

Physical Land Suitability Evaluation for Irrigation in the Lower Alwero River Area of Abobo, Western Ethiopia

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Abstract: Land suitability assessment plays an important role in identifying biophysical constraints and evaluating potential capacity of land and its sustainable use. Physical land suitability evaluation for irrigation was carried out in the lower Alwero river area of Abobo, western Ethiopia, following FAO methodology for general irrigation farming. The irrigation suitability of five land mapping units (LMUs): 1Ac, 1Bc, 1Ec1, 2Cc and 3Ccl were assessed by considering slope, drainage, top soil texture, sub soil texture, surface stoniness, surface coarse fragments, subsurface coarse fragment, rockiness, depth to solid rock or hardpan, lime, gypsum, electrical conductivity (EC) and exchangeable sodium percentage (ESP). The result revealed that LMU 1Ac, 1Bc and 2Cc, with total area of 22,367.9 ha (83.7%), were moderately suitable (S2). The moderate limiting factors were drainage, top soil texture and subsoil texture. On the other hand, LMU 1Ec1, covering an area of 3,677.6 ha (13.8%) was not suitable (N) for irrigation due to subsurface coarse fragments and depth to solid rock or hardpan. For all LMUs, parameters like lime, gypsum, EC and ESP were not considered as limiting factors.

Keywords: Irrigation Suitability, Land Mapping Unit, Limiting Factor

1. Introduction

Assessment of irrigation potential has prime importance for planning of sustainable food production. Irrigation is viewed as a key factor in progress towards achieving food security in Africa. However, while nearly 40% of the world's agricultural production comes from irrigated land [1], only 4 per cent (6 million ha) of the sub-Saharan African total cultivated area is irrigated. [2]. Virtually all food crops production in Ethiopia come from rainfed agriculture with the irrigation subsector accounting for only about 3% of the food crops production [3]. Irrigation of additional lands is, however, a strategic necessity for the food security in the world [4]. Therefore, assessment of soil and terrain suitability for irrigation is imperative.

Land suitability assessment plays an important role in maintaining and developing land use on a spatial basis. It

identifies the levels and geographical patterns of biophysical constraints and evaluates potential capacity of land and its sustainable use. Sustainable management of land resource requires sound policies and planning based on knowledge of these resources. So it is very important for agriculture development planning to take land resources assessment [5]. On the other hand, inappropriate land use leads to inefficient exploitation of natural resources, destruction of the land resource, poverty and other social problems. Part of the solution to the land-use problem is land evaluation in support of rational land-use planning and appropriate and sustainable use of natural resources [6]. The land use planning involves making knowledgeable decisions about land use and the environment [7].

Limits to the productive capacity of land resources are set by climate, soil and land form conditions and by the use and management applied to the land [5]. The soil characteristics are the result of pedogenesis factors and processes, which

influence their physical and chemical properties, and most importantly movement and storage of water in the soil. Assessment of soil potential for irrigation include slope, top soil texture, sub soil texture, surface stoniness, surface coarse fragments, subsurface coarse fragment, rockiness, depth to solid rock or hardpan, lime content, gypsum content, electric conductivity (EC) and exchangeable sodium percentage (ESP) [8].

Ethiopia has a significant irrigation potential identified from both available land and water resources. The total potential irrigable land in Ethiopia is estimated to be around 3.7 million hectares [9] and the potential land for irrigation development in Gambella region, where the present study was conducted, is estimated to be 500,000 ha [10]. The region has a number of perennial rivers including, Baro, Alwero, Gillo and Akobo, which can be used as potential source of irrigation water. Currently, forest land has been changed to rainfed and irrigation land due to agricultural expansion and investment regardless of irrigation suitability assessment in the study area, which may in turn leads to inappropriate land use. To use the land in an optimum way and in a sustainable manner, land suitability evaluation for irrigation is a prerequisite. Taking into account this fact, this study was initiated and carried out to assess the physical land suitability for irrigation in the lower Alwero river area of Abobo, western Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area

The study area, Abobo District, is located at 42 km south of Gambella town and about 808 km from Addis Ababa in the western direction. It lies between 07° 50' 47.3" to 08° 01' 59.3" N and 34° 28' 59.5" to 34° 34' 37.1" E. The altitude of the study area ranges from 446 to 490 meter above sea level (masl) with slope ranging from level (0.2-0.5%) to gently sloping (2-5%).

The climate of the region is influenced by the tropical monsoon which is characterized by high rainfall in the wet period from May to October and has little rainfall during the dry period from November to April [10]. The mean minimum monthly temperature of the area varies from 16.2 to 21.3°C and the mean maximum monthly temperature ranges from 32.1 to 38.2°C, whereas the average annual rainfall is 955.5 mm (Figure 2). The region is drained by a number of

perennial rivers including, Baro, Alwero, Gillo and Akobo and their tributaries.

The geology of Abobo is characterized by undifferentiated Pleistocene Holocene deposits. Granite, gneisses, schist, sandstone and basalt are the rock types existed in the region [11]. The major soils of Abobo District include Dystric and Eutric Plinthosols, Dystric and Chromic Cambisols, Eutric Vertisols and Planosols, where Cambisols occur at the upper slope north of Abobo while Plinthosols and Vertisols exist at the middle and lower slopes, respectively [10].

The Abobo district encompasses forest land, wood land, shrub land, grass land and cultivated lands occupying, 143,086, 75,227, 5,793, 62,997 and 19,854 hectares (ha), respectively [12]. The forest cover is continuously declining due to settlement and agricultural expansion. The major crops grown by farmers include maize (*Zea mays L.*), sorghum (*Sorghum bicolor*), groundnut (*Arachis hypogae*) and sesame (*Sesamum astivum*), whereas cotton (*Gossypium sp.*) and rice (*Oryza sativa L.*) are cultivated by state farms and investors operating at and around the study area.

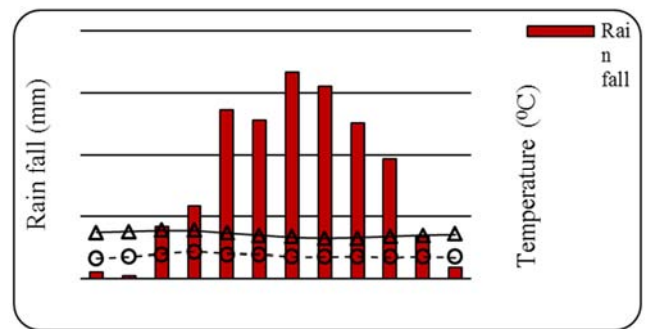


Figure 1. Mean monthly rainfall, and monthly minimum (Min) and maximum (Max) temperatures of Abobo area for the years 1975 to 2011.

2.2. Class Determining Factors for the Evaluation

As depicted in Table 1, the class determining factors for the evaluation were slope (%), drainage, top soil texture (0-25cm), sub soil texture (25-100 cm), surface stoniness (%), surface coarse fragments (0-25 cm) (%), subsurface coarse fragment (25-100 cm) (%), rockiness (%), depth to solid rock or hardpan (m), lime content (%), gypsum content (%), EC mmhos/cm (average 0-100 cm) and ESP (maximum 0-100 cm) [8, 13].

Table 1. Factor ratings for irrigation suitability.

Class determining factors	Factor ratings			
	S1	S2	S3	N
Slope (%)	<2	<5	<8	<25
Drainage	Moderate	Slow to somewhat rapid	Slow to rapid	Very slow to very rapid
Top soil texture (0-25cm)	SL to CL	LS to C-60v	S to C+60v	Sc to Cm
Sub soil texture (25-100 cm)	fSL to CL	LfS to C-60v	LmS to C+60v	Sc to Cm
Surface stoniness (%)	none	<0.1	0.1-3	3-15
Surface coarse fragments (0-25 cm) (%)	<3	3-15	15-35	<35
Subsurface coarse fragment (25-100 cm) (%)	<15	15-35	35-55	55-75

Class determining factors	Factor ratings			
	S1	S2	S3	N
Rockiness (%)	0%	0-2	2-10	10-25
Depth to solid rock or hardpan (m)	>2	1.5-2	1-1.5	0.25-1
Lime content (%)	<15	15-25	25-40	40-75
Gypsum content (%)	<5%	15%	<30	<30
EC mmhos/cm (average 0-100cm)	<4	4-8	8-16	16-30
ESP % (maximum 0-100 cm)	<5	5-15	15-25	25-45

Source: Sys *et al.* (1991b), FAO (1985)

CL: clay loam; C+60s: very fine clayey; SC: sand clay; C-60v: clay; vertic; Lfs: loamy fine sand; fSL: fine sandy loam; LS: loamy sand; Cm: massive clay; SiCm: massive silty clay; S: sand.

2.3. Description and Characterization of Land Mapping Unit

Identification of the land mapping units (LMUs) was based on slope, soil depth and soil texture. The entire study area was categorized into three slopes, four soil depths and two textural classes. Seven representative pedons (A-1 to A-7) were opened across the study area. The pedons were classified according to WRB [14] as Haplic Cambisols, Vertic Luvisols, Mollic Leptosols and Mollic Vertisols (Table 1). The pedons were further categorized into five LMUs: 1Ac, 1Bc, 1Ecl, 2Cc and 3Ccl (Figure 2) for the purpose of land suitability evaluation. The first number and the last small letter in the LMU designation indicate the slope and texture, respectively, whereas the middle capital letter indicates the soil depth. The slope categories were 1(0-1), 2 (1-2), 3 (2-5). There were two texture categories: c (clay) and cl (clay loam). There were four depth categories: A (>150 cm), B (100-150 cm), C (50-100 cm), E (<30 cm) (Table 2).

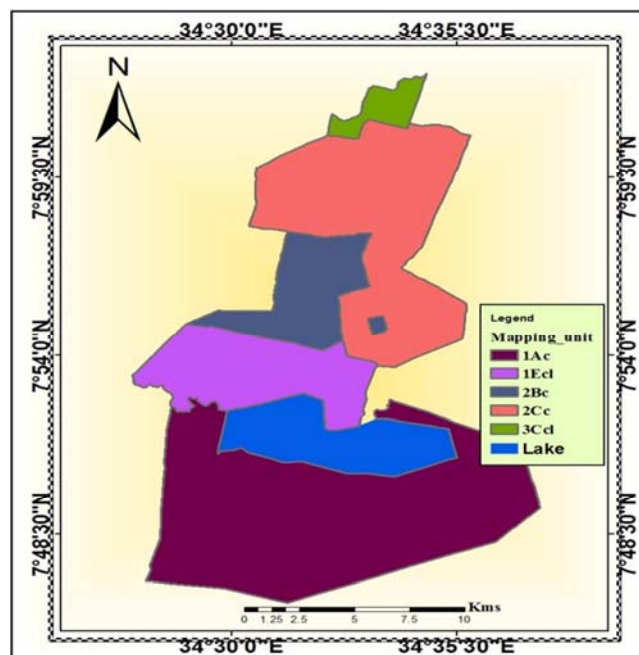


Figure 2. Mapping units of the study area.

Table 2. The identified mapping units and their area coverage in the soils of Abobo area.

Map- ping unit	Slope (%)	Soil depth (cm)	Tex- ture	Area		Soil classification
				ha	%	
1Ac	0-1	>150	C	12,17	45.3	Mollic Vertisols
1Bc	0-1	100-150	C	2,552	9.6	Mollic Vertisols
1Ecl	0-1	<30	CL	3,677	13.8	Mollic Leptosols
2Cc	1-2	50-100	C	7,698	28.8	Vertic Luvisols
3Ccl	2-5	50-100	CL	674	2.5	Haplic Cambisols

C= Clay; CL= Clay loam

2.4. Suitability Analysis and Mapping

The physical irrigation suitability analysis was carried out following FAO method for general irrigation farming [15]. The suitability was carried out by matching the LMUs topographic characteristics and soil properties with factor ratings table of the class determining factors [16]. The irrigation suitability evaluation were presented as S1 (highly suitable), S2 (moderately suitable), S3 (marginally suitable) and N (non suitable). The ArcGIS 9.3 was employed for mapping the physical irrigation suitability of the study area.

3. Results and Discussion

3.1. Characteristics of the Study Area

The topographic characteristics and the soil properties showed variation across the study area. Particle size analysis result showed that LMU 1Ecl and 3Ccl were texturally clay loam where as the rest of the LMUs were texturally clay (Table 3). The slope ranges of all the LMUs were included under highly suitable category, except for LMU 3Ccl, which was categorized under moderately suitable for irrigation. Considering drainage condition, most of the LMUs were well drained, except LMU 1Ac and 1Bc, which were imperfectly and moderately well drained.

On the other hand, surface stoniness, surface coarse fragments, subsurface coarse fragments and rockiness were almost none in most of the LMUs. However, substantial amount of subsurface coarse fragments were observed in LMU 2Cc, 1Ecl and 3Ccl (Table 3). With regards to lime, gypsum, EC and ESP contents, the values were trace to low.

Table 3. Soil description and analysis results of soils of Abobo area.

Parameters	Land mapping unit				
	1Ac	1Bc	1Ecl	2Cc	3Ccl
Slope (%)	0-1	0-1	0-1	1-2	2-5
Drainage	ID	MWD	WD	WD	WD
Top soil texture (0-25cm)	Clay	Clay	CL	Clay	CL
Sub soil texture (25-100 cm)	Clay	Clay	-	Clay	CL
Surface stoniness (%)	N	N	N	N	N
Surface fragments (0-25 cm) (%)	N	N	N	N	N
Subsurface fragments (%)	N	N	86	21	27
Rockiness (%)	N	N	N	N	N
Depth to solid rock (m)	>2	>2	0.5	1.5	1.5
Lime content (%)	0.25	0.2	0.3	0.2	0.25
Gypsum content (%)	Trace	Trace	Trace	Trace	Trace
EC mmhos/cm (average 0-100cm)	0.15	0.15	0.15	0.15	0.15
ESP (%) (maximum 0-100 cm)	0.45	0.5	0.35	0.35	0.55

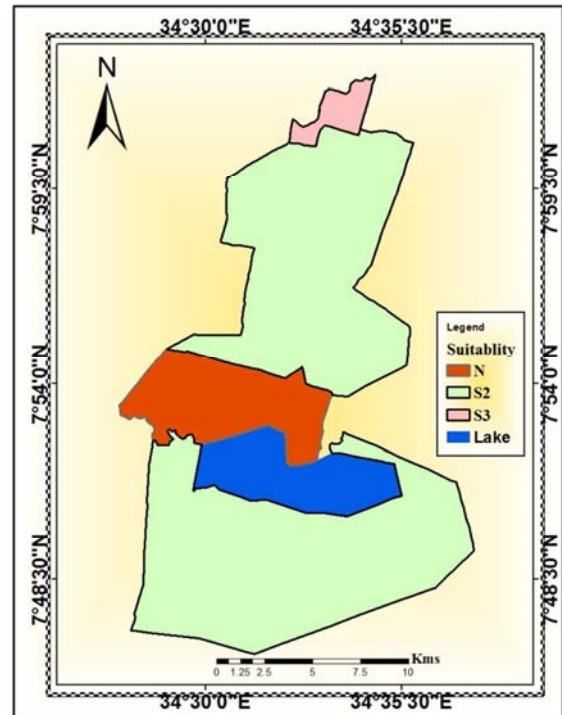
ID = Imperfectly drained; WD = Well drained; MWD = Moderately well drained; CL = Clay loam; N = None

3.2. Physical Land Suitability Evaluation for Irrigation

Physical Irrigation suitability evaluation for lower Alwero river area is presented in Table 4. The result showed that LMU 1Ac, 1Bc and 2Cc, with total area of 22,367.9 ha (83.7%), were moderately suitable (S2). The moderate limiting factors were drainage, top soil texture and subsoil texture. It was found that LMU 1Ecl, covering an area of 3,677.6 ha (13.8%) were not suitable (N) for irrigation due to subsurface coarse fragments and depth to solid rock or hardpan. On the other hand, LMU 3Ccl with an area of 674.4 ha (2.5%) was marginally suitable (S3) for irrigation. The most limiting factor in using irrigation in this LMU would be subsurface coarse fragments; slope also has moderate limitation for this LMU. For all LMUs, parameters like lime, gypsum, EC and ESP were not considered as limiting factors. However, salinity and alkalinity were reported as main limiting factors for irrigation suitability elsewhere [5, 17-20].

Table 4. Irrigation suitability evaluation for lower Alwero river area.

Class determining factors	Land mapping unit				
	1Ac	1Bc	1Ecl	2Cc	3Ccl
Slope (%)	S1	S1	S1	S1	S2
Drainage	S2	S2	S1	S1	S1
Top soil texture (0-25cm)	S2	S2	S1	S2	S1
Sub soil texture (25-100 cm)	S2	S2	S1	S2	S1
Surface stoniness (%)	S1	S1	S1	S1	S1
Surface fragments (0-25 cm) (%)	S1	S1	S1	S1	S1
Subsurface fragments (%)	S1	S1	N	S2	S3
Rockiness (%)	S1	S1	S1	S1	S1
Depth to solid rock (m)	S1	S1	N	S2	S2
Lime content (%)	S1	S1	S1	S1	S1
Gypsum content (%)	S1	S1	S1	S1	S1
EC mmhos/cm (average 0-100cm)	S1	S1	S1	S1	S1
ESP (%) (maximum 0-100 cm)	S1	S1	S1	S1	S1
Over all suitability	S2	S2	N	S2	S3

**Figure 3.** Physical land suitability evaluation map for Irrigation in the lower Alwero river area of Abobo, western Ethiopia.

4. Conclusion

In this study, the physical irrigation suitability of five LMUs was assessed in the lower Alwero river area of Abobo, western Ethiopia. The result revealed that about 83.7% and 2.5% of the study area was moderately (S2) and marginally suitable (S3) for irrigation, respectively; drainage, top soil texture and subsoil texture being the moderately limiting factors. The remaining 14% of the area was not suitable for irrigation due to shallow soil depth.

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