Original Article

Land Suitability Assessment for Sorghum and Maize Crops Using a SLA and GIS Approach in Dera Wereda, ANRS, Ethiopia

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Abstract

The land suitability evaluation for sorghum and maize found in the study area has been done in order to define the land fitness for specific land uses as well as estimating the possible increase of crop production after improving land management. Sorghum and maize are cereals that are considered in the suitability appreciation using GIS to match the suitability for two crops based on their biophysical requirements and the characteristics of land in Dera wereda. The methodology employed combines land quality attributes that most influence crop suitability and biophysical requirements of selected crops for analysis. The suitability assessment for both crops was conducted using the method as described in FAO guidelines of land evaluation for rainfed agriculture. The results of the weighted overlay for biophysical suitability evaluation using the Simple Limitation Approach (SLA) identified that about 40.25%, 59.75%, and 70.67%, 27.36% of the total area of land in the wereda was evaluated as a moderately and marginally suitable for sorghum and maize production, respectively. However, only small patches of the area were weighted as highly suitable and not suitable for maize production. As a result, the largest proportion of the land was only moderately suitable for maize (70.67%), but marginally suitable for sorghum production (59.75%) in the wereda. Therefore, a GIS based approach for evaluating land in terms of potentials and constraints as a useful tool in assessing land for sustainable agricultural planning cannot be overlooked in this study.

Keywords: *suitability evaluation, biophysical requirements, FAO method, GIS based approach, Simple Limitation Approach (SLA), sustainable agricultural planning*

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Introduction

The problem of selecting the correct land for the cultivation of a certain agriculture product is a long-standing and mainly empirical issue (Pirbalouti, et al., 2011). Although many researchers and institutions have tried to provide a framework for optimal agricultural land use, it is suspected that much agricultural land used currently is below its optimal capability in different parts of the world. The classification of land into different capability classes is useful in that some soil, climate, topographic and other attributes of land can be suitable for specific crops and unsuitable for others; therefore precision, of land utilization types is necessary. According to FAO (1976), however, capability is viewed by some as the inherent capacity of land to perform at a given level for a general use, and suitability as a statement of the adaptability of a given area for a specific kind of land use; others see capability as a classification of land primarily in relation to degradation hazards, whilst some regard the terms “suitability” and “capability” as interchangeable. The evaluation process, therefore, provides information on the major constraints and opportunities for the use of land for particular use types which will guide decision-makers on how resources are optimally utilized. It is a particularly important consideration for environmental land use planning. In addition as cited in Ahmed (2012), it also allows in identifying the main limiting factors for agricultural production and enables stakeholders, such as land users, land use planners, and agricultural support services to develop crop management able to overcome such constraints and increase productivity.

Agriculture is the main stay of the national economy employing the greatest proportion of the country population mainly of rural areas. However, it is still in its primitive stage although there are some improvements in inputs in recent times. The production of cereal crops, such as maize and sorghum is economically and socially important in Ethiopia. It is because maize, grown at greater altitudinal ranges, is a staple food in some parts of Ethiopia. In addition, sorghum is commonly grown in warm, moist lowlands and the major semi arid areas of Ethiopia where the amount of precipitation is lower in that it results in lower soil moisture condition and lower growing periods.

On the other hand, besides its importance as a domestic food crop, maize is becoming one of the export items of the agricultural productions of the national economy.

Cereals, such as teff, barley, maize, sorghum, oats, millet and wheat make up 85% and 90% of the total production of field crops and account for over 90% of input consumption in Ethiopia (CSA, 2000). However, accounting to Pender and Gebremedhin (2006) cited in Ahmed (2011), low productivity remains the major constraint of cereal cultivation where yields are less than 1 ton per hectare due to poor technology, increasing degradation of farm lands, low input and other factors. As a result, food security is one of the national issues that still attract researchers and policy makers in the field of sustainable land use planning to ensure production that does not compromise the needs of the coming generation.

Maize is the second most widely cultivated cereal in Ethiopia in terms of area but forms the largest share of production by volume (18%), and appears to be increasing (Chamberlin & Schmidt, 2011). The grains of maize are ground into flour, fermented and made into *injera* and flat bread in different parts of the country. Commonly, the grains are also used as an ingredient of home-brewed alcoholic drinks, such as *araqi*. In Ethiopia maize and sorghum straw from threshed grains (residues) can be used as fodder for animals and source of energy to households complementary to fuel wood and cow dung. Besides, it can also act as a biological measure to improve soil fertility when it is left on the farmland until the next growing season. Therefore, evaluating land suitability for comparable crops in the study area is most important for selecting optimum land use types which will bring sustainable agricultural production.

Objectives

The aim of this study is to determine physical land suitability for sorghum and Maize crops using a GIS and Remote Sensing approach. In addition, it is to identify areas with physical constraints for a range of land uses and the management requirements that will ensure that a particular land use can be sustained without causing significant on-site or off-site degradation to land quality.

Methods and Materials

Study Area Description

Location

Dera is one of the *wereda*s in the Amhara Region of Ethiopia. Part of Debub Gondar Zone, Dera is bordered on the south by the Abbay River which separates it from West Gojjam Zone, on the west by Lake Tana, on the north separated by Gumara River from Fogera, on the northeast by Misraq Estie, and on the east by Mierab Estie bordering Wedjo River. Towns in Dera include Ambasame, Arb Gebeya, Hamusit, and Qorata. The *wereda* lies between $37^{0}25'45''$E-$37^{0}54'10''$ E longitude and $11^{0}23'15''$-$11^{0}53'30''$N latitude with an area of 152,524.13 ha as shown in Figure 3.1.

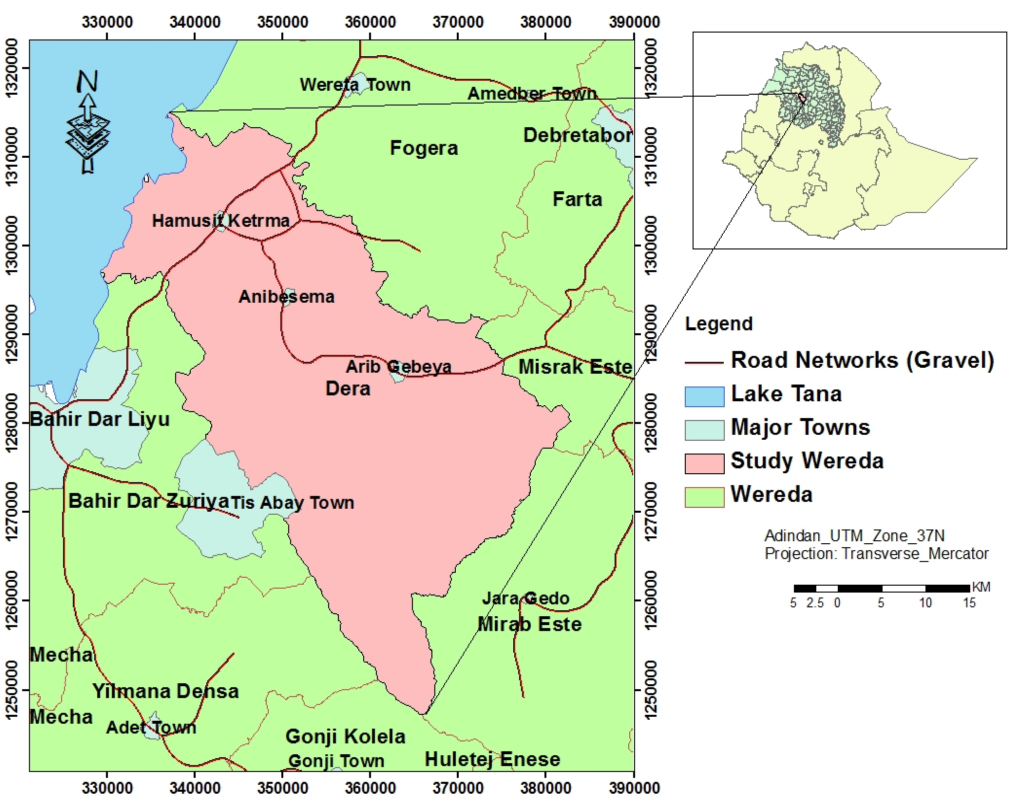

Figure 3.1: Location Map of Dera *wereda* (Ebrahim Esa, 2013)

Physiographic Setting

Dera *wereda* is composed of diverse physiographic settings. The present physiographic setting of the *wereda* is the result of basaltic volcanism that forms the plateau in central and southeast, and the rest is later eroded and dissected by the Gelda, Alata, and Gebetie rivers in the southeast, and the Abbay River bordering West Gojjam Zone in the south-eastern margin. As it is obtained from SRTM image (30 m × 30 m), the altitude ranges from 1,432 in Lake Tana lowland to 2,625 m A.S.L. in the southeast where higher levels of dissection occur with an elevation range of 1,193 m A.S.L. as shown in figure 3.2.

The study area is characterized by volcanic ridges and hills surrounding the *wereda* in the southern and south-western parts, with a relatively gentle and flat land forms in eastern and central parts of the plateau, and the northern part bordering Fogera *wereda* and Lake Tana. That is, the area slopes downwards in the southwest bordering the Abbay River and in the north and north-western parts into Lake Tana.

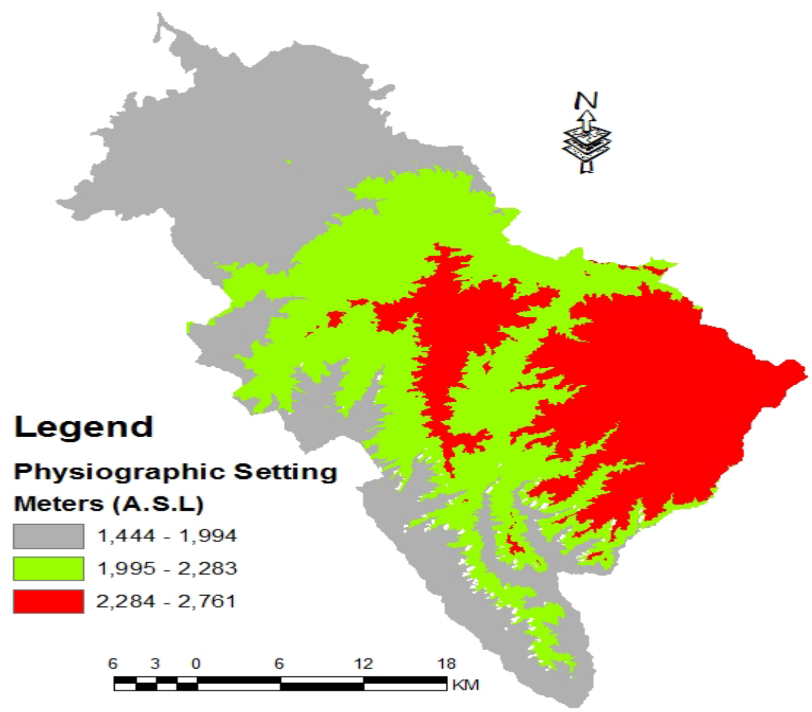

Figure 3.2: The digital elevation model showing the physiographic setting classified from SRTM (30×30m)

The Climate and Agro-ecology

The climate is generally sub-tropical with the average rainfall amount of 1,228.29 mm (taking the mean monthly rainfall of the station with in the *wereda* and other nearby stations) and a maximum effective rainy season of 120 or more days as shown in Tables 3.1 and 3.2. The rainfall pattern is predominantly uni-modal with a long rainy season category (June to early October). The local climate generally is in the *weyna dega* (largest coverage) and *dega* category (Hurni, 1998). The agro-climatic regime of Dera *wereda* is characterized by an average length of growing period ranging from 120-240 days per year (Hurni, 1998).

Rainfall coefficient is the ratio between mean monthly rainfall and one twelfth of the annual mean of the total rainfall (Daniel, 1977). Rainy and dry months in the given hydrologic year (Table 4.5) are classified based on the value of the rainfall coefficient.

$\mathbf{Rc = Pm/(\frac{Py}{12})}$ Where, **RC** = Rainfall coefficient; **Pm** =Mean monthly rainfall depth; and **Py** = Mean annual rainfall depth.

Table 3.1 Mean monthly rainfall and Monthly rainfall coefficient.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
7.14	14.99	29.73	26.68	29.51	153.97	340.72	334.87	198.16	57.46	18.69	16.37	1228.29
0.07	0.15	0.29	0.26	0.29	1.50	3.33	3.27	1.94	0.56	0.18	0.16	RC

Table 3.2 Classification Schemes of monthly rainfall values

Dry Months Rc<0.6	Rainy Months			
	Small rainfall months o.6<Rc<0.9	Moderate C rainfall months 1<Rc<1.9	High C rainfall months 2<Rc<2.9	Very High Rainfall months Rc ≥3
Jan, Feb, Mar, Apr and May	No	June and Sept	No	Jul and Aug

Based on the Agro-ecological zone (AEZ) classification method which combines growing periods with temperature and moisture regimes, the *wereda* has three agro-ecological zones associated with distinct soil, climate and land uses. Tepid moist mid-highlands accounted the highest coverage, i.e., 139,597.89 ha (91.53%) followed by warm moist lowlands of 11,380.61 ha (7.46%) in the South, and a water body of 1,363.93 ha (0.89%) adjacent to Lake Tana as shown in Figure 3.3 and Table 3.3. In traditional climate classifications of Ethiopia, the *wereda* lies within *weyna dega* and Moist *qolla* category with altitude and rainfall ranging from 1,500-2,300 m and 500-1,500 m A.S.L., and 900-1,400 mm/y and less than 900 mm/y, respectively (Hurni, 1998). Based on this classification of local climate system, the mean annual temperature ranges from 20.0–17.5/16.0°C in *weyna dega* (midlands) to 27.5 – 20.0°C in *qolla*, i.e., lowlands (Temesgen, 2010). On the other hand, a survey of the land by the Ethiopian Electric Power Corporation (EEPCO) in this *wereda* shows that 46% is arable or cultivable, 6% pasture, 1% forest or shrubland, 25% covered with water and the remaining 25.9% is considered degraded or other (ESIA, 2006).

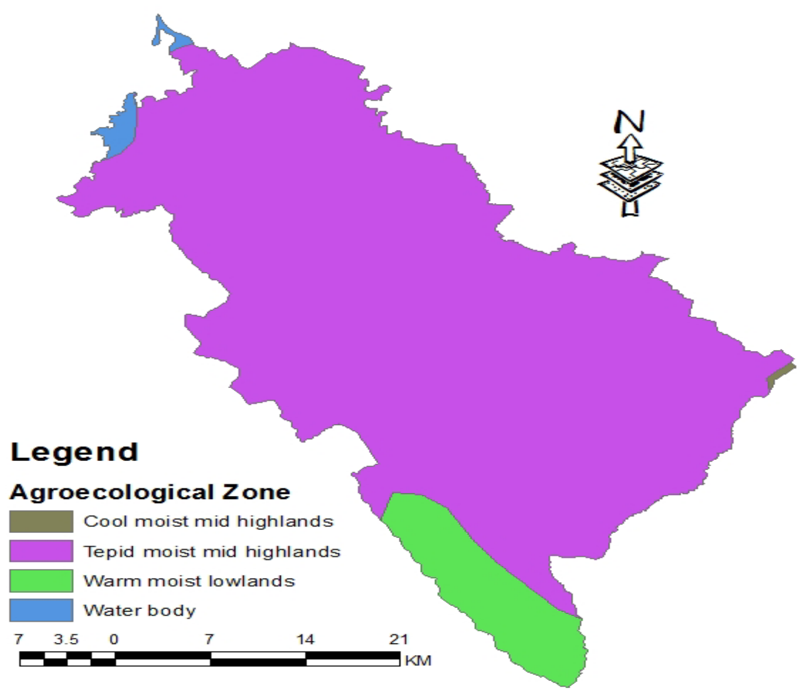

Figure 3.3: Agro-ecological map of Dera *wereda* representing the major zones (adapted from MOARD, 2013)

Table 3.3 Agroecology with area coverage

Agroecology zone	Area (ha)	%
Water body	1,363.93	0.89
Cool moist mid highlands	171,656,021	0.11
Warm moist lowlands	11,380.61	7.46
Tepid moist midlands	139,597.89	91.53
Total		100

Soil

The soil map of the district was obtained from the National Database at the FDRE Ministry of Agriculture and 10 major soil types were distinguished in the *wereda*. Out of the total area of the *wereda*, the soil is predominantly of Dystric gleysols, Dystric Nitosols, Eutric Nitosol and Orthic luvisol comprising 78.7416% while others hold small patches of land of the *wereda* as shown in Figure 3.4 and Table 3.4 below. The soils found in the *wereda* are diverse in that they do have influences on the land use and land cover of the *wereda*, particularly relevant in agriculture. The characteristics of the soils intern determine land use and/or land type of vegetation and crop grown in an area.

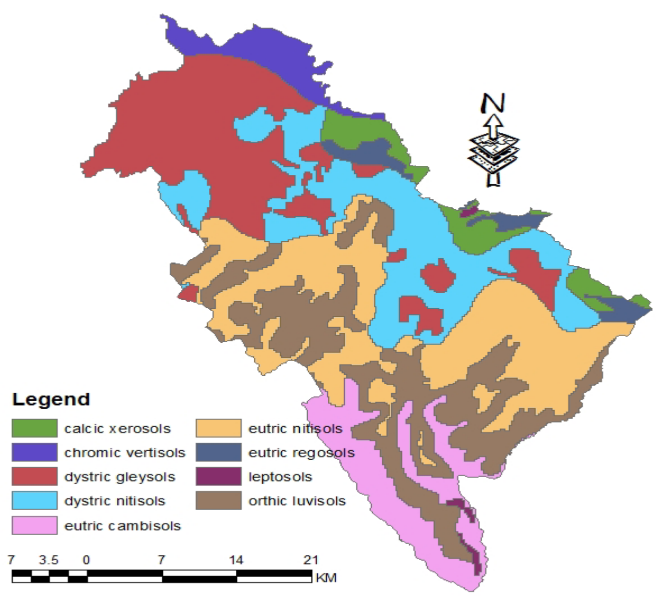

Figure 3.4: Soil map of Dera *wereda* (Adapted from MOARD, 2013)

Table 3.4 Major types of Soils (adapted from MOARD, 2013)

Soil Type	Area (ha)	%
Chromic vertisol	5,954.9	3.90
Dystric gleysols	31,269.68	20.50
Dystric Nitosols	25,895.59	16.98
Eutric Cambisols	14,013.05	9.19
Eutric Nitosol	33,823.34	22.18
Eutric regosol	3,549.53	2.33
Leptosol	654.67	0.43
Orthic luvisol	29,103.4	19.08
Calcic xerosol	6,479.87	4.25
No data	1,770.03	1.16
	152,514.06	**100**

Methodology

The methodology used for the evaluation of land suitability was based on FAO, 1976 guidelines of land evaluation involving matching land characteristics against crop requirements and assigning a suitability rate for each land characteristic using GIS. It was used to match the suitability for two varieties of crops, such as highland maize and sorghum based on their biological requirements and the quality or characteristics of land. The FAO approach defines land suitability as fitness of a given type of land to support a defined use (FAO, 1976; 2007). The basic idea underlying the proposed method of land suitability classification (FAO approach) is that the land should be rated only on its value for a specific purpose (Ahmed, 2012). That means the relevant biophysical variables of soil and climate and topography were considered for suitability analysis. The values of the parameter calculated for each variable provide different suitability classes for each crop in each land mapping unit after it has been rated for each land characteristics as shown in Figure 3.5.

According to the classification proposed by FAO (1976), five different classes, ranging from “Unsuitable” to “Highly Suitable”, whose codes are recognized and constituted by a capital letter (indicating the order) and a number (indicating the class), identify land suitability for a certain purpose as shown in Table 3.5.

Table 3.5 Suitability classes and their description (FAO, 1976)

Suitability Class	Description
Class S1: Highly Suitable	Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.
Class S2: Moderately Suitable	Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land.
Class S3: Marginally Suitable	Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.
Class N1 Currently Not Suitable	Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner.
Class N2: Permanently Not Suitable	Land having limitations which appear as severe as to preclude any possibilities of successful sustained use of the land in the given manner.

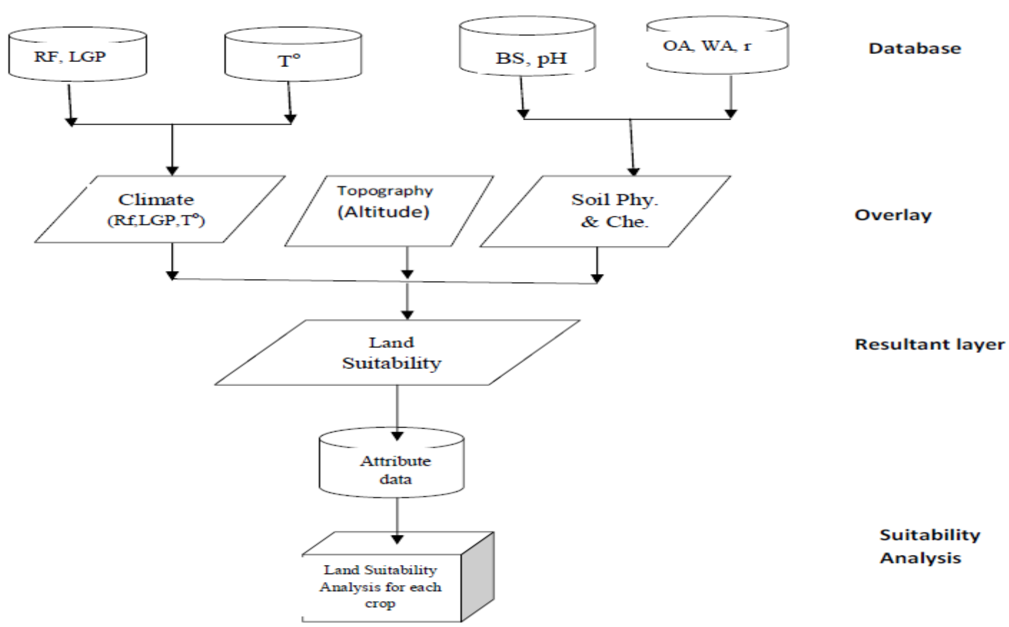

Figure 3.5 Schematic diagram of suitability evaluation process (Ebrahim Esa, 2013)

Soil Data Base

Soil attributes used for suitability evaluation such as oxygen availability (porosity/texture), water availability (soil drainage); base saturation and pH were used to evaluate land quality for sorghum and maize crops. These have been derived from the essential chemical and physical properties of soils found in the study area using soil units from FAO-UNESCO soil classification system and extracted for the purpose at hand. The soil quality index comprising the physical and chemical parameters combined to form a thematic layer generated in Arc GIS 10 environment.

Climate Database

Climatic variables relevant in the suitability evaluation were mean annual temperature and rainfall. This has been obtained from the National meteorological Service Agency database and generated from local agroecology information after which a thematic layer on mean annual rainfall/growing precipitation, length of growing period (LGP), and mean annual temperature used to evaluate this characteristic were extracted.

Suitability Analysis

The diagnostic factors of each thematic layer were assigned values of factor rating as shown in Tables 3.7. These factor ratings represent values indicating how well each land use requirement is satisfied by particular conditions of the corresponding land quality (FAO, 1984). The ratings are signified by lower case letters to avoid confusion with land suitability ratings of land units which are the end products of the evaluation process. This can be done through comparing land quality against the corresponding crop requirement value. The resultant suitability rating values for each category is summarized using the optimum limitation criteria where the lowest suitability rating value in each category is considered to produce a thematic layer. Finally, the evaluation model is defined using the value of factor rating as suitability *(S) =f (C*T*SPhy*SChe)*. The weighted overlay process of these layers was performed to produce a resultant polygonal layer upon which the evaluation model was applied using GIS.

Biophysical Requirements

Table 3.6 Rating for crop requirement of maize in rainfed agriculture in Dera *wereda*, SW Ethiopian Highlands (modified from Sys, et al. 1991; Hurni, 1998; and Driessen and Deckers (eds), 2001).

	Land Use Requirements		**Class, degree of limitation and rating scale**			
Land Quality	**Diagnostic Factor/ Land Characteristics**	**Unit**	**S1 (100-85)**	**S2 (95-60)**	**S3(60-40)**	**N (<40)**
Topogra-phy	Elevation	M	1500-2200	1000-1500/ 2200-2400	2400-3000	<1000/ >3000
Climate	Mean Length of growing period/LGP	Days/y	140-220	120-140	220-270	<120/>300
	Total Growing Season RF/ MARF	Mm	500-1200	1200-1600/ 500-400	>1600/ 400-300	-
	Mean Growing Temp	0C	22-32	20-16/ 32-35	16-14/ 35-40	-
Soil (Phy.)	Water Ava. (Drainage)	-	Well drained	Moderate	Poor	No drainage
	Oxygen Ava. (texture)	-	Loamy & Silty loam	Clay loam	Silt-clay	Clay
	Soil depth (r)	M	>2m	1.5-1.9	1.0-1.4	<0.9
Soil (Che.)	PH	-	5.8-7.8	7.8-8.5	5.2-5.8	>8.5/ <5.2
	BS	%	>75	75-50	-	<50

Table 3.7 Rating for crop requirement of sorghum in rainfed agriculture in Dera *wereda*, SW Ethiopian Highlands (Modified from Sys, et al., 1991; Hurni, 1998; and Driessen and Deckers (eds), 2001)

Land Use Requirements			Class, degree of limitation and rating scale			
Land Quality	**Diagnostic Factor/ Land Characteristics**	**Unit**	**S1 (100-85)**	**S2 (85-60)**	**S3 (60-40)**	**N1 (<40)**
Topography	Elevation	m	500–1,500/1,800	1,500-2,400	-	>2,500/ <500
Climate Chara.	Mean Length of growing period/LGP	Days	≤120	120-140	140-220	>220
	Total Growing Season RF/ MARF	Mm	400-900	300-400/ 900-1,200	300-150/ 1,200 -1,400	-
	Mean Growing Temp	0C	24-32	23-18 / >32	18-15	-
Soil (Phy.)	Water Ava. (Drainage)	-	Moderate	Poor	Well	No
	Oxygen Ava. (texture)	-	Sic, si, sc, l si, sil, c<60v	Sl, c>60v	S, ls, s, lcs	cm, sicm, cs
	Soil depth (r)	Cm	>90	90-50	50-20	<20
Soil (Che.)	PH	-	5.5-8.2	5.3-5.5/ 8.2-8.3	5.2-5.3/ 8.3-8.5	>8.5/ <5.2
	BS	%	>50	50-35	35-15	<15

Results and Discussion

It is difficult if not impossible to directly measure land qualities in a routine survey, but their severity levels or single-factor ratings for each evaluation unit must be inferred from one or more diagnostic land characteristics. It is because; diagnostic land characteristics are land characteristics that will be used to evaluate the land quality. Therefore, these must be measured at the appropriate scale against the land. There may be a choice of land characteristics, in which case the simplest or cheapest to determine should be used. In other words, assigning an evaluation unit to its correct severity level of land quality, given data values for each diagnostic land characteristics, is the most difficult analytical problem in land evaluation, and requires a great skill of judgment. In this study, however, the researcher used a combination of matching tables and GIS to properly handle the process and effectively undertake suitability evaluation for maize and sorghum crops.

Topography

The polygon map for elevation indicated that about 40.12% (60,844.13ha), 34.15 %(51,790.43ha) and 25.73% (39027.3 ha) of the study areas are placed in marginally suitable (S3), highly suitable (S1), and moderately suitable (S2) categories, respectively for maize crop while about 40.12%, 34.15% and 25.73% of the study area fall under highly suitable (S1), moderately suitable (S2), and marginally suitable (S3) categories, respectively for sorghum (Figure 4.1 and Table 4.1).

Table 4.1 Topographic suitability class rating values for maize and sorghum

No	Elevation (m)	Area		Suitability values	
		Hectare	%	Maize	Sorghum
1	1,444-1,994	60,844.13	40.12	S3	S1
2	1,995-2,283	51,790.43	34.15	S1	S2
3	>2,284	39,027.30	25.73	S2	S3

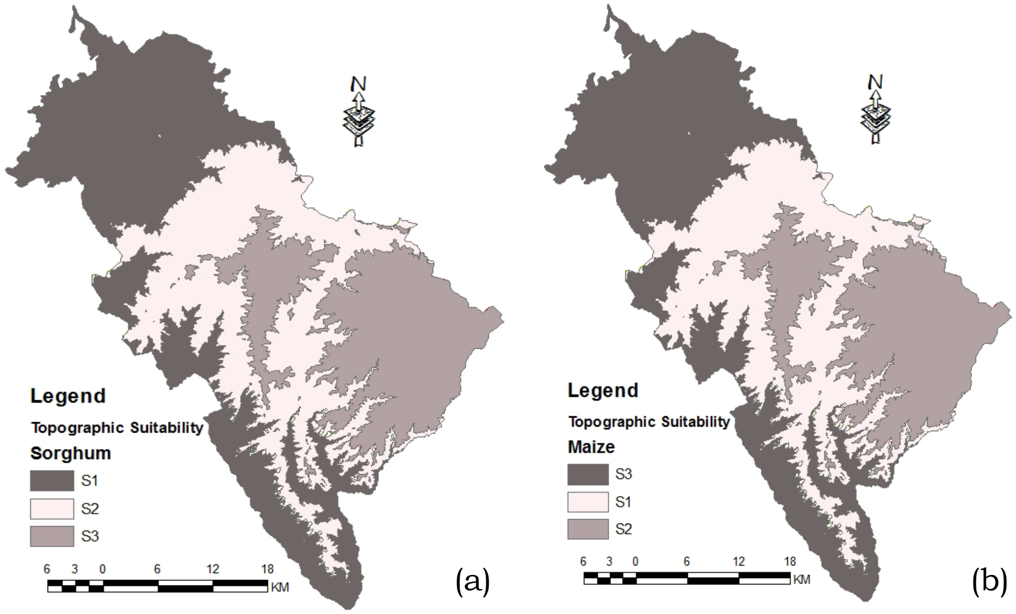

Figure 4.1: Topographic suitability of sorghum (a) and maize (b) for sustainable rain-fed agriculture (Ebrahim Esa, 2013)

Climate

The results of overlay process for climate variables (Length of growing period, mean annual RF and temperature) are extracted from the local agro-ecologic information. Based on the local agro-ecological zoning, the *wereda* is characterized by the associated climatic conditions such as mean annual temperature (20 to17.5/16^{0}C) and (27.5 to 20^{0}C) for cool sub-humid climate (*weyna dega*) and semiarid (moist *qolla*) area, respectively (Belay Simane, et al, 2013). However, the length of growing period (days/year) and mean annual rainfall indicated that there are no significant changes such as it ranges from 120 to 240 days/y; and 900-1,400 mm for warm moist (sub-humid) climate and warm moist lowlands (warm semiarid) areas, respectively (Hurni, 1998).

Therefore, almost all areas of the *wereda*, i.e., 99 %, are evaluated as marginally suitable (S3) and moderately suitable (S2) for sustainable sorghum and maize cultivation under rainfed agriculture (Figure 4.2 and Table 4.2). The rest 0.89 % of the area is unsuitable for both maize and sorghum production due to the permanent cover of the land with water throughout the

Table 4.2 Climatic factors suitability classes for maize and sorghum crops (Ebrahim Esa, 2013)

No.	Climate Characteristics	Maize Suitability		Sorghum	
		Tepid Moist mid lands	Moist lowlands	Tepid Moist mid lands	Moist lowlands
1	Mean Length of growing period/LGP	S2	S2	S2	S2
2	Mean Annual RF	S1/S2	S1/S2	S2/S3	S2/S3
3	Mean Growing Temp	S2	S1/S2	S2	S1/S2

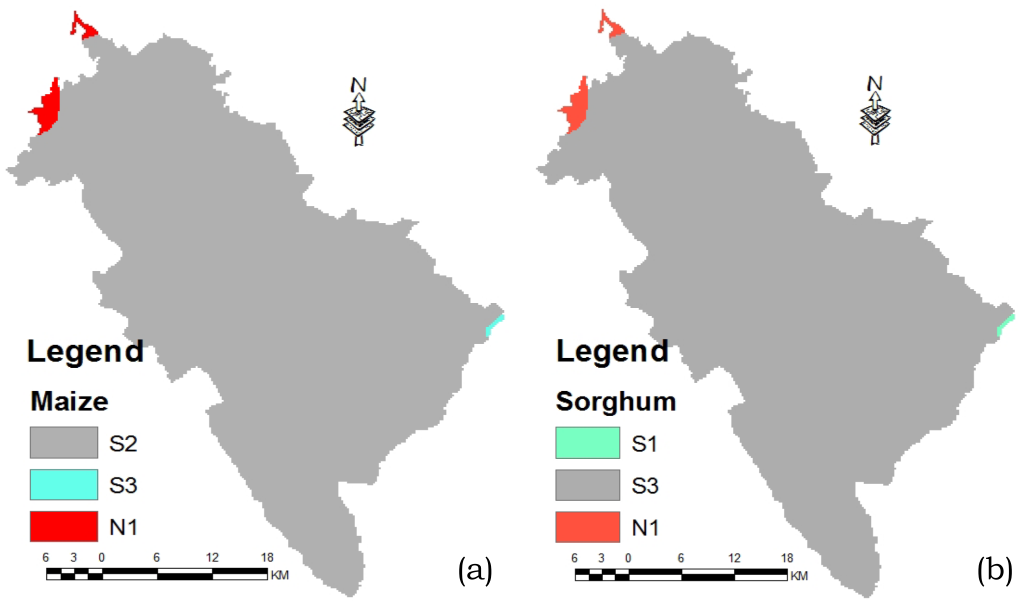

Figure 4.2: Climatic factors suitability map of maize (a) and sorghum (b) for rainfed agriculture (Ebrahim Esa, 2013)

year causing poor drainage and root respiration for both crops (Figure 4.2 and Table 4.2). However, only a small patch of the land (0.11%) on the extreme east of the *wereda* is highly suitable for sorghum and marginally suitable for maize production.

Soil Characteristics

The result of overlay process for soil physical and chemical properties (water availability, texture, base saturation, and pH) was undertaken by a simple limitation approach (SLA). The result of the analysis indicated that most of the land was generally evaluated as moderately and marginally suitable class with 32.62% and 58.80% for maize production, respectively (Figure 4.3 and Table 4.3). However, only small patches of the land were regarded as highly suitable (S1) and not suitable (N1) for maize production. On the other hand, the result of the analysis for sorghum production indicated that the study area was largely evaluated as moderately suitable (S2) and marginally suitable class with 22.51% and 52.79% area coverage, respectively. However, about 20.45% of the land was evaluated as not suitable class as shown in Figure 4.3 and Table 4.3. Therefore, an extremely small area is highly suitable (S1) for the production of maize and sorghum in the *wereda*.

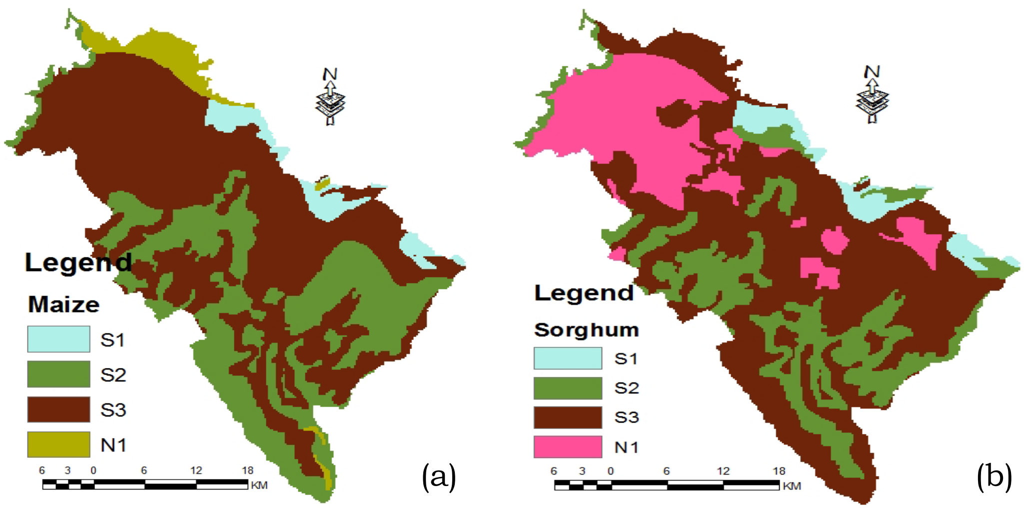

Figure 4.3: Soil suitability class for maize (a) sorghum (b) for rainfed agriculture (Ebrahim Esa, 2013)

Table 4.3 (a) and (b) representing soil suitability classes and limiting factors of Maize and Sorghum for rainfed agriculture, respectively (Ebrahim Esa, 2013)

No.	**Area Coverage**		**Soil Suitability classes for maize**	**Limiting factors**
	Hectare	**%**		
(a)	6,503.48	4.26	S1	None
	49,764.16	32.62	S2	Flooding
	89,700.26	58.80	S3	Flooding, Workability, drainage, erosion
	6,571.63	4.31	N1	Flooding, workability
(b)	**Hectare**	**%**	**Soil Suitability classes for sorghum**	**Limiting factors**
	6,489.48	4.25	S1	None
	34,333.80	22.51	S2	drainage, workability, erosion
	80,524.00	52.79	S3	Flooding, drainage, workability, erosion
	31,188.60	20.45	N1	Flooding, drainage, workability, etc.

Total Suitability

The final suitability maps resulting from the spatial overlay of factors and the corresponding areal coverage in Dera *wereda* are shown in Figure 4.4 and Table 4.4 for sorghum and maize, respectively. The three parameter overlays for land suitability evaluations are given equal weights assuming that they have similar influences in determining the suitability of the land for sustainable production of sorghum and maize crops in rainfed agriculture. The results of the weighted overlay for biophysical (climate, topography and soil) suitability evaluation using the simple limitation approach (SLA) identified that 40.25% and 59.75%, and 70.67% and 27.36% of the total land of the *wereda* was evaluated as moderately and marginally suitable area for sorghum and maize production, respectively. However, only small patches of the area were weighted as highly suitable and not suitable for maize production.

Table 4.4 Suitability classes and limiting factors for Sorghum and Maize in Dera *wereda*, respectively.

	Sorghum		Maize	
Suitability classes	Area (ha)	%	Area (ha)	%
S1	-	-	2,865.35	1.90
S2	60,780.17	40.25	106,684.07	70.67
S3	90,241.11	59.75	41,304.21	27.36
N1	-	-	107.03	0.07

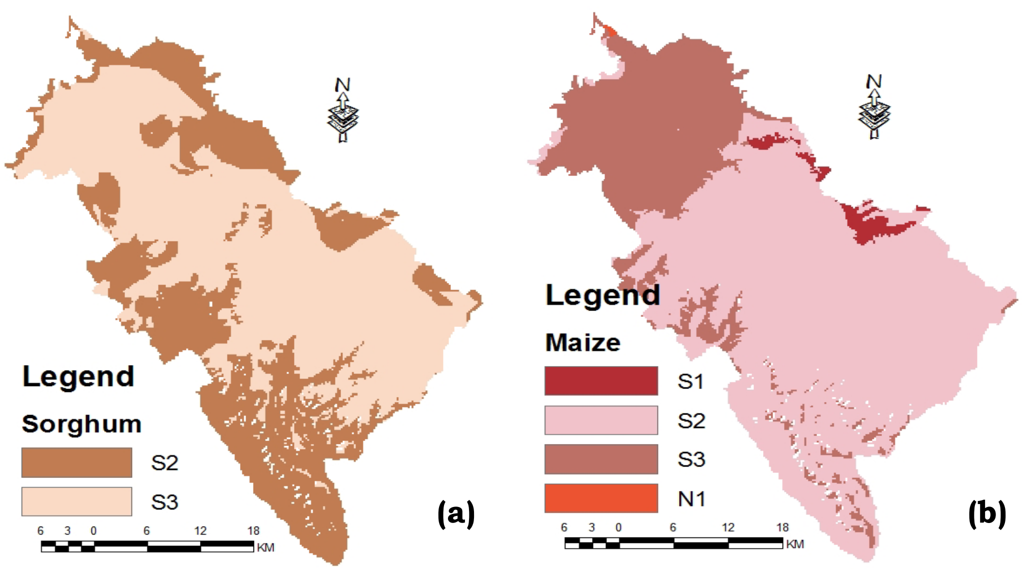

Figure 4.4: Total suitability class values of Sorghum (a) and Maize (b) crops (Ebrahim Esa, 2013)

Therefore, the largest proportion of the land was only moderately suitable for maize (70.67%), but it is marginally suitable for sorghum production (59.75%) in the *wereda*.

Conclusion

Although there were almost no areas which showed no limitations for both, sorghum and maize crops, the largest proportion of the land was only moderately suitable for maize (70.67%), but it was marginally suitable for sorghum production (59.75%) in sustainable rainfed agriculture of the *wereda*. The marginally suitable (S3 class) for sorghum were evaluated as land unit where aggregate limitations are more severe for sustained application of a given use and will thus reduce productivity or increase required inputs that will only be marginally justified. However, the moderately suitable class for the maize represented land unit where limitations will reduce productivity and increase required inputs to the extent that the overall productivity will still be attractive for sustained application of a given use.

The main restricting factors observed for good land suitability in the study area were water logging and the resulting poor aeration for rooting conditions, workability problems during the wet season cultivation in the north and northwest and poor nutrient availability in some patches of northern and eastern parts of the *wereda*. In addition, areas in the south and southeastern parts of the *wereda* are sensitive to erosion hazards due to changes in altitude more frequently than in the other parts of the *wereda*. Therefore, improved drainage conditions, soil inputs like fertilizers and sustainable soil conservation are an important land management approaches to enhance sustainable productions in the study area.

The study provides information about the suitability of sorghum and maize in the study area and hence offers farmers alternative land uses to lessen the risk of crop failure. The suitability maps can be overlaid with the district administrative map and be used to show specific locations or sub-locations where the two crops are at different suitability classes.

Land suitability evaluation in rainfed agriculture is a very important piece of information in order to help agriculture development planners and decision makers for sustainable crop productions. The suitability maps could also be used by extension agents and farmers to make choice of appropriate uses for specific areas. Therefore, a GIS based approach cannot be overlooked in this study as a useful tool in land suitability assessment for agricultural planning.

Acknowledgements

I would like to acknowledge Dr. Mohammed Assen (Associate Professor, AAU) for his professional advice and encouragement in this work. I would also like to thank the University of Gondar, College of Social Science and the Humanities and the *Ethiopian Renaissance Journal of Social Sciences and Humanities* (ERJSSH) for publishing this research work.

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