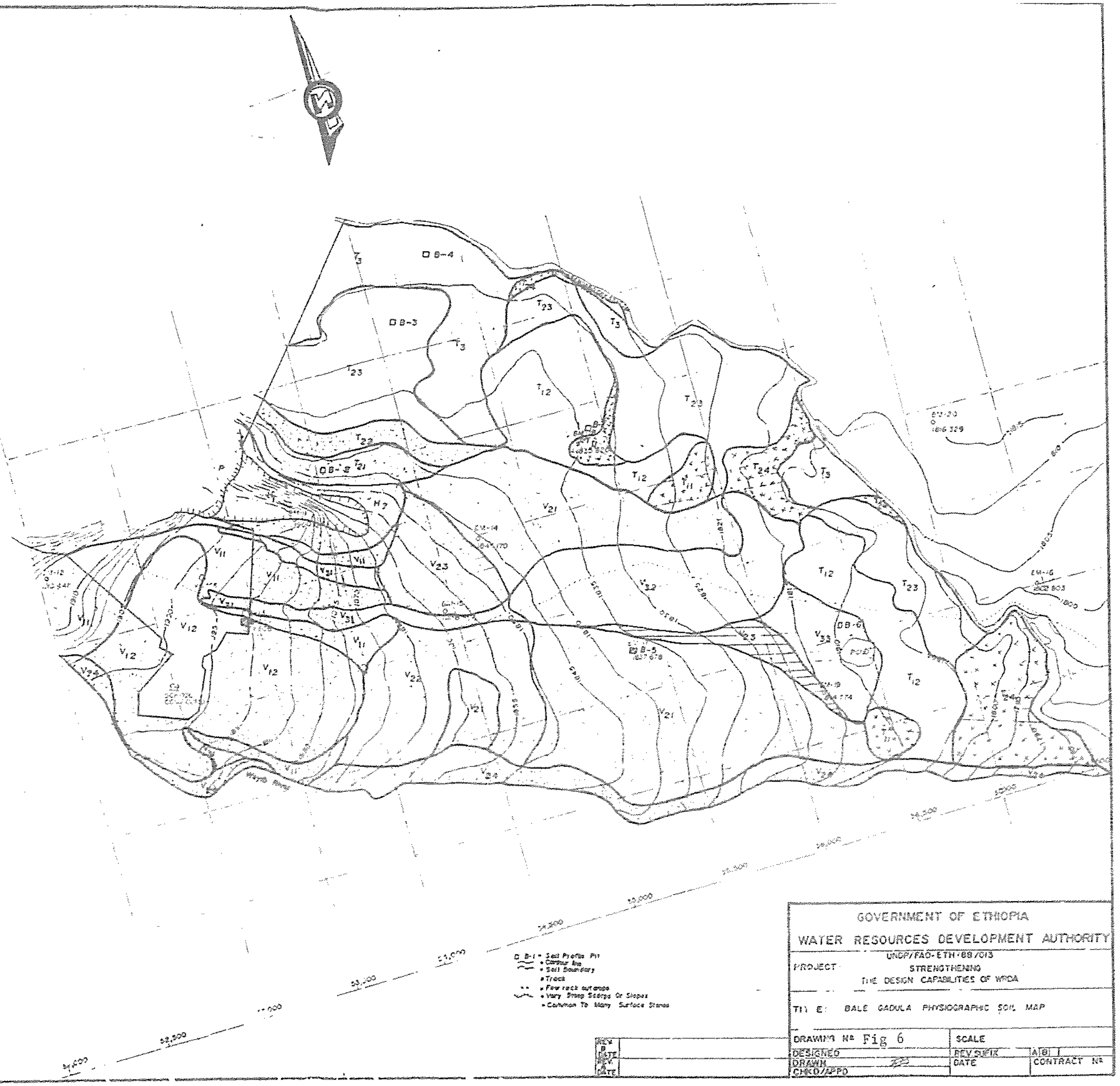
Laboratory Procedures

Description	Method	Procedure
''re	Hydrometer	Weight 50 g soil, if the soil is sandy weitht 100 g. Transfer to the dispensation cup and fill 2/3 with water. Add 10 cm3 calgon solution stir for 30 minutes pour into the sedimentation cylinder and make up to 1 dm3 with water. Heep the sedimentation cylinder in a constant temperature bath at 20 C, if this is not available keep the cylinder on the work bench. Mix the suspension very well. Note the time as soon as the cylinder is kept at rest. Take the temperature and the hydrometer reading at the end of 40 sec., 4 min and 2 hours.
PH water Ratio 1:2.5	Potentiometer	Weight 10 gm of soil sample and add 25 ml of distilled water. Shake for 30 minutes using electrical shaker and let it for overnight. Using pH meter measure the PH.
pH Potassium Chloride Ration 1:2.5	Potentiometer	Weight 10 gm of soil sample and add 25 ml of 0.01 MKCL solution shake for 15 minutes and take the pH reading
Organic cabon %	Walkely and Black Chromic acid oxidation	Take soil sample & pass it through 0.2 mm sieve weight 1 gm or less & transfer to conical flask Add 10 ml of potassium dichromate solution and swirl gently the flask to mix the reagent with the soil. Add 20 ml of conc. H2SO4. Swirl the flask and allow it to stand for about 30 minutes, add 200 ml of distilled water to each flask, place 10 ml of phosphoric acid. Cool it using ostwald pippet add two or three drops of diphenyl amine indicator solution. (Titrate the excess dichromate with Mohr'salt solution) carry out the Blank titration the same way.
Calcium Carbonate	Bernard's Calcimeter	Place 0.1 gm of soil in a conical flask using small test tubes add 10% diluted HCl in to conical flask pour the HCl from the meter. Do, triple 0.1 gm of calcium carbonate as standard
Electrical Conductivity of Saturation Extract	Conductimetry	Take 50 gm of soil and using distilled water make saturation till the soil show falling freely from spatula take the EC reading

Exchangeable cations Sodium	Ammonium Acetate method Flame photometer	Take 10 gm of soil and leach the soil by Neutral Ammonium Acetate till the total volume 250 ml Standardized the flame photometer using potassium standards and run the extract.
Calcium & Magnesium	Titration	Take 25 me the extract and titrate the extract by 0.01 N EDTA complex
CEC	Calcium Chloride	Take 10 gm of soil and saturated with 1 N CaCl2, 2H20 let it for over night and leach the soil till the solution comes 450-500 ml discard the solution and equilibrate with 0.1 N CaCl2, 2H20 replace the calcium ion with 1 N Potassium nitrate and collect in 500 volumetric flask. Titrate the exess chloride using KSCN or Mercuric nitrate and titrate the calcium ion.

PHYSIOGRAPHIC SOIL MAP LEGEND OF THE BALE-GADULA AREA

MAPPING UNIT SYMBOLS		Physiographic Description, including vegetation cover type, slope classes and depth to bedrock	Soil series name (Soil Taxonomy, FAO, 1988, variants, phases) and major soil profile characteristics	Irrigation Suitability subclasses
	P	Plateau, outside project area	not surveyed	not relevant
	H	Steep Hills and Footslopes, prod. under grassland and many surface stones		
▭	H_1	Very Steep and Rocky Summits and upper slopes	Rockland (vesicular basalt)	N_{2tr}
▭	H_2	Steep footslopes (8–9% slopes); ≤1½ m deep to bedrock	soil name (Rudic Fluvisols, rudic phase) Moderately deep, well drained brownish black, silty loam over gravels	N_{2t}
	V	Prod. Gullied and Undulating Older Valley Bottom		
	V_1	Undulating or Convex Upper Part, prod. 3–4 m deep to bedrock; Common to many surface stones (vesicular basalt)		
▭	V_{11}	Strongly sloping (4–7% slopes) upper slopes, more dissected	Kubsa soil series (Chromi-Calcic Vertisols sodic, rudic phase)	N_{1sd}
▭	V_{12}	Gently Convex Lower Slope (2½–3 slopes)	Kubsa soil series (Chromi-Hypo Calcic Vertisols, sodic, rudic phase) Very deep somewhat imperfectly drained, brownish black, cracking clays, with a calcic horizon within 125 cm depth (Repr. profile: B-11)	S_{3ds}
	V_2	Gently Undulating Lower Part, prod 5–8½ m deep to bedrock; Common to many surface stone (vesicular basalt)		
▭	V_{21}	Nearly level to very gently undulating summits (1½–2% slopes)	Wayib soil series (Pelli-Eutric Vertisol, rudic phase) Very deep, somewhat imperfectly drained, black, cracking clays (Repr. profile: B-5)	S_{2dw}
▭	V_{22}	Gentle Convex (2½–3% slopes)	Wayib soil series Rudic phase as above	S_{2dw}
▭	V_{23}	Convex (3½–4%) Slopes	Wayib soil series Rudic Phase as above	S_{3sd}
▭	V_{24}	Steep (4–7%) Sideslopes to Wayib River valley	Wayib soil series Rudic phase as above	N_{1sd}
	V_3	Nearly Level to Gently Sloping Drainage Ways and Depressions, Prod 3–5m deep to bedrock, mostly none or few surface stones		
▭	V_{31}	Narrow, Concave drainage ways (3½–4% slopes)	Wayib soil series as above but non rudic	S_{3sd}
▭	V_{32}	Broad depression without surface stones	Wayib soil series, non rudic	S_{2dw}
▭	V_{33}	Broad depression with many surface stones	Wayib soil series (Pelli-Eutric Vertisols, sodic, rudic phase) Very deep, somewhat imperfectly drained, sodic cracking clays (Repr. profil: B-6)	S_{3sd}
	T	Nearly Level River Terrace with Scattered Bush Vegetation		
	T_1	Upper Terrace		
▭	T_{11}	Slightly convex Summits up to 2½% slopes, few rock outcrops, prod. (3m deep to bedrock	Wayib soil series (Pelli-Eutric Vertisols) See T_{12} unit	$S_{3d'w}$
▭	T_{12}	Nearly level Summits, 1–1½% slopes, prod 3–4m deep to bedrock	Wayib soil series (Pelli-Eutric Vertisols, non-rudic phase) (Repr. profile: B-7)	S_{2dw}
	T_2	Middle Terrace		
▭	T_{21}	Transitional footslope below H; 6–7% slopes; many surface stones; prod > 2 m deep to bedrock	Asendabo soil series (Pelli-Hypo Calcic Vertisols, rudic phase) Very deep, Somewhat imperfectly drained, black to brownish black cracking, silty clays with a calcic horizon within 125 cm depth (Repr. profile, B-2)	N_{1sd}
▭	T_{22}	Very gently sloping (2% slopes); Common to many surface stones, prod > 5m deep to bedrock	Asendabo soil series (Pelli-Calcic Vertisols, rudic phase)	S_{2dw}
▭	T_{23}	Nearly level summits 1–1½% slopes prod. > 3m Deep to bedrock	Asendabo soil series (Pelli-Calcic Vertisols, non-rudic but sodic phase) Very deep, somewhat imperfectly drained, black, cracking, sodic, silty clays, with a calcic horizon within 125 depth (Repr. profile: B-3)	S_{2sdw}
▭	T_{24}	Sideslopes (3½–4% slopes) with few rock outcrops, prod < 3m deep to bedrock	Asendabo soil series as above, slightly rocky	$S_{3d's}$
▭	T_3	Lower Terrace Nearly level ½–1% slopes) prod 3–5m deep to bedrock	Wayib soil series (Pelli-eutric vertisols) Very deep, somewhat imperfectly drained, black, cracking clays (Repr profile B-4)	S_{2dw}
▭	A	Alluvial valleys, outside project area	Not surveyed	Not relevant
	A_1	Asendabo dry valley, with basaltic boulders		
	A_2	Wayib valley		



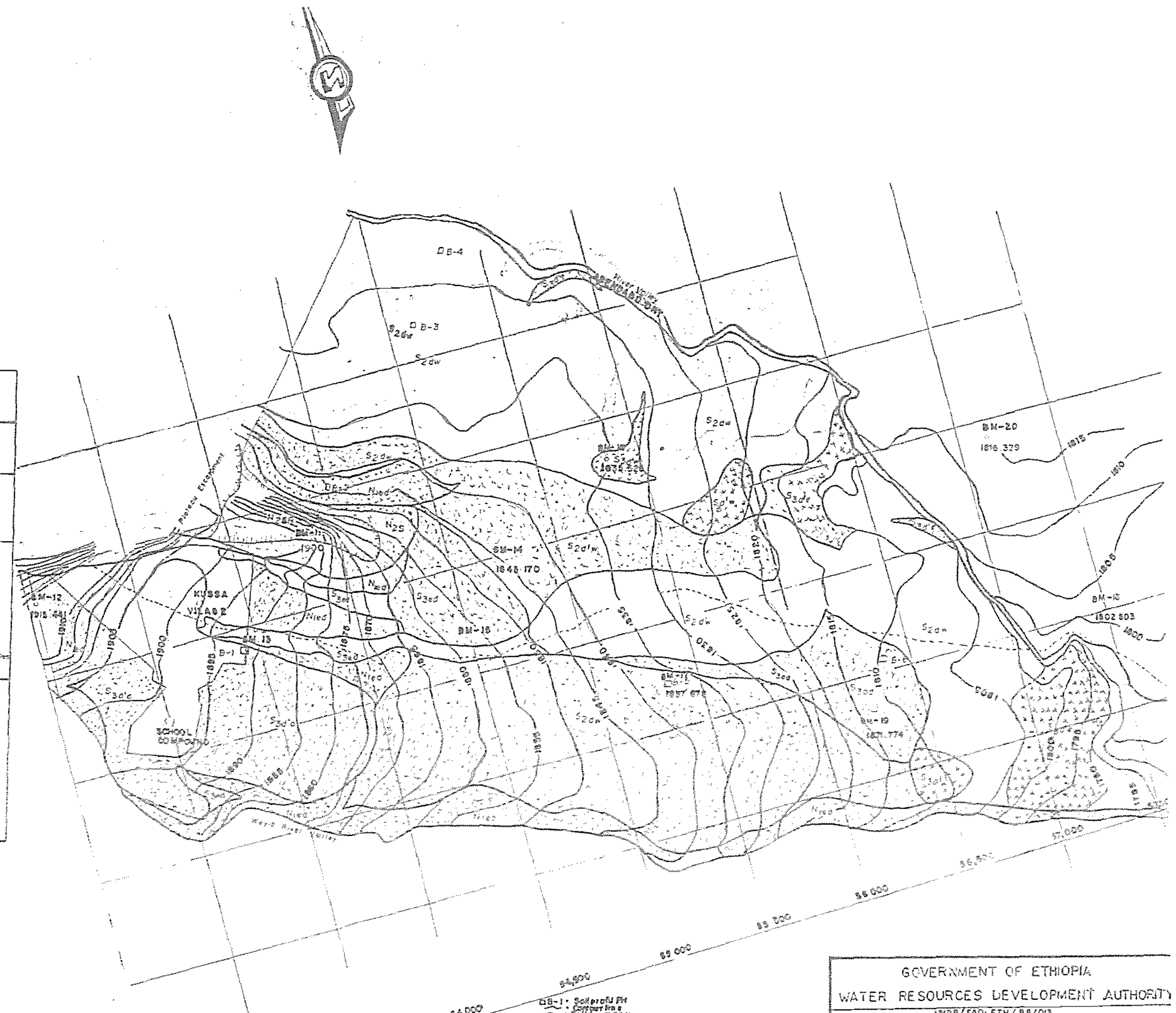
GOVERNMENT OF ETHIOPIA

WATER RESOURCES DEVELOPMENT AUTHORITY

PROJECT	UNDP/FAO-ETH/88/013 STRENGTHENING THE DESIGN CAPABILITIES OF WRDA
TITLE:	BALE GADULA PHYSIOGRAPHIC SOIL MAP
DRAWING № Fig 6	SCALE
DESIGNED	REV SUFIX
DRAWN	DATE
CHKD/APPD	CONTRACT №

IRRIGATION SUITABILITY LEGEND

Irrigation Suitability Classes and Subclasses		Type of limitations indicated by lower case letter suffixes
Sub (class) Symbols		
S	Suitable Land	
S_1	Highly suitable	not present
S_2	Moderately Suitable	d = restricted subsoil drainage
S_{2dw}		w = difficult workability
S_3	Marginally Suitable	w and d as above
S_{3de}		d' = restricted subsoil drainage in combination with limited subsoil depth: 2–3m only
$S_{3d'e}$		
S_{3ed}		a = (very) strong alkalinity/sodicity
$S_{3d'a}$		
$S_{3d'w}$		e = (sheet) erosion hazard $3\frac{1}{2}$–4% Slopes
N	Not Suitable Land	1 = presently not suitable
N_{1ed}		2 = permanently not suitable
N_{2se}		e = erosion hazard 4–7% slopes
N_{2s}		s = very steep slopes >7%
		r = rock land and/or restricted root ability
	[illegible]	



DB-1 = Soil profil Pit
= Contour line
= Soil boundary
= Track
= Very steep escarpment (Slopes)
= (Very) Few rock outcrops
= Common to many surface stones

50,500 51,000 51,500

GOVERNMENT OF ETHIOPIA	
WATER RESOURCES DEVELOPMENT AUTHORITY	
PROJECT:	UNDP/FAO-ETH/88/013 STRENGTHENING THE DESIGN CAPABILITIES OF WRDA
TITLE:	BALE SADULA IRRIGATION SUITABILITY MAP
DRAWING Nº	Fig A
DESIGNED	REV SUFIX A.B.
DRAWN	DATE
CHKD/APPD	CONTRACT Nº

REV B DATE
REV A DATE