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Geospatial agro-climatic characterization for assessment of potential agricultural areas in Somalia, Africa

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ABSTRACT

Somalia nation has been in the past classified as a volatile and of low economic value since 1990s when the government was deemed to have collapsed. Currently the independent Somalia is turning out to be one economic back bone of the Northern and Eastern parts of Africa in trade and agriculture. This paper focuses on the agricultural potential of Somalia using geospatial techniques through characterization. Climate is characterized and described, terrain models are derived, Soil analysis and hydrological assessment are also analyzed. Agroclimatic maps are developed to show suitable and unsuitable areas for agricultural production. The terrain of Somalia is more of a flat plain coupled with river basins that can be used as arable lands for agriculture. The ground water points can sustainably irrigate large number of parcels for crop production. Through GIS technology adopted for this particular work, two basins were mapped out to be possible agricultural potential areas: Juba and Shabelle. The assessment indicates that crop production can be achieved through irrigating of the arable plains and not relying so much on rain-fed agricultural systems. Agro-climatic zones of Somalia are delineated mainly due the amount of rainfall, temperature ranges and terrain patterns. With this study, farmers can be advised on which area to focus for crop production. The agricultural potential that lies in Somalia is so huge it could be named the future food basket of Africa, who knows?

1. Introduction

Somalia is on the horn of Africa and is bordered by Kenya to the southwest, Ethiopia to the west and Djibouti to the far northwest in the Gulf of Aden. Somalia is officially divided into 6 proposed regional states; Somaliland, Puntland, Galmudug, Jubaland, South West State and Hir-Shabelle. It lies between latitudes 2°S and 12°N, and longitudes 41° and 52°E. Strategically located at the mouth of the Bab el Mandeb gateway to the Red Sea and the Suez Canal, the country occupies the tip of a region that, due to its resemblance on the map to a rhinoceros' horn, is commonly referred to as the Horn of Africa.

Somalia's total land area is 637,540 km^2, of which 30% is classified as desert land unsuitable for agricultural production, 45% is covered by rangelands suitable for livestock grazing, 14% is covered by forest or woodland, and the remaining 11% is classified as arable land (Food and Agriculture Organization,1995). Livestock production was a major industry until the 1990s, accounting for over 60% of exports. Arable farming was also an important industry, though the Ministry of Agriculture (Yearbook of agricultural statistics 1989/1990, Mogadishu, Somalia) statistics indicate that only 22% of the designated arable land was viable for cultivation, and only 12% was cultivated, predominantly

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with maize and sorghum. The under-utilization of potential arable land was due to the predominantly arid climate that limits rain-fed agriculture and causes a heavy reliance on irrigation.

Groundwater is used throughout Somalia, obtained mainly from shallow hand-dug wells, though a few strategic boreholes are used to reach deeper aquifers, which act as an important reserve during the dry season. However, the groundwater quality is generally regarded as poor. In the downstream reaches of rivers, small freshwater lenses located mainly along the river banks are recharged during periods of high flow, and partially drained during the dry season. Therefore, the water resources of the Juba-Shabelle basin are particularly important for irrigation, as well as for Somalia's general development (e.g. domestic and industrial water supply. The river flows also provide the safety-net required to sustain livestock herds during periods of serious drought. Several large-scale irrigation schemes used to exist on both rivers, and small-scale irrigation schemes were common on the flood plains throughout the Somali reaches. The rivers are prone to seasonal flooding, with flood recession agriculture being practised in natural depressions adjacent to the river banks.

With a growing population, demands for water for irrigation and domestic supply are increasing sharply. Effective water and land management are both essential to ongoing relief and rehabilitation efforts which require good quality information on the country's water and land resources, primarily the Juba and Shabelle rivers.

1.1. Agriculture and livestock

Somalia contains a variety of mammals due to its geographical and climatic diversity. Wild fauna is found throughout the territory, including the cheetah, lion, giraffe, baboon, civet, serval, elephant, bush pig, gazelle, ibex, kudu, dik-dik, oribi, Somali wild ass, reedbuck and zebra, shrew, rock hyrax, golden mole and antelope. It also has a large population of the dromedary camel. Somalia is currently home to around 727 species of birds. Of these, eight are endemic, one has been introduced by humans, and one is rare or accidental. Birds' species are found exclusively in the country. Somalia's territorial waters are prime fishing grounds for highly migratory marine species, such as tuna. A narrow but productive continental shelf contains several demersal fish and crustacean species.

Agriculture is an important economic activity in Somalia not only in terms of meeting the food needs of the population but also in terms of generating income through crop sales and agricultural labour opportunities. With roughly 50% of population's cereal requirements are met through domestic production, Agriculture is a major component particularly for two of the main rural livelihood systems in the Horn of Africa country: Agro-pastoralist, mix of agriculture and livestock production-based livelihood and agriculturalist, agriculture-based livelihood. Crop production performance and its potential is determined by the bi-modal rainfall. The two main agricultural seasons are: Gucrop production, from April to June and Deyr crop production is from October to December.

Two areas are considered high potential for crop production with rainfall ranging from 400mm to 600mm: a small area in the Northwest (west of Hargeisa) and a much larger inter-riverine area between the Shabelle and Juba river valleys.

1.2. Pastoralism

Pastoralism is a means of livelihood for the majority of people living in the drylands of northern Kenya, southern Ethiopia, and southern and central Somalia. Pastoralist communities in the Horn of Africa are very diverse and differ in religion, culture, and in the form of pastoralism practiced. Some keep cattle, others keep camels, and a few communities keep both, often combined with keeping small stock such as goats and sheep (Lewis, I.M). In Somalia and the Somali region of Ethiopia, the Borane and Somali are the main pastoralist groups, whereas overall Somali pastoralists can be further divided into numerous other clans and sub clans

Somalis are predominantly nomads, and to many nomads, the camel hold a special importance to their livelihoods, and has thus become an important figure in their lives. Nomads, by definition, constantly travel, and the Somali nomads depend on camels for this travel. Camels provide food (with their milk) on long trips, can carry heavy cargo, and do not require frequent water. To Somalis the camel is almost like a religious totem (Farah, Z, M Mollet, M Younan, and R Dahi. 2007). The lack of data on these nomadic cultures challenges access to health care in some cases. Throughout Africa, the nomadic populations have the least access to health services.

2. Materials and Methods

2.1 Study area

The area of study is Somalia and its administrative regions as shown in Figure 1.

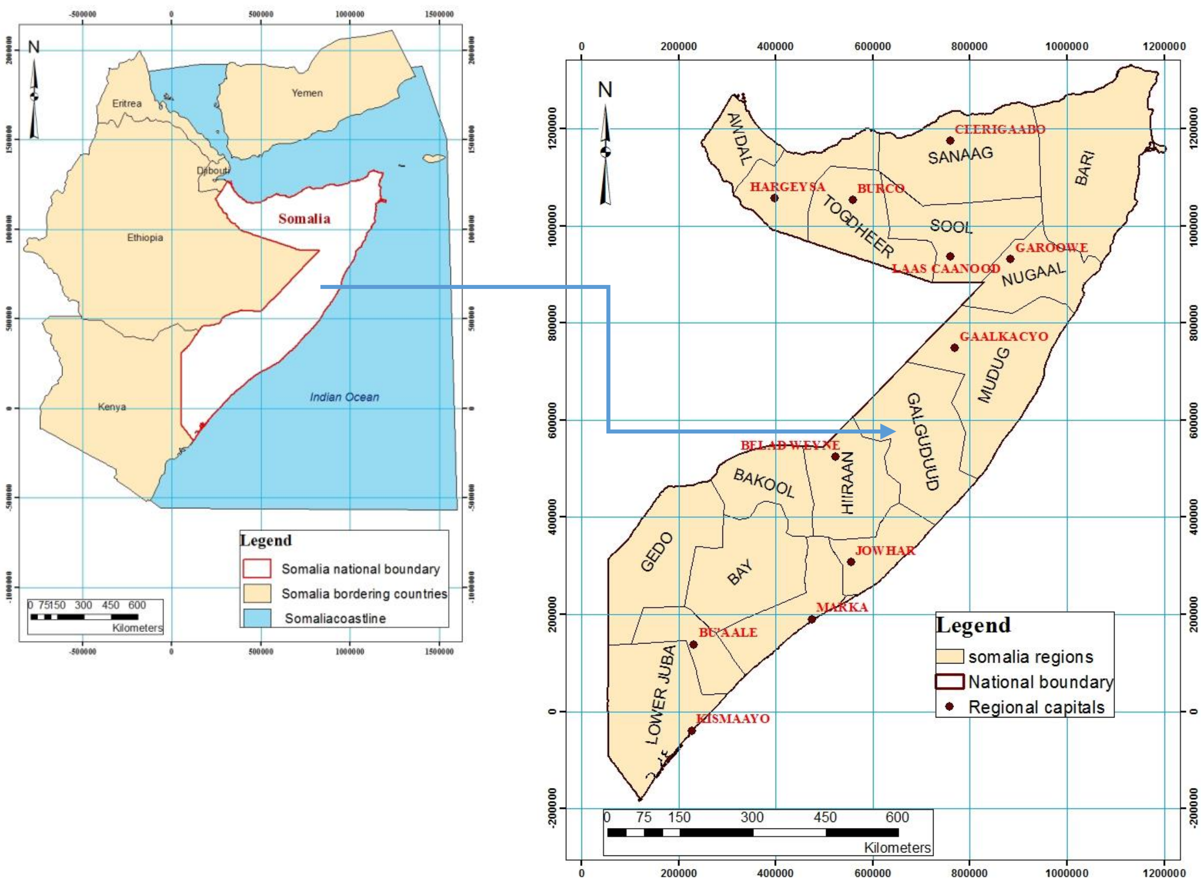

Figure 1. Somalia showing its administrative regions and Somalia coastline.

The study was done using various raster and vector datasets to show land use/land cover, hydrological components, land characterization and agro-climate changes. Data collected from desired sources were analysed using the applications of GIS techniques. This was achieved by using the following methods: Data collection, data integration, data processing, overlay analysis, multi-clustering algorithms and results analysed. The datasets used are shown in the table below.

Table 1. Data types and their sources.

DATA	TYPE	SOURCE
Digital elevation model (DEM)	Raster	DIVA GIS
Climate estimates (5m)	Raster	Global climate data (ESRI grids)
Land use and Landcover	Raster	FEWSNET Data Portal
Roads	shapefile	FAOSWALIM
Administrative regions	shapefile	Humanitarian Data Exchange

Water point sources	shapefile	FAOSWALIM
Major rivers	shapefile	ILRI
Manual and automatic weather stations	shapefile	FAOSWALIM
Land cover	shapefile	FAOSWALIM
Irrigation schemes	shapefile	FAOSWALIM
Drainage basins	shapefile	FAOSWALIM
soils	shapefile	FAOSWALIM

2.2. Geographic information system (GIS)

GIS is a collection of computer hardware and software, data and skilled personnel for managing and analysing geographic data. At present, GIS technology is widely applied in several fields such as natural resource management, agriculture management, commercial, urban and regional management to address complex and multidisciplinary planning and management problems at regional and global scales. GIS has gained widespread acceptance as an important versatile tool because of its ability to carry out complex spatial operations and capability to link spatial and non-spatial data.

GIS has the capability to manage many layers, integrate and analyse spatial data from different sources, with diverse formats, structures, projections and helps in spatial modelling. GIS is a collectively broad term that contains a number of technologies, processes, and methods. It is attached to many operations and has wider applications related to engineering, planning, management, transport/logistics, insurance, telecommunications, and business.

The study developed the use of a GIS land and climate assessment criteria to assess the agricultural potential areas. It utilized the land use/ cover, climate analysis of temperature and rainfall, slopes derived from elevation model, surface and ground water hydrology and the understanding of soil erodibility of the area. Workflow in Figure 2 shows the graphical procedure adopted.

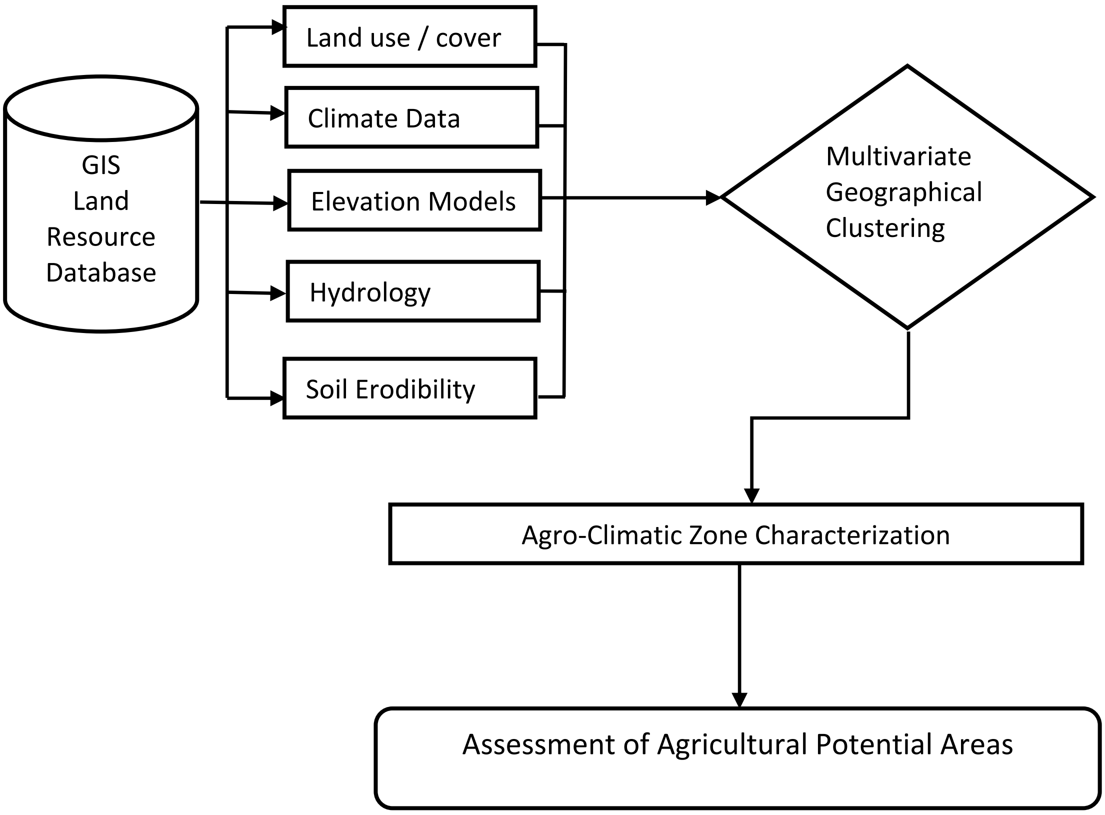

Figure 2. Workflow for land assessment for agricultural potential areas.

3. Results and Discussions

3.1. Landuse/landcover types

Vegetation in Somalia consists chiefly of coarse grass and stunted thorn and acacia trees. Aromatic flora, producing frankincense and myrrh, are indigenous to the mountain slopes. In southern Somalia, eucalyptus, euphorbia, and mahogany trees are found.

The region encompassing the Shabelle and Jubba rivers is relatively well watered and constitutes the country's most arable zone. The lowland between the rivers supports rich pasturage. It features arid to sub arid savanna, open woodland, and thickets that include frequently abundant underlying grasses. There are areas of grassland, and in the far southwest, near the Kenyan border, some dry evergreen forests are found.

Other vegetation includes plants and grasses found in the swamps into which the Shabelle River empties most of the year and in other large swamps in the course of the lower Jubba River. Mangrove forests are found at points along the coast, particularly from Chisimayu to near the Kenyan border. Uncontrolled exploitation appears to have caused some damage to forests in that area. Other mangrove forests are located near Mogadishu and at a number of places along the north-eastern and northern coasts.

Moreover, other types of land uses include rain-fed agriculture, irrigated agriculture and forestry. Most of the northern part of Somalia is dry and cannot support rain-fed agriculture except for small pockets of land in the areas around Hargeisa, Gebiley and Borama. In the rest of the region, sparse rainfall means that agriculture is only possible where there are alternative groundwater sources to support irrigation. This is common within the alluvial plains where shallow wells and permanent springs provide supplementary water for irrigated agriculture.

In the South, rain-fed agriculture is practiced in the Shabelle and Juba river basin. There are two crop growing seasons, coinciding with the Gu and Deyr rain seasons. The crops grown include sorghum, millet, maize, groundnuts, cowpeas, mung beans, sesame, cassava and vegetables. These crops are produced for both human consumption and animal fodder. Crop production is limited by factors such as shallow and stony soil, low soil moisture, rainfall variability, soil erosion and low soil fertility. A number of soil and water conservation measures such as soil bunding, terracing, and water storage (in dams and other reservoirs) are used to conserve soils and water and extend the growing season.

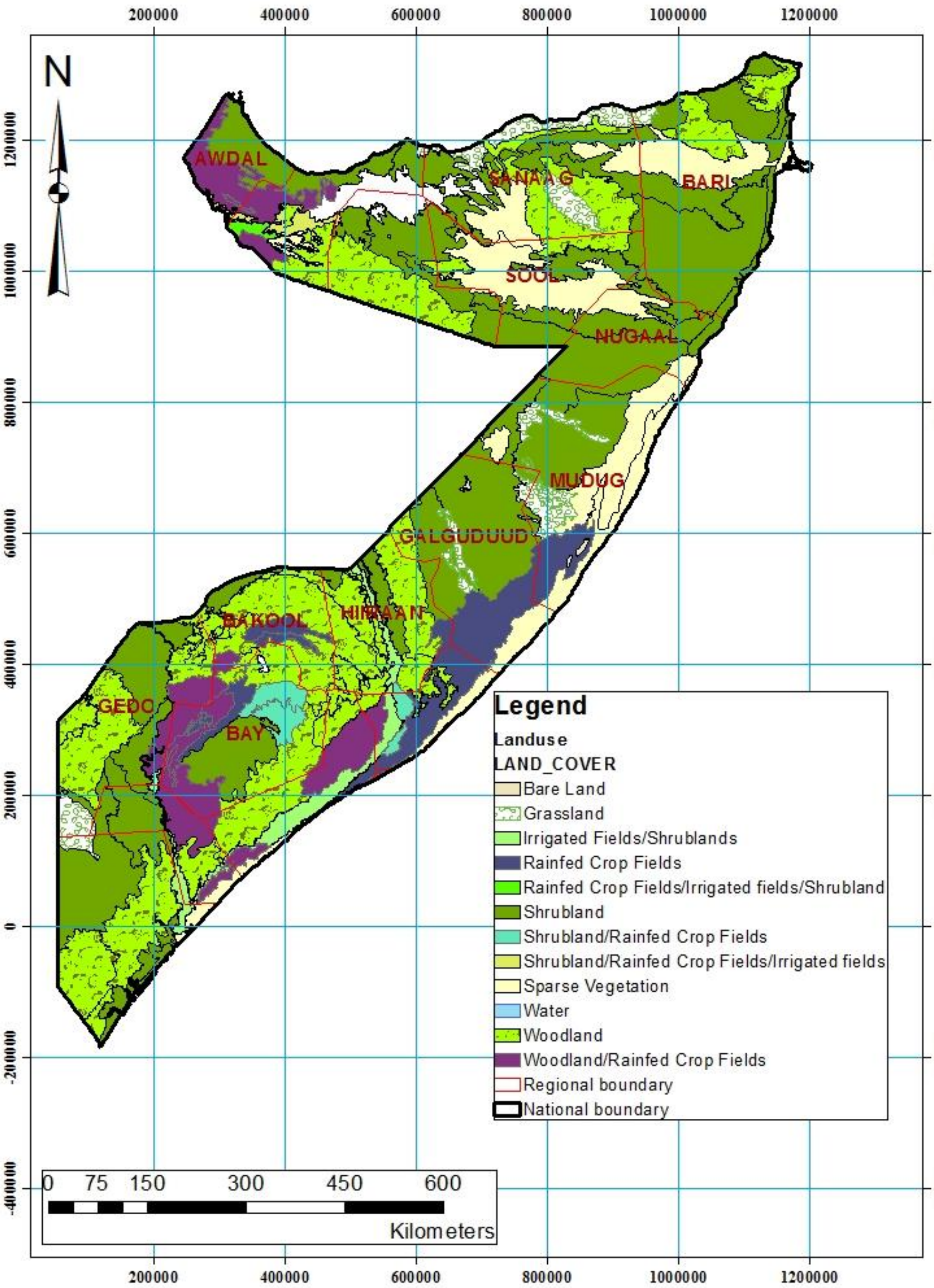

Figure 3. Map showing different types of land use in Somalia.

3.2. Climate

Climatic conditions in Somalia range from arid in the north-eastern and central regions to semiarid in the northwest and south. Due to Somalia's proximity to the equator, there is not much seasonal variation in its climate. Hot conditions prevail year-round along with periodic monsoon winds and irregular rainfall (Conway 200).

3.2.1. Rainfall

Somalia has two rainy seasons: the Gu (April to June) and the Dayr (October to November). Droughts usually occur every two to three years in the Dayr and every eight to ten years in both the Dayr and the Gu. The coastal region in the south around Mogadishu and Kismaayo has an additional rainy season, the Xagaaye (July to August), in which isolated rain showers occur. In the northeast, annual rainfall is less than 100 mm; in the central plateaus, it is about 200 to 300 mm. The north-western and southwestern parts of the nation, however, receive considerably more rain, with an average of 510 to 610 mm falling per year (Kammer 1989). Although the coastal regions are hot and humid throughout the year, the hinterland is typically dry and hot.

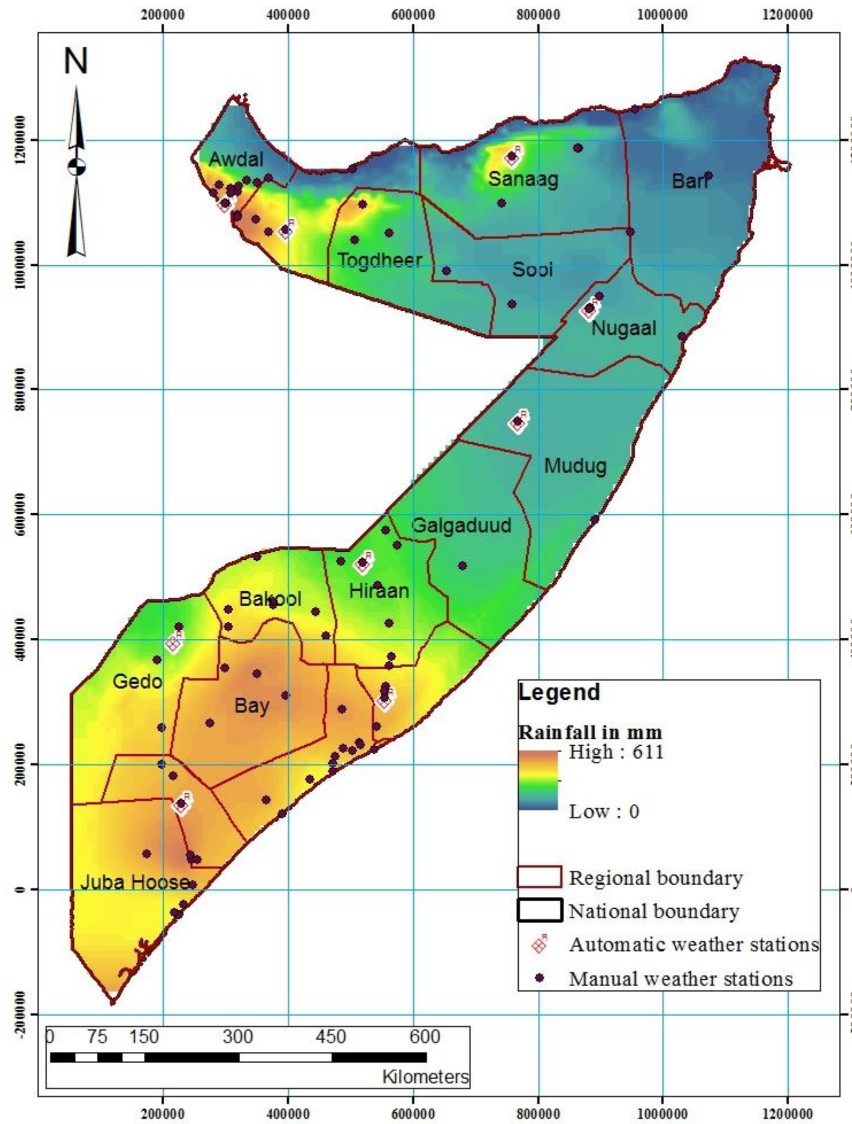

Figure 4. Mean annual rainfall received between 1960-1990 in mm.

3.2.2. Temperature

Mean daily maximum temperatures range from 30 to 40 °C except at higher elevations along the eastern seaboard, where the effects of a cold offshore current can be felt. In Mogadishu, for instance, average afternoon highs range from 28 to 32 °C in April. Berbera on the north-western coast has an afternoon high that averages more than 38 °C from June through September. Nationally, mean daily minimums usually vary from about 15 to 30 °C. The greatest range in climate occurs in northern Somalia, where temperatures sometimes surpass 45 °C in July on the littoral plains and drop below the freezing point during December in the highlands.

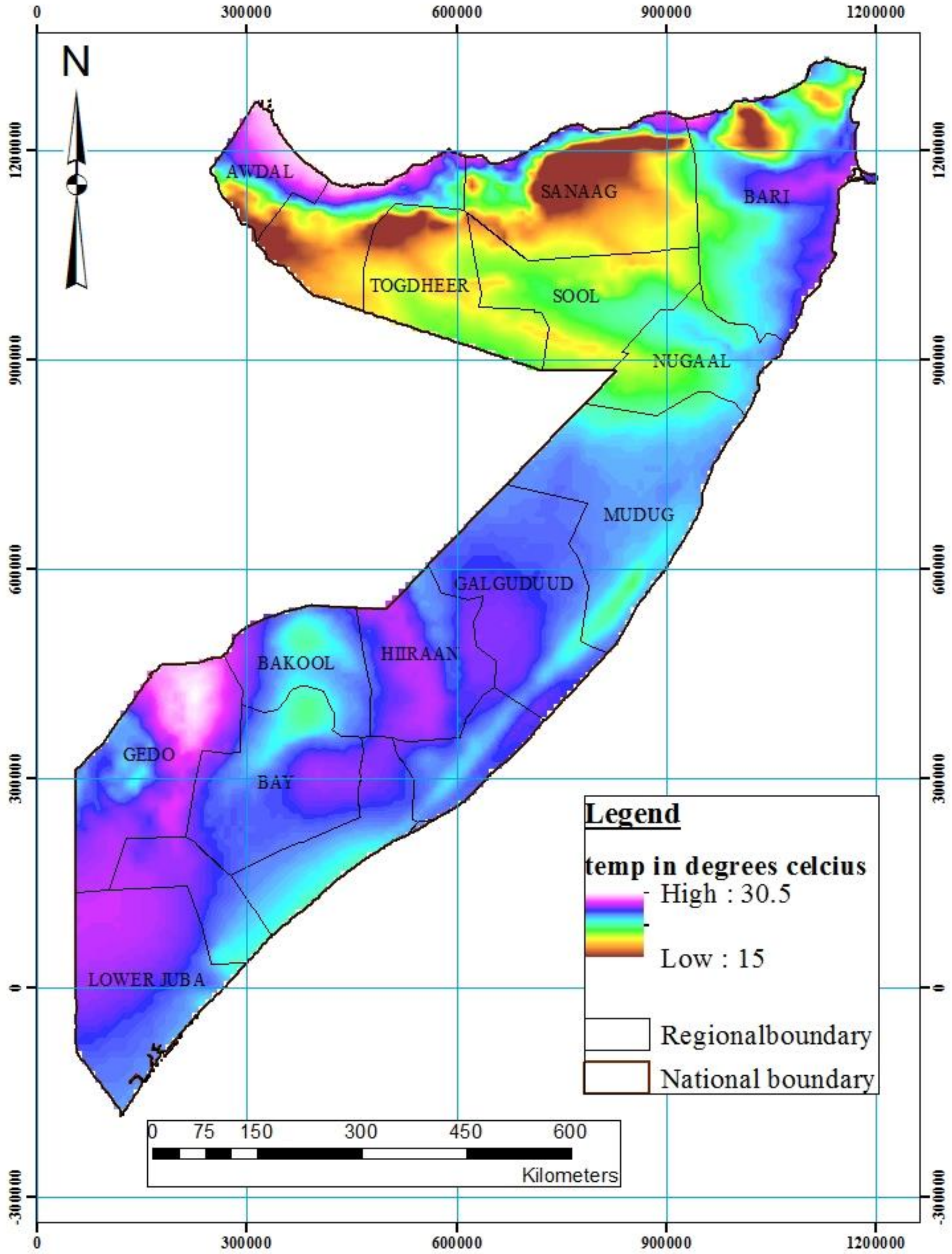

Figure 5. Annual average temperature recorded in degrees Celsius.

3.3. Digital Elevation Model

Somalia's terrain consists mainly of plateaus, plains, and highlands. In the far north, the rugged east-west ranges of the Karkaar Mountains extend from the north-western border with Ethiopia eastward to the tip of the Horn of Africa, where they end in sheer cliffs. The general elevation along the crest of these mountains averages about 1,800 meters above sea level south of the port town of Berbera, and eastward from that area it continues at 1,800 to 2,100 meters. The country's highest point, Shimber Berris, which rises to 2,407 meters, is located near the town of Erigavo.

Southwestern Somalia is dominated by the country's only two permanent rivers, the Jubba and the Shabelle. With their sources in the Ethiopian highlands, these rivers flow in a generally southerly direction, cutting wide valleys in the Somali Plateau as it descends toward the sea; the plateau's elevation falls off rapidly in this area. The western part of the Ogo plateau region is crossed by numerous shallow valleys and dry watercourses. Annual rainfall is greater than in the east, and there are flat areas of arable land that provide a home for dryland cultivators. Most important, the western area has permanent wells to which the predominantly nomadic population returns during the dry seasons. Enhancing the value of the Haud are the natural depressions that during periods of rain become temporary lakes and ponds. The adjacent coastal zone, which includes the lower reaches of the rivers and extends from the Mudug Plain to the Kenyan border, averages 180 meters above sea level.

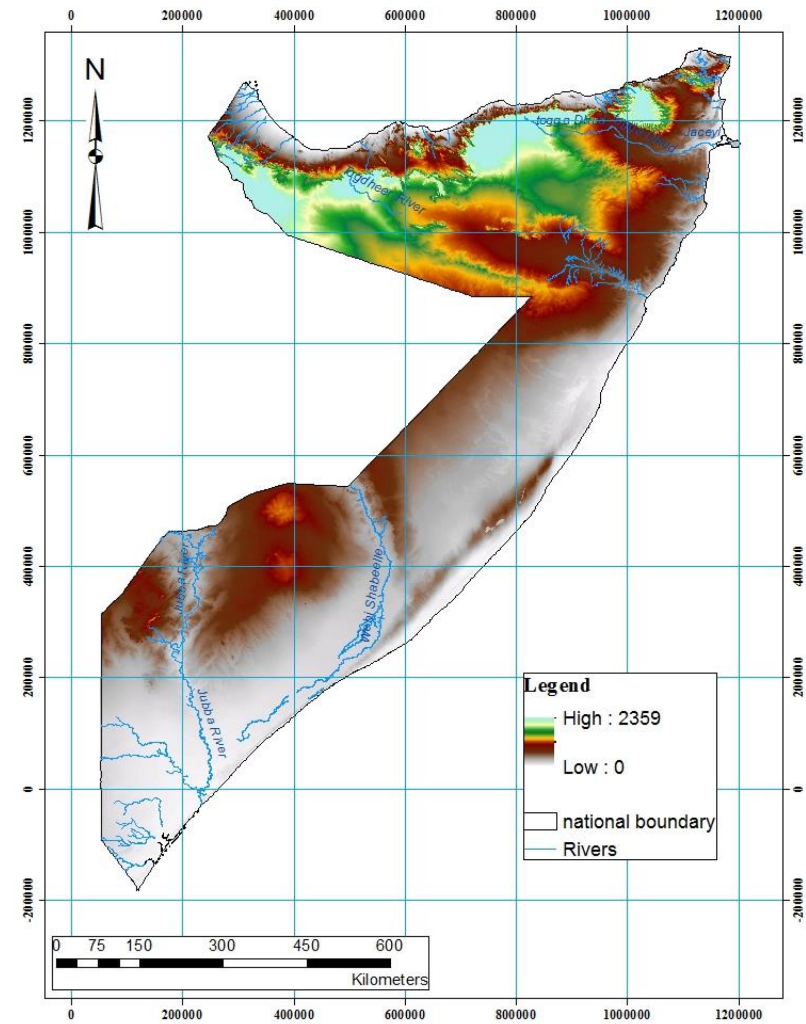

Figure 6. Digital elevation model.

3.4. Hydrology of somalia

The Juba and Shabelle rivers originate in the Ethiopian Highlands, where the main streams and their tributaries are deeply incised into the steep slopes of the upper reaches. However, in Somalia, in the middle and lower reaches, there is a virtual absence of tributaries and other drainage channels; there are some spring-fed streams and some local runoff, but these contribute to river flow only in times of heavy rainfall. Over long reaches, particularly on the Shabelle, the riverbanks lie above the level of the surrounding land, so that any spillages are lost permanently from the river and no return flow occurs.

The areas of the Juba and Shabelle basins are 218 114 km^2 (to Jamaame, excluding Shabelle basin) and 296 972 km^2 (to the Juba confluence). The two basins share many common characteristics. Around two-thirds of the area of both basins lies in Ethiopia, and 5% of the Juba basin also lies in Kenya. Both basins range in altitude from just above sea level in the south to more than 3000 m in their headwaters in the Ethiopian Highlands.

The Juba River has three main tributaries which all flow south-eastwards, joining near the Ethiopia–Somalia border and the Somali town of Luuq. There the Juba turns south to the coast. The total length of the Juba River is about 1100 km (measured on the longest tributary), of which half lies in Ethiopia and half in Somalia.

The Shabelle River flows south-eastwards to the Ethiopia–Somalia border. There it turns south towards Mogadishu, but then turns southwest before it reaches the capital city and continues roughly parallel to the coast from which it is separated by a range of sand dunes. Halfway along the coastal stretch, it runs into a series of swamps. Downstream of the swamps the river resumes a defined channel, but flows are very much reduced and the Shabelle discharges into the Juba only in times of exceptional flood. The total length of the Shabelle River is about 1700 km, again approximately half lying in Ethiopia and half in Somalia (Conway, 2000).

Figure 7. Hydrology of Juba and Shabelle rivers.

3.5. Surface water situational analysis

The surface water situation for Somaliland and Puntland has been comprehensively described by SWALIM (2009) in their "Inventory of Drainage Basins of Northern Somalia". The major drainage basins in the region are: The Gulf of Aden Basin, Dharoor Basin, Togdheer/Nugaal Basin and Ogaden Basin (Figure 6). In addition to these, the narrow strip of land along the Indian Ocean has short drainage networks and there is not much flow in these drainage channels that reaches the Indian Ocean.

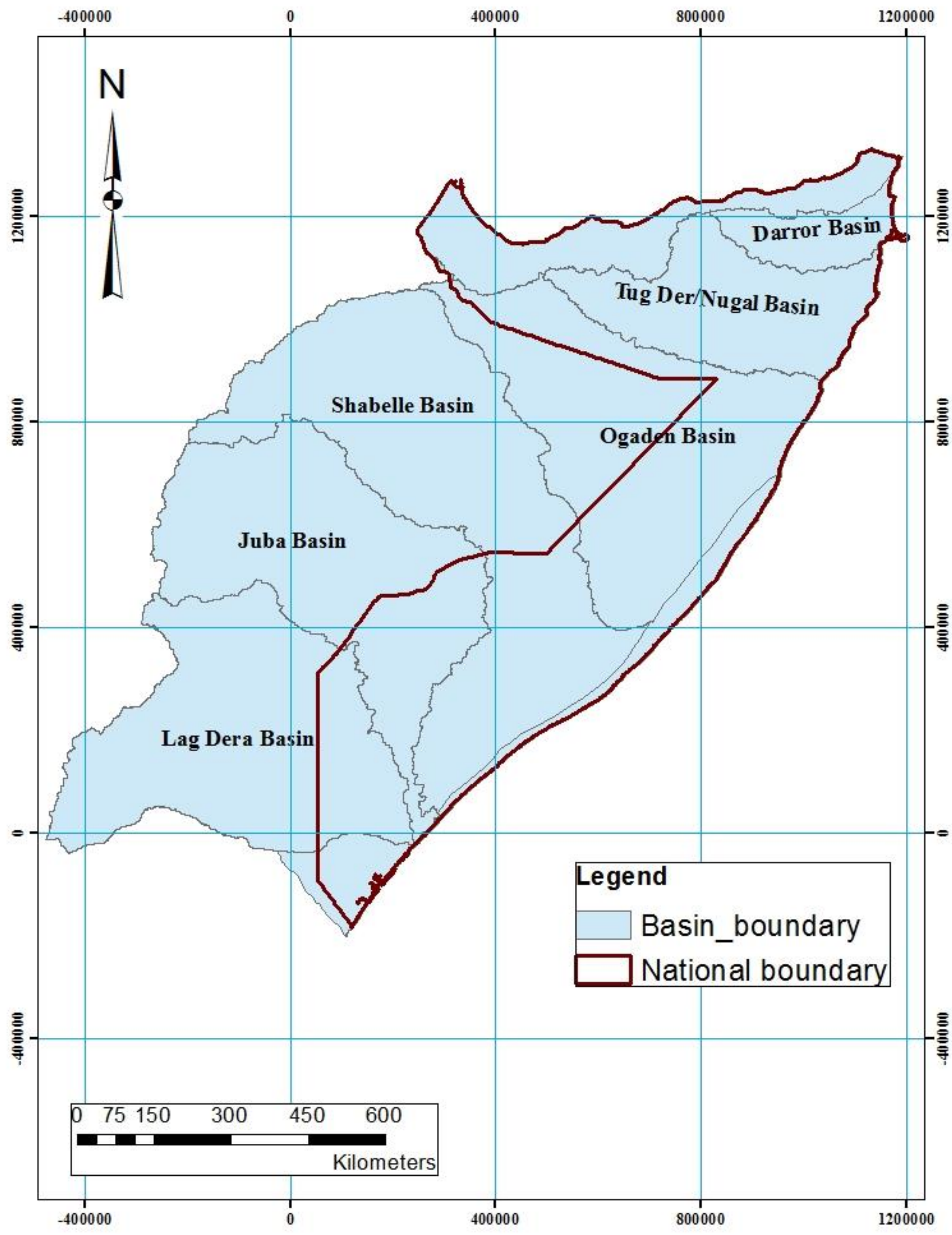

Figure 8. Somalia major drainage basins.

3.6. Groundwater situational analysis

While locally varying, the general hydrogeological conditions in Somaliland and Puntland can be described as challenging with regards to water availability and water quality (Johnson, 1987). Climatic conditions range from semi-arid to arid and surface water availability as well as shallow groundwater levels fluctuate with the rainfall intensities in the different seasons. High salt concentrations in the groundwater of many wells render them marginally suitable or unsuitable for humans and/or livestock. Groundwater, being the primary source of water supply, is generally obtained from boreholes, dams, dugwells and springs. An overview of the distribution of these water sources is shown below;

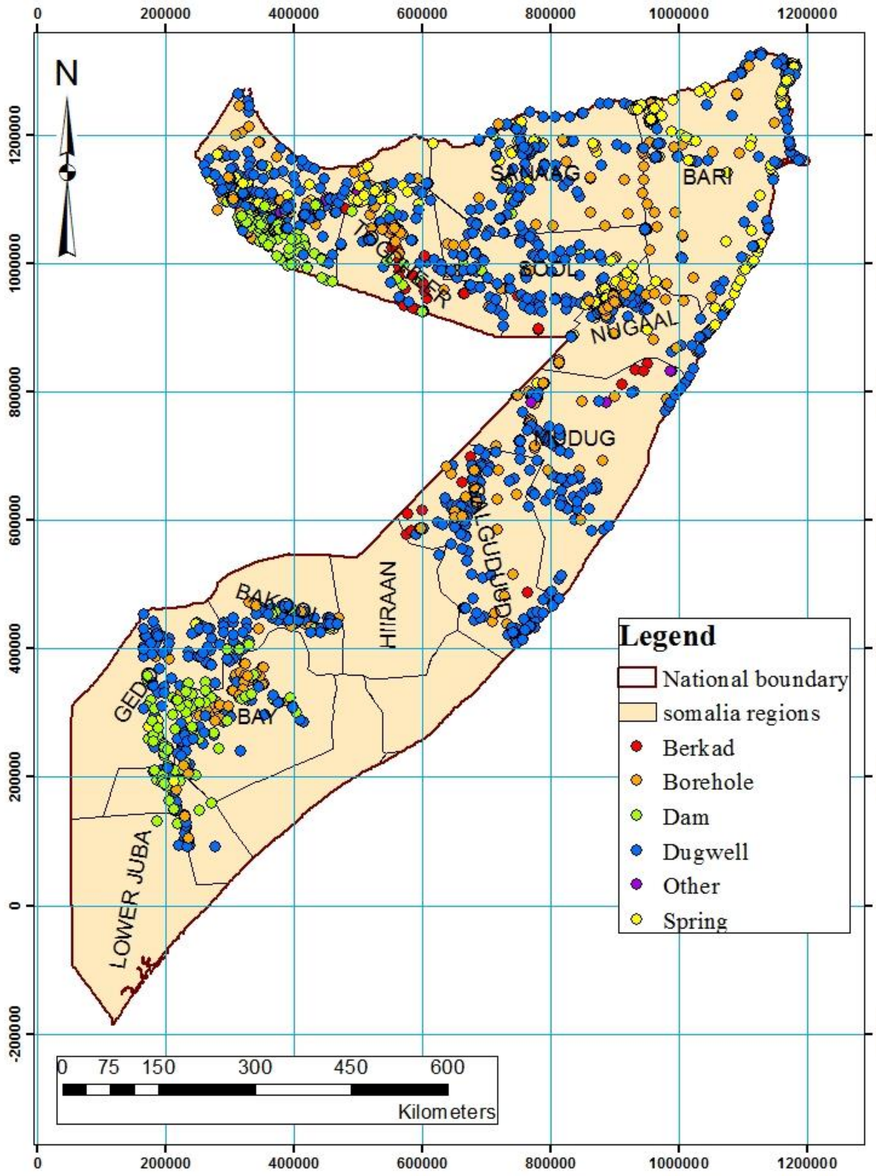

Figure 9. Distribution of various water sources in Somalia.

3.7. Soil erodibility analysis

The quality of the soil is an essential and determinant component of Somalia's agricultural productivity and natural ecosystems. But soil is a fragile and non-renewable resource. It is easily degraded and difficult, slow, and expensive to regenerate. Soil depletion and degradation is directly related to Somalia's and the world's hunger crisis. Somalia has various soil types, primarily according to climate and the parent rock. The northern part of the country (Somaliland and Puntland) has shallow sandy and/or stony soils and some deeper lime-rich soils. In the highlands around Hargeisa, relatively high rainfall has raised the organic content in the sandy calcareous soils characteristic of the northern plains. This soil supports some rain-fed farming. South of Hargeisa begins the "Haud" region whose red calcareous soils continue into the Ethiopian Ogaden and support vegetation which is ideal for camel grazing. Deep clay soils are found south of Gebiley in Somaliland. The central part of the country is dominated by sandy soils along the coast and moderately deep loamy soils with a high content of calcium carbonate and/or gypsum further inland. Prominent in southern Somalia are low-lying alluvial plains, associated with the Juba and Shebelle Rivers. These plains mainly have clayey soils, some of which have poor drainage and/or high content of salts. Some of the riverine areas are also liable to flooding. The inter-riverine areas have both shallow soils (particularly towards the border with Ethiopia) and deep loamy and clayey soils. Figure 10 shows the soil unit characterization.

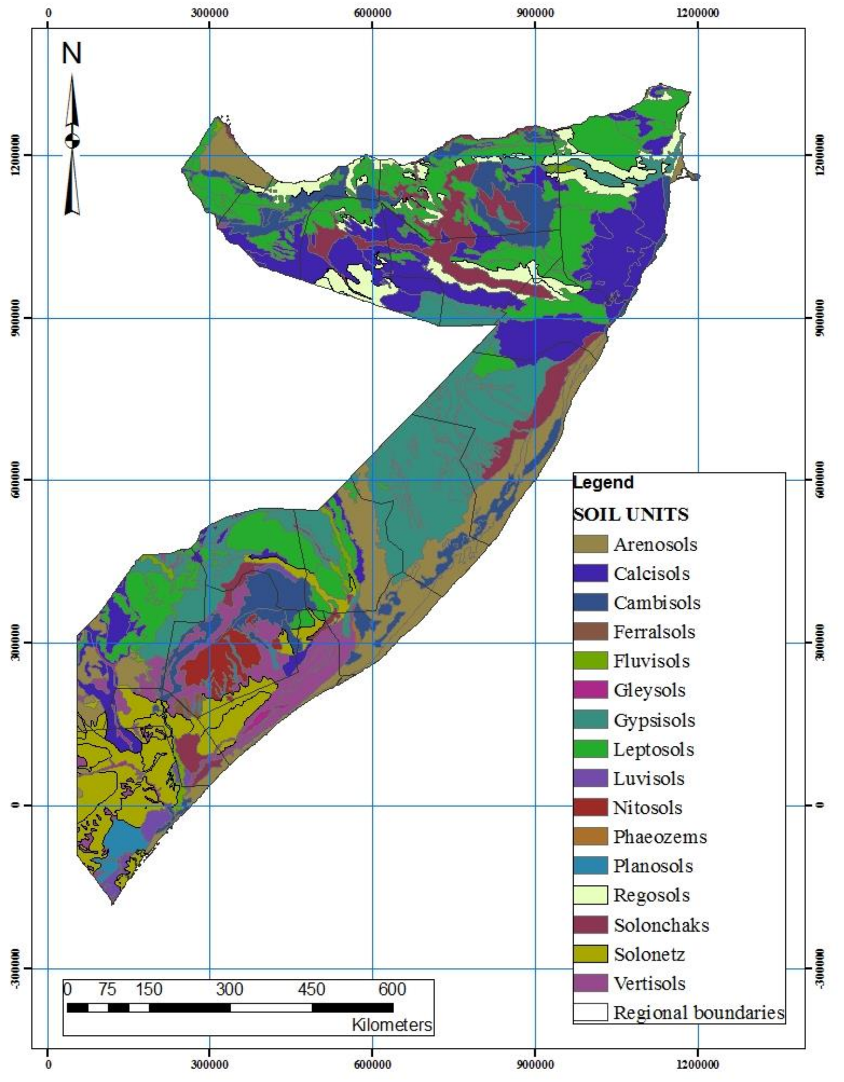

Figure 10. Soil units' map analysis.

The soil erodibility analysis for Somalia was modelled from harmonized soil database with three main combination that largely characterize its erodibility. The soil gravel content, the depth or available water content and the texture was analysed in this category and classified according to the ease with which soil can easily be washed if the available cover is weak. The classification criteria classified gravel content that is above 10% as slightly erodible, 1 to 10% as moderately erodible and those less than 1% to be highly erodible, whereas the available water content of between 0 to 15mm/m as highly erodible, 50 to 100mm/m as slightly erodible and above 100mm/m to be of low erodibility.

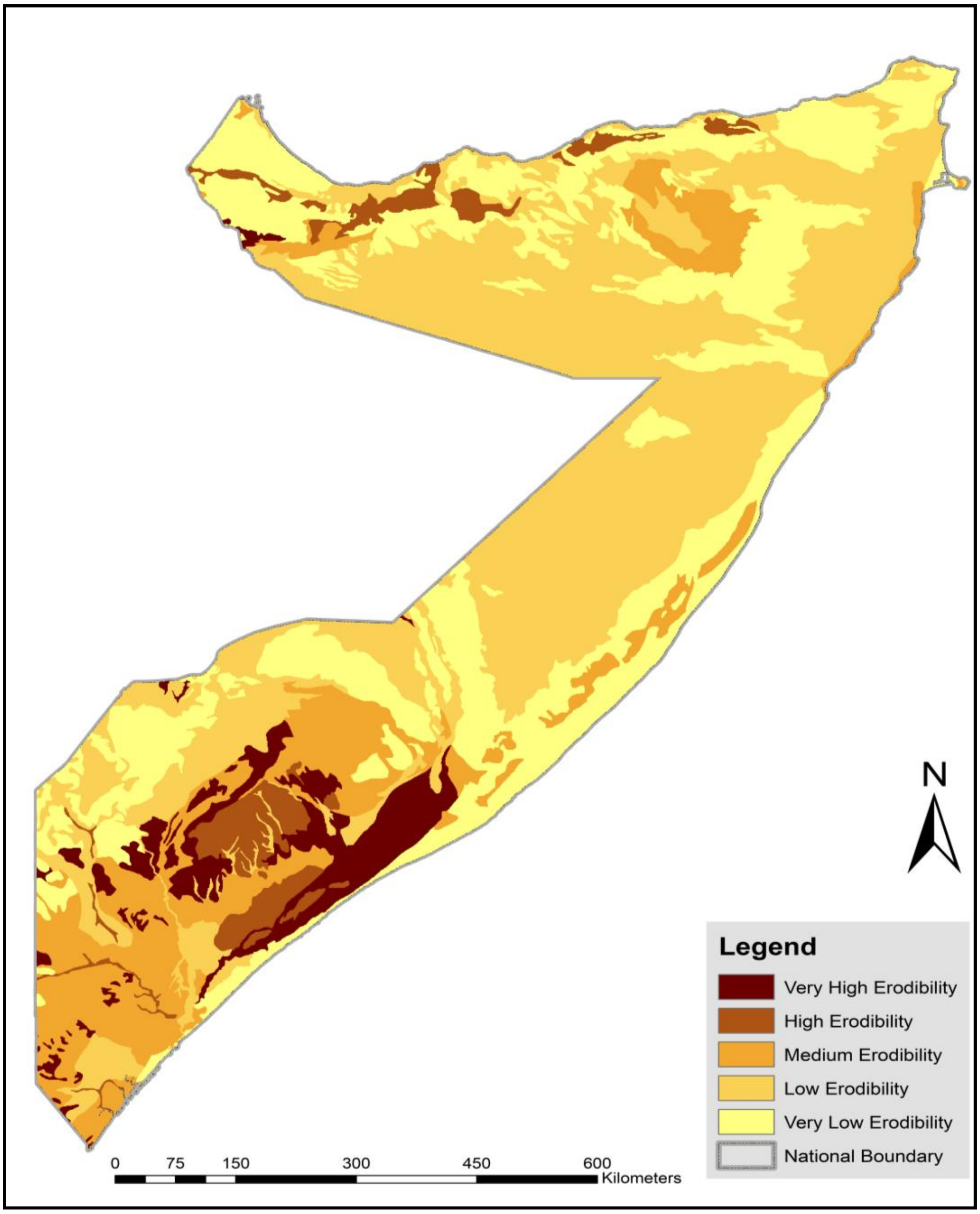

Figure 11. Characterized soil erodibility map.

The soil texture in this combination was classified based on the particle size and type where the Loam (L), Silty loam (SiL), sandy loam (SL) and silt was classified as highly erodible due to their particle sizes. The moderately erodible soil was sandy clay (SCL), Clay (CL), Silty clay (SiCL), Loamy Sand (LS) and Sand(S) with low erodible soil contains; sandy Clay (SC), Clay and silty clay (SiCL).

3.8. Multivariate Geographical Clustering for Agro-climatic zoning

Multivariate clustering analysis represents a relatively recent development, characterizing discontinuities into subsets according to multiple parameters, such as orientation, spacing, and roughness, where rather than considering one variable at a time, a number of parameters can be treated simultaneously, so that the interactions between parameters are taken into account. Several investigators have recognized the potential of geographic multivariate clustering for delineating homogeneous regions objectively within small maps. Multiple geographic areas can be classified into a single common set of quantitative eco-regions to provide a basis for comparison, or maps of a single area through time, can be classified to portray climatic or environmental changes geographically in terms of current conditions. This tool in ArcGIS software (*geoprocessing tool*) was used to delineate the agro-climatic zones of Somalia using the climate data (temperature and rainfall), hydrology, land use, soil erodibility and terrain. It requires the geographical geolocation of all raster data components and uses a statistical clustering in a multivariate layering approach. The results obtained indicated suitability zones / areas for agricultural development. (Figure 12).

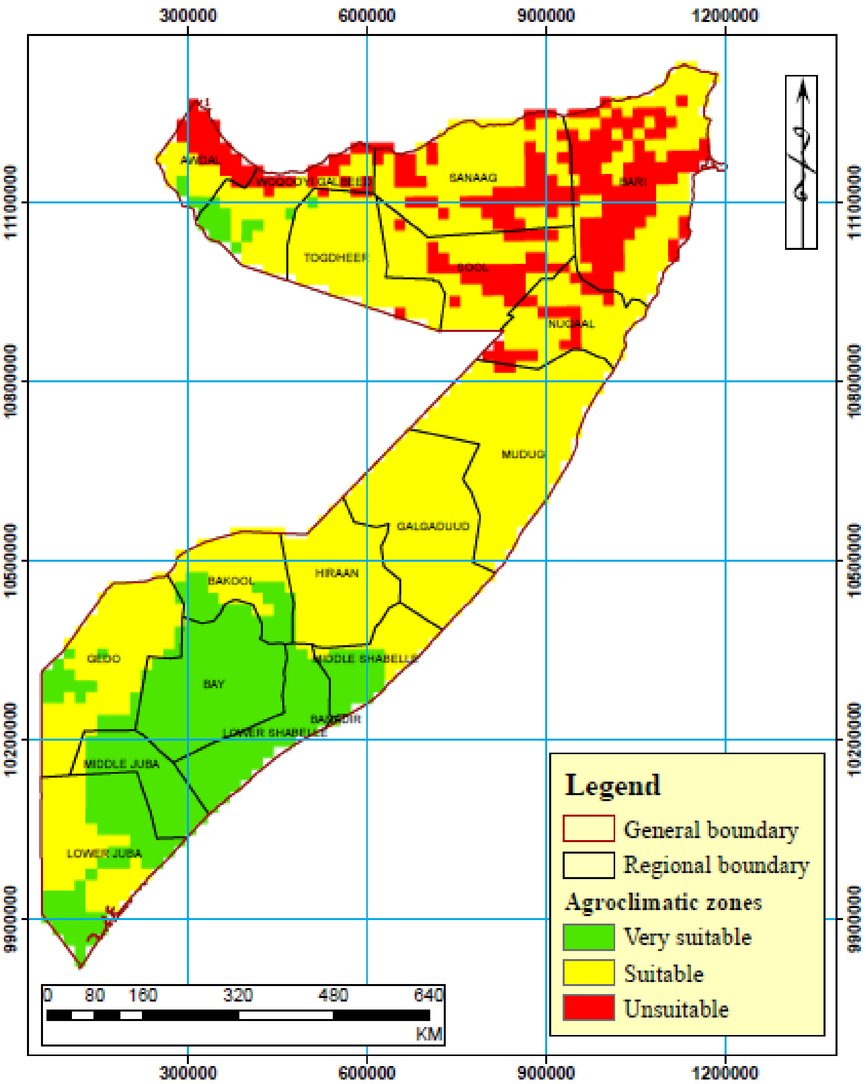

Figure 12. Characterized Agro-climatic map of Somalia.

3.9. Assessment of Potential Areas for Agriculture in Somalia

Irrigated agriculture is practiced in the floodplains along the permanent rivers in south Somalia (the Juba and the Shabelle) and along the seasonal streams and springs. In northern Somalia, water is available within pockets of deep soil for irrigated orchards, or from shallow wells and springs, which are the major sources of water for crop irrigation, with water pumped to the fields. These fields in their respective locations shows that the land is productive for agricultural development with no much need for additional nutrients. Irrigated crops grown on a small scale include maize, sesame, fruit trees and vegetables, while crops such as bananas, guava, lemon, mango and papaya are grown on a large-scale for domestic consumption.

Considering the hydrology of Somalia, it is seen that the Ethiopian headwaters of the Juba and Shabelle, surface water resources are abundant. In the middle reaches, where runoff is highly localized and seasonal, the rivers themselves still carry considerable volumes of water during most of the year. Downstream of the Ethiopia-Somalia border, discharges reduce progressively with the Shabelle often ceasing to flow in its lower reach in the early part (January–March) of the year. It is therefore prudent to say that Shabelle has a substantially greater catchment area than the Juba, even though the flow in the Juba is about three times as large as the Shabelle flow. This is partly due to higher average annual rainfall, but also due to a much better developed drainage network in the upper part of its basin, with three tributaries producing high runoff volumes indicating agricultural potential.

In terms of soil variables as indicated in (Figure 10) brings a clear soil erodibility indication. The map indicates that the south-central parts of Somalia especially the convergence zones of river Juba and Shabelle which is moderately to highly erodible among other parts in the country can be productive. The erodibility serves as indicator of areas or regions with fragile fertile soils that are productive with fine top soil that is rich and can support food production. Vegetation cover in this areas or zones coupled with conservation measures is highly desirable to contain the top fine and productive soil for sustained agriculture. Figure 12 demarcates the zone areas that are deemed suitable for cropping.

The agricultural potential that lies in Somalia is so huge that one can imagine of one day being the main agricultural producing country in the Northern part of Africa. The climate, the hydrology, the soil erodibility and the land cover through a multivariate geographical clustering of a GIS presents an idea of where to target for agriculture. The existing ground water sources (boreholes) and surface water basins (juba and Shabelle basins) coupled with gentle sloppy terrain indicates a promising availability of water, which is a major requirement to food crops especially for the irrigate landscapes.

Conclusion and recommendation

GIS is one of the easiest ways of providing management tool for mapping all the land use, climatic change and other human activities. Remote Sensing integration with GIS is a versatile and user-friendly application that can be employed to provide an appropriate framework through the manipulating, visualizing and spatial analysis to support planning and decision-making process relevant to irrigation management. The integration of GIS with the available data management tools is more powerful and effective when dealing with large area and complex temporal data.

Higher temperatures and less rainfall will reduce the flow of rivers and streams, slow the rate at which aquifers recharge, and make the entire region more arid. These changes will have a series of effects, particularly on agriculture, energy and food security, and contribute to malnutrition, famine and starvation. Agriculture yields, especially in rain-fed areas, are expected to fluctuate more over time, and to stabilize at largely lower averages over the long-term.

Acknowledgement and future research

The authors acknowledge the support by department of Geomatic Engineering and GIS of Jomo Kenyatta University of Agriculture and Technology and also the capacity development provided by the department of research and development of Mapinfotek Geomatiks Ltd in seeing this work was accomplished. Further research is to understand the impacts of climate change or climate variability on the agricultural potential areas and to develop a national agro –ecological zone chart for the country. Much thanks goes to FAO and KITE (University of York) for providing access portal to the datasets used.

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