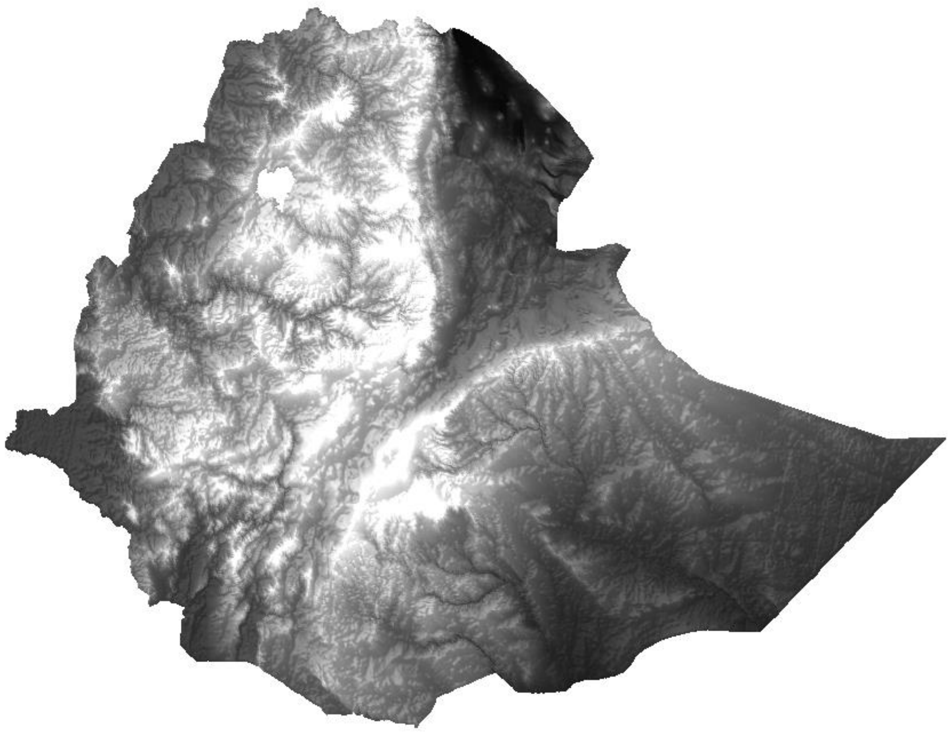
Biophysical and Socioeconomic Geodatabase for Land Productivity Dynamic Assessment in Ethiopia



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1. Introduction

Land degradation includes all process that diminishes the capacity of land resources to perform essential functions and services in ecosystems (Hurni et al., 2010). It is caused by two interlocking complex systems: the natural and the human social system. Understanding of these two complex system is very essential in the process of restoring degraded landscape. The direction for proper design of restoration plans and options depends on the availability of detailed information about the land condition and identifying precisely the causative factors responsible for land degradation. In this regard, systematic information gathering (mapping, measuring and monitoring) allows for evidencing the land degradation problem from a scientific point of view and enhance our capacity in prioritizing areas for rehabilitation work. These days, the advancement of satellite and geospatial technologies helps a lot in terms of information gathering, monitoring land degradation and mapping hotspot areas. Time series satellite products like the Normalized Difference Vegetation Index (NDVI) and the Net Primary Productivity (NPP) are the very common proxies and have been used for land degradation monitoring and mapping hotspot areas that require priority intervention at national, continental and global scales.

Though monitoring and mapping of land degradation are the most important tasks in land degradation studies, understanding the causal factors is equally important. Generally, the causal factors can broadly be grouped into natural (e.g., climate) and human (e.g., land use, land management). These factors are interlocked within a complex system. It is necessary to disentangle the human-induced causes of land degradation from those caused by climate change for clear understanding of the problem and for the planning of suitable restoration options. For instance, for climate-related causes, relevant measures can be designing adaptation or mitigation mechanisms, while for human-induced causes appropriate measures can be designing and implementing improved land use and management practices.

The first task, to map and assess land degradation and understand the major causal factors involves collecting data that potentially can be used as indicators for land degradation. It is also necessary to collect all relevant data that are supposed to be used to understand the cause of land degradation. Since the causes of land degradation vary at different spatial and temporal scales, time series spatial data are the most convenient for such kind of study. In this regard, multi-temporal satellite products like NDVI can be used as indicator to monitor and map land degradation. On the other hand, time series biophysical and socioeconomic geospatial data can be used integrate with satellite products and evaluate the major drivers to devise mechanisms of tackling the problem.

2. Background

Ethiopia is one the developing countries facing severe challenges of land degradation. The cost of land degradation includes reduction of agricultural production and productivity, losses of biodiversity, stream sedimentation affecting water quality and storage, and many more. One of the major causes of land degradation in Ethiopia is soil nutrient depletion. It is reported that it is the highest among sub-Saharan Africa. This is mainly associated with soil erosion that is estimated at 42 t/ha/yr on cultivated land (Stoorvogel and Smaling, 1990; Pender et al., 2001). Another important factor responsible to land degradation in Ethiopia is drought during El Niño years. This periodic drought is the major cause for frequent decline of the overall agricultural production in the Ethiopian agricultural system and consequently the country's economy. In the recent past, it is believed that drought and its effects have been intensified in frequency, magnitude and spatial extent. Other factors that are responsible to land degradation in Ethiopia including deforestation, overgrazing, expansion of crop land, and unsustainable use of natural resources (Descheemaeker et al., 2011).

Many studies indicated that the cause of land degradation in Ethiopia is either human induced (e.g. poor land management), climate driven (e.g. El Niño induced drought), or a combination of both factors. In addition, these causative factors operate at different spatial and temporal scales. This makes the issue of land degradation very challenging. As a result, the solution suggested for one place cannot be easily used to upscale covering a large domain. In response to this challenge, systematic monitoring of land degradation using satellite products integrating with other geospatial data helps in understanding the cause of land degradation at different spatial and temporal scales as well as devising suitable solutions to sites specific and time dependent problems.

In this work, relevant data that can be used to monitor land degradation and assess the major drivers were collected. These data are mainly categorized as biophysical and socioeconomic. The first task to accomplish this goal is to establish a platform that can integrate all data collected from different sources with different dimensions. For this case, geodatabase development is one of the option that can facilitate integrating and standardizing the collected data and making it suitable to use for further study. To achieve this, the ArcCatalog of ArcGIS, which is one of the favorite tool for geodatabase development, is used in this work to develop database consisting of biophysical and socio-economic factors.

This work is initiated and supported by the Soils program of CIAT with the aim of understanding the major drivers of land degradation in Ethiopia. This will help designing strategies to restore degraded areas through suitable management interventions. It can also help design appropriate policies and institutions to properly and efficiently materialize the restoration practices.

3. Objective

The main objective of this study is to collect all relevant biophysical and socio-economic data and develop a geodatabase that are supposed to contribute for the assessment of land and soil degradation dynamics in Ethiopia.

4. Approach to develop the geodatabase

4.1. Dataset Inventory

The initial step was to make an inventory of the necessary dataset based on the required type of data in relation to land degradation and its drivers. Key dataset considered were summarized in Table 1, along with its information content, geographic coverage, effective scale, latest update, and relevance.

Table 1. Dataset considered in the geodatabase development

No.	Dataset	Source	Scale/ resolution
1	Administrative divisions • Region • Zone • Woreda (district) • Kebele (county)	Central statistics Authority (CSA), 2007 (unofficial)	
2	Agroecology	Ministry of Agriculture and Natural resources (MoANR), 2005	
3	Climate • Weather station location • Precipitation • Maximum temperature • Minimum Temperature • REF2-SEDI	▪ National Meteorological agency of Ethiopia (NMA) ▪ National Oceanic and Atmospheric Administration (NOAA) & NMA	11 km
4	Geology	Ethiopian Geological Survey	1:2,000,000
5	Hydrology • River • Lakes • Dams and Irrigation schemes	Ministry of Water Resources and Energy (MoWRE) and Ministry of Agriculture and Natural resources	1:250,000
6	Infrastructure • Road • Settlement (Towns, villages and cities)	Ethiopian Road Authority Central Statistics Authority, UNOCHA	
7	Soil • Soil type • Soil properties	▪ Food and Agriculture Organization (FAO) Global Soil and Terrain Database (SOTER) 1997 ▪ ISRIC , 2015	1:1,000,000 250 m
8	Elevation (digital elevation model, DEM)	Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model Version 2 (ASTER GDEM V2), 2011	30 m
9	Land cover	Regional Center for Mapping Resources for Development (RCMRD), 2008.	30 m
10	Vegetation condition • NDVI (MOD13A2)	United State Geological Survey(USGS) & National Aeronautics and Space Administration (NASA)	1 km & 16 days

10	Woreda and Zonal level statistics
	• Human development
	  ○ Population
	  ○ Educational characteristics
	  ○ Economic activity
	• Crop statistics
	  ○ Areal coverage
	  ○ Crop Yield
	  ○ Fertilizer input
	  ○ Improved seed
	• Livestock population
		Agricultural sample survey and demography and housing census data from the
		Central Statistical Agency of Ethiopia	

4.2. Geodatabase development

Collecting relevant spatial data which can be used as proxies for mapping and monitoring land productivity in Ethiopia requires development of geodatabase to facilitate retrieval, storage, sharing and analysis. The process could also serve as a framework from which to expand other data creation activities into more complex geodatabase configurations.

One of the convenient ways to establish a geodatabase is to use the ArcCatalog in the ArcGIS environment. This geodatabase maintains data integrity, possible to create controlled attribute, enables transfer of project and inherent data as a discrete unit. The geodatabase development task follows the standard procedure to develop the geodatabase of this project. This includes proper creation of feature datasets, feature classes, create domains and setting proper spatial reference system (Fig. 1).

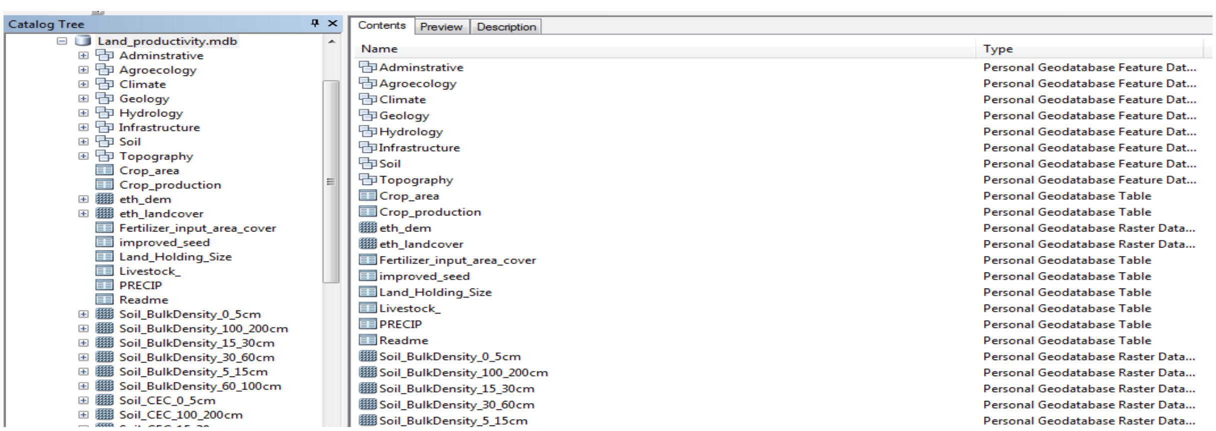


Figure 1: Schema of the geodatabase of this project

5. Analysis and Mapping

5.1. Administrative and boundaries

5.1.1. Administrative division

There are four level of administrative divisions in Ethiopia. The higher level division is called a Region, which is equivalent to a state e.g. in the United States of America. There are nine regions and two chartered cities in the country (Fig. 2). The regions are composed of zones which themselves are composed of woredas. A Woreda is equivalent to a district, managed by a local government. The lowest level of administrative division is a Kebele (=county), the smallest unit of local government. Theses administrative divisions are important for collecting, organizing and mapping relevant socio-economic and statistical data. It is also helpful to contextualize the analysis results, facilitate interpretation and enhance planning and decision making.

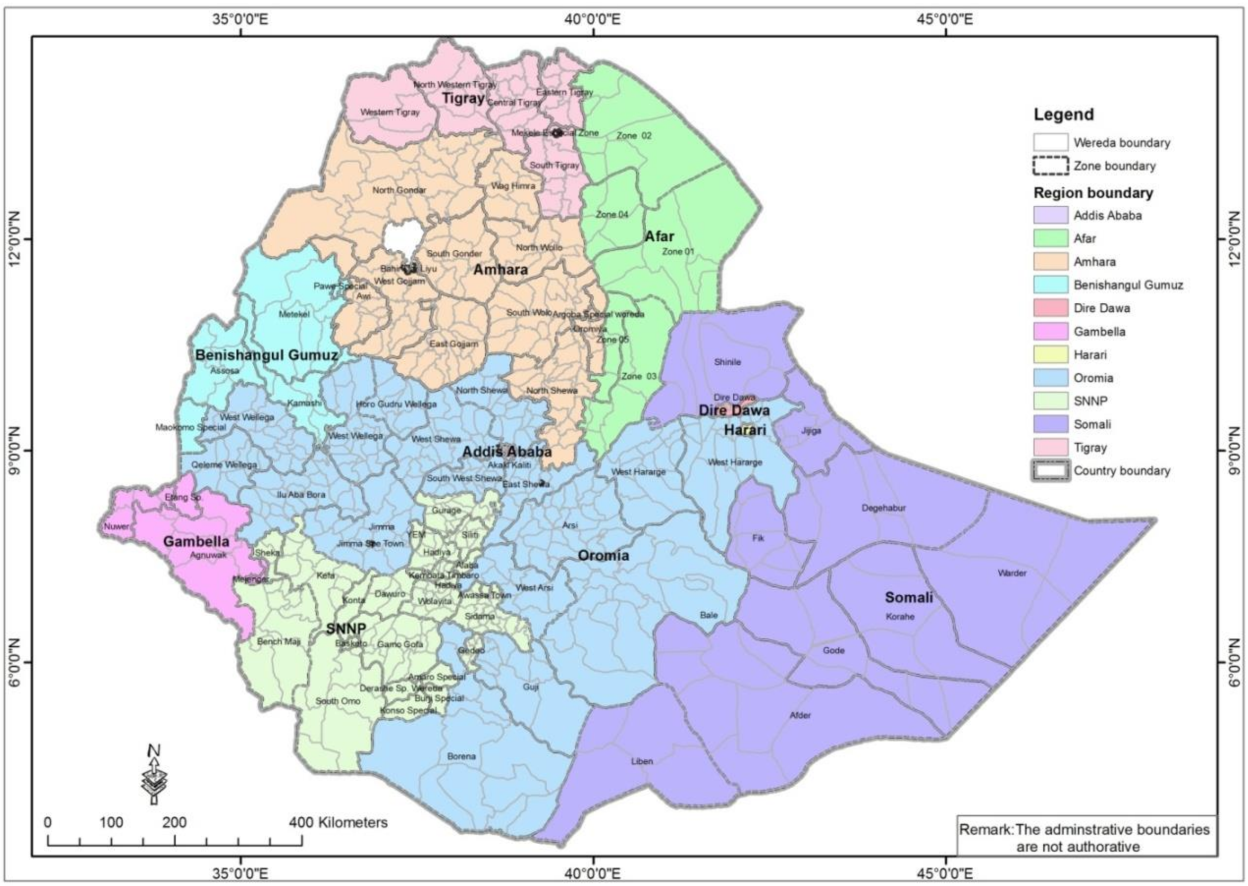


Figure 2. 2007 administrative divisions in Ethiopia (own analysis). Date source: CSA (personal communication)

5.1.2. Settlement and road network

Settlement and road network can be considered as an important infrastructures for accessibility to market, services, information and technologies. According to Ethiopian road authority, the total length of road network in Ethiopia was 46,812 km and the road density was 42.6 /1000 km^2 by the end 2009. Settlement development strongly depends with infrastructure development especially road network. This is evidenced by the spatial association of settlement density and road network density. It is clearly seen in Figure 3 that more dense settlements are found along the road network.

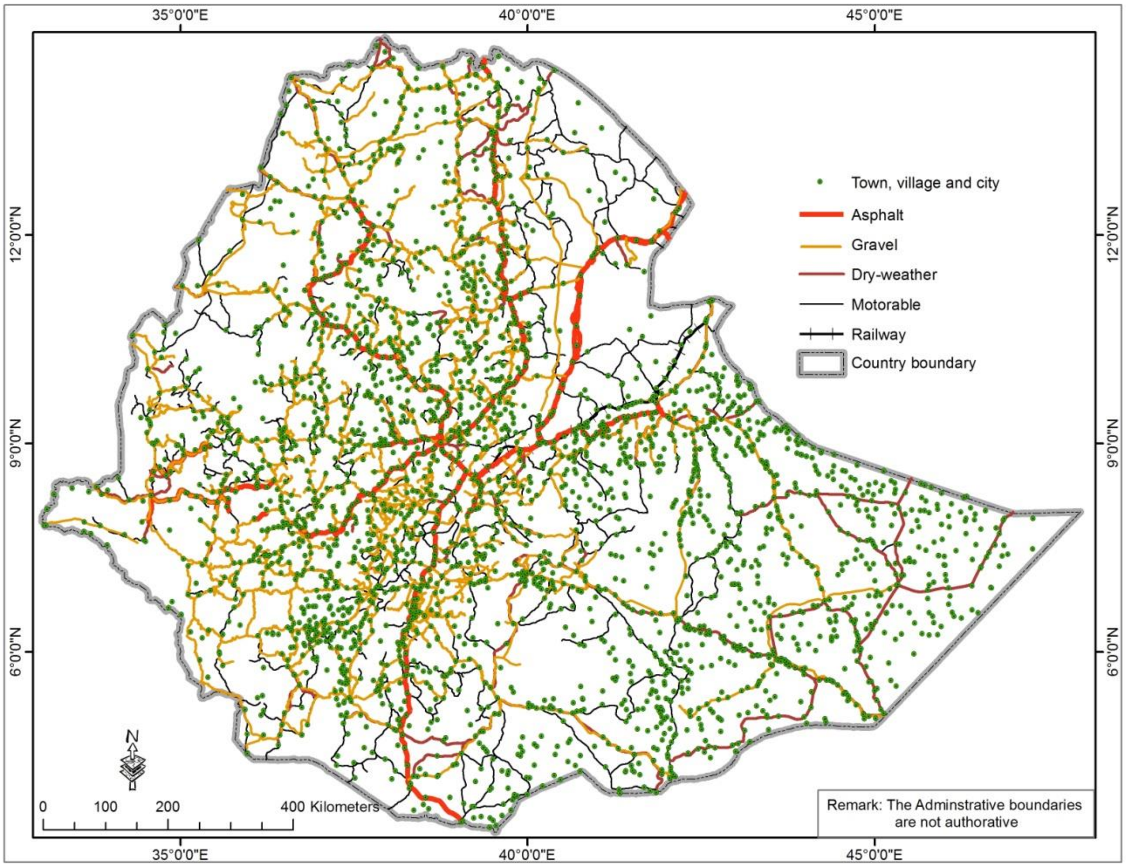


Figure 3. Settlement and road network (own analysis). Date source: Central Statistical Authority (CSA) and Ethiopian Road Authority (ERA)

5.1.3. Elevation

Ethiopia is a country of geographical contrasts, varying from as much as -116 m below sea level in the Danakil depression to more than 4,542 m above sea level in the mountainous regions. The Great Rift Valley is the most distinctive feature that separate the country into western and eastern parts. The Western part is characterized by a very rugged topography marked by mountain ranges. The highest elevation is found in this massive land. In the Eastern part of the Great Rift Valley, the Somali Plateau—arid and rocky semi desert, extending to the Ogaden, which covers the entire southeastern section of the country. The Great Rift Valley itself covers a large portion of the country that extends from Denakil depression of Afar in the north to the Omo valley in the south. The lowest elevation is found in this part of land.

Thus, elevation is one of the important determinant of land productivity/degradation in Ethiopia. Elevation has a strong influence on climate through modifying of temperature and rainfall at local scale. Thus, it is considered as a fundamental dimension which determine agriculture activities and overall land productivity condition.

Figure 4 shows digital elevation model of the country. It is processed and analyzed in this work based on the data extracted from Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model Version 2 (ASTER GDEM V2), 2011.

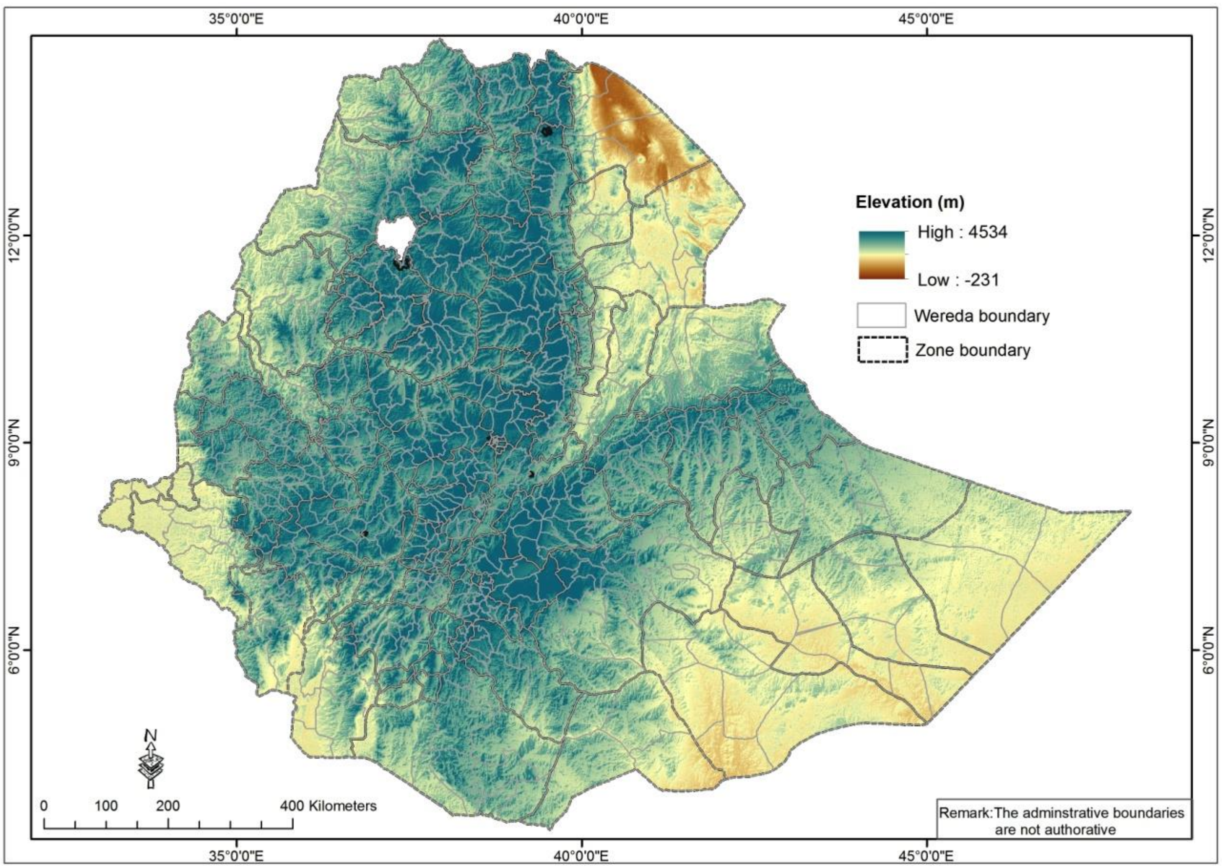


Figure 4. Ethiopian elevation (own analysis). Date source: ASTER GDEM V2

5.1.4. Hydrology

Ethiopia is considered the water tower of Eastern Africa. It is the home for many rivers and lakes. Ethiopian highlands are the source for the major perennial rivers. There are 12 major river basins and 8 major natural lakes. Most of the natural lakes are situated in the rift valley. The 12 major river basins form four major drainage systems; the Nile basin (including Abbay or Blue Nile, Baro-Akobo, Setit-Tekeze/Atbara, and Mereb) covers 33% of the country and drains the northern and central parts westwards, the Rift Valley (including Awash, Denakil, Omo-Gibe, and Central Lakes) covers 28% of the country, The Shebelli-Juba basin (including Wabi-Shebelle and Genale-Dawa) covers 33% of the country and drains the southeastern mountains towards Somalia and the Indian Ocean and the North-East Coast (including the Ogaden and Gulf of Aden basins) covers 6% of the country (Fig. 5).

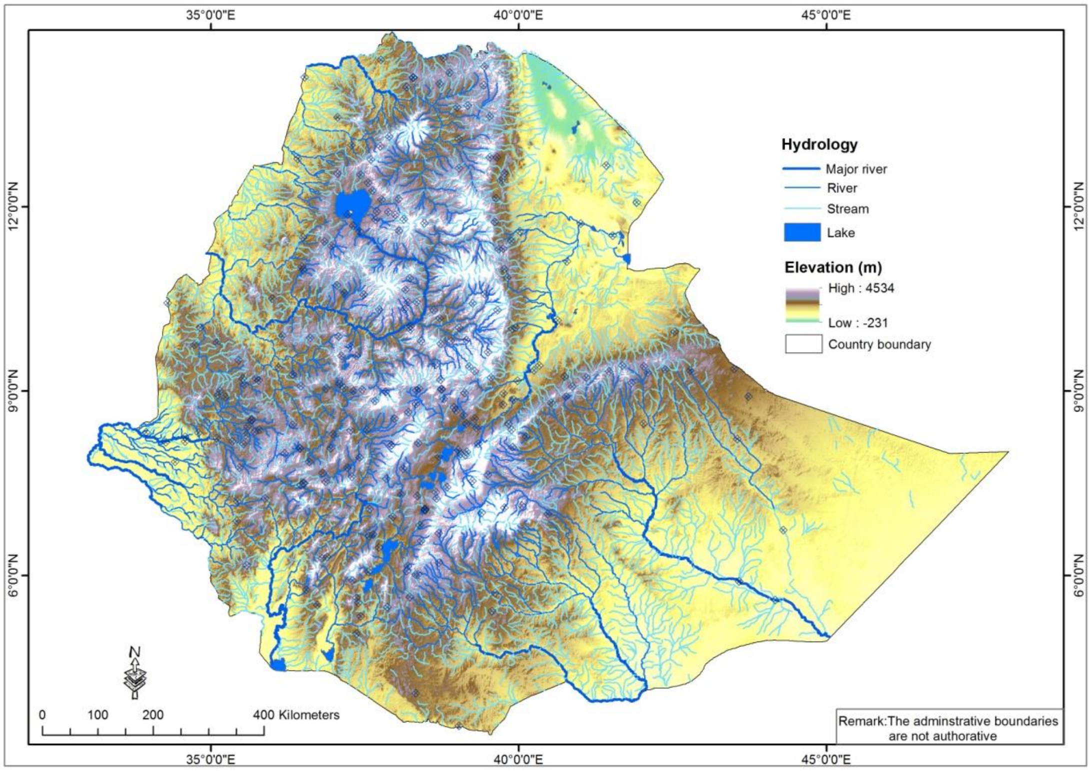


Figure 5. River network and lakes in Ethiopia (own analysis): Data source: Ministry of Water Resources and Energy (MoWE)

Though Ethiopia has enormous surface water resources, it is under developed and utilized. Limited number of water schemes (dams, diversions, etc.) were constructed for different purposes like hydropower generation, irrigation and drinking water supply. Few number of large and medium dams are constructed for hydropower generation, irrigation and water supply to the cities like Addis Ababa and Gondar. Some small dams (micro-dams) were constructed for irrigation and supplement rainfed (Fig. 6).

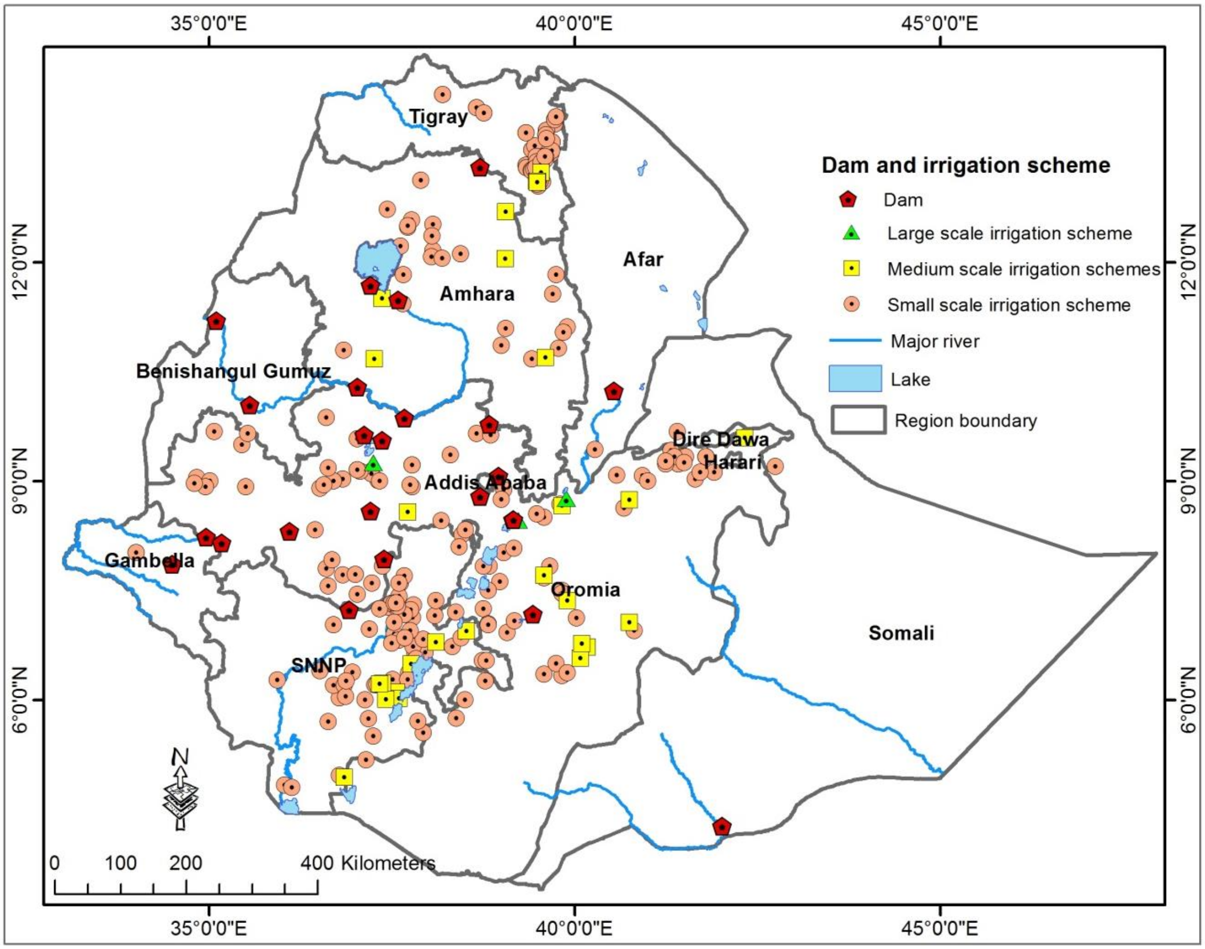


*Figure 6. **Distribution of dam and irrigation schemes (own analysis): Data Source: MoWE & MoANR***

5.1.5. Agro-ecology

Agroecological zones are areas where predominant physical conditions guide relatively homogenous agricultural land use option. Ethiopia has a diverse agroecological zones because of varied topography, vegetation, soil and climate settings. There are 32 agroecology zones significantly influenced by altitude, of different crop and livestock production potential of the country across the (arid eastern and humid western) lowlands and the highlands, which are moister in the west than in the north ((MoA, 2000, Fig. 7). In terms of area coverage, hot and warm arid lowlands together cover more than one third of the country.

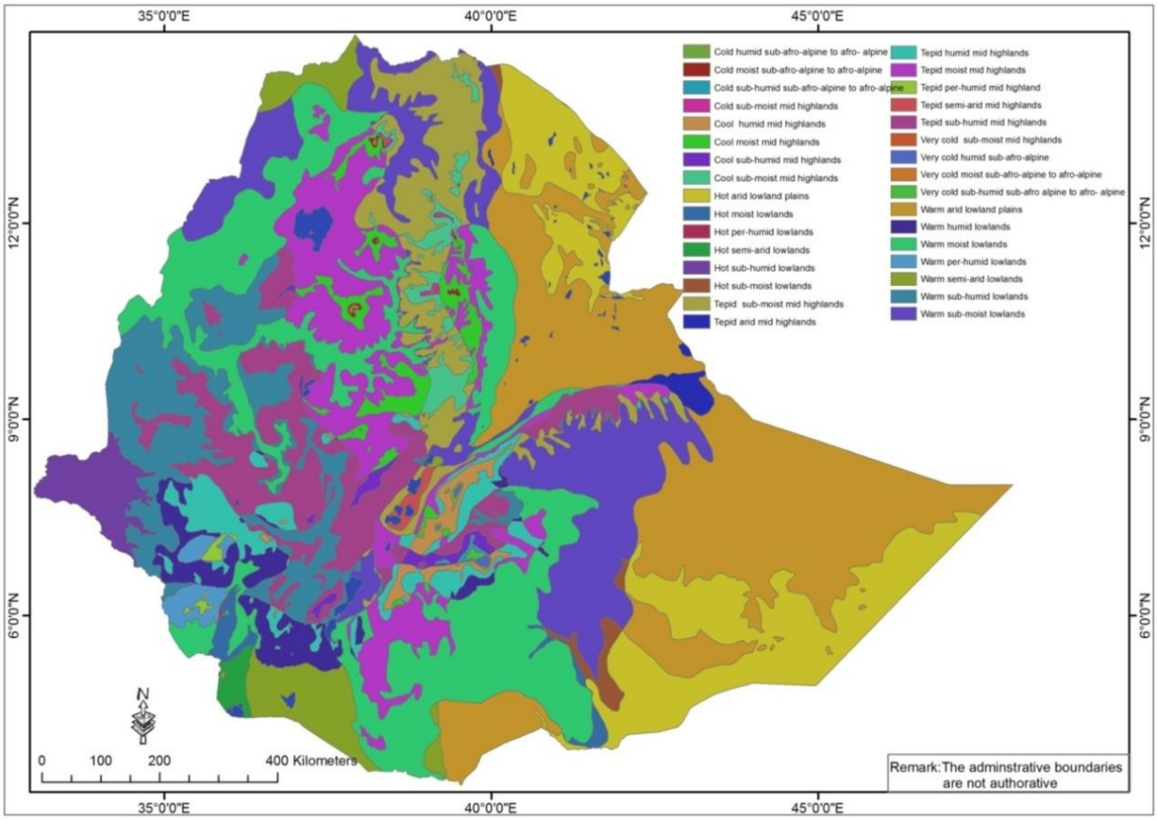


Figure 7. Agro-ecologies of Ethiopia (own analysis). Data source: MoANR

5.1.6. Land cover

Land cover refers to the vegetative coverage of the earth's surface, as well as the observable evidence of land use for economic activities. Figure 8 show the land cover map extracted from Landsat imageries in 2008 by RCMRD. It identified 17 major land cover types for Ethiopia. From the 17 major land covers, annual crop covers 17% of the land area and is the second largest one after open shrub land which accounts more than one third of the total land cover. Open grassland, closed shrub land and sparse forest also cover substantial amount of land of the country.

In Ethiopia, natural vegetation clearance because of agricultural land expansion is the major concern. On the other hand, the natural vegetation is the main source of fuel wood and construction material for house among the rural communities. As a result there is high pressure on natural vegetation. Several studies also confirmed that deforestation is the major issue in Ethiopia from natural resource conservation point of view. Thus continuous mapping and monitoring of land cover is considered important indicator to assess the extent and trend of land degradation as a result of vegetation clearance.

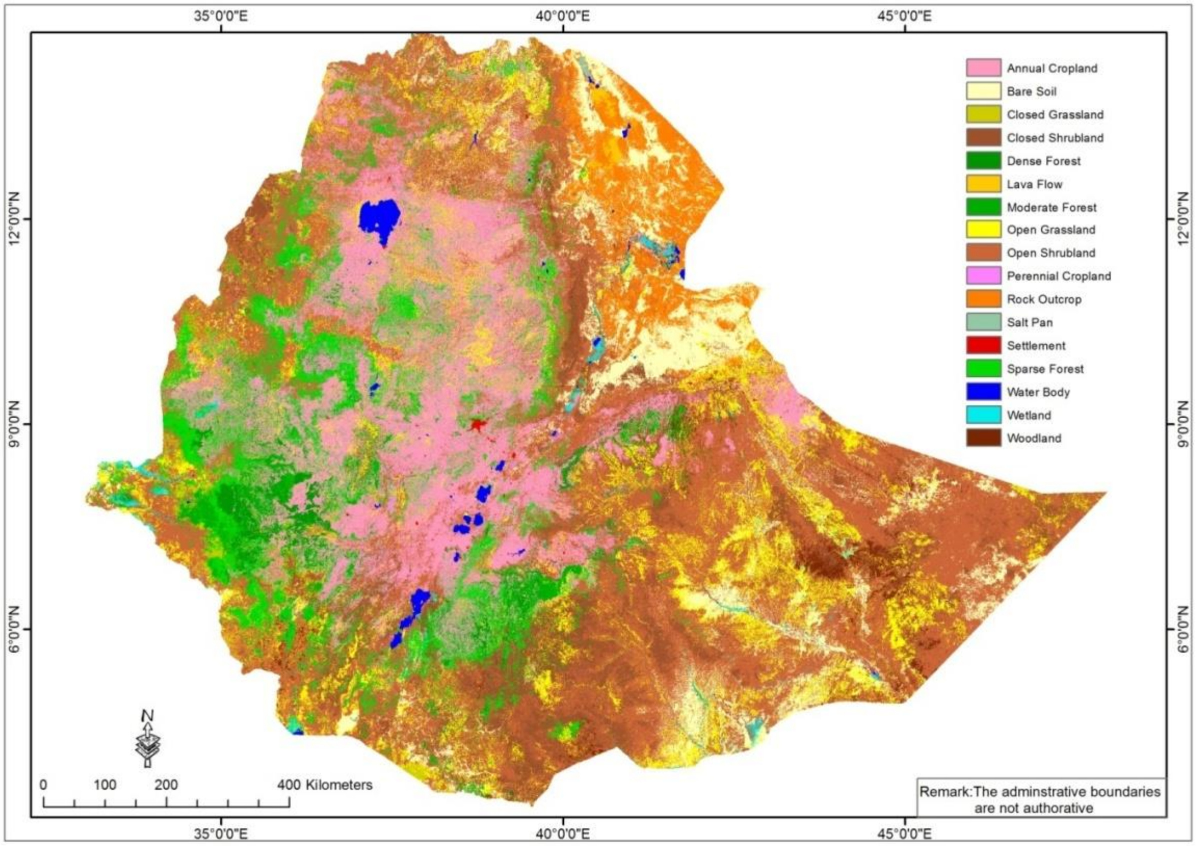


Figure 8. Land covers of Ethiopia (own analysis): Data source RCMRD, 2008

5.1.7. Soil type and properties

Soil is one of the important resources that determine the potential of land for agricultural activities and development. Major soil associations for Ethiopia were extracted from the FAO Global Soil and Terrain Database that classify soils on the basis of predominant chemical and physical properties, derived from parent geological material and modified by weathering and other transformative processes (Fig. 9). Based on their areal coverage, the orders are in the following: Leptosols (29.8 % of total land area) are mostly found in the north, Nitosols (12.5 %) are mostly found in the west. Vertisols (10 %) have wider distribution. Other soils including Cambisols (9.4 %), Calcisols (9.3 %), and Luvisols (7.8 %). Gypsisols (7.6 %) mostly found in the eastern lowlands. Other soils including Cambisols, Calcisols, and Luvisols have relatively good physical and chemical properties for agricultural production. Gypsisols in the eastern lowlands have limited agricultural potential.

Soil properties for Ethiopia were extracted from the dataset which were released very recently by the International Soil Reference and Information Center (ISRIC, 2015; African soil grids 250 m), and all relevant layers were integrated in the geodatabase system (Table 2).

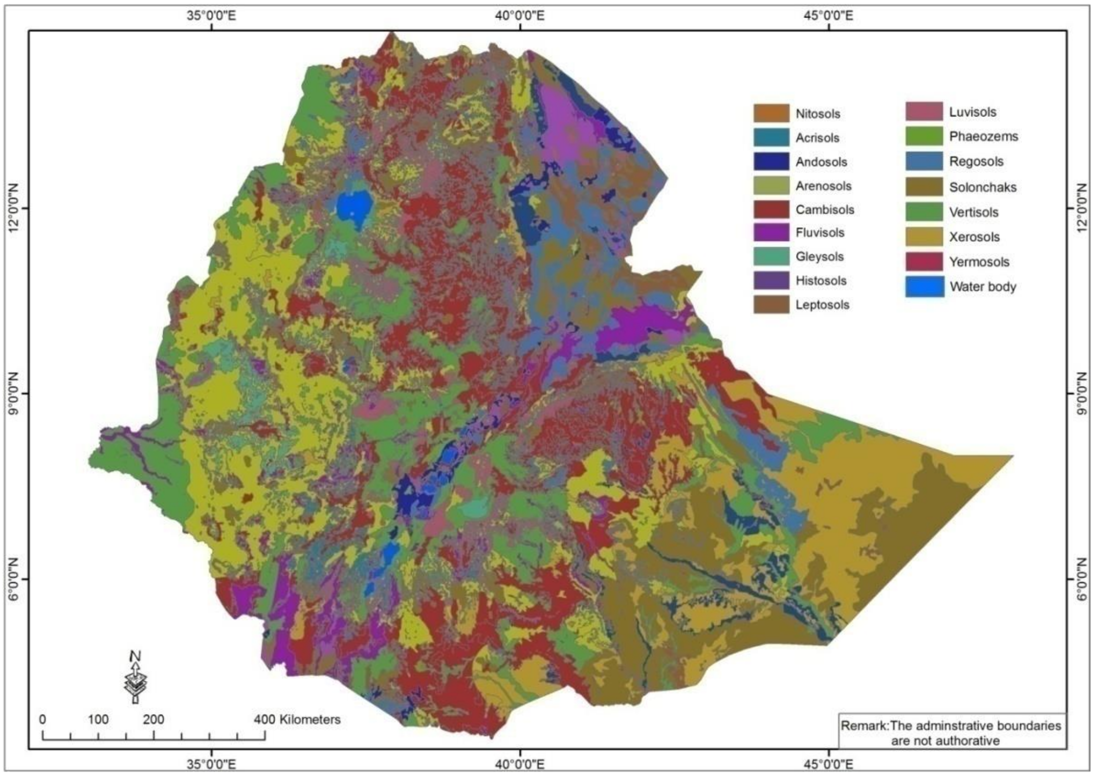


Figure 9. Major soil associations in Ethiopia (own analysis). Data source: FAO SOTER 1997

Table 2: Soil properties according to 250 m resolution ISRIC, African soil map

Soil properties	**Depth (cm)**					
	0-5	5-15	15-30	30-60	60-100	100-200
Soil organic carbon concentration	x	x	x	x	x	x
Soil pH in H_2O	x	x	x	x	x	x
Coarse fragments volumetric	x	x	x	x	x	x
Soil texture fraction sand	x	x	x	x	x	x
Soil texture fraction silt	x	x	x	x	x	x
Soil texture fraction clay	x	x	x	x	x	x
Bulk density	x	x	x	x	x	x
Cation exchange capacity	x	x	x	x	x	x
Total nitrogen		x		x		
Aluminum concentration		x		x		
Exchangeable acidity	x		x	x	x	x
Exchangeable calcium		x		x		
Exchangeable magnesium		x		x		
Exchangeable sodium		x		x		
Drainage class				x		
Depth to bed rock				x		

5.1.8. Geology

Geology is a base for determining what type of soil properties can develop. Thus, it can be considered as indicator for evaluating the potential and constraint of a given land from agricultural activity and development point of view. Fig 10 shows the map processed in this work based on the data obtained from Ethiopian Geological Survey.

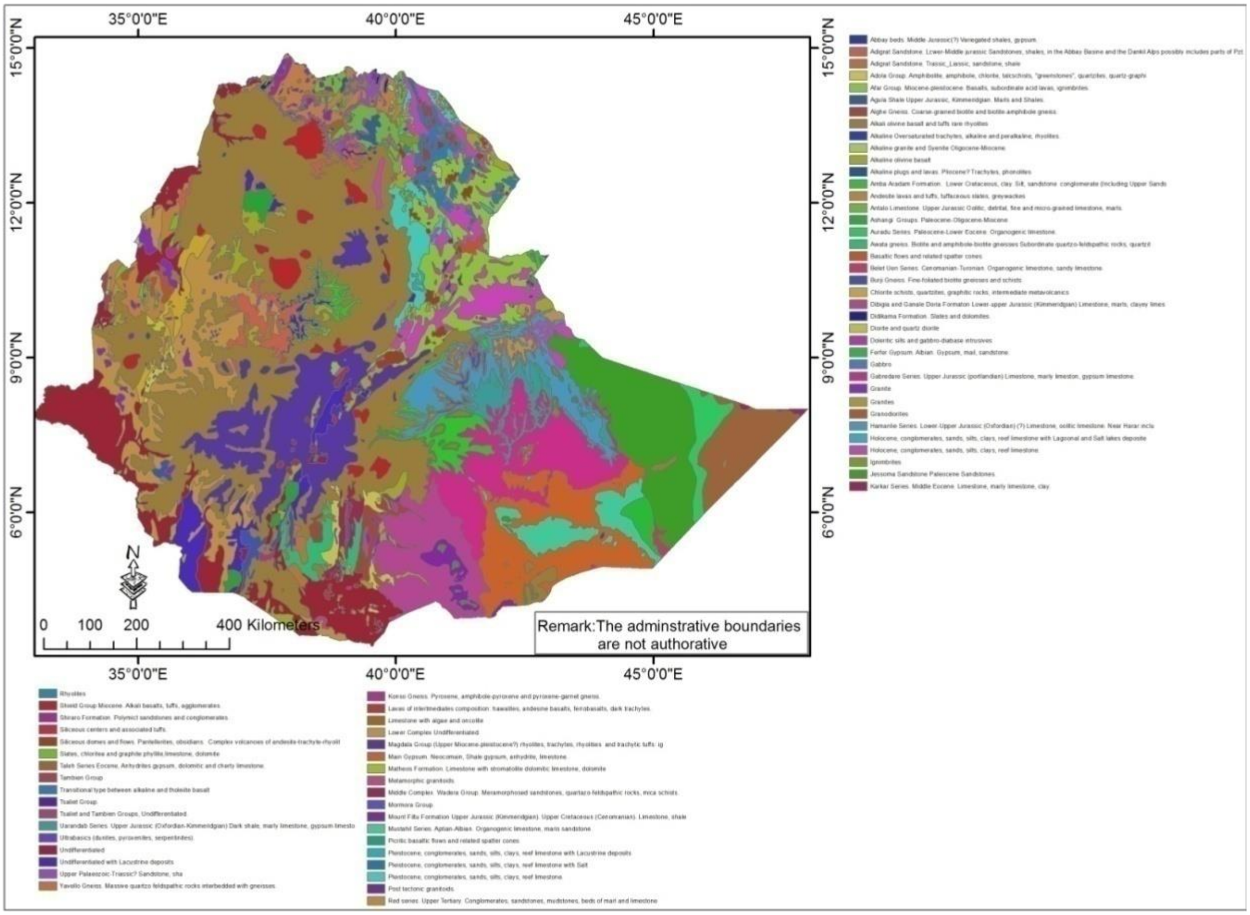


Figure 10. Geology of Ethiopia (own analysis). Data source: EGS

5.1.9. Climate data

Ethiopia has a wide range of climatic features suitable for different agricultural production systems. Climatic heterogeneity is a general characteristic of the country. Temperature and rainfall are the most important climatic factors for agricultural production in Ethiopia. Taking the two extreme altitudes, mean annual temperatures can reach maxima of 34.5 °C in the Danakil Depression, while minimum temperatures fall far below zero in the upper reaches of Mt. Ras Degen (4,620 m) with a mean annual of less than 0 °C.

Rainfall in Ethiopia is generally correlated with altitude. Middle and higher altitudes (>1,500 m) receive substantially greater rainfall than the lowlands, except the lowlands in the west where rainfall is high. Generally annual rainfall of areas above 1,500 m exceeds 900 mm. In the lowlands (<1,500 m) rainfall is erratic and averages below 600 mm. There is strong inter-annual variability of rainfall all over the country. In this work, rainfall data has been collected and integrated from two sources: station and satellite.

Station data

In this work, daily rainfall and temperature data are collected from 258 stations which are found across the country for the period from 1995 to 2013 (Fig 11). Monthly data is computed from the rainfall and temperature record after running quality control check (Fig. 12).

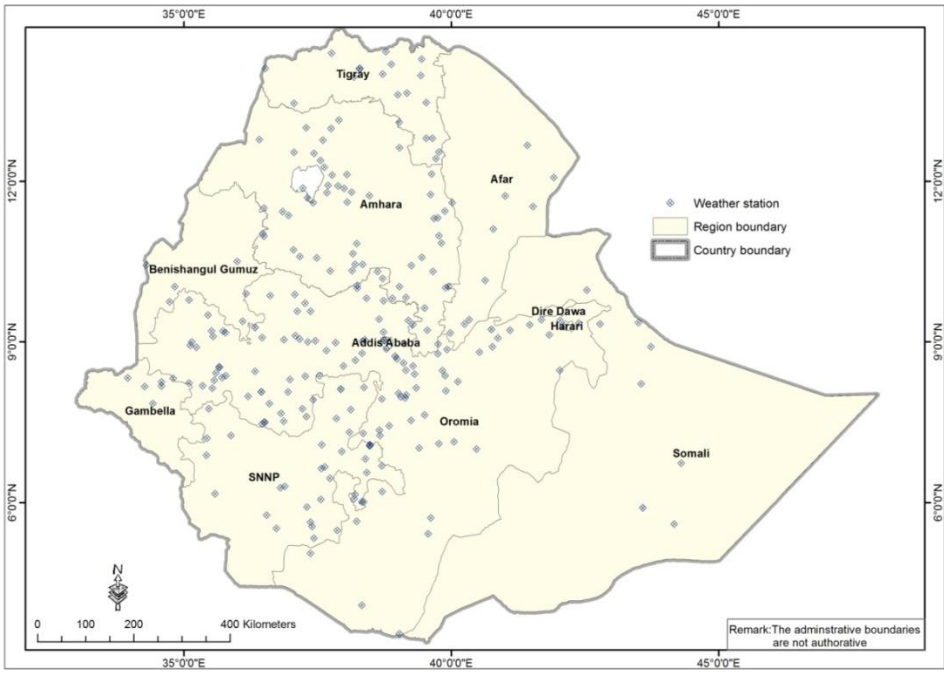


Figure 11. Weather station distribution (own analysis). Data source: NMA

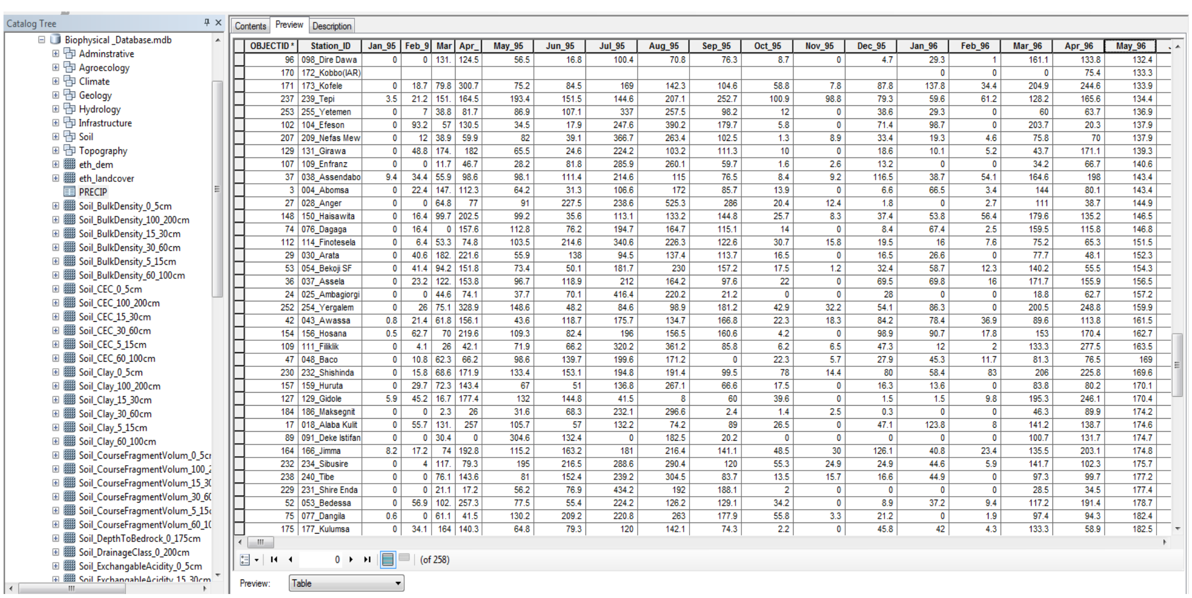


Figure 12. Monthly precipitation data. Source: NMA

Satellite based estimates

The other dataset integrated in the geodatabase system is surface rainfall data estimated from satellite in combination with ground station data. In this case the REF 2 10-Day (decadal) Africa rainfall estimates were extracted from United States Climate Prediction Center in support of the USAID/FEWS project. The estimates were produced by combining satellite temperature data, rain gauge measurements, and modelled wind and relative humidity to obtain decadal precipitation totals from 20W-55E, 40S-20N with 0.1 degree resolution. For further explanation, see: *http://www.cpc.ncep.noaa.gov/products/fews/rfe1.shtml*.

The Satellite Enhanced Data Interpolation (SEDI) method is used to combine point ground station data with gridded satellite estimate data into an even better spatial estimate than both data sources can provide separately. The SEDI method is described in a separate document:
http://www.hoefsloot.com/Downloads/The%20SEDI%20interpolation%20method%20.pdf

In this work, monthly rainfall data were generated and processed from 1995 to 2014 in order to analyze the long year monthly average rainfall and the linear trend of the rainfall for each months. Figure 13 shows the long year average rainfall (1995-2014) and its linear trend for January.

Long years average rainfall for January	Slope of the linear trend for January rainfall

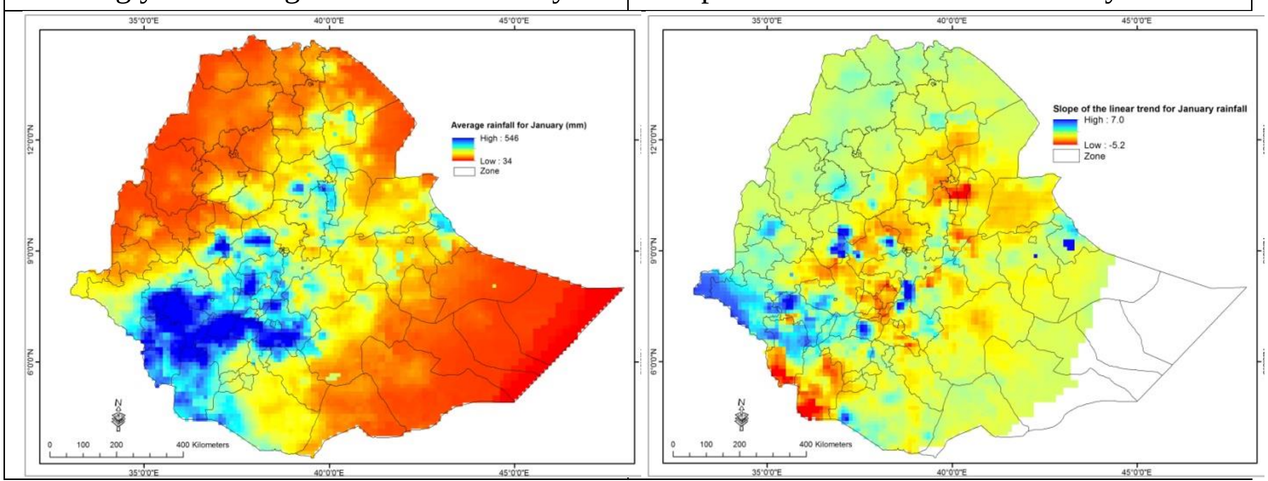


Figure 13. Monthly rainfall (own analysis). Data source: NOAA & NMA

5.2.9. Vegetation condition (NDVI)

Normalized Difference Vegetation Index (NDVI) is a numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum, and is adopted to analyze remote sensing measurements and assess whether the target being observed contains live green vegetation or not. Vegetation production and biomass can be estimated with NDVI data. NDVI can be related to biophysical variables that control vegetation productivity and land-atmosphere fluxes. It has also been used to estimate vegetation change, either as an index or as one input to dynamic vegetation models. It is also one of the good proxy to assess the dynamics of land degradation, though it is necessary to eliminate false alarms arising from climatic variability and land-use change that mislead the reality in the ground. Thus, it should necessary analyzed together with climate and land use data.

In this work, 14 years of 16-days composite NDVI data derived from MODIS (Moderate Resolution Imaging Spectrometer) imageries between 2000 and 2014 were collected and integrated in the geodatabase. Together with other biophysical data, it can be used to analyze land degradation dynamic. Here, average NDVI trends were computed based on 14 years data for the period June, July, August and September (Kiremet season), which is the main growing season for most part of Ethiopia is shown (Fig. 14).

2000-14 average NDVI for Kiremet season *Slope of the linear trend for Kiremet season NDVI*

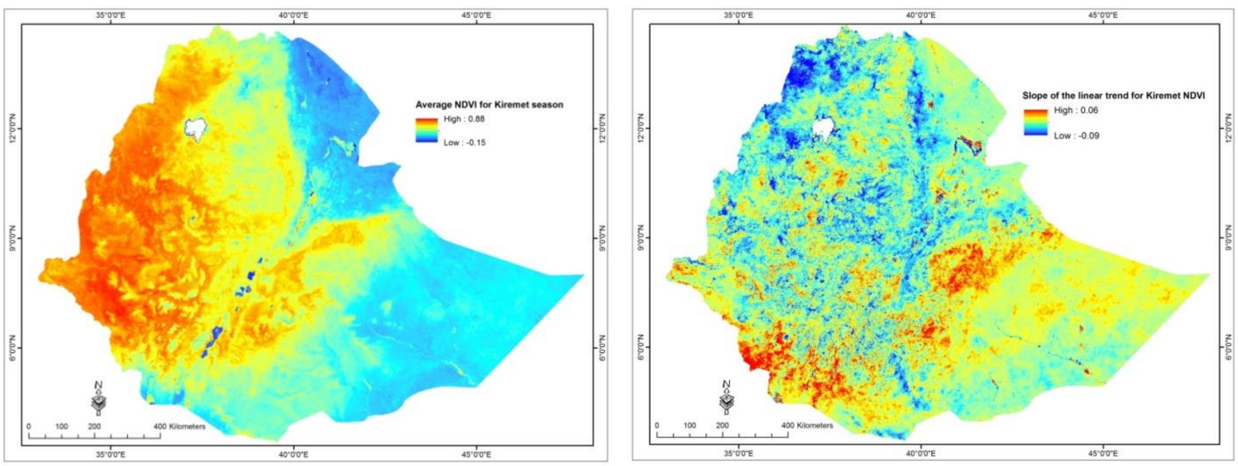


Figure 14. NDVI for Kiremet season (JJAS) (own analysis). Data source: USGS

5.3. Socio-economic data

5.3.1 Population development

Human population is the major driver for environmental change due to the increasing requirements of food and agricultural products. In addition, it is associated with energy consumption. To cover vital energy needs, most households in developing countries resort to freely available biomass fuels, including crop residues and animal dung and, most of all, fire wood.

In this work, human population dynamic for rural areas are considered and time series data are collected at zonal administrative division.

Population count

The Population of Ethiopia is estimated 73.7 million based on the 2007 census data. From the total population 37.2 million are males and 36.5 million are females.

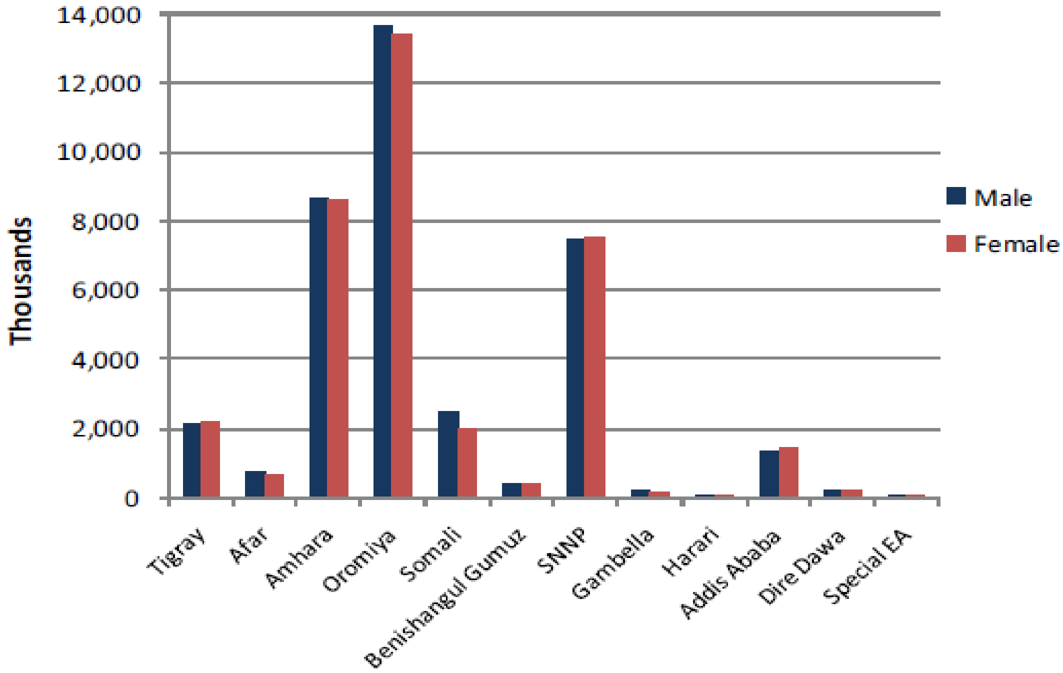


*Figure 15. **Total population count by sex and regions. Source: CSA 2007***

Human settlement is basically associated with suitability of the biophysical environment for living and agricultural activities. In this regard, highland is the suitable places from the context of Ethiopia and it is evidenced by higher population count in the highland (Fig. 16).

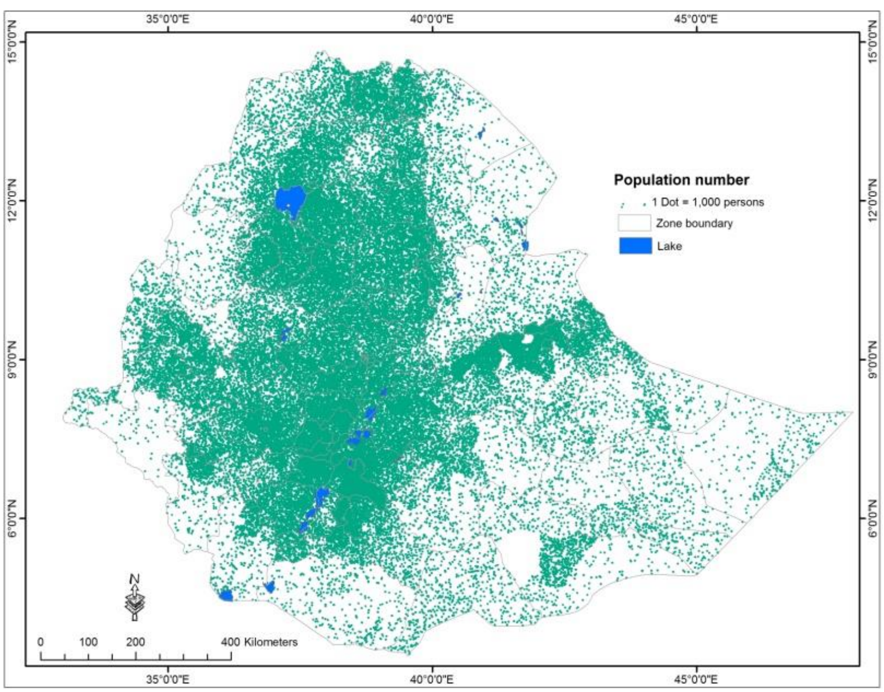


*Figure 16. **Population count based on the 2007 census (own analysis). Data source: CSA 2007***

Population density

Population density is expressed in number of persons per square kilometer. Like the population count, higher population density is found in the highland part of the country.

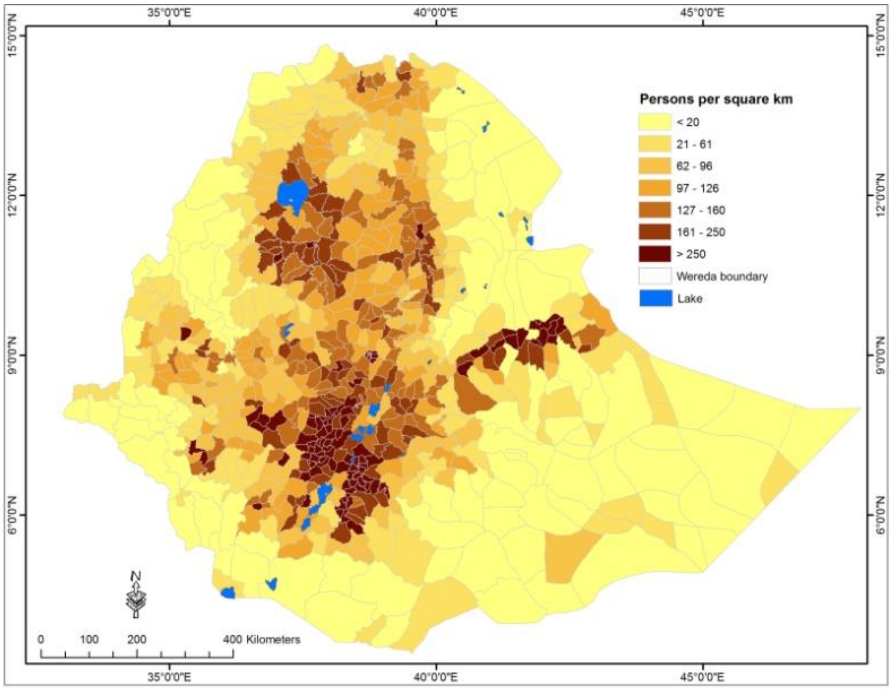


Figure 17. Woreda level population density (own analysis). Data source: CSA 2007

More than 250 persons per kilometer are found in some part of SNNP region and western part of Oromiya region. On the other hand most low land parts of the country have less than 20 persons per kilometer. This contrast is clearly shown in the Woreda level population density map of Ethiopia (Fig. 17). There is also a clear overlap of population density and road network infrastructures of the country.

Sex ratio

National level statistics indicates that the male to female ratio is almost one. However this ratio is not maintained if we consider the spatial pattern. Rather clear differences is observed between the lowland and highland part of the country. Somali region and Afar region have the highest sex ratio implies that there are more females than males. On the other hand, Tigray, Addis Ababa and SNNP have lower sex ratios (Fig. 18).

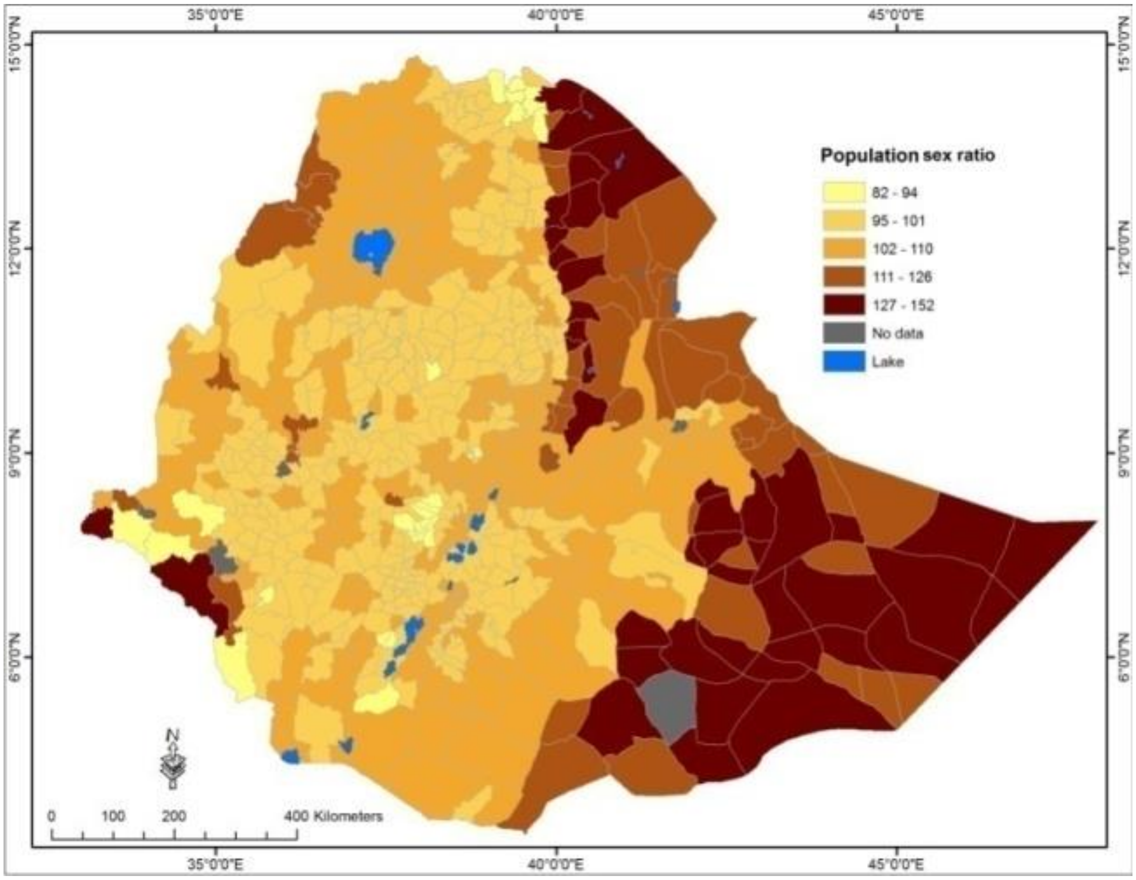
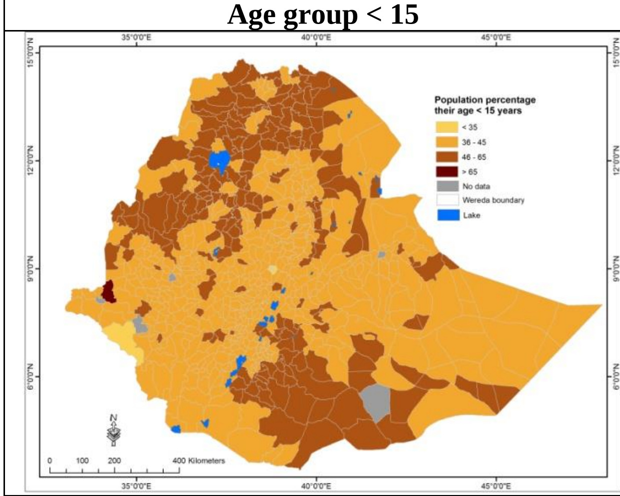


Figure 18. Sex ratio (own analysis). Data source: CSA 2007

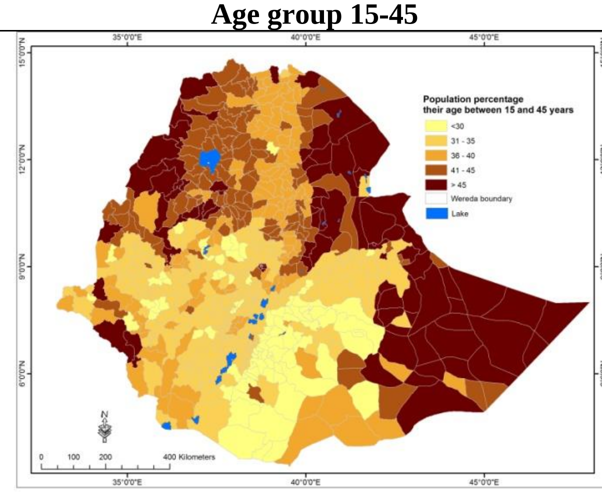
Distribution of population by age group

Nearly 65 % of the total population is under 15 years-old. It is the dominant age group in Amhara region, Tigray region and some part of Oromiya region. Afar region, Somali region and Benishengul region are dominated by age group, 15-45 years. Above 45 years is the principal age group in most part of Oromiya region and some part of SNNP region (Fig. 19).

Age group < 15



Age group 15-45



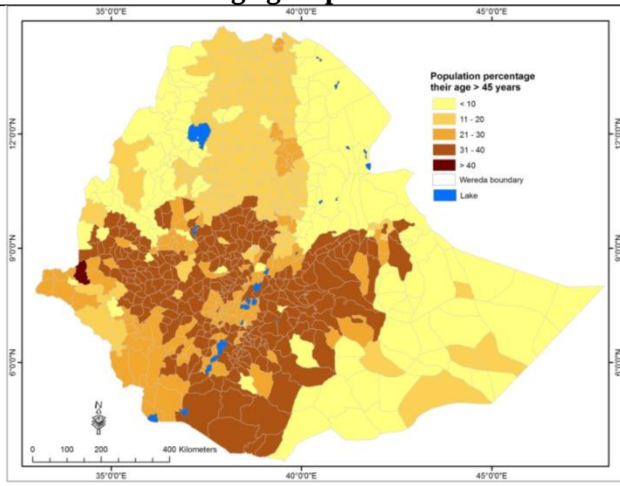
Age group > 45	
	

*Figure 19. **Population distribution by age group (own analysis). Data source: CSA 2007***

5.3.3 Educational characteristic

Literacy rate is one of the proxies for assessing the basic educational level of a population. Based on the 2007 census data, the average literacy rate of Ethiopia is around 40 %. There is significant variation from place to place. The two chartered cities, Addis Ababa and Dire Dawa and Harari region have the highest literacy compared with the other regions. The literacy rate for Addis Ababa, Dire Dawa and Harari region are 85, 61 and 60 %, respectively. Somali region and Afar region have the lowest literacy rate (Fig. 20).

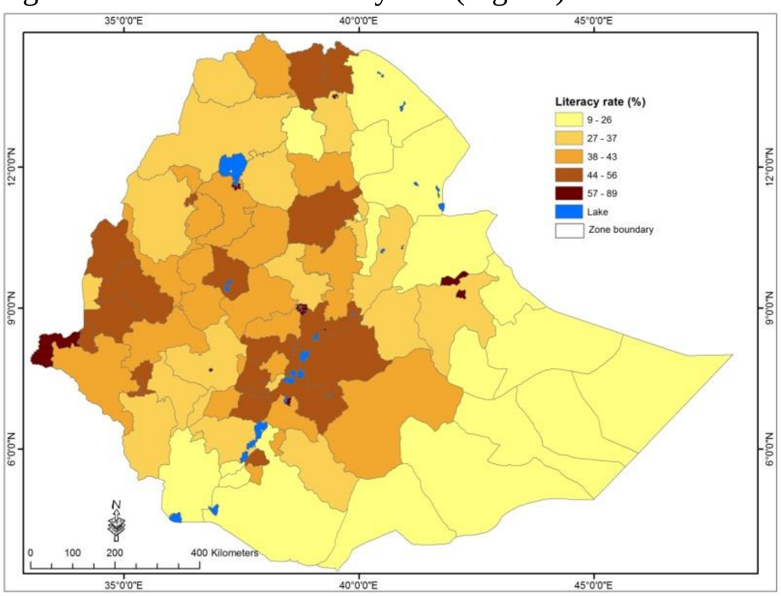


*Figure 20. **Literacy rate (own analysis). Data source: CSA 2007***

5.3.4 Economic activity status

Economic activity status refers to the size and distribution of the work force of economically active and non-active population. Following standard international definitions, the working population is defined as those aged 15-64 years. The ratio of the economically active to non-active population is called dependency ratio. The highest dependency ratio is found in SNNP region. The second highest is found in the Somali region (Fig. 21). The spatial patterns of dependency do not follow simple environmental trends. For example, in arid lowland pastoralist areas, ratios vary from high (Somali) to low (parts of Afar).

Dependency ratio | *Unemployment rate*

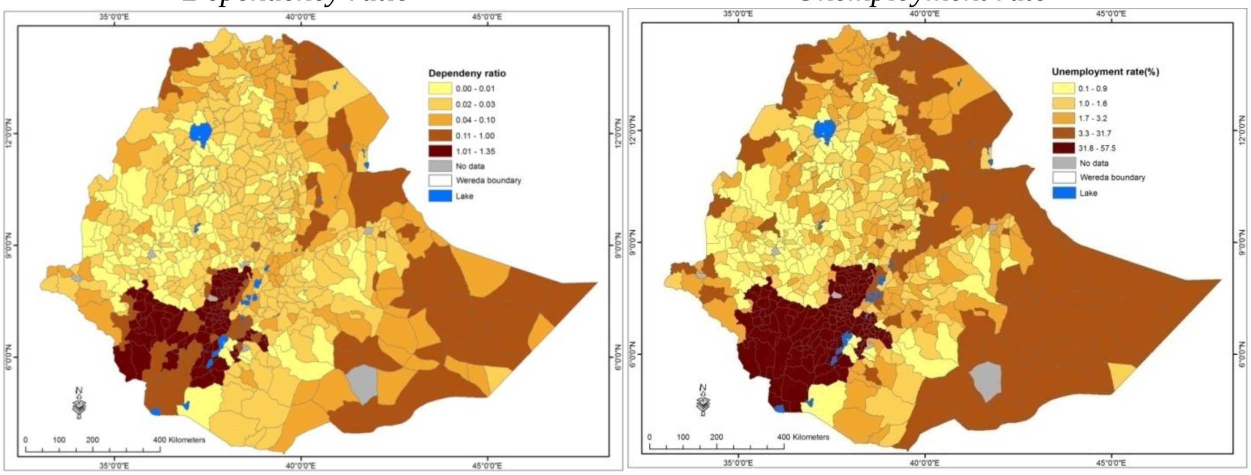
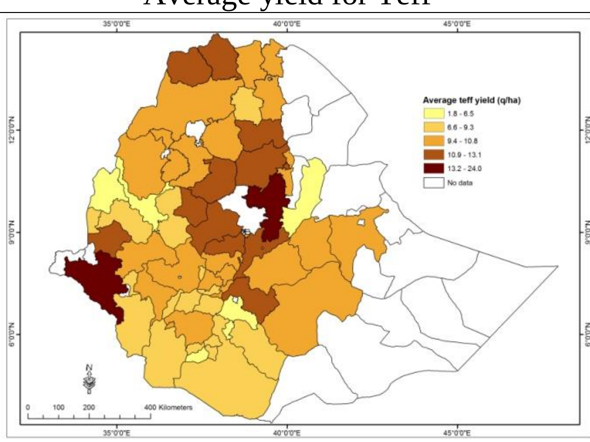
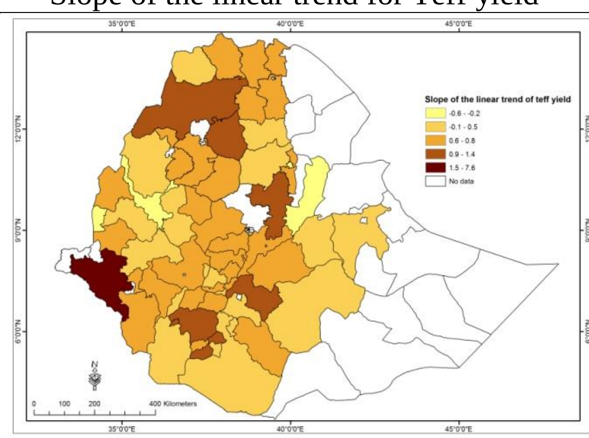


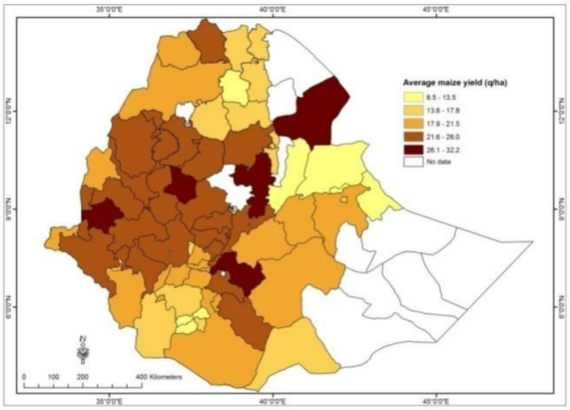
Figure 21. Dependency ratio and unemployment rate (own analysis): Data source CSA, 2007

5.3.1 Crop statistics

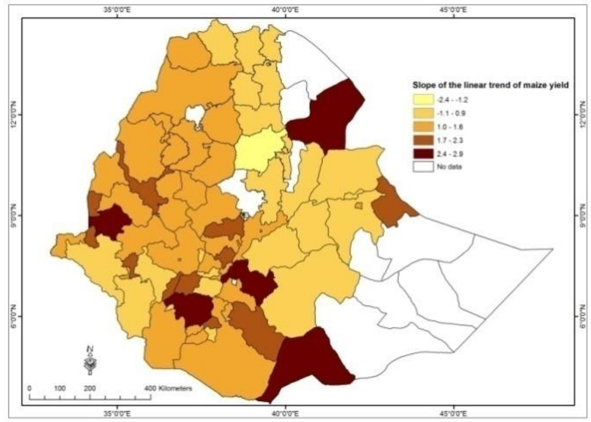
Agriculture is the main economic activity in Ethiopia. Crop production is the dominant practice in the highland part of the country. From the type of crops grown in Ethiopia, cereals account for almost 80 %. In terms of cover, teff constitutes little more than a quarter of total cultivated area (26 %), followed by maize (24 %), sorghum (17 %), wheat (15 %) and barley (13 %, Fig. 22). Elevation is the most determinant factor of the spatial distribution of these crops. Teff and wheat are grown in higher and cooler environments. On the other hand, maize and sorghum are common mainly in the warm and low altitudes.

Average yield for Teff	Slope of the linear trend for Teff yield
	

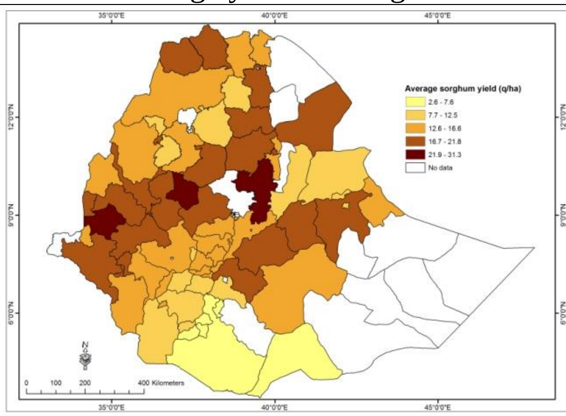
Average yield for Maize



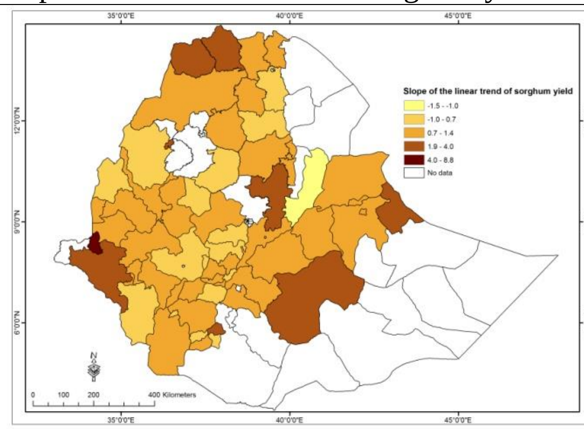
Slope of the linear trend for Maize yield



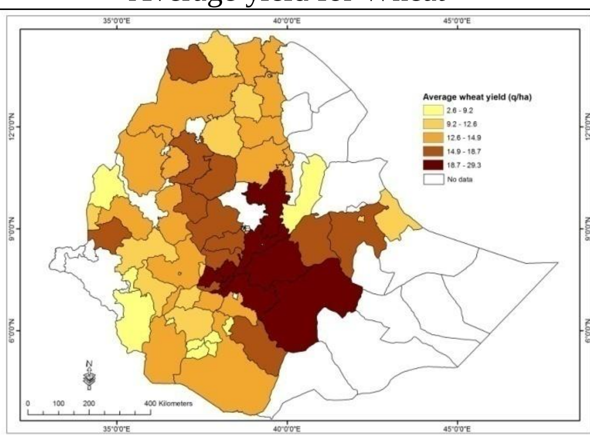
Average yield for Sorghum



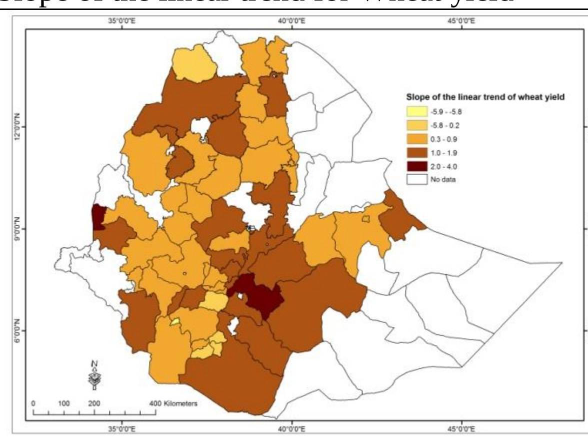
Slope of the linear trend for Sorghum yield



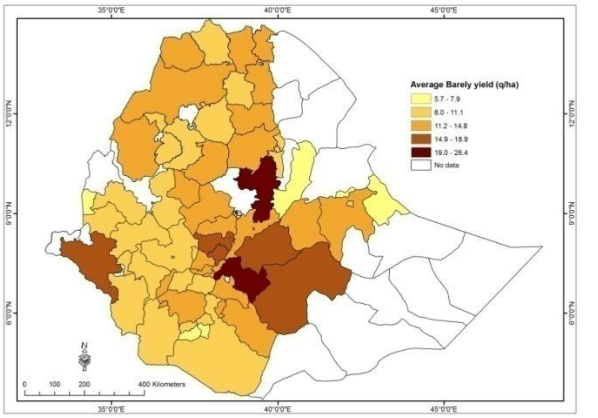
Average yield for Wheat



Slope of the linear trend for Wheat yield



Average yield for Barley	Slope of the linear trend for Barley yield



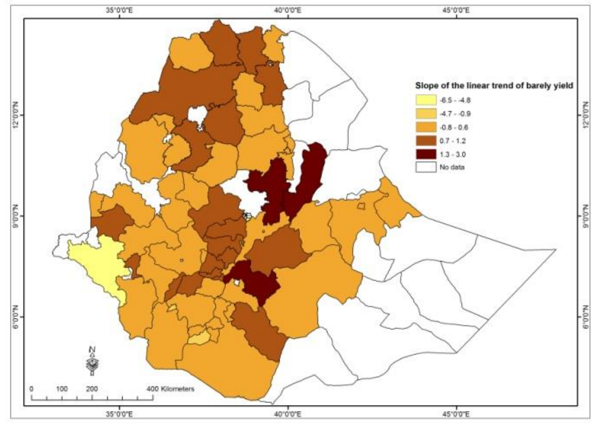
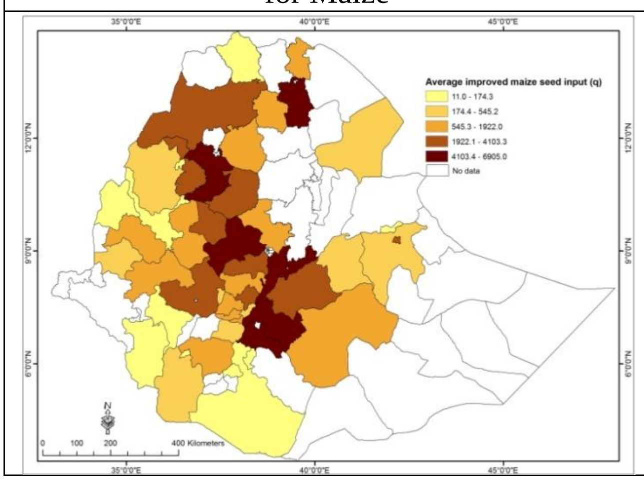


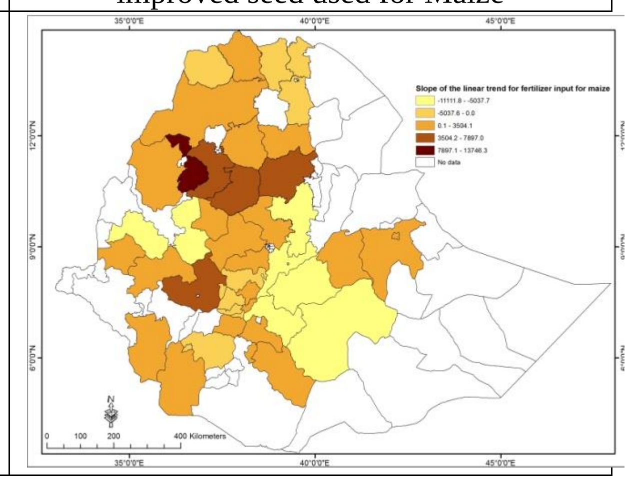
Figure 22. Yield and yield trend for major cereal crops (own analysis). Data source: CSA, yearly agricultural survey data

5.3.2 Agricultural Inputs – mineral fertilizer and improved seeds

In the Ethiopian context, mineral fertilizer and improved seeds are the main ag.-inputs. The amount of land on which mineral fertilizer and improved seeds are used, is an indicator for enhanced/intensified crop production in smallholder farm. Thus, time series data of these inputs applied to the major cereal crops were collected, organized and integrated in the geodatabase system. These data were also summarized at zonal administrative division (Fig. 23).

Average fertilizer and improved seed amount for Maize	Slope of the linear trend of fertilizer and improved seed used for Maize





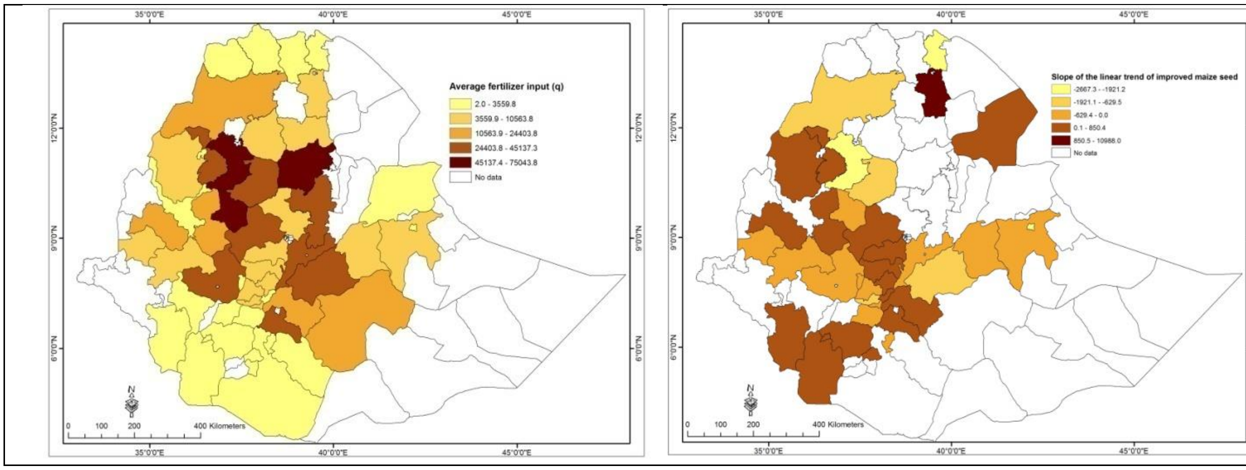


Figure 23. Average fertilizer and improved seed amount used for Maize and its temporal trend. Source (own analysis). Data source CSA yearly survey data

5.3.2 Livestock population

Cattle population

Ethiopia is known for its largest the number of cattle population in Africa. Cattles are found widely in both the lowlands and the highlands of the country. Herds tend to be smaller in the highland, probably because of the limited land holdings and access to grazing and feed. Cattle is consider as an important household asset especially in drought prone areas.

With regard to land degradation, livestock population is often associated with overgrazing. Excessive pressure on grazing lands by animals are a crucial problem. Thus, in this work, time series data of livestock population specifically for cattle, goat and sheep were collected and integrated in the geodatabase system (Fig. 24).

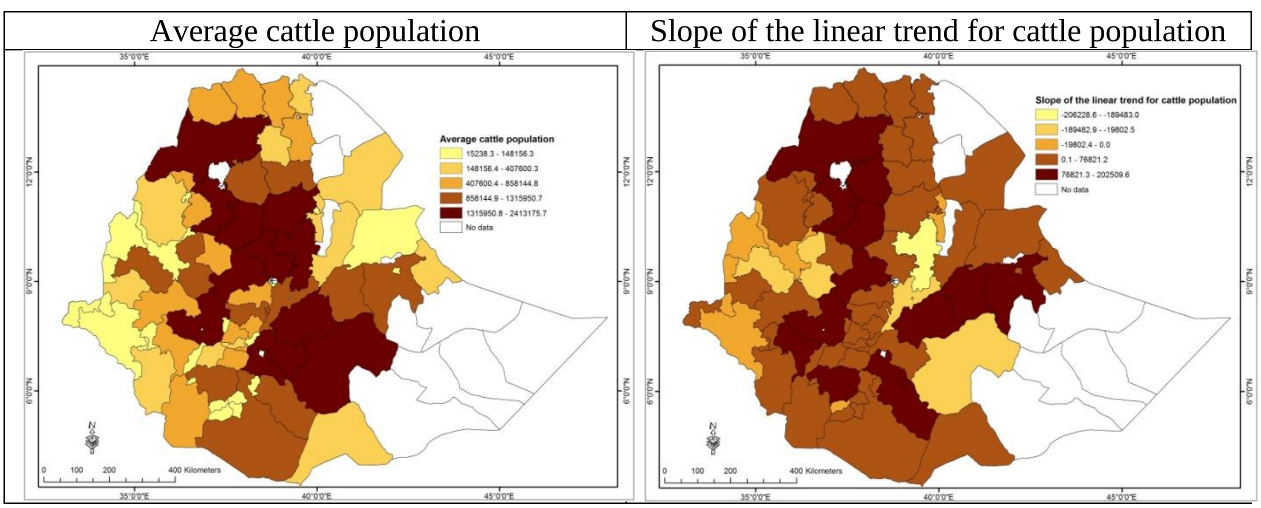


Figure 24. Cattle population (own analysis). Data source: CSA, yearly livestock survey data

6. Further work

The major purpose of this work was to collect, organize and establish geodatabase having different biophysical and socio economic data which are relevant to assess land and soil degradation and productivity dynamics in Ethiopia. Accordingly, different data were collected from different sources and integrated in the geodatabase system.

One of the focus in the further work should be studying land degradation dynamics using indicators that integrate time series NDVI with biophysical and socioeconomic data which are considered significant factors influencing land degradation dynamics. The output from this study would enhance our understanding as to how the human and the natural factor influence land degradation.

Further, an index should be developed that can be used to monitor land degradation from the context of Ethiopia. In line with this, to have a clear understanding about the influence of natural causes to land degradation, much emphasis should be laid on the occurrence, length and intensity of droughts.

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