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Rangeland Suitability Evaluation for Livestock Production using Remote Sensing and GIS Techniques in Dire District, Southern Ethiopia

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Rangeland Suitability Evaluation for Livestock Production using Remote Sensing and GIS Techniques in Dire District, Southern Ethiopia

Berhanu Keno Terfa [α] & K. V. Suryabhagavan [σ]

Abstract- Management of complex ecosystems such as rangelands needs adequate knowledge to consider its capability for sustainable utilization. Land suitability analysis is needed to make proper land-use planning. GIS and Remote Sensing techniques offer a convenient and powerful platform to integrate spatially complex and different land attributes for performing land suitability analysis. The present study was intended to analyze and map suitable areas for livestock production in Dire district using remote sensing and GIS techniques. The study made use of Landsat TM 2011 remote sensing satellite image for land-use/land-cover analysis, and Multi Criteria Evaluation in a GIS environment to come up with the final suitability map. In this study, factors such as rainfall, land-use/land- cover, soil, slope, access to water, veterinary service and livestock market center were considered as factors. The result of the suitability analysis revealed that 5.6 %, 4.9 %, 5.4 %, and 10.1 % of study area was highly suitable for cattle, sheep, goat and camel, respectively; 44.75 %, 44.15 %, 45.5 % and 58.6 % of the land was classified as moderately suitable for cattle, sheep, goat and camel, respectively. Furthermore, 45.7 %, 46.5 %, 51 % and 31% of the land was classified as marginally suitable for cattle, sheep, goat and camel, respectively, and 4 %, 4.5 %, 1.1 % and 0.4 % was not suitable for cattle, sheep, goat and camel, respectively. Thus, the study showed that the large area of the rangeland in Dire district is only marginally suitable (with major limitations) for livestock production. Therefore, implementation of appropriate rangeland management plan in the district is essential.

Keywords: GIS, livestock, multi criteria evaluation, rangeland, remote sensing, suitability analysis.

I. Introduction

Land suitability analysis is the evaluation and grouping of specific areas of land in terms of their suitability or capability for a defined use. It involves the application of criteria to the landscape to assess where land is most and least suitable for a particular purpose. The suitability of a given land is based on its natural ability or the biological productivity for and its applied a specific purpose. Analyzing suitability is mainly based on the land qualities satisfying the requirements of the land-use.[1] Thus, the common way of determining land quality from land characteristics is determining land quality from land characteristics is mainly by assessing and grouping the land types in to different classes according to their values.[2]

A number of technological developments have facilitated the implementation of land evaluation principles and models. In order to incorporate different land attributes that differ spatially and to identify the best suitable land-use, Geographic information System (GIS) has proved to be a useful tool.[3] The powerful query, analysis and integration mechanism of GIS makes it an ideal scientific tool to analyze data for land-use planning. Management of natural resources based on their potentials and limitations is essential for development of rangeland on a sustainable basis. Today, GIS is a tool that can assist a community to plan and to support the information management during the rangeland production process, while ensuring balance between competing resource values. It can enhance the accessibility and flexibility of information and can improve the linkages and understanding relationships between different types of information.[4]

Land resource is limited in nature and its use is not only determined by the user but also by the processes of the land, its characteristics to sustain the production of required goods and services. Inappropriate land-uses lead to inefficient exploitation and destruction of the land resource, leading to poverty and other social problems. Society must ensure that land is not degraded and that it is used according to its capacity to satisfy human needs of the present and future generations, maintaining the ecosystem processes. 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 and human resources. Most pastoralists occupy a naturally dry environment, which is unsuitable for conventional rain-fed agriculture.[5] Yet, this very same land is ideal for extensive livestock production, the kind of life style that pastoralists are so familiar at managing. In such a fragile setting, proper land management is an absolute necessity. Until very recently, the Borana rangeland of Southern Ethiopia was considered to be

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one of the best grazing lands in east Africa.[6] Since the early 1980s, there is evidence that the system in the Borana rangeland is experiencing a decline in productivity, associated with periodic losses in cattle populations.[7] This was probably related to extreme climate change and variability, changes in land-use, animal diseases, bush encroachment, suppression of fire that resulted in the proliferation of bush encroachment, a general decline in forage production and over estimation of the grazing capacity.[8,9] The Dire district is one of the Borena Zones, which is situated in arid and semi-arid lands (ASALs), which experiences low and erratic rainfall and high temperature that hinder any significant crop production. However, high population growth has resulted in increased demand for arable land leading to reduced amount of land for natural grazing and forage production. Increasing land-use conflicts, which could lead to fast depletion of land resources, land degradation and bush encroachment is also associated with the population growth, and human activities have exerted excessive pressure on the extents of grazing lands.

Locating suitable areas for livestock production using spatial models of GIS would be indispensable to improve livestock productivity.[10] To get the maximum benefit out of the land, proper use for specific purposes is inevitable. Therefore, the most important criterion for sustainable animal production is the selection of appropriate land areas, which meet biophysical, environmental and socio-economic restrictions. Hence, it is of paramount importance to identify suitable land for livestock production, which enhances resilience of the environment. Although livestock production is a vital component of agricultural systems, it has so far been overlooked in integrated land and water management for food security in poverty alleviation strategies. There is a need for research and capacity building to understand the complex issues of water, livestock and land management of the district, so as to enhance national and local capacity to deal with water and livestock issues to enhance food security, reduce poverty and speed up national economic developments. The present study was aimed to evaluate and map suitable land areas for livestock production in Dire district using GIS and remote sensing techniques.

II. The Study Area

The present study area is bounded by latitudes 4° 37' 0" – 4° 37' 10"N and longitudes 37° 56' 0" –38° 31' 0" E in Borena Zone, Oromia Regional State, Ethiopia, and covers a total area of 3921 km2 (Fig. 1). The altitude ranges from 750 to 1870 m asl and the topography consists of isolated mountains, valleys and depression. This area is considered as a good representative site of the Borana rangelands of Ethiopia.

The rainfall of the study area ranges between 300–900 mm with bi-modal monsoon rainfall type, where 60 % of the annual rainfall occurs during March to May and 40 % between September and November.[11] The period from June to September is characterized by heavy cloud cover, mist and occasionally short showers, while the main dry season occurs from November to March with high evaporation (BLPDP, 2004). The overall average temperature ranges from an annual mean minimum of 13.3°C to annual mean maximum of 29.5° C.

The general vegetation type of the study area is *Acacia* savannah, the major trees being *Acacia drepanolobium* in black cotton soil, and *Acacia brevispica* and *Acacia horrida* on the slopes. According to,[12] *Commbertum Terminalia* and *Acacia commiphora* woodlands characterize the lowlands of Borana zone. Bushlands and thickets, which cover major parts of the lowlands are dominated by *Acacia* and *Commiphora* species. Besides, species of the genera *Boscia, Maerua, Lannea, Balanites, Boswellia* and *Aloe* are common in the study area.[13]

a) Methods

b) Rangeland suitability analysis

In the present study, four environmental land parameters were considered such as land-use/land-cover, soil, slope and rainfall. Socio-economic parameters were access to drinking water, veterinary services and access to market. Assessment of these parameters provides information about the limitations of the land for agricultural development.

i. *Environmental factor analysis*

For the present study, the following four environmental land parameters were considered: soil, slope, rainfall and land -use/land-cover. Assessment of these parameters provides information about the limitations of the land for agricultural development.

a. *Land-use/ land-cover*

Cloud free LANDSAT TM image (path 168 and row 057) acquired in January 2011 during the dry season was analyzed to classify the land-use/ land-cover of the study area. Geometric correction and image enhancement were conducted using ERDAS Imagine 9.2. Unsupervised classification of the study area was performed prior to field visit and representative points thought to represent the various land-cover classes were marked using GARMIN GPS during field visit. Using ERDAS Imagine 9.2, 24 *in-situ* data points were selected from each classified group to be checked in the field. Later, some points were added in the field for land-use/land-cover identification from the image. The overall accuracy and the Kappa value of field data vs automated classification results were 86.05% and 0.84, respectively. False color composite was prepared using the order of 4, 3, 2 band sequence and then different

enhancements were made to increase the visual interpretation of the image. Based on the field check points, supervised classification approach with the maximum likelihood classifier system was applied to improve the accuracy of the land-use classification of the image. According to the current land-use/land-cover analysis, eight classes such as Forest, Open bushland, Dense bushland, Open shrubland, Dense shrubland, Grassland, Farmland and Bareland were made.

b. *Soil*

For this study, soil mapping unit of Dire District was used as one of the parameters for suitability analysis. Physical properties of soil were considered for interpretation and analysis. FAO Soil Classification was used in the Suitability Modeling.[14]

c. *Slope*

Slope was generated from SRTM data in GIS platform using Geostatistical Analyst's surface analysis technique.

d. *Rainfall*

The mean monthly average rainfall of six stations (1 within the study area and 5 from the adjoining districts) for 16 years was collected from National Meteorological Services Agency (NMSA), Ethiopia. Subsequently, a surface was interpolated from the points data in a GIS platform using Geostatistical Analyst's ordinary Kriging technique.

ii. *Socio-economic factor analyses*

Socio-economic factors in the rangeland includes road and transport condition, communication system, market outlets, veterinary clinics and services, health centers/health posts, abattoirs, skins and hides collecting and preserving systems, communication and training systems. The highly managed rangelands need to have a range management station office to serve in case of emergencies such as disease outbreaks, executing, monitoring and reporting day to day activities. In this study, three infrastructural indicators were used namely access to drinking water, access to veterinary services and access to market.

a. *Distance to drinking water resource*

A map of distance to water was obtained first by combining artificial water point in water map. The water map was rasterized and then a distance map was calculated from it.

b. *Distance from veterinary services and market center*

This was calculated by buffering from the veterinary and market center points and rasterized to reclassify and a distance map was calculated from it.

All the above mentioned parameters have been considered for the analysis towards the identification of suitable areas for livestock production, they were mapped separately. Each of the criteria map displays land suitability measured on ordinal scale for land suitability and assigned values of high, medium and low suitability depending on land attributes.

c) Factor/Criteria rating

Factor ratings are sets of values which indicate how well each factor/criterion is satisfied by particular conditions of the corresponding land quality. Thus, as a first step, compilations of the livestock production requirements that will be considered in the evaluation were made. In the present study, both bio-physical and infrastructural parameters of the area were used as factors for suitability analysis. Then, the second stage is to decide on the factor ratings for each livestock species. Factor ratings were made in terms of five classes such as highly suitable (S1), moderately suitable (S2), marginally suitable (S3), currently not suitable (N1), and permanently not suitable (N2). All the above mentioned parameters were considered for the analysis for the identification of suitable areas for livestock production.

d) Criteria standardization

The module named reclass (in ArcGIS environment) for standardization/reclassification of the factors was used. Thus, each factor has an equivalent measurement basis before any weight is applied. Accordingly, all the factors used for this study were reclassified into five classes (S1,S2, S3, N1 and N2) with the range of values 1 to 5, where the value 1 represents the most suitable and 5 represents the least suitable for the factors considered.

e) Assigning criterion weights

In the procedure for multi-criteria evaluation (MCE), it is necessary that the weights sum to 1. Accordingly, in IDRISI, the weight module utilizes the pair-wise comparison technique to help develop a set of factor weights that will sum to 1. In pair-wise comparison matrix, factors are compared two at a time in terms of their importance related to the stated objective. The matrix is symmetrical and only the lower triangle actually needs to be filled in. The remaining cells are the reciprocals of the lower triangle. After all possible combinations of two factors were compared, the module calculates a set of weights and a consistency ratio. This ratio indicates any inconsistencies that may arise during the pair-wise comparison process. The module allows repeated adjustments to the pair-wise comparisons and reports the new weights and consistency ratio for each interaction.

The combination procedure follows the conventional scheme for GIS based MCDA. It involves three main steps. First, the criterion maps were standardized/ reclassified using Spatial Analyst's Reclassify tool. Thus, each factor has an equivalent measurement basis before any weights are applied. Accordingly, all the factors used for this study were reclassified into five classes (S1, S2, S3, N1 and N2)

with the range of values 1 to 5 as explained earlier. This step is necessary because the criterion maps contain the ordinal values (high, medium and low) that indicate the degree of land suitability with respect to a particular criterion (criteria standardization), and the derivation of the relative criterion importance using the pair-wise comparison method. The criterion weights are automatically calculated once the pair-wise comparison matrix is entered in IDRISI-AHP weight derivation module. Finally, the criterion weights and the standardized criterion maps were combined/aggregated by means of weighted overlay technique analysis. Figure 2 shows methodological flow chart.

III. Results

a) Parameter-wise suitability of environment

i. *Land-use/land-cover*

A major factor curtailing the suitability of rangeland in the study area was its dominance by dense bush- and shrub- lands that produce leaf biomass of low palatability to cattle and sheep. It was also responsible for hindrance for the movement of livestock while foraging. Land-use/land-cover suitability analysis revealed that a large a portion of the area (33.12 %, 1298.7 km^2) is marginally suitable for grazers (cattle and sheep) and 47.34 % (1856.13 km^2) for browsers (goat and camel). A relatively small area of ~16.9 % rangeland is highly suitable for cattle, sheep and goats and 32.35 % for camels. Out of the total rangeland area in the District, 16.9 % (662.83 km^2) is highly suitable for grazers (cattle and sheep), moderately suitable 32. 35 % (1268.5 km2) for goats and 19.6% (768.52 km^2) for camels. Further, of the total rangeland area, 30.27 % (1186.8 km^2) fell into currently not suitable category for cattle and sheep, while 0.11% (4.15km^2) fell into permanently not suitable category for goats and camels and a meager 0.11 % (4.15km^2) also into the same category for all livestock (Table 1).

ii. *Rainfall suitability*

Rainfall suitability analysis showed that 100 % of the rangeland in the district fell under highly suitable category for camels, whereas the same fell into moderately suitable category for cattle, sheep and goat (Table 1).

iii. *Soil and slope suitability*

Soil suitability analysis revealed that the district is more favorable for all livestock categories with 54.6 %, 10.1 %, 33.24 % and 2.1 % of the rangeland being highly suitable, moderately suitable, marginally suitable and currently not suitable, respectively, leaving no area under permanently not suitability category (Table 1). Slope suitability analysis reflected that a large area of the district is relatively flat and as such over 80% of the rangeland area is highly suitable for all livestock categories together. However, about 3.75 %, 3.16 %, 3.44 % and 3.1 %, 3.8 %, 5.85 % and 4.1 % of this entire area is either currently or permanently not suitable for cattle, sheep, goats and camels, respectively, while ~3 % goes for tourism and wildlife habitats (Table 1, Fig. 3).

iv. *Distance from water resources, livestock market and veterinary services*

Suitability analysis of distance from water resources for different livestock categories revealed that 39.8 % and 55.1 % of the rangeland area is highly suitable for cattle and camels, respectively, and a proportion of 17.8 % for sheep and goats (Table 1). Further, 43.44 % of the area is moderately suitable for cattle. Large portion (44.85 %) of the area is found not suitable for sheep and goats. The district is constrained with the distance of the rangeland from water resources in the case of sheep and goats. Distance from livestock market suitability analysis showed that ~34.4 % of the rangeland area is moderately suitable for cattle and camels, while 47.32 % is currently not suitable for sheep and goats. As regards veterinary service suitability, ~40.1% of the district is moderately suitable for all livestock categories.

Thus, the results portray that biophysically the areas with flat to gentle slope, grassland and areas with mean annual rainfall >800 mm were highly suitable for cattle and sheep production. Availability of water, animal health services and livestock market within 5, 10 and 15 km distance, respectively, were found highly suitable for cattle, while areas with a distance of <5 km to water source as well as veterinary services together with <7 km of distance from market were identified as highly suitable for sheep and goat production.

Table 1 : Factor-wise suitability classes with respective area of coverage for cattle, camels, sheep and goats

		Factors													
Livestock	Suitability	LU/LC (km^2)	%	RF (km^2)	%	Slope (km^2)	%	Soil (km^2)	%	Access to Water (km^2)	%	Access to veterinary service (km^2)	%	Access to Market (km^2)	%
Cattle	S1	662.83	16.9			3137.7	80	2140.5	54.6	1560.7	39.8	819.5	20.9	1329.1	33.9
	S2	768.52	19.6	3921	100	382	9.74	395.6	10.1	1703.5	43.44	1573.8	40.1	1348.7	34.4
	S3	1298.7	33.12	-	-	134	3.42	1303.6	33.24	489.4	12.5	873.8	22.3	702.5	17.9
	N1	1186.8	30.27	-	-	147.7	3.75	81.3	2.1	167.4	4.27	653.9	16.7	540.2	13.8
	N2	4.15	0.11	-	-	119.6	3. 1	-	-	-	-	-	-	-	-
	Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**
Camels	S1	1268.5	32.35	3921	100	3137.7	80	2139.7	54.6	2161.4	55.1	819.5	20.9	1349.1	34.4
	S2	768.52	19.6	-	-	382	9.74	396.7	10.12	1101.7	28.1	1572.8	40.1	1338.7	34.4
	S3	1856.13	47.34	-	-	137.4	3.51	1303.4	33.24	607.6	15.5	874.8	23.3	706	18
	N1	23.7	0.6	-	-	124	3.16	81.2	2.1	49.3	1.3	653.9	16.7	527.2	13.44
	N2	4.15	0.11	-	-	139.9	3. 8	-	-	-	-	-	-	-	-
	Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**
Sheep	S1	662.83	16.9			3137.7	80	2139.7	54.6	698.6	17.8	819.2	20.9	635.7	16.21
	S2	768.52	19.6	3921	100	420.8	10.7	396.7	10.12	862.1	22	1573.3	40.1	713.4	18.2
	S3	1298.7	33.12	-	-	135	3.44	1303.4	33.24	601.8	15.35	874.1	22.3	716.3	18.27
	N1	1186.8	30.27	-	-			81.2	2.1	1758.5	44.85	653.7	16.7	1855.6	47.32
	N2	4.15	0.11	-	-	227.5	5.8 5	-	-	-	-	-	-	-	-
	Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**
Goat	S1	768.52	19.6			3137.7	80	2139.7	54.6	698.6	17.8	819.2	20.9	635.7	16.21
	S2	1268.5	32.35	3921	100	516.5	13.2	396.7	10.12	862.1	22	1573.3	40.1	713.4	18.2
	S3	1856.13	47.34	-	-	107	2.73	1303.4	33.24	600.8	15.35	874.1	22.3	716.3	18.27
	N1	23.7	0.6	-	-			81.2	2.1	1758.5	44.85	653.7	16.7	1855.6	47.32
	N2	4.15	0.11	-	-	150.8	4. 1	-	-	-	-	-	-	-	-
	Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**

LU/LC: Land-use/ land-cover, RF: Rainfall, S1: Highly suitable, S2: Moderately suitable, S3: Marginally suitable, N1: Currently not suitable, N2: Permanently not suitable

v. *Overall environmental suitability*

Results of environmental factors (land-cover, rainfall, soil and slope) analysis showed that the District is marginally or moderately suitable for livestock production (Table 2, Fig. 4). Of the total area, 41.57 %, 41.57 %, 51.7 % and 45.46% of the area is marginally suitable while 40.39 %, 40.29 %, 40.24 % and 33.3 % of the area is moderately suitable for cattle, sheep, goats

and camels, respectively. In contrast, only a small area is highly suitable for cattle (8.21 %), sheep (8.4 %), goats (7.42 %) and camels (20.76 %). Further, a small extent of the area, though scanty for the requirement of browsers (goats and camels) than grazers (cattle and sheep) also fell into currently not suitable and permanently not suitable categories.

Table 2 : Land suitability classes for livestock production based on environmental factors

Suitability Classes	Livestock category							
	Cattle		Sheep		Goats		Camels	
	Area		Area		Area		Area	
	(km^2)	(%)	(km^2)	(%)	(km^2)	(%)	(km^2)	(%)
Highly suitable	321.75	8.21	329.38	8.4	291.11	7.42	814	20.76
Moderately suitable	1583.5	40.39	1579.7	40.29	1578.02	40.24	1306.85	33.33
Marginally suitable	1629.9	41.57	1629.71	41.56	2026.94	51.7	1782.35	45.46
Currently not suitable	385.85	9.84	382.21	9.75	24.93	0.64	17.8	0.45
Permanently not suitable	0.58	0.01	0.63	0.02	0.46	0.01	-	-
Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**

vi. *Socio-economic suitability*

The suitability analyses results based on socio-economic factors (access to water, livestock market and veterinary services) revealed that the District is moderately suitable for camel and marginally suitable for cattle, sheep and goats (Table 3, Fig. 5). Rangeland of 36.3 %, 27.9%, and 44.3 % extent are moderately suitable for cattle, camels and sheep/ goats, respectively. Similarly, 37.5 %, 38.6 % and 23% of the areas are marginally suitable for cattle, sheep/ goats and camels, respectively. Further, small areas are also highly suitable for small ruminants (sheep and goats 8.25 %), cattle (13.8%) and camel (26.2). But, an area of 25.25 %, 12.3% and 6.5 % fell into currently not suitable category for small ruminants (sheep and goats), cattle and camels, respectively.

Table 3 : Land suitability classes for livestock production based on socio-economic factors

Suitability Classes	Livestock category							
	Cattle		Sheep		Goats		Camels	
	Area		Area		Area		Area	
	(km^2)	(%)	(km^2)	(%)	(km^2)	(%)	(km^2)	(%)
Highly suitable	539.8	13.8	323.4	8.25	323.4	8.25	1029.2	26.2
Moderately suitable	1423	36.3	1093.2	27.9	1093.2	27.9	1741	44.3
Marginally suitable	1476.7	37.5	1514.3	38.6	1514.3	38.6	897.9	23
Currently not suitable	481.5	12.3	990.1	25.25	990.1	25.25	252.9	6.5
Permanently not suitable	-	-	-	-	-	-	-	-
Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**

vii. *Final suitability analysis*

A wide area of the rangeland in the District is classified as marginally suitable category for cattle, sheep and goats, while about half of the area fell under moderately suitable category for camels. Further, 45.7 %, 46.45 %, 51 % and 30.9 % of the rangeland were found marginally suitable for cattle, sheep, goats and camels, respectively. Similarly, 44.75 %, 44.17 %, 42.52 % and 58.6 % of the land is recognized as moderately suitable category for cattle, sheep, goat and camels, respectively, while small portions of 4 %, 4.48 %. 1.11 % and 0.38 % of the area are currently not suitable for cattle, sheep, goat and camels, respectively (Table 4, Fig. 6). The study does not show areas classified as permanently not suitable even though there were factors in which permanently not suitable classes were observed.

Table 4 : Final land suitability classes for livestock with their respective areas of coverage

Suitability Classes	Livestock Species							
	Cattle		Sheep		Goats		Camels	
	Area (km^2)	Area (%)	Area (km^2	Area (%)	Area (km^2	Area (%)	Area (km^2	Area (%)
Highly suitable	218.77	5.6	192.25	4.9	211.52	5.4	396.84	10.12
Moderately suitable	1754.7	44.75	1732.01	44.17	1667.72	42.52	2298.3	58.6
Marginally suitable	1791.8	45.7	1821.29	46.45	1998.14	51	1211.02	30.9
Currently not suitable	155.73	4	175.45	4.48	43.62	1.11	14.84	0.38
Permanently not suitable	-	-	-	-	-	-	-	-
Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**

IV. Discussion

Animal husbandry in rangelands has been an important economic activity in Ethiopia for a very long time. Due to land scarcity, the degree of importance attached to a specific rangeland area reflects its productivity as well as its availability for alternative sources of income. Appropriate land-use decisions are vital to achieve optimum productivity of the land and to ensure environmental sustainability. In Ethiopia, as in most other developing parts of the world, animal husbandry is the most productive means of using semi-arid zones bordering the desert. Therefore, the concept of range inventory was applied in the present instance to recognize and evaluate the actual production capabilities of rangelands for optimal utilization of these valuable natural resources for domestic livestock production.

While adapting grazing suitability analysis on rangelands, due consideration was given to land- use/ land-cover, rainfall, topography, soil, water availability, access to market, animal health services and socio-economics as the effective factors and the extent of limitations they impose are important in selecting appropriate areas within the total spread of rangelands determined rangeland suitability for the grazing of sheep and goats using a livestock grazing model considering three components, namely forage production, water resources, and the sensitivity of the soil to erosion. [15, 16, 17, 18, 19] Rangeland is in conflict with industrial development but compatible with forestry in compliance of management and control principles.[20]

Land cover is a product of human activities altering the terrestrial surface. In turn, it also governs the kind of activities that can take place over a given piece of land. A major limitation in the acceptance of rangeland in Dire District for all livestock categories is that under land-use /land-cover, a wide area fell into marginally suitable category. As against this, only a small area of the rangeland is highly suitable for livestock production because rest of the area is dominated by bush and shrubs (unpalatable for cattle and sheep) than grasses.

Slope is a very important factor determining the suitability of rangelands for livestock production. Animals can easily graze in flat and gentle slopes and most of the consumed feed goes in for fattening without much energy loss. But, places with high slope (>30%) are not suitable for livestock grazing due to their impassability and loss of energy in wandering through the steep slopes for feed and water resulting in decreased food conversion function.[21]

Rangelands characterized by the usage of different systems of grazing resources and management of communal grazing lands based on water resources offers opportunities to monitor changes in species composition and response of grasses to prolonged and intensive disturbance.[13, 22] Dire district is currently not suitable regarding water access for small ruminants (sheep and goats) and moderately suitable for cattle while highly suitable for camels. One of the intentions of the present attempt is to determine optimal creation of additional water sources to increase cattle distribution. Creation of new water sources in presently “unsuitable” areas would help in augmenting the availability of grazing areas to a large extent.

Sale of livestock and livestock products is the main source of cash income. The distance from main marketing centers influences the price of animals. Long distances and trekking to markets are major impediments for pastoral folks to profitably sell their livestock. During drought periods, animals lose weight on journey to the market, thereby losing their value significantly. In situations of surplus stock, remaining animals turn too weak to embark upon homeward journey, forcing the producers to sell them at a very low price or to go even for bartering them for food.

A comprehensive analysis of the physical settings of the Dire District rangeland revealed four major environmental variables (land-cover, rainfall, topography and soil) as most important criteria in land suitability assessment. Rainfall determines the amount of water available for plant growth. Minimal rainfall for rangeland plant growth is not so inadequate. Usually, annual rainfall of 400 mm is considered suitable. Terrain is important for maintaining slope stability and is critical

to the distribution of other variables at a local scale (*e.g.,* in order to prevent soil erosion, a steep terrain should not be tilled). Soil type, slope of the area governs the type of vegetation that could grow most productively in an area, and vegetation (*e.g.,* its presence and health) indicates whether the land can be productively used or not. Usually, heavy soils with deep slope are made use for agriculture, whereas medium to coarse gravel or rubble stone soils, semi- evolved with moderate to shallow slopes remain as rangeland.[23] Further, the rangeland management system in southern pastoral areas of Ethiopia is strongly based on water management. The availability of surface water sources such as ponds and wells in order to suffice the water needs of plants and livestock together with veterinary services are essential for livestock production. The role of each of these factors in an environment varies with land-cover due to their changing dominance in different areas with different influences. Many researchers [24, 25, 26] have adopted similar methods as in the present attempt to analyze rangeland suitability through GIS techniques followed by multi-attribute decision making approach in different situations.

V. Conclusion

Assessment of rangelands is a task that frequently challenges managers in livestock industry, environmental protection and rangeland management. Rangeland suitability for livestock is a very important information for livestock development and future planning. Of the total land area in Dire District, only about 6.5 % land is found highly suitable for different livestock categories because of bush encroachment followed by poor accessibility to water resources, veterinary services and market centers. In contrast, a large extent of the rangelands is only marginally suitable for cattle, sheep and goats but moderately suitable for camels. About half of the area of the District is inaccessible to market and is devoid of major water sources or deep wells to serve the needs especially of small ruminants (sheep and goats). Acute shortage of permanent water resources for livestock especially during the dry season is a major impediment to the propagation of livestock enterprise in the region. In order to make these areas suitable on a sustainable basis, proper interventions are required to be undertaken calling for implementation of appropriate rangeland management plans in the District to encourage good livestock production for long.

VI. Acknowledgments

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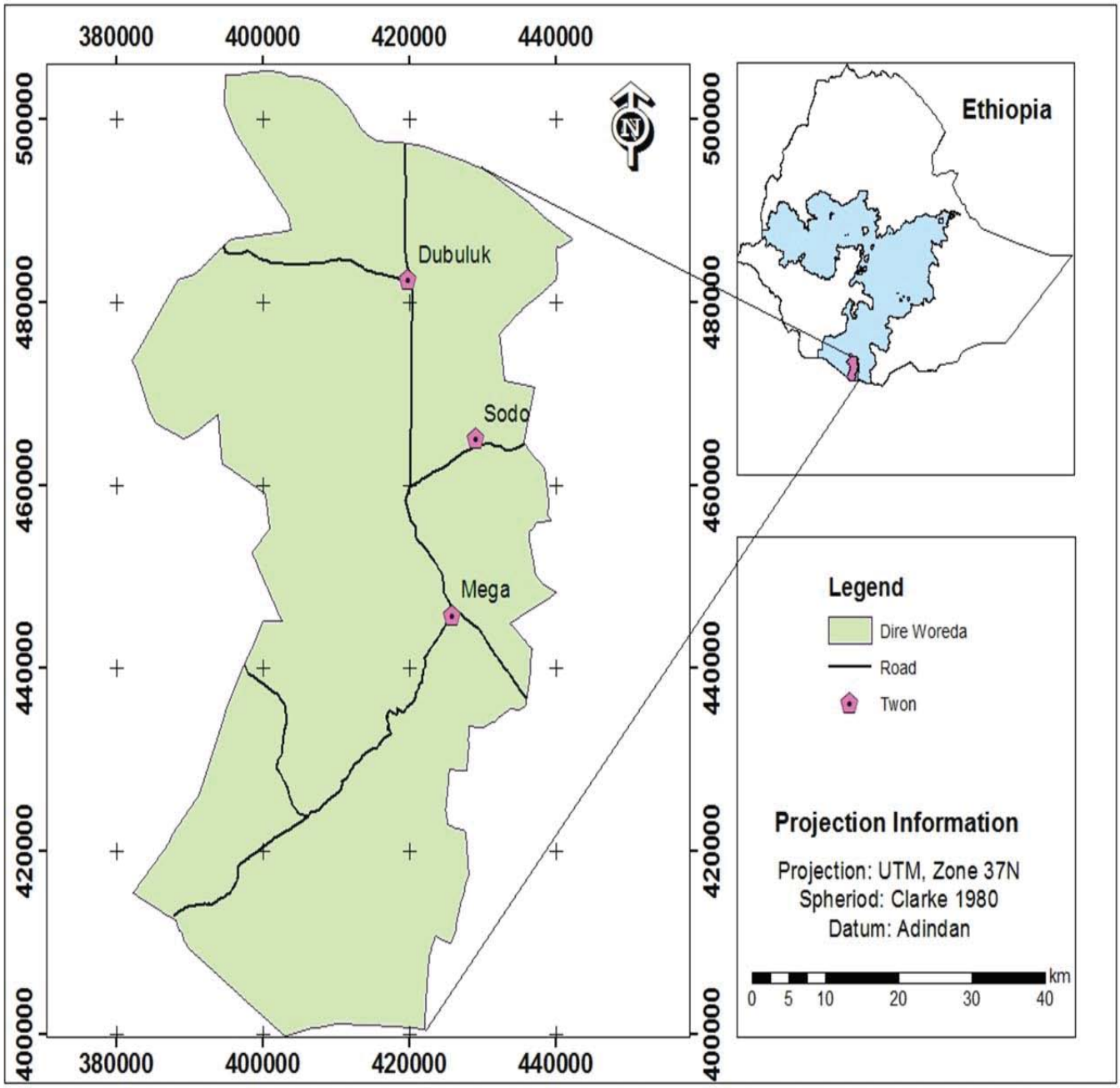

Figure 1 : Location map of the Study Area

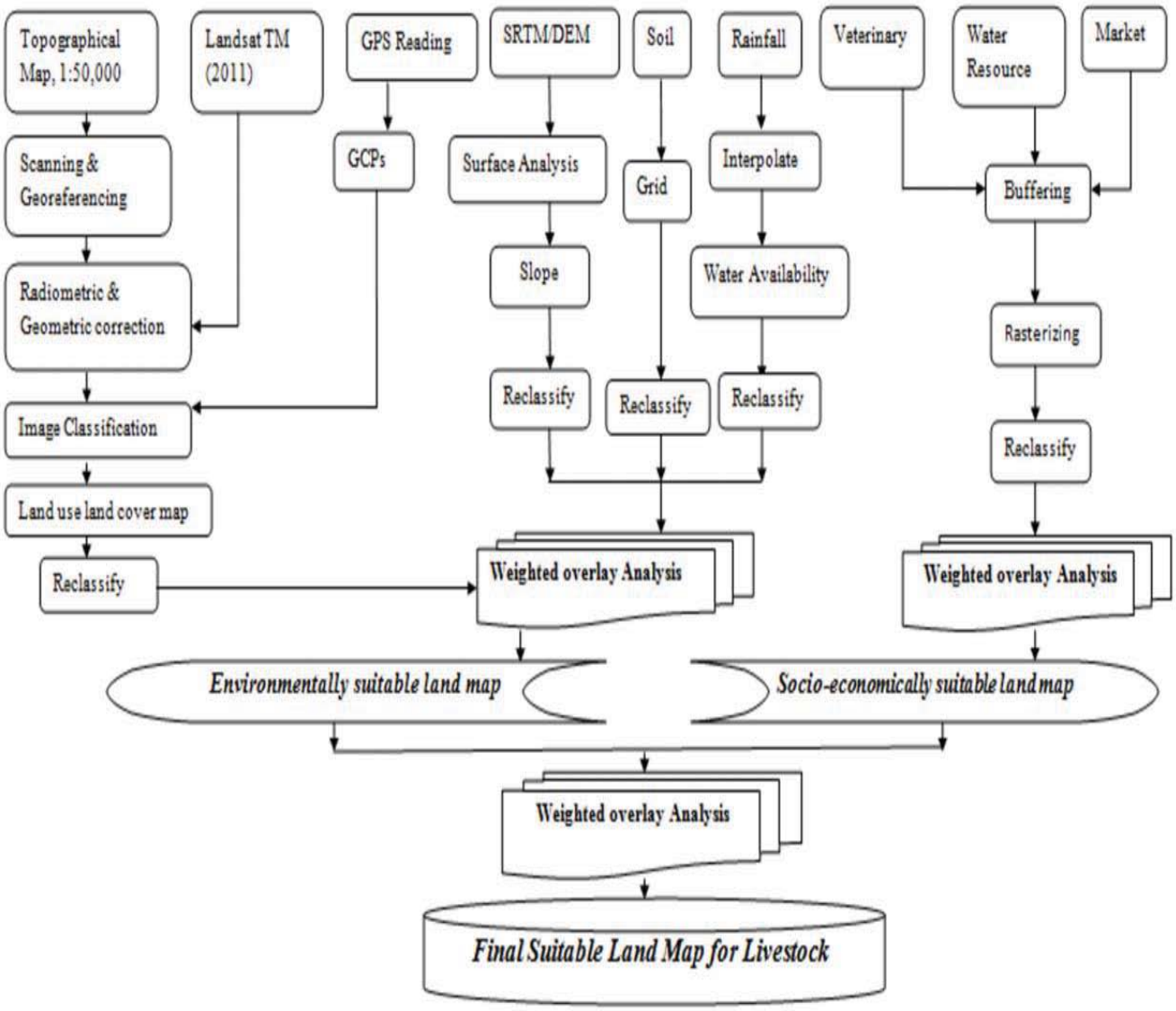

Figure 2 : Methodological flow chart

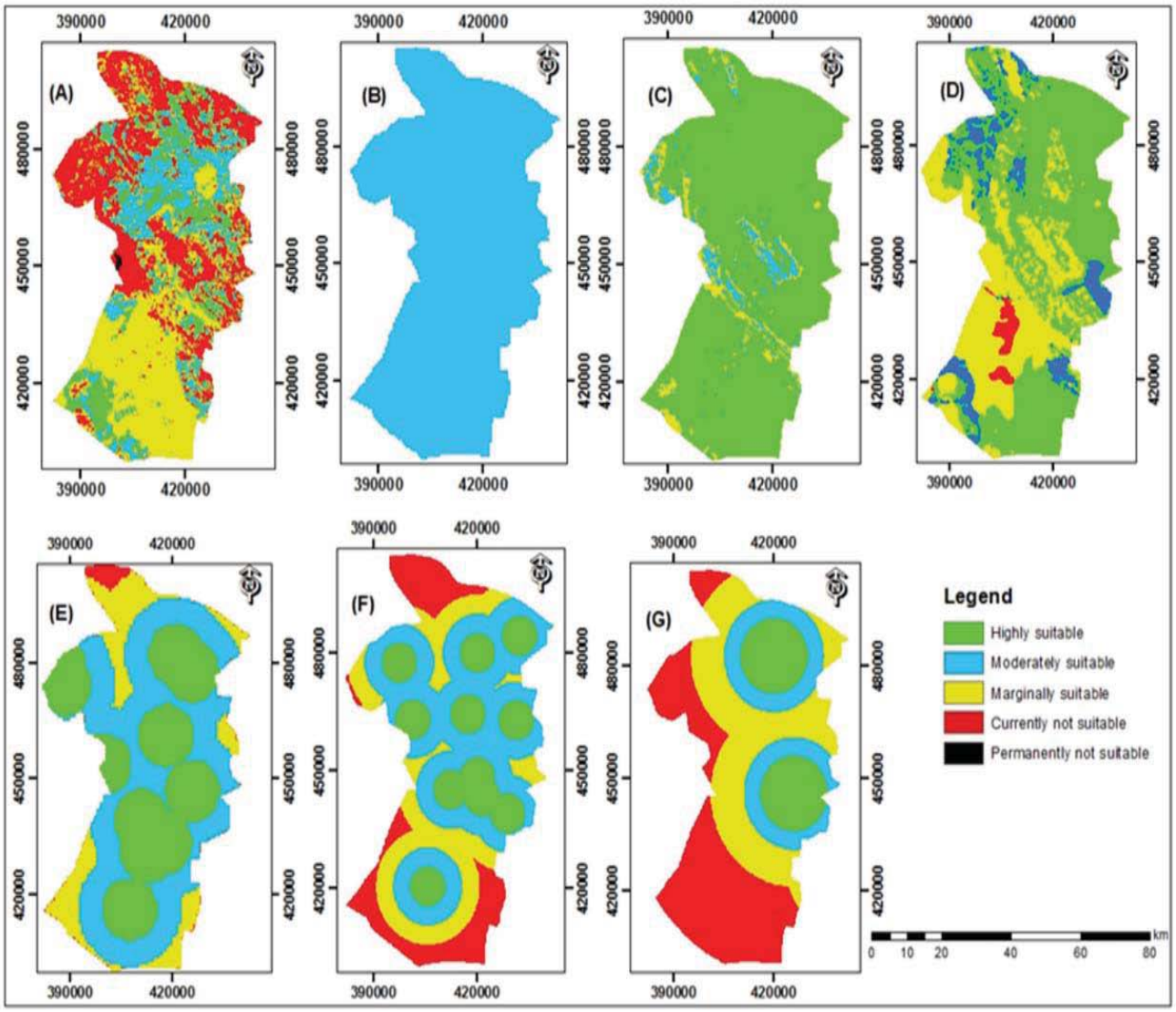

Figure 3 : Factor-wise suitability maps for Livestock
(A. Land-use/land-cover, B. Rainfall, C. Slope, D. Soil (texture), E. Water availability, F. Animal health services and G. Market access).

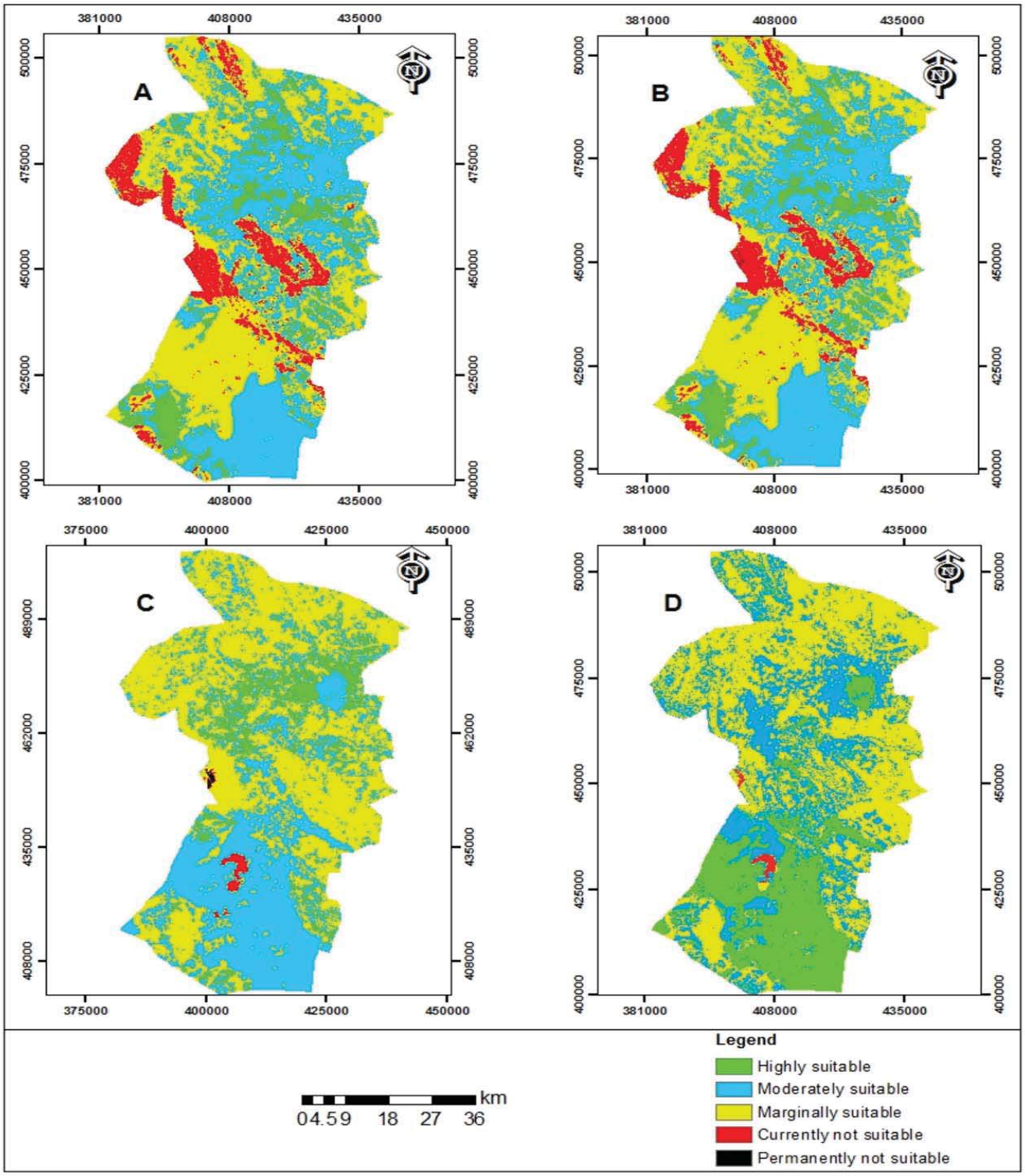

Figure 4 : Land suitability map based on Environmental parameters for A) Cattle, B) Sheep, C) Goats and D) Camels

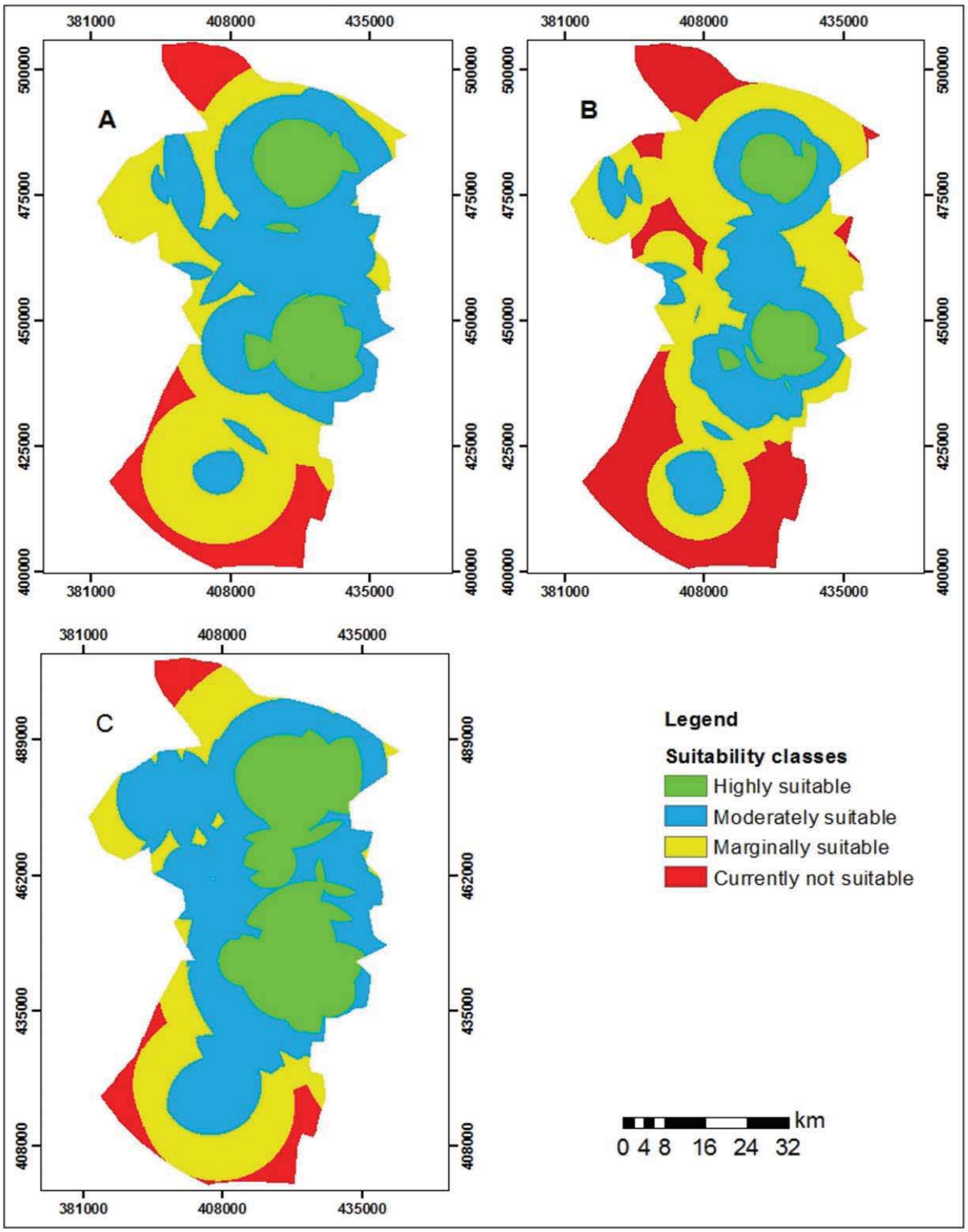

Figure 5 : Land suitability map based on Socio-economic parameters for A) Cattle, B) Sheep and Goats and C) Camels

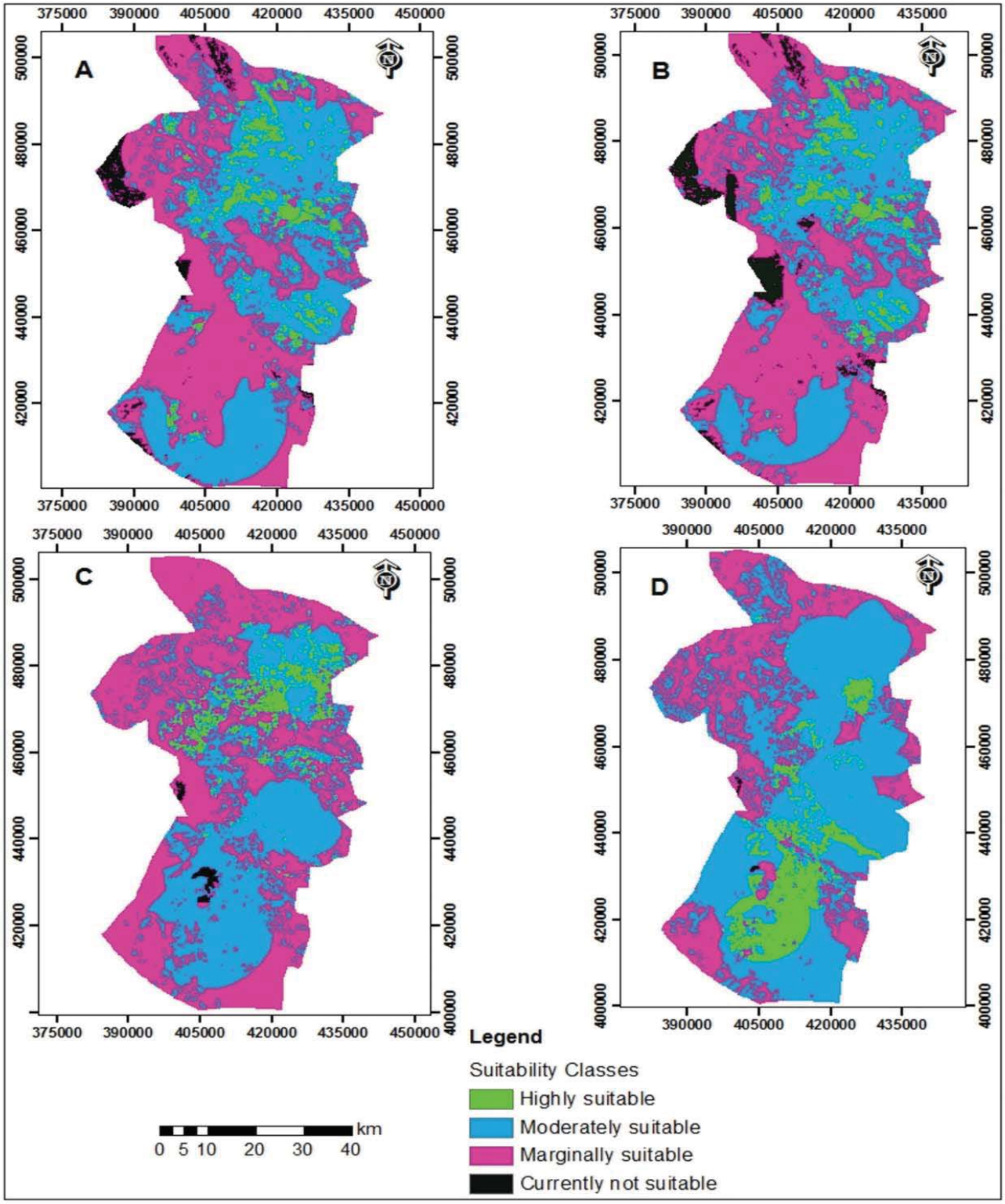

Figure 6 : Final suitability map based on both environmental and socio-economic factors for A) Cattle, B) Sheep, C) Goats and D) Camels

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