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The Role of Rainfall Amount and Distribution on Agriculture Systems and Crop Cropping Systems of Different Agro-Ecological Regions of Ethiopia: A Review

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ABSTRACT

Ethiopia is situated in horn of Africa that 65% of its land is usable for arable farming. It has different ecologies which ranges from tropical to temperate. Due to those diversified ecologies the country is a center of origin and biodiversity for many cultivated crops and their wild relatives. The country's agriculture is mainly dependent on smallholder farmers which have been unable to satisfy high demands of agricultural products. Population growth, inappropriate policy, financial shortage, inappropriate technology, climate change and such factors collaboratively resulted food insecurity and poverty on most societies. Variable rainfall amount and distribution are the most visible factors which can be influence the agriculture systems especially crop cropping systems at different agro-ecological regions of the country. Common methods to classify Ethiopian agro-ecological regions are traditional and agro ecological zones (AEZs) systems which consider rainfall amount and distribution. Based on traditional systems the climatic regions can be classified as wurch, dega, woynadega, kola and berha whereas based on AEZs it can be classified as arid, semi-arid, sub-moist, moist, sub-humid and humid, and per-humid. Different agricultural systems and crop-livestock productions in the regions are dependent on rainfall amount and distribution. Rainfall amount and distribution have been observed variable across regions and seasonsand they are determinant of farming systems and length of growing periods. Thus, rainfall amount and distribution are the key determinants of agricultural systems and crop cropping system of different regions in the country.

Keywords: *Rainfall, Amount, Distribution, Agriculture, cropping, System, Agro-ecology*

INTRODUCTION

Ethiopia is a landlocked country situated in the horn of Africa bounded to the north by Eritrea, to the west by Sudan, to the south by Kenya and to the east by Somalia and Djibouti. It lies within the tropics between 3°24` and 14°53` North, and 32°42` and 48°12` East. It has a population of nearly 104,344,901million during 2017 and a surface area of 1.2 million square kilometers, of which 65% is suitable for arable farming (Alemayehu, 2006; Tesfaye, 2017; www.worldometers.info/world-population;fao. org/ag/agp/agpc/doc/counprof/ethiopia).

Ethiopia is known for its ecological diversity that ranges from tropical to temperate conditions. Altitude ranges from 126 meters below sea level in the Danakil Depression in the northeast to 4620 meters above sea level in the Ras-Dashen Mountains in the northwest.In central highland plateaus, where major cereal crops are grown, elevation ranges from 1800 to 3000 meters above sea level with mean annual rainfall ranging from 950-1500 mm and mean annual temperature from 11-21°C. Ecological and socio-cultural diversity creates favorable conditions to support tremendous diversity of fauna and flora such that the country is a center of origin and biodiversity for many cultivated crops and their wild relatives (Alemayehu, 2006; Tesfaye, 2017; http://www.yieldgap.org/ ethiopia).

Ethiopian agriculture is mainly managed and operated by smallholder subsistence farmers. For instance, about 97% of crop production and 98% of the total area under crop cultivation is operated by private peasant holders, with average landholding size of 1.16 ha (CSA, 2009; Matous*et al.*,2013). Moreover, limited financial, human and physical resource capacity of the country hinders progress in the agricultural sector and the intended economic growth (Deressa, 2007; Gebremedhin *et al.*, 2009; Mideksa, 2010). In spite of considerable attention given by the Ethiopian government to

the agricultural sector as the driving force to improve the overall economy, the sector is growing by far less than the growth rates of population and associated food demand (Gebremedhin *et al*., 2009). The slow pace of agricultural growth is reflected in the stagnant economic development of the country. Lack of appropriate policy interventions and technology options in response to changes in climatic conditions such as rainfall variability and other shocks have limited the ability of farmers to adapt to adverse climate conditions. These further aggravate food insecurity and poverty in the country (Degefe, 2002; Awulachew *et al*., 2005; Kedir, 2005; Lencha, 2008).

The opportunities and constraints facing Ethiopian agriculture are strongly influenced by conditions which vary across geographical space. These conditions include basic agricultural production potentials, access to input and output markets, and local population densities which represent both labor availability and local demand for food (Jordan and Emily, 2011).

The variability in the amount and temporal distribution of rainfall is also one of the most important factors that determines the fluctuation in crop yield (Woldeamlak, 2009). Rainfall in much of the country is often erratic and unreliable; and rainfall variability and associated droughts have historically been major causes of food shortages and famines. These impacts of rainfall on crop production can be related to its total seasonal amount or its intra-seasonal distribution (Taddsse, 2000; Woldeamlak, 2009). Due to this reason this review has been prepared for the following objectives;

- To review the role of rainfall amount and distribution on agriculture systems of different agro-ecological regions of Ethiopia,
- To review the role of rainfall amount and distribution on crop cropping systems of different agro-ecological regions of Ethiopia and
- To organize available information's on impact of rainfall amount and distribution of the country for further studies

The Role of Rainfall Amount and Distribution on Agriculture Systems and Crop Cropping Systems of Different Agro-Ecological Regions of Ethiopia

Agro-Ecological Regions of Ethiopia

Agro-ecological zonation can be defined as a spatial classification of the landscape into area units with "similar" agricultural and ecological characteristics (Hurni, 1998).According to global agro-ecological zone classification based on length of growing period (IIASA/FAO, 2010), the major crop growing areas of the country are found in the sub humid, humid and moist semiarid climatic zones. On the other hand, the Ministry of Agriculture and Rural Development (MoARD, 2005) classified the country into 32 major agro-ecological zones and categorized about 51% of the total land area of the country under arid, semi-arid and sub moist zones and the other half in moist to humid zones. From among 18 major soil types, Nitosols (23%), Cambisols (19%), and Vertisols (18%) comprise more than half the arable land area in the different agro-ecologies of the country (Paulos, 2001).

The climate of Ethiopia is mainly controlled by the seasonal migration of the Inter-tropical Convergence Zone (ITCZ), which follows the position of the sun relative to the earth and the associated atmospheric circulation, in conjunction with the 4complex topography of the country (NMSA, 2001). There are different ways of classifying the climatic systems of Ethiopia, including the traditional, the Köppen's, the Throthwaite's, the rainfall regimes, and the agro-climatic zone classification systems (Yohannes, 2003).

The most commonly used classification systems are the traditional and the agro-ecological zones (AEZs). According to the traditional classification system, which mainly relies on altitude and temperature, Ethiopia has five climatic zones (Table 1).

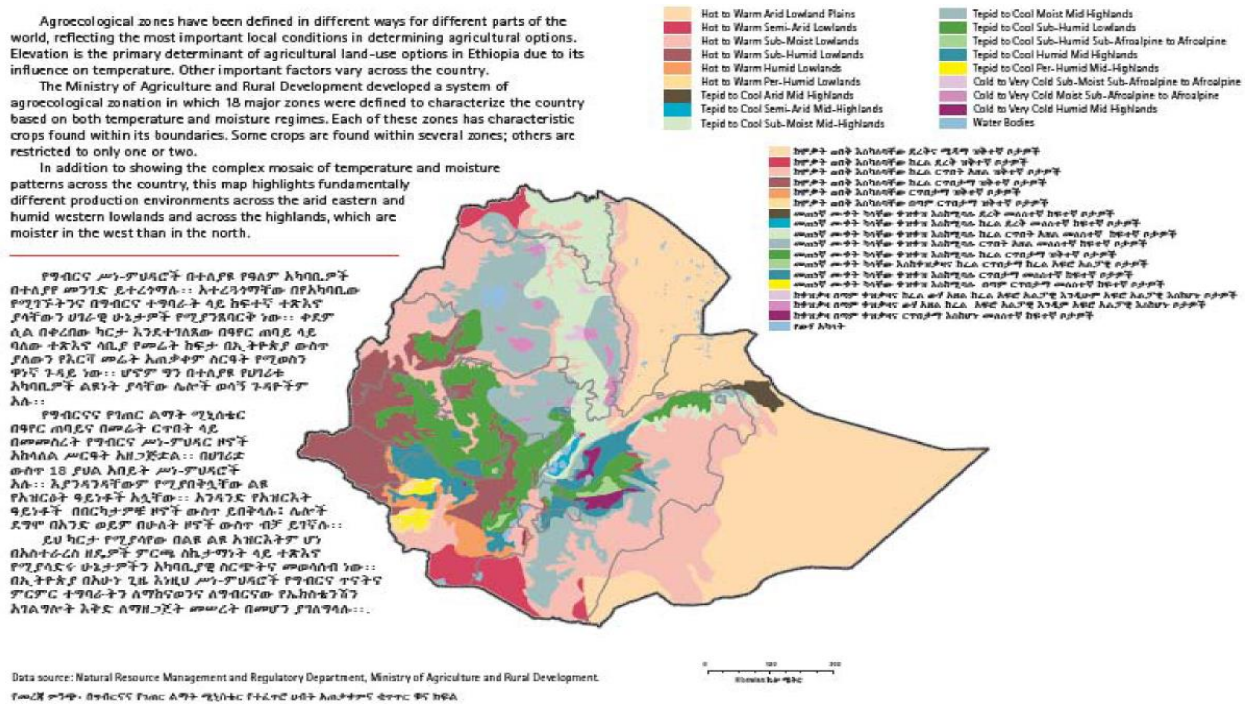
The AEZ classification method on the other hand is based on combining growing periods with temperature and moisture regimes. According to the AEZ classification system, Ethiopia has 18 major AEZs, which are further subdivided into 49 AEZs (Figure 1).

Table1. *Traditional climatic zones and their physical characteristics*

Zone	Altitude (meters)	Rainfall (mm/year)	Average annual temperature (°C)
Wurch (upper highlands)	3200 plus	>2200	<11.5
Dega (highlands)	2,300 –3,200	1,200 –2,200	17.5/16.0–11.5

Weynadega (midlands)	1,500 –2,300	800 –1,200	20.0–17.5/16.0
Kola (lowlands)	500 –1,500	200 –800	27.5 –20.0
Berha(desert)	Under 500	Under 200	>27.5

Source: *MoA (2000)*



Source: *Adapted from Deressa, 2010*

Figure1. *Agro-ecological zones of Ethiopia*

These AEZs are also grouped under six major categories (MoA, 2000), which include the following:

- **Arid zone**: This zone is less productive and pastoral, occupying 53.5 million hectares (31.5 percent of the country).
- **Semi-arid:** This area is less harsh and occupies 4 million hectares (3.5 percent of the country).
- **Sub-moist:** This zone occupies 22.2 million hectares (19.7 percent of the country), highly threatened by erosion.
- **Moist:** This agro-ecology covers 28 million hectares (25 percent of the country) of the most important agricultural land of the country where cereals are the dominant crops.
- **Sub-humid and humid:** These zones cover 17.5 million hectares (15.5 percent of the country) and 4.4 million hectares (4 percent of the country), respectively. They provide the most stable and ideal conditions for annual and perennial crops and are home to the remaining forest and wildlife, having the most biological diversity.
- **Per-humid:** This zone covers about 1 million hectares (close to 1 percent of the country) and is suited for perennial crops and forests.

Agriculture Systems of Different Agro-Ecological Regions of Ethiopia

Ethiopia with its extremely variable agro climatic conditions has several major ecological systems that support large and very diverse genetic resources. The topographic diversity of the country has resulted in the formation of a multitude of **agro ecological zones and sub zones** with varied **farming systems** (FAO, 1984). Despite to this the poor performance of agriculture is reflected in the national annual food deficit. The sector has been beset by natural disasters, in particular periodic severe droughts which is directly related to amount and distribution of annual rain fall, so the substantial natural potential of the highlands, their fertile soil and good rainfall and irrigation have not been realized (Alemayehu, 2006).

Agriculture is the country's largest economic sector which plays a central role in the economic and social life of the nation and is a cornerstone of the economy, contributing about 43% of the country's GDP and employing more

than 85% of the working population. Production systems are dominated by smallholder farming under rain-fed conditions with little mechanization. Smallholders, the backbone of the sector, cultivate 95 percent of the cropped area and produce 90-95 percent of cereals, pulses and oilseeds. Subsistence mixed farming with crop cultivation and livestock husbandry is practiced on most farms and yields are generally low (Alemayehu, 2006; Tesfaye, 2017).

As a country agricultural potential is unevenly distributed over space, and the distribution of production patterns reflects this landscape. Thus, characterizations generally seek to reduce complexity by prioritizing characteristics which are most meaningful to the production systems of interest. Agro-ecological zones are perhaps the predominant methodology used to organize geographic space to understand actual and potential agricultural production (Jordan and Emily, 2011)

Ethiopian farmers have long recognized that altitude, climate, water availability, vegetation and other physical and biotic factors are interrelated to agricultural potential and production. The traditional classification, developed over thousands of years, divides the country into major and minor agro ecological groups based primarily on altitude and **rainfall**. Each zone and sub zone is further characterized by variations in economic activity, population density and other socio- cultural attributes such as cropping and livestock rearing patterns. The dominant agricultural enterprises in all agro ecological zones are small-scale **subsistence farms** in the *highlands* and **livestock rearing** in the *lowlands* (Alemayehu, 2006).

The subsistence agricultural system of Ethiopia in regarding of crop production is traditional and rain-fed, with very limited areas of irrigation. Small scale traditional irrigation has been practiced for decades in the **highlands agro-ecology**, where small streams are diverted seasonally for limited dry season cropping. Medium and large-scale schemes are of more recent origin, particularly in the Rift Valley; which is a **lowland agro-ecology** (EPA, 1997).

According to Alemayehu (1998; 2002) description Ethiopian agricultural system in case of livestock has the largest population in Africa. Those are found in different agro-ecological regions of the country. For example, in 2002 about 70 percent of the cattle and sheep and 30 percent of the goats are in the highlands above 1,500 meters, whereas the left and all camels are in the lowlands

Smallholder Crop Production

In the higher part of the mountains, the proper Afro-alpine zone ('Wurch'), plants are exposed to intense radiation, with much greater rise in the temperature of the aerial parts in contrast to their underground parts; transpiration is higher than the absorption of water by the plant, so, though moisture is not limiting, plants are mostly adapted to moisture deficiency. The soil is often shallow, even though very rich in unde-composed organic matter. With the steepness of the terrain and the frequent heavy rains, the zone is vulnerable to erosion following human activity. In the sub-afroalpine zone, the lower 'wurch' area, (3,200-3,700 metres) cropping is limited to barley, with two crops per year sometimes being possible with rainfall above 1,400 mm/annum; only one crop is possible in areas with 900 – 1,400 mm. Sheep are the main livestock but cattle are kept and contribute to farm power. The major agricultural enterprise is small-scale mixed farming. Population density is relatively lower, but black soil areas are degraded due to cropping for thousands of years without any protectionAlemayehu, 1998; 2002).

Small to Medium Scale Crop-Livestock Production

The most productive zones are between 3,200 and 1, 500 meters highland, ('dega') and lowland ('Woinadega'). In this agro-ecological zone a wide range of crops are grown and many species of livestock kept for different ends. Production systems are, in fact, of a mixed crop plus livestock type with draught power being important. Rainfall is generally not limiting except in the far north and growing seasons are often very long, with two crops per year in some areas. Due to high population, farming is dominated by smallholdings. Medium–scale private crop production is beginning as a result of the recent state farms privatization and the new investment policy. Medium or large-scale dairying is found around big towns and cities (Alemayehu,2006).

Small to Large-Scale Livestock Production

In many agro-ecological zones at low altitudes 1,500-500 meters (kola-zone) growing seasons are short to very short, so only drought resistant crops can be grown, unless irrigation is possible. Livestock are important throughout this zone. The poor conditions for crops and the extensive

system of livestock production imply low human population. There is large-scale ranching, particularly fattening for domestic and export markets (Alemayehu, 2006).

The lowlands are the home of a diverse array of pastoral people who depend on livestock, which feed on native vegetation, and net productivity is very variable over time and space. The lowlands are home to 29 ethnic groups, of which more than 90 percent are pastoralists. Livestock provide subsistence and employment for more than 10,000,000 people and are a source of meat, milk and fiber for residents of some two dozen major towns and cities within or adjacent to the lowlands. Subsistence nomadic and semi-nomadic pastoralists are the major stockholders on the grazing land. Afar, Somali and Borana are the major pastoral groups in the north eastern, eastern and southern grazing lands (Alemayehu 2006).

On another way based on crop and livestock productions agricultural systems can be classified into the following groups;

- Integrated crop-livestock production system
- Highland annual crop and livestock farming system
- Highland perennial crop farming system and
- Pastoral system

Crop Cropping Systems of Different Agro-Ecological Regions of Ethiopia

In terms of land area, Ethiopia is the 10th largest country in Africa, with a total of 1.2 million km^2 and about 51.3 million hectares of arable land. However, only about 11.7 million (20% of the potentially arable land) area is currently being cultivated (MoAD, 2010).

About 15% of the country's area is currently used for the production of major food crops. Major staple crops include cereals, pulses, oilseeds, roots and tubers, vegetables and coffee. According to the Ethiopian Central Statistical Agency report (CSA, 2013), grain crops (cereals, pulses and oil crops) are cultivated on 13.9 Mha with annual production of 25.1 million metric tons (MMt). For example, according to the same report, cereals, pulses and oil crops constituted 78, 15, 7% of the cultivated area and 85, 12 and 3% the total grain production of the country, respectively in the main **rainy season** of 2012/2013. Cereals are the most important field crops and the chief element in the diet of most Ethiopians. Principal cereals are tef (an indigenous principal staple crop), wheat, barley, maize, sorghum and millet. Wheat is grown mostly between 1,500 and 2,700 meters above sea level whereas maize, sorghum and millet are cultivated at lower elevations in the warmer areas of the country. Sorghum and millet, which are drought resistant, are grown in regions with low and uncertain rainfall. Maize is mainly grown between 1,500 and 2,200 meters above sea level and requires relatively higher seasonal rainfall to ensure good harvests. These major food crops are produced in almost all regions of the country but with large variations in terms of volume of production.

The most important cereal farming system zones are located in the north, northwestern, central, eastern and southwestern highlands (USAID, 2010). Cereal mixed farming dominates the northern, northwestern and central highlands while maize-sorghum based cropping dominates the eastern highlands. Whilst Barley-wheat cropping dominates the Arsi and Bale highlands, coffee, maize and horticultural crops farming characterize the major farming system of the southern and southwestern highlands. The lowlands (areas below 1500 m above sea level) areas also grow short maturing maize, sorghum, wheat, and tef varieties along with some oil crops and lowland pulses.

Moreover, among perennial crops coffee, chat, enset, eucalyptus, avocado and mango are the majors grown in the country. Ethiopia, the place of origin of coffee Arabica, is the world's 3rd largest coffee producer and the largest producer and exporter of coffee in Africa (Petit, 2007; Chesley and Tefera,2012). As such, coffee is one of Ethiopia's main export agricultural commodities followed by chat. About one million Ethiopian smallholder farmers produce coffee and more than 25% of Ethiopians directly or indirectly depend on coffee for their livelihood. Coffee also accounts for about 34% of export earnings (Petit, 2007; Petty *et al.*, 2004).

The land use and cover from production in 2009 in Ethiopia overall and the two study regions (Oromia and SNNPR) in particular are presented in Table 2. During the time in Ethiopia, the total crop area under cereals, pulses and oilseeds was about 70% (8.8 million hectares), 13% (1.6 million hectares) and 7% (0.9 million hectares) respectively. The Oromia

region showed roughly similar land cover pattern to the national figures. However, in the SNNPR region, the distribution of crop area was tending to be more diverse: cereals, pulses, coffee and enset production accounts for about 55%, 12%, 7% and 14% of the total crop area respectively.

Table2. *Distribution of area over crop categories for Ethiopia and the two study regions during 2009*

	National		**Oromia region**		**SNNPR region**	
Crop type	Area (in ha)	Share a		Share b	Total area (in ha)	Share c
Total crop	12,493,989		5,724,657		1,439,947	
Cereals	8,770,118	70.19%	4,064,069	70.99%	785,304	54.54%
Pulse	1,585,236	12.69%	616,035	10.76%	171,584	11.92%
Oilseed	855,147	6.84%	393,167	6.87%	7,491	0.52%
Vegetables	162,125	1.30%	61,839	1.08%	50,637	3.52%
Root crops	145,742	1.17%	66,175	1.16%	42,016	2.92%
Fruit crops	47,990	0.3 8%	18,321	0.32%	24,898	1.73%
Coffee	391,296	3.13%	284,630	4.97%	97,185	6.75%
Enset	278,668	2.23%	82,216	1.44%	196,066	13.62%
Chat	138,145	1.11%	96,326	1.68%	25,900	1.80%

Source: *CSA 2009; a, is the share of each crop category in total crop area for Ethiopia, b and c are the shares of each crop category in Oromia and SNNPR regions respectively.*

According to CSA 2009 in the Ethiopian setup, the total area under crop production can be classified into eight main categories: cereals, pulses, oilseeds, vegetables, root crops, fruit crops, stimulant crops and sugar cane. Stimulant crops consist of chat, coffee and hops. Areas for sugarcane and hops were not presented in the table, as their share of the total crop area is insignificant

In another study ESSP (2011) described that in Ethiopia, most agricultural production takes place in the Dega and WeynaDega zones, where land productivity has traditionally coincided with the densest rural populations. Specific crops and livelihood choices within and outside this band are conditioned by moisture and temperature regimes, among other factors. The crops most suited to grow in the Dega and WeynaDega zones in Ethiopia are also the most commonly produced crops in Ethiopia. Most producers in these zones are smallholders, occupying on average less than a hectare of land per household. Smallholder production is dominated by five major cereal crops accounting for almost three-quarters of the total cultivated area and about 68 percent of total production. Each of the major cereals: teff, maize, wheat, sorghum and barley havetheir own distribution defined primarily by bioclimatic ranges (Table 3).

Table3. *Traditional ecological zones and selected crop altitudinal ranges*

Meters above sea level	More than 3700			**HIGH WURCH** None
	3700 to 3200		**MOIST WURCH** barley	**WET WURCH** Barley
	3200 to 2300		**MOIST DEGA** barley, wheat, pulses	**WET DEGA** barley, wheat, pulses/oilseeds
	2300 to 1500	**DRY WEYNA DEGA** wheat, teff, (maize)	**MOIST WEYNA DEGA** maize, sorghum, teff, wheat, oilseeds, barley, (enset)	**WET WEYNA DEGA** teff, maize, enset, oilseeds, barley
	1500 to 500	**DRY KOLLA** (sorghum), (teff)	**MOIST KOLLA** sorghum, (teff), pulses/oilseeds	
	Below 500	**BERHA** only irrigated crops		
		Less than 900	900 to 1400	More than 1400
		Annual rainfall (mm)		

Source: *ESSP 2011*

Rainfall Amount and Distribution at Different Agro-Ecological Regions of Ethiopia

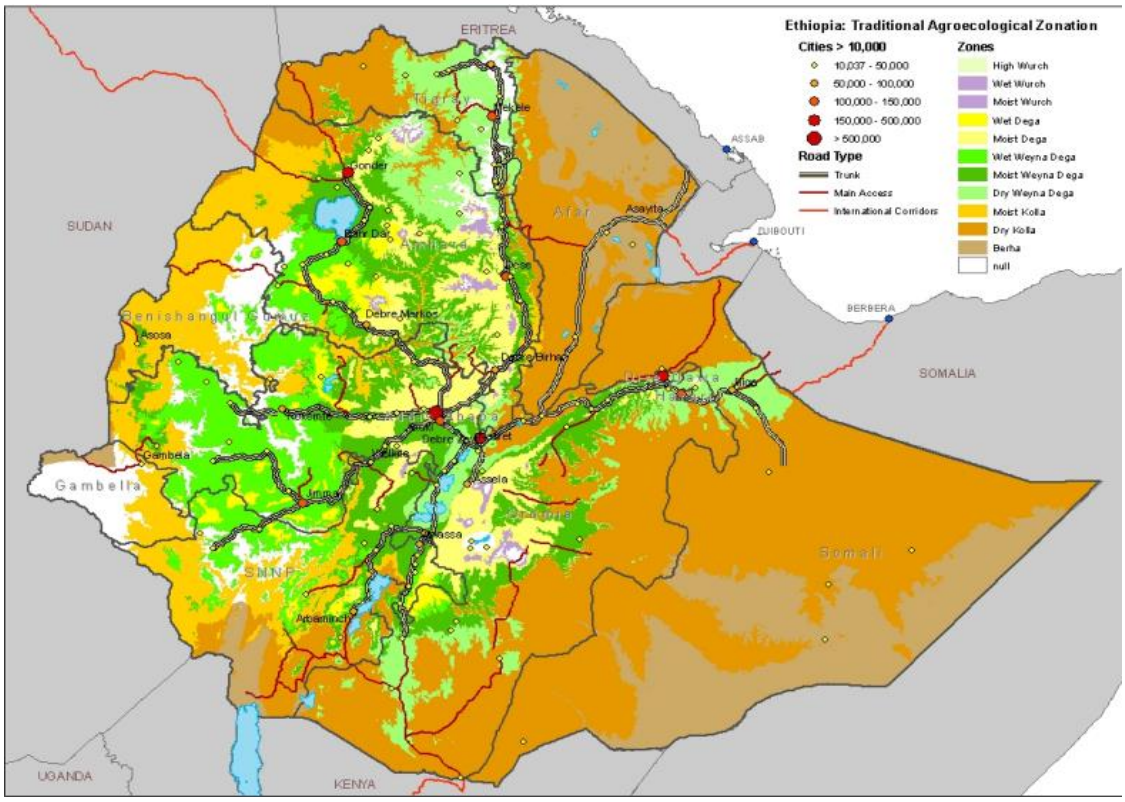
The country normally receives its highest rainfall (50-80%) when the low-pressure center/trough is established in northern equatorial region following the sun's apparent movement towards the northern hemisphere.

Some areas in the eastern and northeastern parts of the country also receive short ('belg') rain from as early as February to May as a result of

the penetration of rain bearing winds into Ethiopia during this period (Camberlin and Philippon, 2001).

Studies of FAO (1984) and Taddesse (2000) described that rainfall in Ethiopia is generally correlated with altitude. Middle and higher altitudes (above 1,500 meters) receive substantially greater falls than do the lowlands, except the lowlands in the west where rainfall is high. Generally average annual rainfall of areas above 1,500 meters exceeds 900 mm. In the lowlands (below 1,500 meters) rainfall is erratic and averages below 600 mm. There is strong inter-annual variability of rainfall all over the country. In the north of the country the rainfall pattern is mainly bimodal; with the shorter of the seasons around March/April and the second rainy season often begins around June/July. In some areas the two seasons combine into a unimodal pattern; this is commoner in the west and some northern parts of the country where rainfall is generally higher. Between these extremes, in the central highlands, there is a tendency for the two seasons to merge. The lowlands of the east and southeast contrast with the rest of the country by having a bimodal rainfall distribution, and have marginal rainfall for crop production (FAO, 1984 ; MoA, 2000).

Agro-ecological zonation utilizes biophysical attributes of soil, terrain and climate to organize land-use types or production systems into relatively homogenous units (FAO 1978, Hurni 1998). Hurni (1998) implemented a set of agro-ecological zone definitions for Ethiopia, based on traditional zone designations widely used by rural residents. He linked these designations with specific elevation and rainfall parameters, which allowed map able boundaries to be imposed on agro-ecological zones (Figure 2).



Source: *Hurni, 1998*

Figure2. *Characteristics of rainfall and altitude*

Weather in Ethiopia is characterized by significant regional variations in the distribution of rainfall and temperature. For instance, the mean annual temperature fluctuates between 10^0C to 35^0C in the highland and lowland areas of the country, respectively.

Similarly, the mean annual rainfall ranges from 2000 mm in the southwest to less than 250 mm in the lowland area of Ogden (ENMA 2007; Woldeamlak 2009; Deressa, 2010).

Agro-climatic regions would on the one hand be composed using generalized rainfall pattern regions and transects and on the other hand adapted to generalized cropping seasons. This can be used to do an interpretation of agro-climatic regions (figure 3) (Hurni, 1998).

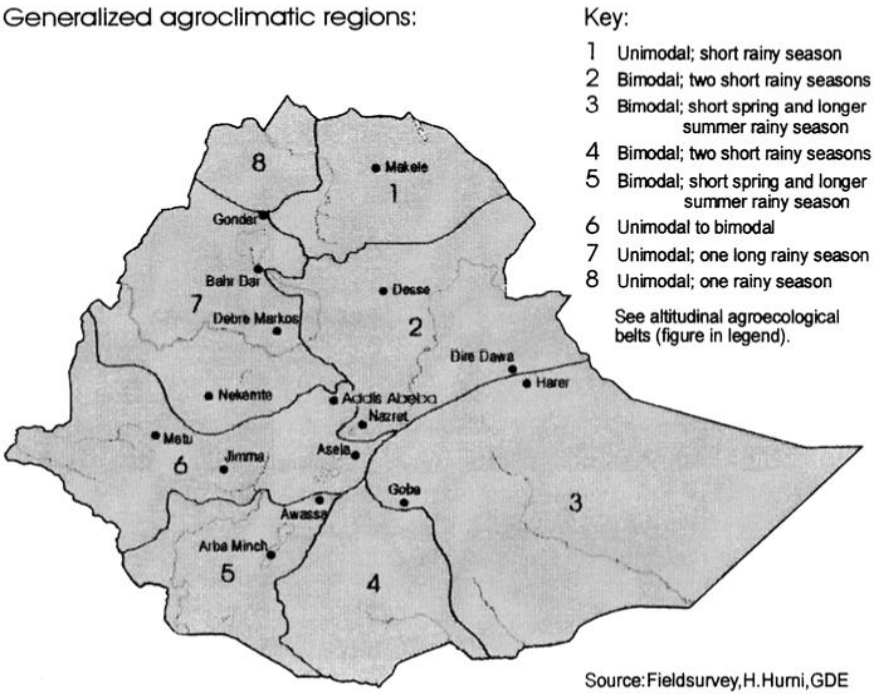


Figure3. *Generalizedagro-climatic regions of Ethiopia based on annual rainfall*

The rainfall is highly variable both in amount and distribution across regions and seasons (Mersha, 1999; Tilahun, 1999; Tesfaye, 2003). The seasonal and annual rainfall variations are results of the macro-scale pressure systems and monsoon flows which are related to the changes in the pressure systems (Haile, 1986; Beltrando and Camberlin, 1993; NMSA, 1996). The most important weather systems that cause rain over Ethiopia include Sub-Tropical Jet (STJ), Inter Tropical Convergence Zone (ITCZ), Read Sea Convergence Zone (RSCZ), Tropical EasterlyJet (TEJ) and Somalia Jet (NMSA, 1996). The spatial variation of the rainfall is thus influenced by the changes in the intensity, position and direction of movement of these rain-producing systems over the country (Taddesse, 2000).

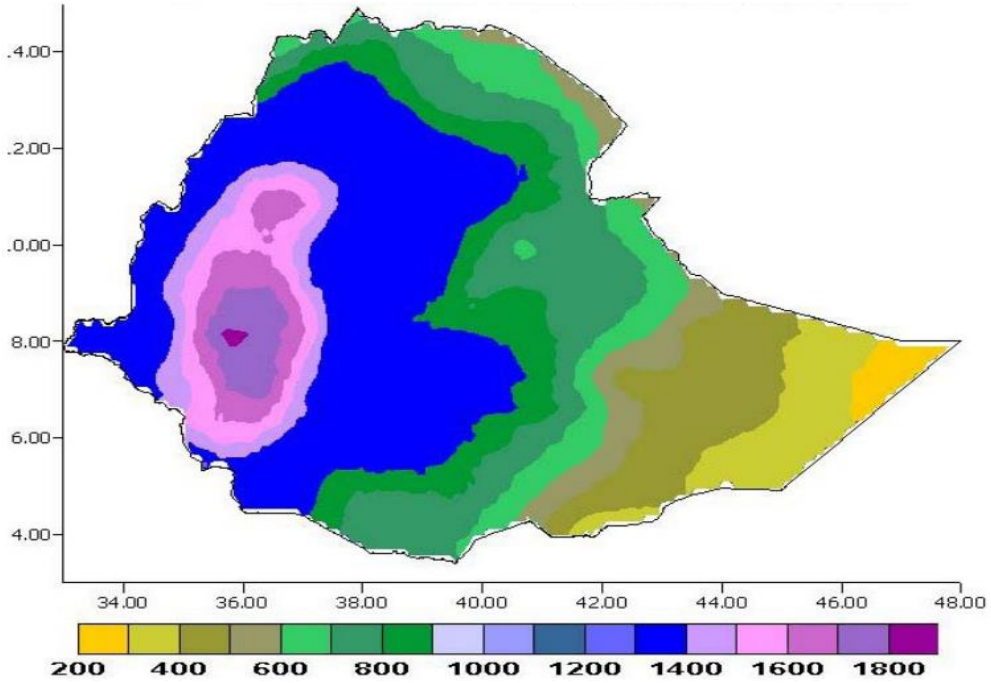
The Role of Rainfall Amount and Distribution on Agriculture Systems of Different Agro-Ecological Regions of Ethiopia

From the past studies Westphal (1975) have been identified four major farming systems for Ethiopia that are being influenced by amount and distribution of rainfall. Those are: **seed farming**, **enset planting**, **shifting cultivation** and **pastoral complexes**. The seed-farming complex focuses on grain production, particularly cereals, but also pulses and oilseeds. Grain-based, seed-farming production systems are found throughout the central, northern and eastern highlands and involve the majority of Ethiopian small farmers. Crop choice within the grain-based systems varies widely, as these systems are found from kola (500 masl) to wurch (3,200 masl) altitudinal bands, in moisture conditions ranging from dry to wet. Similarly, the enset-planting complex (grown in moist and wet dega and weynadega) allows for flexibility of production whereby enset could be the principal staple, a co-staple with cereals and/or tubers, or a minor component of cereal or tuber-based systems. Finally, shifting cultivation and pastoral complexes are most common in the western and eastern lowlands, respectively. In the humid western lowlands (primarily moist kola), disease is a limiting factor for livestock. The arid and semi-arid lowlands in the eastern part of the country (mostly bereha), lack available moisture which limits rain-fed crop production. In both areas, population densities are low, reflecting the low carrying capacities of land resources under current technologies.

Agriculture is highly dependent on **rainfall**, and hence the onset, duration, **amount** and **distribution** of the rainfall determines the performance of the agriculture sector and the economy of the country in general. More than 95% of the country's agricultural output is generated by subsistence farmers who, on average, own less than 1 ha of cultivated land with poor soil fertility as a result of continuous cropping and little input of nutrients to replace removal with harvest (Tesfaye 2017).

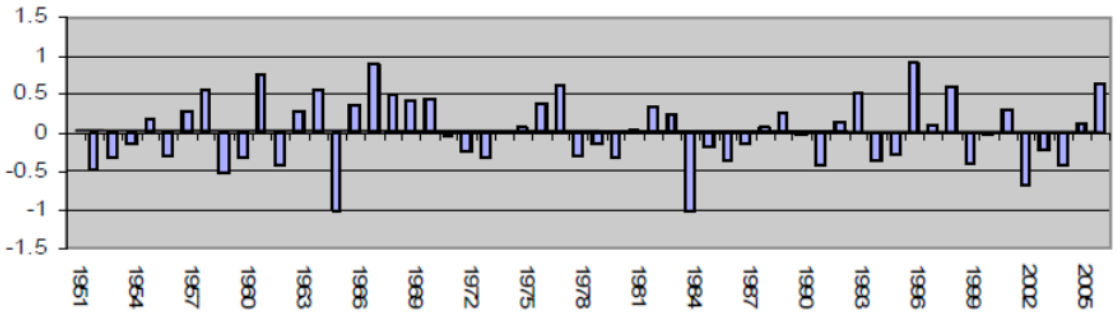
The average annual rainfall of the country showed a very high level of variability over the past years even though the trend remained more or less 9 constants (FAO 1984; NMS, 2007).

FAO, 1984 described as despite variable rainfall which makes agricultural planning difficult, a substantial proportion of the country gets enough rain for rain-fed crop production (Figure 3).



Source: *Adapted from FAO, 2006*

Figure4. *Long term average annual rainfall (mm.)*



Source: *NMS, 2007*

Figure5. *Year to year variability of annual rainfall and trend over Ethiopia expressed in normalized deviation (compared to 1971-2000 normal)*

On contrary NMS, 2007 described that over the past 60 years, some of the years have been characterized by dry rainfall conditions resulting in drought and famine whereas the others are characterized by wet conditions (Figure 4). Subsistence agriculture is almost entirely rain-fed and yields are generally low (Alemayehu, 2006). Droughts in Ethiopia can shrink household farm production by up to 90 % of a normal year output (World Bank, 2003). Most often, many farmers die of hanger or depend on foreign food aid during extreme drought periods. For instance, during the 1983/84 drought periods, about one million people died due to drought that led to famine and many households have also been affected during drought periods over different years in the same vain (Table 3).

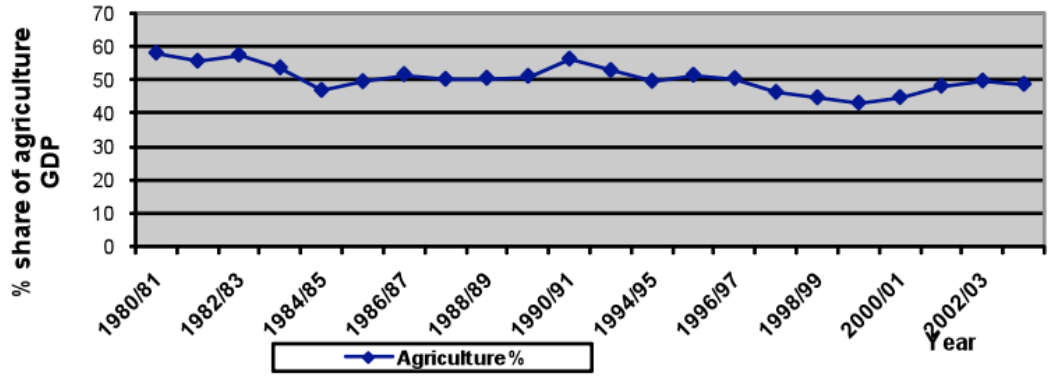
Table4. *Chronology of the effect of drought/famine in Ethiopia (1965-2009)*

Years	Regions Affected	Effects
1964-1966	Tigray and Wello	About 1.5 million people affected
1972-1973	Tigray and Wello	About 200,000 people and 30 percent of livestock died
1978-1979	Southern Ethiopia	1.4 million people affected

1983-1984	All regions	8 million people affected; one million people died
1987-1988	All regions	7 million people affected
1992	North, Eastern and Southern regions	About 500,000 people affected
1993-1994	Tigray and Wello	7.6 million people affected
2000	All regions	About 10.5 million people affected
2002-2003	All regions	About 13 million people affected
2008-2009	All regions	About 5 million people affected

Sources: *Government of Ethiopia (2009)*

The trends of the contribution of agriculture to total GDP of the country clearly explain the relationship between the performance of agriculture, climate and the total economy. As can be seen in figure 6, years of drought and famine (1984/1985, 1994/1995, 2000/2001) are associated with very low contributions, whereas years of good climate (1982/83, 1990/91) are associated with better contributions.



Source: *CSA, 1997, 2005*

Figure6. *Percent share of Agriculture GDP*

The Role of Rainfall Amount and Distribution on Crop Cropping Systems of Different Agro-Ecological Regions of Ethiopia

Rainfall is the most important climatic factor for agricultural production in Ethiopia. Altitude is a factor that determines the amount as well as distribution of rainfall that influences the crops to be grown, rate of crop growth, natural vegetation types and their species diversity (Alemayehu, 2006). Moreover, rainfall is erratic and unpredictable particularly during growing periods (Deressa *et al*., 2009). The unpredictable distribution of rainfall at critical months such as during the planting or harvesting stage of crops is also a prominent feature of rainfall in Ethiopia (Seleshi and Zanke, 2004; ENMA, 2007; Woldeamlak, 2009).

In the extreme case of droughts with very low total seasonal amounts crop production suffers the most. But more subtle intra-seasonal variations in rainfall distribution during crop growing periods without a change in total seasonal amount can also cause substantial reductions in yields. This means that the number of rainy days during the growing period is as important, if not more, as that of the seasonal total. Jackson (1989) notes that even in wet locations rainfall variability at the daily time scale is critical to plant growth particularly in the early part of the rainy season before soil moisture reserves have been built up. Generally, the effect of rainfall variability on crop production varies with types of crops cultivated, types and properties of soils and climatic conditions of a given area.

According to a study by Conway *et al*. (2005), in the second half of the 20thcentury negative rainfall irregularity has become the prominent feature of Ethiopia. Similarly, using precipitation concentration index (PCI) for northern Ethiopia. Woldeamlak (2009) indicates that about 60% of the years between 1975 and 2002 experienced rainfall below the long-term average. Moreover, studies on different regions of the country revealed that there is no uniform trend in temperature and rainfall pattern which affects crop yield (Alexandrov and Hoogen boom, 2000).

Table5. *Area coverage of cereal crops in Ethiopia over a course of 5 decades*

	Tef	Wheat	Maize	Sorghum	Barley	Finger Millet	Other cereals	Total
Cereal cultivated area (M ha)								
1961/62-1969/70	2.1 1	0.97	0.8	1.09	0.96	-	0.3	6.23
1970/71-1979/80	1.67	0.78	0.83	0.87	0.84	-	0.27	5.25
1980/81-1989/90	1.23	0.52	0.84	0.71	0.86	-	0.15	4.3
1990/91-1999/00	1.76	0.75	1.12	0.95	0.73	-	0.29	5.6
2000/01-2008/09	2.17	1.27	1.59	1.35	0.96	-	0.38	7.72
2012/2013	2.73	1.71	2.01	1.62	1.02	0.43	0.08	9.6
Area share from total cereal cultivated area (%)								
1961/62-1969/70	33.9	15.6	12.8	17.4	15.4	-	4.9	100
1970/71-1979/80	31.8	14.8	15.7	16.6	15.9	-	5.1	100
1980/81-1989/90	28.7	12.0	19.5	16.4	19.9	-	3.4	100
1990/91-1999/00	31.3	13.4	20.0	17.0	13.1	-	5.2	100
2000/01-2008/09	28.1	16.5	20.6	17.5	12.5	-	4.9	100
2012/2013	28.4	17.8	20.9	16.9	10.6	4.5	0.8	100

Source: *Alemayehu et al., 2011*

In terms of crop production for example the area coverage of maize, wheat, sorghum and finger millet account for 47% of cultivated grain crop area of the country during 2012/13 cropping season (Table 5 & 6). However, the productivities of these crops are very low despite their large production area. National average yields for maize, wheat and sorghum, and finger millet were 3.0, 2.0 and 1.7 t ha, respectively in 2012/ 2013 (Table 6). Available evidence suggests that yields of major crops under farmers' management are still far lower than what can be obtained under on station and on farm research managed plots (Table 6). This is a clear indication of large yield gaps. There are several factors believed to contribute to the low productivity including moistures stress **(rainfall amount** and **distribution)**, shortage of seeds for improved varieties, soil fertility degradation, insect pests, diseases, weeds and birds (CSA, 2013; Tesfaye, 2017).

Table6. *Nationally reported average yields compared to yields reported from on station and on farm experiments*

Crop	Area (M ha)*	Total Production (MMT)*	National Average Yield (t/ha)*	On station yield (t/ha)	On farm yield (t/ha)	Varieties considered for on-station and on-farm reports
Maize	2.01	6.16	3.01	9.0-12.0	6.0-8.0	BH-660
Wheat 1	1.63	3.43	2.1	3.5-5.5	2.5-5.0	Dendea
Sorghum	1.71	3.60	2.1	1 4.2	3.3	Chare
Finger millet	0.43	0.74	1.72	3.1	2.8-2.9	Tadesse

Source: ** MMT = million metric tonnes, from CSA (2013) report; from MoARD (1995-201 1) crop variety register books*

Length of Growing Period (LGP)

Another interesting thing which determines almost all crop and cropping system availability is that length of growing period. This is directly dependent on amount as well as distribution of rainfall. Among many studies Hurni (1998) stated that about 40% of the country has a length of growing period of less than 120 days per year, another 40% is moist with 120-240 days of growing period per year and only about 20% has a wet climate, with over 240 days of LGP per year.

Higher parts of Ethiopia are largely situated in the moist to wet moisture regimes, while lower parts are clearly situated primarily in the moist to dry regimes (Figure 7).

Length of growing period's show that different agro-climatic zones of the country; namely south-western, western and north-western parts of the country, the Weyna Dega and Kolla Belts extend much further down than in the eastern parts of the country (Figure 7). This is due to rainfall regime and moisture availability, and has considerable influence on the occurrence of rain-fed agriculture (Table 7). Along the eastern escarpment, the lower boundary of such agriculture extends to roughly 1,200 m a.s.l., while in the western parts of Ethiopia, rain-fed agriculture can be as low as 600 m a.s.l.

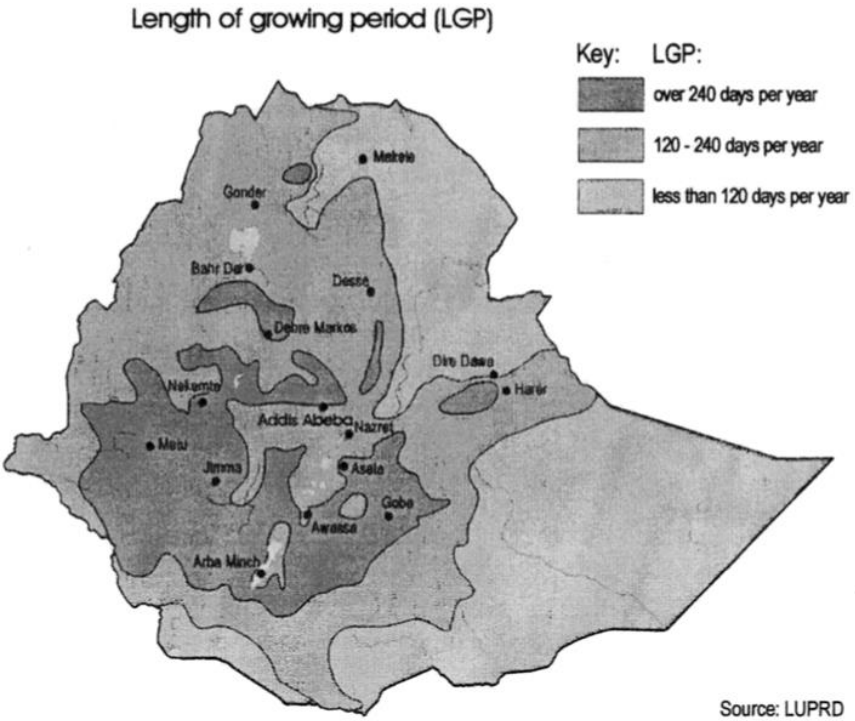


Figure7. *Length of growing period map for Ethiopia (three categories only)*

Table7. *Area coverage for each agro-ecological belt in Ethiopia, subdivided in different LGP zones in each belt (see Figure 7)*

Agroecological Belts 1000qkm]	Area of Length of Growing Period (LGP)			Sum
	Dry (<120 days)	Moist (120-240 days)	Wet (>240 days)	
I (Wurch)	0,00	0,41	2,44	*2,85*
II (High Dega)	0,00	2,95	4,95	*7,89*
III (Dega)	2,24	23,46	19,77	*45,47*
IV(WeynaDega)	11,26	171,44	159,41	*342,11*
V (Kolla)	26,54	135,91	22,02	*184,4 7*
VI (Berha)	409,66	121,83	10,01	*541,50*
Lakes				*8,79*
Sum	*449,69*	*456,00*	*218,61*	*1133,09*

Source: *Hurni, 1998*

On another study NMSA (1996) classified Ethiopian agro-ecology zones into three based on the water balance concept, the **length of the growing season** (including onset dates) at certain probability levels. Thus he has been identified three lengths of growing periods namely the area without a significant growing period (N), areas with a single growing period (S) and area with a double growing period (D) (Figure 8).

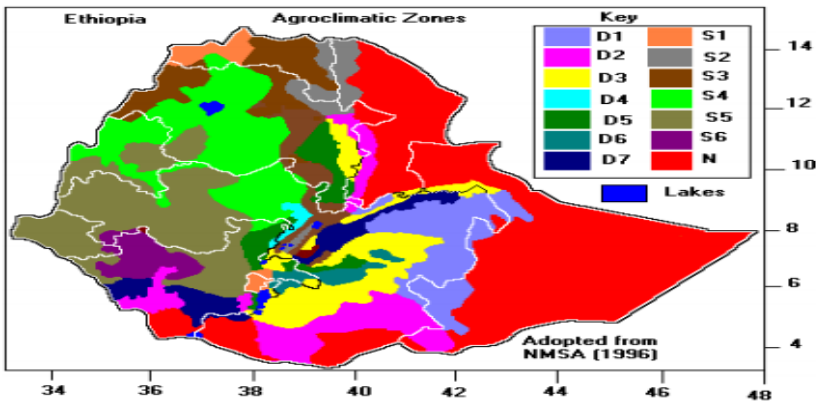


Figure8. *Agroclimatic zones of Ethiopia*

CONCLUSION

Ethiopia is a tropical country which is characterized by different agro-ecologies. The diversification agro-ecological nature has its own opportunities and constraints for agriculture. Since agriculture is the back bone of the country's economy identifying important factors is the primary concern. Among multi factors the main and key determinant is rainfall in terms of its amount and distribution. Thus, this paper has been reviewed 'the role of rainfall amount and distribution on agriculture and crop cropping systems of different agro-ecological regions of Ethiopia' and the following possible summaries have been extracted.

- Agriculture is the source of livelihood to the overwhelming majority of Ethiopia's population
- Ethiopia's agricultural production is characterized and determined by smallholder rain-fed agriculture practices
- It is also characterized by extreme dependence on rainfall, so amount and distribution of rain fall play significant roles in different agro-climatic regions of the country
- Variety of crops and livestock are produced throughout the country in different agro-ecologies depend on the amount and distribution of rainfall
- These agro-ecological regions are dynamic, however where rain fall is insufficient in amount or distribution over continuous growing seasons, crop and livestock productions may cease to be a viable livelihood option
- Ecological conditions usually relate to climatic parameters such as amount of rainfall, rainfall distribution and variability
- Thus, proper agro-climatic zoning, identifying seasonal amount and distribution of rainfall and forecasts are crucial elements in minimizing climatic risks of variable rainfall amount and distribution.

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