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Impacts of Climate Change on Land Use/Land Cover in Kembata Tembaro Zone, Southern Ethiopia

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Abstract

Climate change is one of the major challenges of our time, disproportionately affecting the livelihoods of smallholder farmers, creating considerable stress to the human and natural system. The impact of climate change on smallholder farmers' land use/land cover change is multidimensional and complex in nature. This work assessed the impact of climate change on land use and land cover of smallholder farmers in Kembata Tembaro zone of Southern Ethiopia based on Enhanced Thematic Mapper Plus and Thematic Mapper Landsat images taken in 1984, 2000 and 2017. The results showed that there has been a dynamics of Land Use Land Cover changes between 1984 and 2017. Cropland was commonly dominant land use land cover type occurred in increasing trend in all livelihood zones, while forestland has shown a decreasing trend in Cereal and Enset livelihood zone, Ginger livelihood zone and Coffee livelihood zone. Accordingly, impact of climate change on land use land cover across different livelihood zones show variations in adopting new crop types, extinction of few crops, and changes in land allocation decision among smallholder farmers. Thus, efforts are needed to manage the impact of climate change on land use land cover taking into account of local level geographic, agronomic and overall livelihood systems through well integrated landscape planning to ensure sustainable land management practices.

Keywords: Land Use/Land Cover, Remote sensing, Climate Change, Livelihood Zone, Impact

1. Introduction

There is overwhelming scientific evidence indicating that climate change is no longer a distant prediction but a reality whose imminent impacts on ecosystems and people are often underestimated. Impacts on natural and human systems from global warming have already been observed (IPCC, 2018). The impacts of increased temperature from global warming and changes in rainfall patterns resulting from climate change are expected to reduce agricultural production and put further pressure on marginal land (Lobell and Field, 2007; Van de Steeg et. al., 2009). Specifically, for developing world, it is expected to further exacerbate the already existing burden of multidimensional poverty and wellbeing of billions of people. Human activities have modified the environment for thousands of years. According to Smith, & Zeder, (2013), as cited in Ashebir et.al., (2018); the impact of human activities on ecosystems has long been recognized and, now, there is increasing evidence to support the hypothesis that we have entered into an Anthropocene. Significant population increase, migration, and accelerated socioeconomic activities have intensified these environmental changes over the last several centuries. Thus, it is essential that impacts of climate change on LULC change is detected accurately, at appropriate local scales, and in a timely manner so as to provide improved prediction of future trends of the climate and better understand their impacts on lives and livelihoods of the rural smallholder agriculture.

Like many other developing countries across the globe, significant land-cover changes have occurred in Ethiopia since the last century. These changes were primarily due to anthropogenic activities, in connection with population increase and due to land use changes, including deforestation, over-grazing, and improper cultivation of agricultural land which led to accelerated soil erosion and associated soil nutrient deterioration (FAO, 1986; Hurni, 1993; Gebresamuel et. al., 2010; Eleni et. al., 2013). Ethiopia's location close to the equator and its altitudinal diversity gives rise to varied agro-ecologies for the existence of diverse agricultural farming and production systems. This heterogeneity in elevation has led to have different livelihood zones and crop production areas across the country.

In Ethiopia, many researchers have studied land use and land cover change at the local level, mostly on a catchment scale (Binyam, 2015); Tolessa et. al.,(2017); Ashebir et.al., (2018); Temesgen, (2017); Alemayehu, (2010); Desalew and Hejamady Gangadhara Bhat (2018); Mengistie et.al.,(2015); Woldeamlk and Solomon (2013); Eleni et.al.,(2013); Amare (2016); Wakjira et.al.,(2016); Berhan (2010); Mesfin et.al., (2009); Hassen et.al.,(2015); lacking to integrate the livelihood system with geographical settings of a given area. This calls for the need to investigate on the impact of climate change on LULC changes based on the context of a given farming system and livelihood zones. This study fills knowledge gaps on the impact of climate change on smallholder farmers' LULC change based on livelihood zone approach in Kembata Tembaro zone, southern Ethiopia. The objective of the study is to identify the impacts of climate change on smallholder farmers' land-use practices and livelihood systems.

2. Methodology

2.1 Description of the study area

The study area, Kembata Tembaro Zone, is located in Southern Nations, Nationalities, and Peoples' Region (SNNPR), which is one of the nine regional states of Ethiopia. According to CSA (2013), the study area is projected to have a population size of **902,073** by the end of 2017, of which **442,883** are male and **459,190** are female. Kembata Tembaro Zone is located within the **7010'- 7061'** latitude and **370 34'- 380 07'** longitude, has a total area of **1523.6 sq.km**, and elevation from **1400** to **3028** masl. It is one of the most densely settled areas in Ethiopia, with a population density of 665 per square kilo metre, much higher than the estimated regional average of 164 (CSA, 2013).

In this study, Sustainable Livelihood Approaches (SLA) has been adapted to contextualize the social, geographical and economic situations of the study communities, as the approach is flexible and adaptable to specific local settings and the objectives defined. According to the livelihoods zone classification, there are 175 different livelihood zones in Ethiopia, out of this 40 are found in SNNPR (DRMFSS, 2010). As depicted in Table 1, the study area covers five main livelihood zones, namely; **Kambata Cereal and Enset LZ, Kedida-Badewacho Coffee LZs, Badewacho-Alaba Maize LZ, Hadero-Ginger LZ** and **Alaba-Mareko Lowland Pepper LZ** (DPPC 2005b).

Table 1: Description of Livelihood Zones (LZs)

Livelihood Zone	Altitude Range (masl)	Major Crops Grown	Location
Kembata Cereal and Enset LZ	2200-3028	False banana, Wheat, Barely, Beans, Peas, etc	North West
Kedida-Badewacho Coffee LZ	1900-2200	Coffee, False banana, Taro, etc	South Central
Hadero-Ginger LZ	1500-2100	Ginger, False banana, Banana, Avocado, etc	South West
Badewacho-Alaba Maize LZ	1400-1800	Maize, Teff, Soybean, Millet, etc	South East
Alaba-Mareko Lowland Pepper LZ	1600-1800	Pepper, Millet, Sorghum,etc	North East

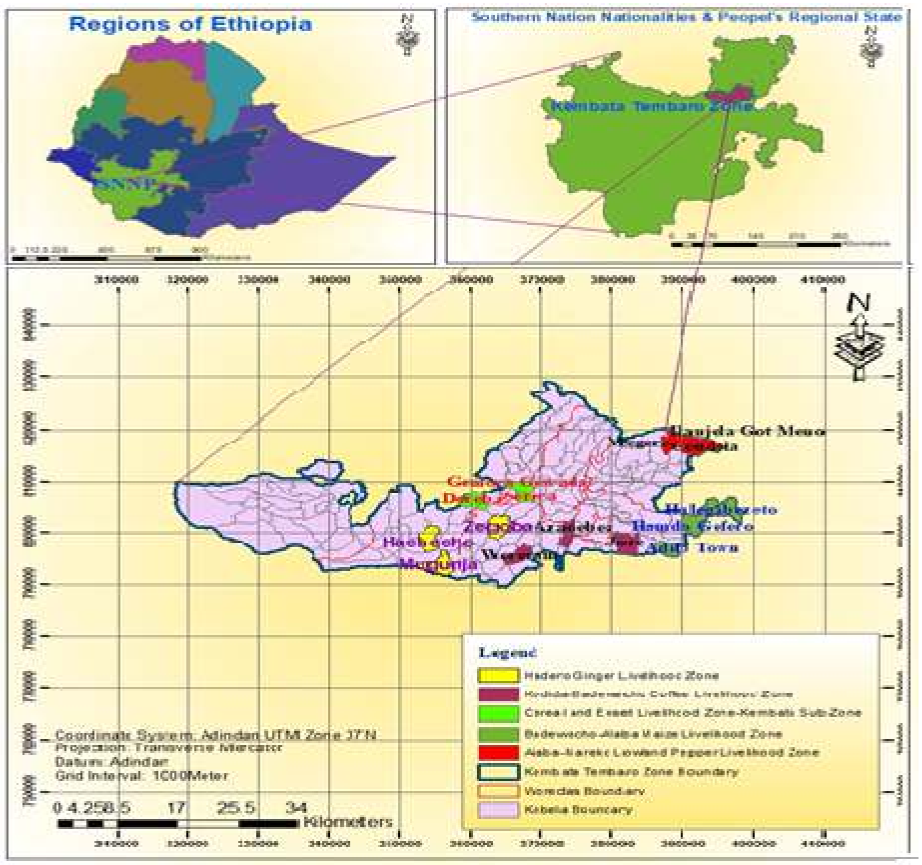

Figure 1: Map of the study area

2.2 Data Source and Methods of Data Collection

The land use land cover classification analysis is based on Enhanced Thematic Mapper Plus (ETM+) and Thematic Mapper (TM) Cloud-free Landsat satellite Images captured in 1984, 2000 and 2017 accessed from Ethiopian Geospatial Information Agency, acquired in the same season and with the same level of resolution which is helpful for assessment of changes occurred. Finally, ground-level checking for data validation was carried out through extensive and random field visits to cross-check the interpreted data with existing features for verifying the accuracy of interpreted data through field observation. The socio-economic, biophysical, and institutional data were collected through questionnaires, focus group discussions (FGDs), field observations, and key informant interviews were carried out. Zonal and district level reports were used from the respective Agriculture and Natural Resources Offices. Observed temperature and rainfall data were also secured from National Meteorological Agency of Ethiopia, covering the period from 1984 to 2014.

2.3 Target Population and Sampling Technique

The target population of the study was smallholder farmers engaged in agricultural activities across five livelihood zones in Kembata Tembaro zone and the heads of the households were the unit of analysis. In terms of administrative units, the study area comprised of seven districts, namely, **Kedida Gamela, Kacha Bira, Angacha, Danboya, Hadero-Tunto, Tembaro** and **Doyogena**. However, it is difficult to divide the districts proportionally to each livelihood zones, as livelihood zones do not normally follow the formal administrative boundaries. Out of the total of seven districts, five districts, namely**; Doyogena, Kachabira, Hadero-Tunto, Kedida Gamela** and **Damboya** are purposefully selected, based on representation of the typical livelihood zone settings. In order to determine the sample size of households, the formula set by Kotari (2004, p. 179) in the case of finite population was used and **690** farm households were randomly drawn from the selected kebeles, using the formula:

$$n=\frac{z^2*p*q*N}{e^2(N-1)+z^2*p*q}$$

2.4 Data Analysis Techniques

It is often inadequate to quantitatively describe the changes in the structure and pattern of a landscape (Bürgi, et.al., 2017; Narumalani, et.al., 2004); and Southworth, (2004). Hence, linking information obtained through Earth Observation (EO) with social science approaches is helpful in gaining a comprehensive understanding of LULC changes. The socioeconomic, biophysical, and institutional data were collected through questionnaire, focus group discussions (FGDs), field observations, and key informant interviews were analyzed qualitatively and quantitatively across the five livelihood zones to substantiate the information obtained from satellite imagery. A Mann-Kendall trend analysis was used to detect long-term trend of the meteorological variables (temperature and rainfall) of the study area from 1984 to 2014.

Table 1: Description of Land use and land cover classes

Land Use and Land Cover Classes	LULC Description
Cropland	Areas allotted to rain fed and irrigated cultivation, including fallow plots, cultivated land mixed with some bushes, trees and the scattered rural settlements included within the cultivated fields.
Enset land	Areas covered with Enset around homestead
Forest land	Land spanning at least 0.5 ha covered by trees and bamboo, attaining a height of at least 2m and a canopy cover of at least 20% or trees with the potential to reach these thresholds in situ in due course.
Shrub/Bush Land	Land covered by small trees, shrubs and bushes and sometimes such lands are mixed with grasses; less dense than forests.
Built up (Settlement)	Areas of land covered with structures, construction of buildings, and other infrastructures, which included towns and rural villages
Water body	Areas covered by rivers and streams, manmade small dams, seasonal water bodies and permanent water bodies.
Bare Land	Land areas not covered with any type of vegetation

3. Results and Discussion

3.1 Patterns of Land Use/Land Cover Change

The trend analysis made for two consecutive periods, from 1984 to 2000 and from 2001 to 2017, has indicated the existence of several spatio-temporal changes in LULC classes. Based on the context and objective of the study, Cropland, Ensetland, Forest land, and Water body are found relevant for further analysis as follows.

3.2 Land Use/Land Cover Change in Crop Land

In the Ethiopian agricultural systems, cereals are the most extensively grown crops in terms of the magnitude of the area under crops and volumes crop production. Land productivity and crop yield have been expected to decline because of climate change more or less continuously in recent times, and have experienced sharp decline in some places (Asha et.al., 2012). Conversion of land to cropland is a dynamic process, but it is a process that can reach a steady state. In Ethiopia, a significant increase in cultivated land at the expense of forest land was found to have occurred at national and regional levels. These include in northwest (Gete and Hurni, 2001); north-eastern (Kebrom and Hedlund, 2000); western (Bezyayehu and Gerret, 2008); central (Aklilu, 2006); and eastern (Mohammed, 2011) Ethiopia, as cited in Wubie et.al., (2016). During the earlier part of 2000's, cropland area expansion was the primary contributor to increases in agricultural GDP. However, in more recent years, rising crop yields coupled with continuing agriculture area expansion contributed to agricultural GDP growth (Bachewe et.al., 2018). Similarly, Tshopp et.al., (2010) indicated that pasturelands are also increasingly being put under crops.

The rapid population increase in the study area induced an increased expansion of cropping into areas previously considered marginal for crop production. Expansion of cropland due to population pressure has shrinked the size of grazing land. Traditionally, restoration of soil fertility in particular and maintenance of a stable ecosystem in general have been made possible because of sufficient rest period. However, the traditional fallow that used to restore soil fertility in the study area in general, and specifically in Ginger, Coffee and Cereal and Enset LZs in particular have been disrupted due to land shortage. Moreover, continuous cropping has gradually depleted the organic matter content of the soil and increased its vulnerability to erosion and other forms of soil degradation. According to Holden and Shiferaw (2002), production losses in Ethiopia approaching 1.1 percent per year have been linked to increasing erosion and topsoil loss in the highlands.

From the result, it is possible to state that different LZs undergone different LULC changes. Major annual crops grown in the study area include bread wheat, barley, maize, ginger, teff, pepper, sorghum, faba bean, haricot bean, taro, millet, field pea, Ethiopian cabbage, potato, sweet potato and check pea (CSA, 2009). Likewise, enset, coffee, banana, avocado, sugarcane, mango, and hop are major perennial crops grown in the study area. In recent years, there is an increasing trend of allocating more size of crop land to grow apple in Cereal and Enset LZ.

Table 2: LULC Coverage area at different period of time in Alaba Mareko Lowland Pepper Livelihood Zone

LULC Class	1984		2000		2017	
	Area(Ha)	%	Area(Ha)	%	Area(Ha)	%
Bare Land	971	39.3	169	6.85	170	6.89
Built up(Settlement)	17	0.69	24	0.97	44	1.79
Bush Land	44	1.78	68	2.76	70	2.84

LULC Class	1984		2000		2017	
	Area(Ha)	%	Area(Ha)	%	Area(Ha)	%
Crop Land	1395	56.5	2142	86.8	2143	86.83
Enset	30	1.22	24	1.01	17	0.69
Forest	10	0.41	40	1.62	23	0.93
Water Body	1	0.05	1	0.05	1	0.05
Total	**2468**	**100**	**2468**	**100**	**2468**	**100**

Source: Land Sat Image Analysis, from Ethiopian Geospatial Information Agency

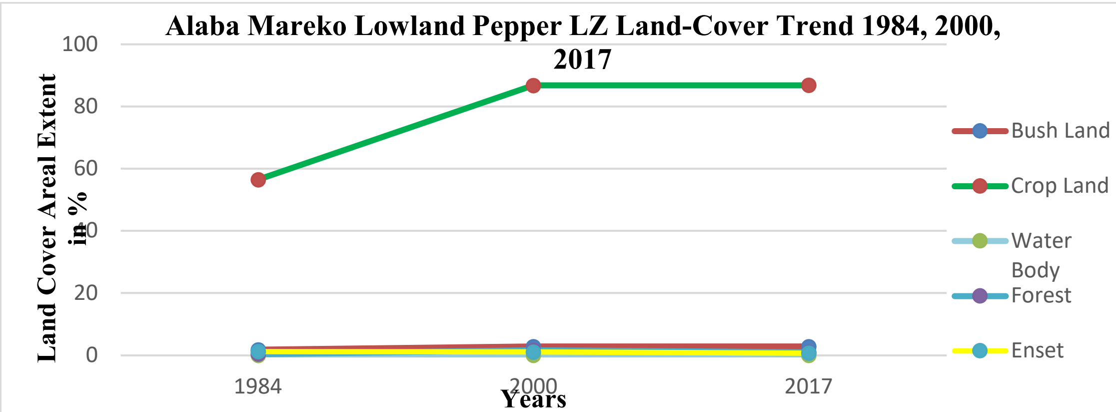

Figure 2: Trends of LULC in Alaba Mareko Lowland Pepper LZ; **Source:** Ethiopian Geospatial Information Agency

Hence, crop land expansion was the major driver of land use change, commonly resulted in increasing trend from 56.5% (1395 ha) in Pepper LZ, 66.5% (1332 ha) Cereal and Enset LZ, 94.61% (3180 ha) Ginger LZ, 56.29% (1718 ha) Maize LZ and 86.58% (2549 ha) Coffee LZ in 1984 to 86.83% (2143 ha) Pepper LZ, 89.09% (1784.5 ha) Cereal and Enset LZ, 95.33% (3204 ha) Ginger LZ, 86.30% (2634 ha) Maize LZ and 93.51% (2753 ha) Coffee LZ in 2017, respectively (see Tables 5.2., 5.3., 5.4., 5.5., and 5.6). More specifically, the change of crop land of those of Ginger and Coffee LZs show a relatively narrow in range of 0.72% (24 ha) in the context of Ginger LZ and 6.93% (204 ha) in the context of Coffee LZ (see figures 5.3 and 5.4).

Table 3: LULC Coverage area at different period time in Kedida Badewacho Coffee Livelihood Zone

LULC Class	1984		2000		2017	
	Area (Ha)	**%**	**Area (Ha)**	**%**	**Area (Ha)**	**%**
Bare Land	140	4.76	144	4.91	147	4.99
Built up (Settlement)	13	0.44	15	0.51	17	0.58
Bush Land	207	7.03	184	6.27	6	0.20
Crop Land	2549	86.58	2570	87.25	2753	93.51
Enset	10	0.34	12	0.41	15	0.51
Forest	22	0.75	15	0.51	1	0.03
Water Body	3	0.10	4	0.14	5	0.17
Total	**2944**	**100.00**	**2934**	**100.00**	**2944**	**100.00**

Source: Land Sat Image Analysis, from Ethiopian Geospatial Information Agency

Cropland was the most dominant LULC type in the study area during the 1984 to 2000 and from 2001 to 2017 with the share of an average 89.11%, 72.14%, 95.02%, 80.05% and 76.71% of Coffee, Maize, Ginger, Cereal and Enset and Pepper LZs, respectively (see Tables 5.2, 5.3., 5.4., 5.5., and 5.6.).

Table 4: LULC Coverage area at different period of time in Cereal and Enset Livelihood Zone

LULC Class	1984		2000		2017	
	Area(Ha)	%	Area(Ha)	%	Area(Ha)	%
Bare Land	442	22.07	140	6.99	17	0.85
Built up (Settlement)	6	0.23	11	0.55	43	2.15
Bush Land	23	1.15	9	0.45	8	0.34
Crop Land	1332	66.5	1693.5	84.55	1784.5	89.09
Enset	94	4.69	118	5.89	128	6.39
Forest	105	5.24	31	1.55	22	1.10
Water Body	1	0.05	0.5	0.03	0.5	0.03
Total	**2003**	**100**	**2003**	**100**	**2003**	**100**

Source: Land Sat Image Analysis, from Ethiopian Geospatial Information Agency

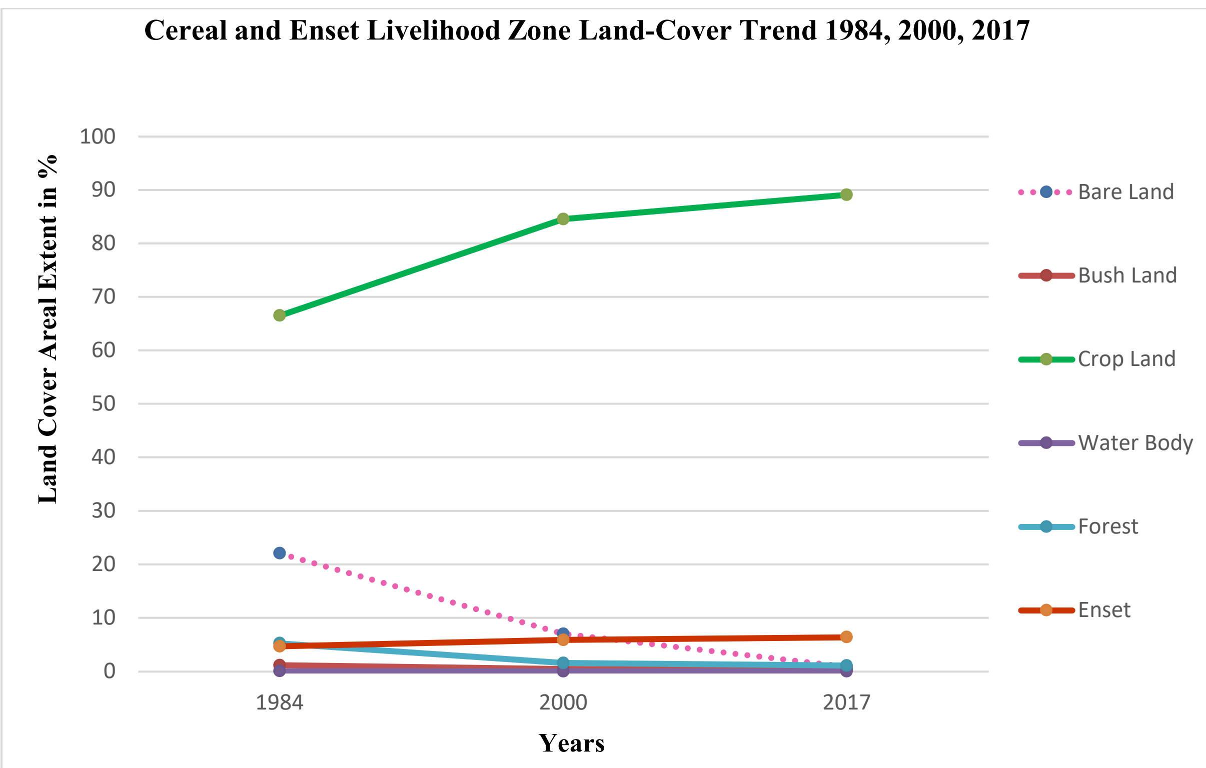

Figure 3: Trends of LULC in Cereal and Enset LZ, **Source:** Ethiopian Geospatial Information Agency

Table 5: **LULC Coverage area at different period time in Badewacho Alaba Maize Livelihood Zone**

LULC Class	1984		2000		2017	
	Area(Ha)	%	Area(Ha)	%	Area(Ha)	%
Bare Land	402	13.17	710	23.26	343	11.24
Built up(Settlement)	7	0.23	15	0.49	19	0.62
Bush/Shrub Land	872	28.57	19	0.62	15	0.49
Crop Land	1718	56.29	2253	73.82	2634	86.30
Enset	15	0.49	17	0.56	22	0.72
Forest	27	0.88	29	0.95	11	0.36
Water Body	11	0.36	9	0.29	8	0.26
Total	3052	100.00	3052	100.00	3052	100.00

Source: Land Sat Image Analysis, from Ethiopian Geospatial Information Agency

Specifically, the change of cropland added in Ginger LZ from 1984 to 2000 (17 ha, 0.51%) is slightly higher than the change of cropland added from 2001 to 2017 (7 ha, 0.21%), indicating that about 0.3% (10 ha) of increase in crop land is registered from 2001 to 2017. In general, the increase in crop land from 2001 to 2017 is lower than the increase from 1984 to 2000, mainly related with increase in population pressure, as Ginger LZ has the highest family size and the lowest farmland size, as compared with the rest LZs.

Table 6: **LULC Coverage area at different period time in Hadero Ginger Livelihood Zone**

LULC Class	1984		2000		2017	
	Area(Ha)	%	Area(Ha)	%	Area(Ha)	%
Bare Land	69	2.05	66	1.96	60	1.79
Built up(Settlement)	15	0.45	18	0.54	22	0.65
Bush/Shrub Land	64	1.90	60	1.79	53	1.58
Crop Land	3180	94.61	3197	95.12	3204	95.33
Enset	5	0.15	6	0.18	10	0.30
Forest	19	0.57	7	0.21	6	0.18
Water Body	9	0.27	7	0.21	6	0.18
Total	3361	100.00	3361	100.00	3361	100.00

Source: Land Sat Image Analysis, from Ethiopian Geospatial Information Agency

When assessing future potential for agricultural area expansion, according to Schmidt and Thomas (2018), their analysis suggests that agricultural area expansion in the highlands is reaching its maximum economic potential, especially in the drought-prone highland agro-ecological zone. Selected areas in the lowlands have greater potential to expand the share of their land areas devoted to agriculture.

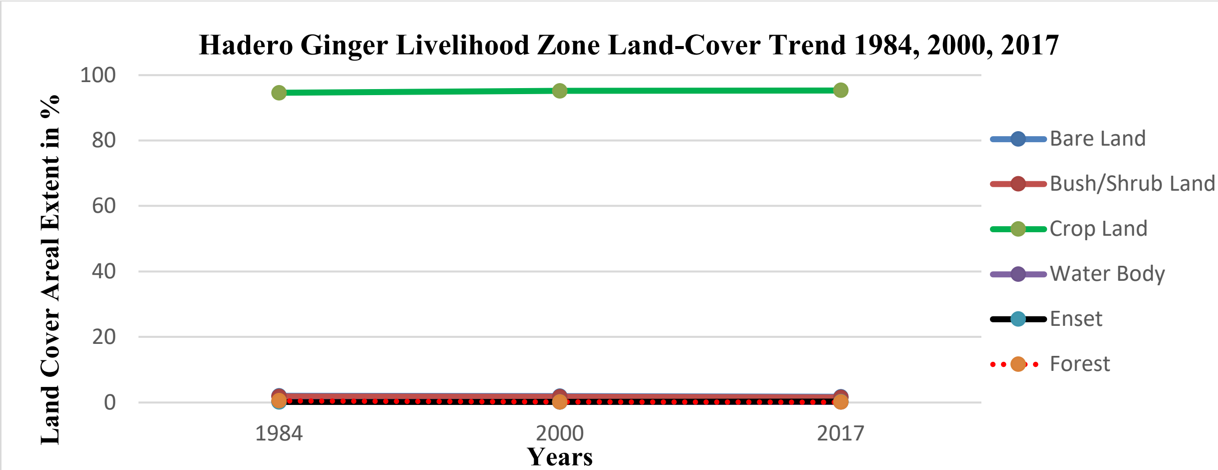

Figure 4: Trends of LULC in Hadero Ginger LZ, **Source:** Ethiopian Geospatial Information Agency

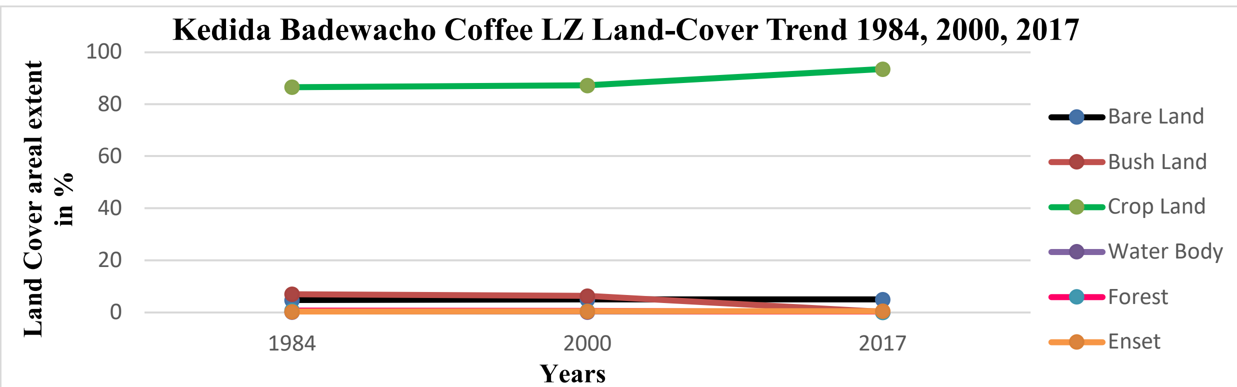

Figure 5: Trends of LULC in Kedida Badewacho Coffee LZ, **Source:** Ethiopian Geospatial Information Agency

Agro-ecologically, Ginger and Coffee LZs are located in mid-land altitude, ranging from 1650-2300masl, which makes it conducive for having moderate temperature relatively suited for settlement. On the other hand, Pepper LZ, Maize LZ and Cereal and Enset LZs (see tables 5.2, 5.5. and 5.4) have registered 30.33% (748 ha), 30.01% (916 ha), and 22.59% (452.5 ha), increase in crop land size in 33 (1984-2017) years, respectively. The highest size, 916 ha of crop land has been added in Maize LZ from 1984 to 2017, indicating that much of the land is deforested (see figure 5.5). Specifically, the change of cropland added from 1984 to 2000 (535 ha, 17.53%) is higher than the change of cropland added from 2001 to 2017 (381 ha, 12.48%), indicating that about 5% (154 ha) of increase of crop land is registered from 2001 to 2017.

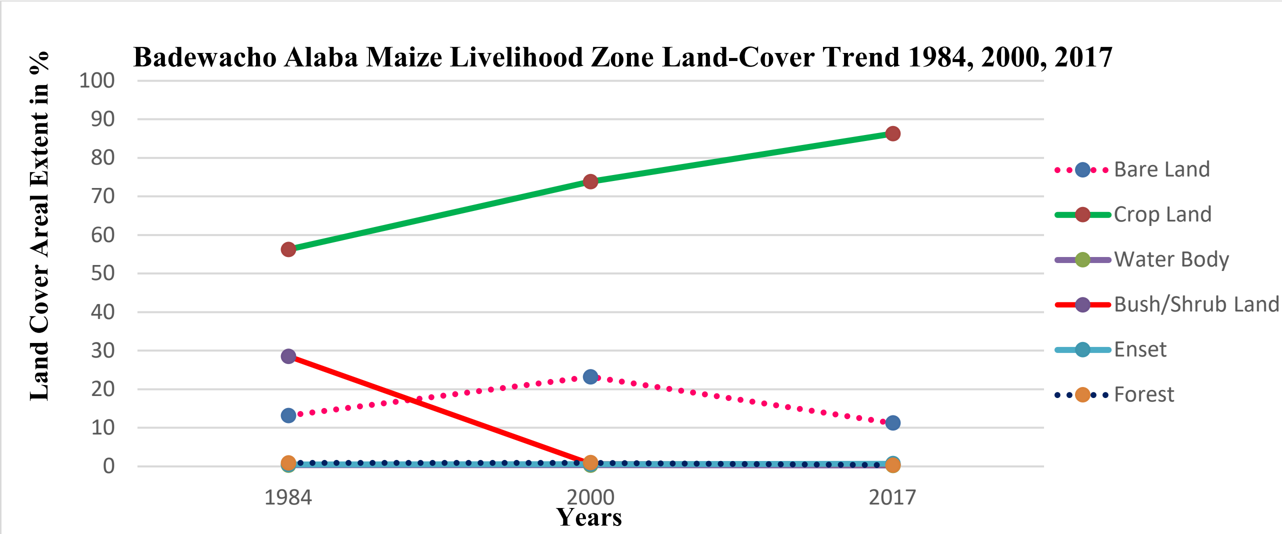

Figure 6: Trends of LULC in Badewacho Alaba Maize LZ, **Source:** Ethiopian Geospatial Information Agency

3.3 Land Use/Land Cover Change in Forestland

The other LULC change influencing the trend in all livelihood zones is forest land. It is known that forests are a source of vital ecosystem services which provide people with food, water, fuel wood and regulatory services such as climate and flood regulation. A study published on drivers of deforestation and forest degradation in Ethiopia conducted by MEFCC, (2018) indicated to be driven mainly by free livestock grazing, fodder use and fuelwood collection/charcoal production in all regions followed by farmland expansion, land fires and construction wood harvesting. The underlying causes of deforestation and degradation based on framework analysis were identified to be population growth, unsecure land tenure and poor law enforcement. Every year, between 80,000 and 200,000 ha of forest are estimated to have been cleared from the highlands of Ethiopia (EPA, 1997). As a result, vital ecological services by vegetation cover, such as control of run-off and soil erosion, replenishment of ground water and climate change regulation are disrupted and gave away to a drought flood cycle phenomenon.

The vegetation coverage of the study area, other than crop varieties, are very scarce in distribution and include natural forest remnants (especially in Pepper and Maize LZs) and human planted tree species such as *Eucalyptus spp*., *Juniperus procera* (yeabesha tid), *Juniperus spp.*(yeferenj tid), *Gravilia robusta, Ficus sur* (Shola), *Ficus basta* (Warka), *Acacia spp*, *Milletia ferruginea, Susbania spp*, *Aningeria baphia*, *Podocarpus gracilus*, *Hyperthenia flipendula* (in grassland), *Papyrus typha* (in swampy areas), etc, and the endangered Ethiopian tree species of *Cordial Africana, Olea africana* (woyra) and *Crotaon macrostachys* (Bisana) in lesser extents (Kembata Tembaro Zonal Report, 2016).

The result revealed that there is a general trend of decreasing forest land area in Cereal and Enset LZ: 5.24% (105 ha) in 1984; 1.55% (31 ha) in 2000; and 1.10% (22 ha) in 2017; Ginger LZ: 0.57% (19 ha) in 1984; 0.21% (7 ha) in 2000; and 0.18% (6 ha) in 2017; and Coffee LZ: 0.75% (22 ha) in 1984; 0.51% (15 ha) in 2000; and 0.17% (5 ha) in 2017. This implies that in more densely settled LZs (Agro-ecologically Midland and Highland), the forest coverage does not show any improvement; rather a trend of decreasing in size. The decrease in farm size due to population increase has also contributed to deforestation of vital trees, which are important for soil conservation and fertility maintenance. The trend of continuously decreasing of forestland has an implication in that the midland and highland livelihood zones are known for relatively having a topography of hilly and mountainous, which contributes for soil erosion. In the meantime, there was a significant increase in cropland size, indicating that there was a conversion of forestland into cropland.

On the other hand, the trend of forestland in both Pepper and Maize LZs show an apparent increase during 1984 to 2000, more specifically in Pepper LZ, an increase from 0.41% (10 ha) in 1984 to 1.62% (40 ha) in 2000 is the highest size. Whereas from 2001 to 2017, there was a significant decrease in size, implying that there was a conversion of forestland into cropland. Agro-ecologically, the two livelihood zones are situated in between lowland and midland, attitudinally ranging in between 1400-1800 masl. Topographically, plain land scape relatively dominates the two LZs.

With regards to the perception of farmers towards the trend of indigenous tree species in all LZs, the result revealed that the majority of farmers, more than 75%, perceive that indigenous trees coverage are decreasing in their farm land. The highest percentage (98.02) of Maize LZ farmers perceives that indigenous trees are decreasing in size; whereas, 18.18% of farmers in Pepper LZ perceive that indigenous trees are increasing in their farm land. This result has an implication in that the farm land size is relatively higher in Pepper LZ as compared with other LZs and there are remains of natural vegetation in some kebeles of Pepper LZ.

Table 7: Perception for Trends of Indigenous Tree Species across LZs

Trends of Indigenous Tree Species	**Trends of Indigenous Tree Species by LZ**									
	Cereal and Enset		Coffee		Ginger		Maize		Pepper	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Increasing	5	3.73	13	12.87	5	5.95	-	-	16	18.18
Decreasing	128	95.52	81	80.20	73	86.90	99	98.02	66	75.00
Remain the same	1	0.75	7	6.93	6	7.14	2	1.98	6	6.82
Total	**134**	**100.00**	**101**	**100.00**	**84**	**100.00**	**101**	**100.00**	**88**	**100.00**

Source: Household Survey

Whereas, in Coffee, Ginger, Maize and Cereal and Enset LZs, the natural vegetation has already been destroyed and the grazing lands, specifically in Ginger and Coffee LZs have also been pushed to the front yards in the homesteads. The Federal Environmental Protection Authority, EPA (2003) reported that the environmental situation of Kambata Tembaro (KT) zone is marked by problems of soil erosion, deforestation, and energy and water scarcity. The magnitude and degree of seriousness of these problems vary from woreda to woreda depending on a number of factors.

In an interview held with an elderly farmer from Ginger LZ stated that**:**

> *"…even though we like to grow indigenous trees in our surrounding and home steads, in my estimation starting from the last twenty years onwards, most farmers in our surroundings do not prefer to plant indigenous trees because of mainly three reasons. The first reason is the longer time it takes to reach at their mature stage. As compared with eucalyptus trees, indigenous trees take in general longer time to reach at their mature stage for use. Comparatively, eucalyptus trees take shorter time period to mature. Even though eucalyptus trees may not reach at their mature stage, it is possible to sell them even at their early and middle growth stage as a source of cash for meeting financial needs. On the contrary, it is difficult to use indigenous trees as a source of money especially at their earlier stages, which makes them less preferred to grow. The second reason, …in my view, space*

wise, eucalyptus trees most of the time tend to grow straight, are suited to construction and save much space allowing to grow more number of trees relatively within small area of land, whereas, indigenous trees comparatively take much wider space to grow through their branches, which consume our short land area to be covered by the trees, creating land shortage… The third reason is in relation with social status…. in that farmers who do not have eucalyptus trees are given low social status,.hence, timewise, space wise, economically and socially planting eucalyptus trees is much better than planting indigenous trees…"

On the other hand, eucalyptus, which is the most preferred tree by the farmers, is mostly planted in front of the grazing land, along the roads, rivers and even sometimes at farm borders. The eucalyptus trees are known for their disadvantages of reducing the productivity of the farmland, but still planted because of the above reasons. According to khawas and Shehata, (2005); Forrester et.al., (2006) and Jiregna Gindaba (2006), eucalyptus has detrimental effects on soil productivity. Also studies conducted in the highlands of Ethiopia have shown reduction in crop growth and yield when agricultural crops are grown close to eucalypts (Jagger and Pender, 2003; Jiregna Gindaba, 2003; Selamyihun Kidanu et.al., 2004,2005; Tilashwork Chanie et.al., 2013; as cited in Alemu, et.al., 2016). Some of the hills and mountains were devoid of trees. Farmers say, the eucalyptus trees are drying their soil, but there is no effort to separate the fields planted to this tree and the food crops farm.

In Focus Group Discussion (FGD) conducted with elderly farmers in Cereal and Enset LZ, farmers perceive that indigenous trees attract rain from the atmosphere, whereas eucalyptus trees do not attract rain from the atmosphere. Instead, eucalyptus trees absorb water from the soil and make the land more drier using its long roots scattered in the ground and make the land unproductive. Focus Group Discussion participants further discussed that, water wells which were used as a source of potable water about fifteen years ago, by now are dried and do not serve for drinking. This situation is observed in the farm with the increasingly planting of eucalyptus trees, absorbing the water through their roots and making the land more dry. In addition, farmers mentioned that rivers which used to flow water throughout the year about ten years ago, are now getting drying from year to year, especially during the peak dry seasons (February and March), creating water stress for animals.

As they recall from their child stage, most of the area of their surrounding was covered with natural vegetation. The name of the kebele itself, 'Hobicheka', tells us that it was covered with natural forest and wild animals like lions used to live in the natural forest. Through time, the natural forests are cleared into farm lands and the rest replaced by eucalyptus trees. Farmers say that traditionally, there is a possibility of using eucalyptus trees and the farmland harmoniously. This can be done by digging a ditch (30 cm wide and 50 cm deep) and 50 cm away from the tree towards the farmland. The practice aims at preventing the roots from growing towards the cultivable land, but others argue that this hardly protects the cropland from being unproductive, because the leaves are the most damaging.

3.4 Land Use/Land Cover Change in Enset Land

The 'false banana' tree (*Ensete ventricosum*) whose corm and stem provide a starch-based food is a common perennial crop planted around the homestead, and is used for both human food and livestock feed. It grows best at altitudes above 1600 meters above sea level, not because it cannot withstand heat, but because it needs adequate soil moisture. It can survive seasonal rainfall shortages, but succumbs to prolonged droughts. Enset takes up to seven years to attain its full maturity, however, the pseudo stem and the corm can be processed after three years. The seedlings (suckers obtained from the corm of a three to four years old enset plant) are transplanted two to four times before transferring it to permanent field.

From the result, it is possible to state that except from Pepper LZ, there is a general trend of increasingly allocating more size of land to grow Enset. Specifically, the increase of allotting more size of land to grow the crop has the highest percentage in Enset and Cereal LZ, from 4.69% (94 ha) in 1984 to 6.39% (128 ha) in 2017. The change of growth from 1984 to 2000 is 1.2% (24 ha) more than twice higher than the change of growth from 2000 to 2017, which is 0.5% (10 ha). The result further revealed that in Pepper LZ (see Table 5.2), the land size of the crop has reduced from 1.22% (30 ha) in 1984 to 0.69% (17 ha), registering about 0.53% (13 ha) difference in 2017. Enset plant is a perennial self-mulching crop and natural/live mulch; it has an important effect on soil fertility maintenance. That is to say, the old leaves which fall of it are constantly mulched under it and also help to conserve moisture and contribute to the soil fertility in the homestead fields. This shows that the crop is in the process of decreasing in size and the land is exposed for soil erosion. It is known that more coverage of perennial crops help reduce in soil erosion as compared with those areas with less coverage.

According to Schmidt and Thomas (2018), elevation and terrain are important factors in cropland area conversion. In general, higher elevations are associated with greater area converted to cropland. The trend of continuously decreasing the size of Enset land size in Pepper LZ coincides with what was outlined by elderly participants in FGDs held at Pepper LZ. Accordingly, the crop was used to grow about thirty years ago, while they were at childhood stage in their homesteads, which by now are unable to grow in their surroundings, mainly attributed to increase of extreme temperature. On the other hand, in Maize LZ (see Table 5.5), the change of land size of Enset crop from 0.49% (15 ha) in 1984 to 0.72% (22 ha) in 2017 shows a very slight increase in size.

3.5 Land Use/Land Cover Change in Water Body

Ethiopia’s water resources depend on rainfall and are characterized by high spatial and temporal variability (Negash, 2012). As have been seen in the next section, a changing temperatures and rainfall variability will affect both the supply and demand side of the agricultural water. In some areas of the country, annual rainfall is projected to decrease while increases are expected in others (McSweeney, et.al., 2010). The decrease in rainfall amount will cause decrease in ground water recharge, flow of streams and rivers thereby resulting in a declining amount of water available for irrigation (Ethiopian Panel on Climate Change, 2015). In general discrepancy of the rainy season, which emanates from climate variability, results in water shortage. Consequently, the ecosystem, which is the source of rain and water resource, will be affected. Rainwater scarcity would affect the aquatic life by deteriorating the quality and quantity of a water body. Climate change has direct effect on the available water bodies, either increasing in area coverage or decreasing the area coverage based on the trends of mainly rainfall and temperature.

The result revealed that the study area has passed through different water body changes from 1984 to 2017 (33) years. Accordingly, Pepper LZ coverage has remained the same, registering 0.05% from 1984 to 2017; in Coffee LZ, there is an increasing trend from 3 ha (0.10%) in 1984 to 4 ha (0.14%) in 2000; and 5 ha (0.17%) in 2017 with constantly increasing 1 ha in every 15 years. The increase in size is mainly because of the irrigation project constructed by NGO in the last fifteen years. On the other hand, a decreasing trend is registered in Ginger, Maize and Cereal and Enset LZs, registering 9 ha (0.27%) in 1984 to 7 ha (0.21%) in 2000; with 2 ha difference in ten years, and 6ha (0.18%) in 2017, indicating that climate change has a negative effect in reducing the water cover of the three LZs.

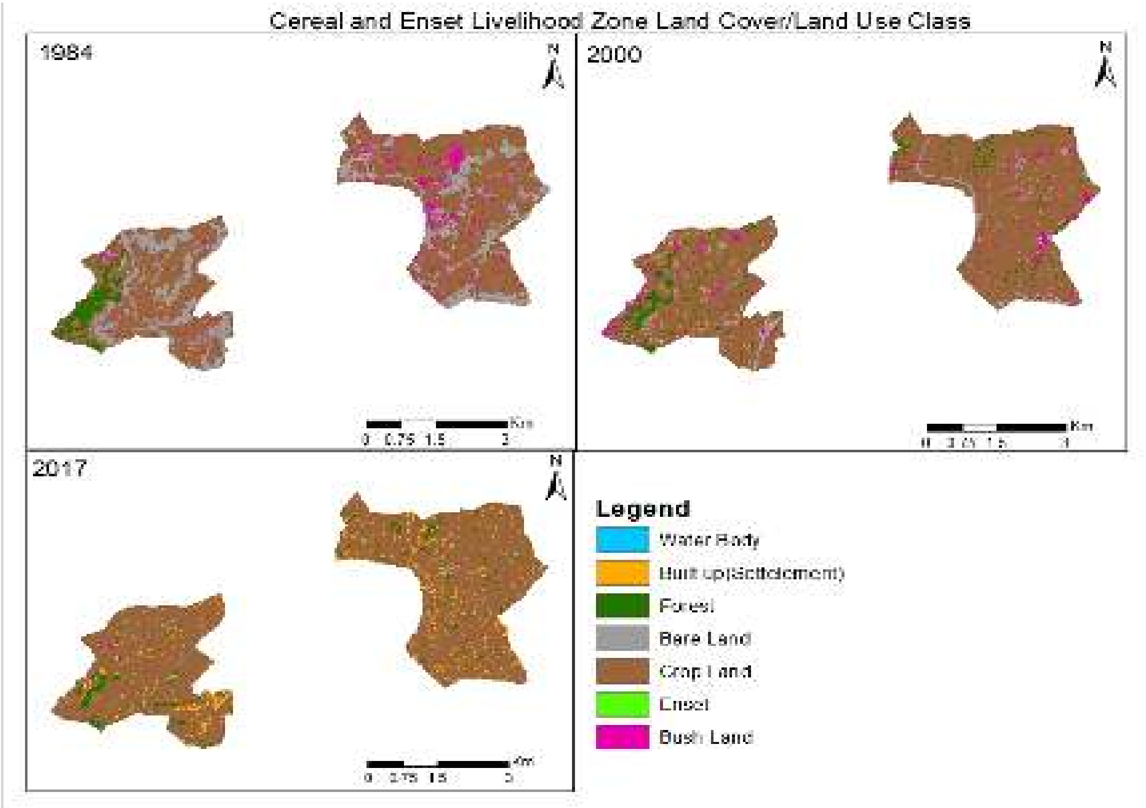

Figure 7: Trends of LULC Classes in Cereal and Enset LZ; **Source:** Ethiopian Geospatial Information Agency

3.6 Effect of Climate Change on Land Suitability

Climate change is projected to lower the productivity of major crops as compared to a baseline scenario without climate change in all regions, and this effect will cause prices to increase and will, to varying degrees (and with varying degrees of uncertainty), trigger more intensive management practices, area expansion, changes in international trade and reduced consumption across regions (Nelson et al., 2014; IPCC, 2014a, p. 632). Hence, to improve production and productivity in the face of climate change, appropriate land use planning is critical to systematically allocate land to the best uses considering the biophysical potentials, socio-cultural and economic factors. The impacts of climate change on change of crop types and land suitability in the study area is discussed as follows.

3.7 Impacts on Change of Crop Types

With the trend of climate change, it is necessary to understand the impact of climate change on crop types at local scales when considering for planning and designing appropriate adaptation strategies. In this regard, Perveen et.al., (2007) discussed that crop-land suitability analysis is a pre-requisite to achieve optimum utilization of the available land resources for sustainable agricultural production. Previous assessments of climate change impacts on crop production in Ethiopia were either at the national (Deressa and Hassan, 2009; Admassu, 2004) or larger scale such as the East African regional levels (Bryan et.al., 2009; Tornton et.al., 2009). There are only a few studies undertaken at subnational levels in Ethiopia (e.g., Alemayehu and Bewket, 2016; Muluneh et.al., 2015). With the recent trend of climate variability and change, the existing indigenous crop types in most areas is becoming unsuitable, demanding to adjust with the changed climate. It is known that moisture conditions affect the development and character of soils. Without precipitation and consequently soil water and the chemicals dissolved therein, plant life is impossible. The absence of plant life diminishes the organic matter content and thereby the fertility of a soil. As precipitation is the source of soil water, the amounts of precipitation received by a soil affects the rate and degree of leaching, elevation and illuviation that occur, and thereby the rate of soil formation and horizon development. Mahoo, et.al., (2013) indicated that the main effects of climate change on crop production will be changes in regular crop planting times, length of growing season, and shifts in suitable crop types or cultivars.

One of the agricultural seasons in the study area, severely disrupted in recent years is Belg season. In general, the *Belg* season suffers from greater rainfall variability than the Kiremt season and most *Belg* season growing areas (eastern, north eastern and southern part of the country) are suffering from unreliable onset of the season and frequent crop failures. The late arrival and general un-reliability of the belg rains, which occur between February and May, implies significant impacts to food security (USAID, 2015). The trend analysis result indicated that moisture is undertaken a decreasing trend for the last 33 years (1984-2017), and becoming more erratic from year to year.

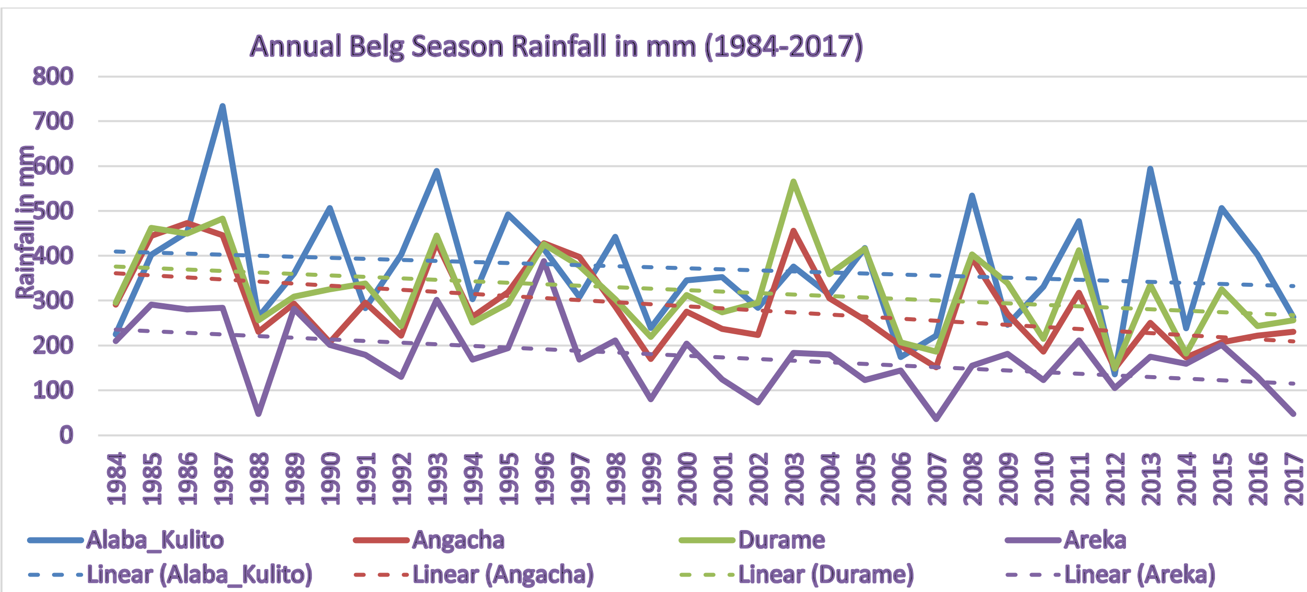

Figure 8: Historical Mean Annual Belg Season Total Rainfall; **Source:** Computed based on raw data from the National Metrological Agency (NMA) of Ethiopia**.**

Looking at the precipitation trends in annual and seasonal graphs, there is inter-annual and inter-decadal rainfall variability with various amount of rainfall reduction. The result revealed that there is a general decreasing and erratic trend of Belg season in all stations. The highest annual rainfall reduction is registered at Angacha station, with -4.62 mm of rainfall. The Belg rains are vital for this LZ for the production of crops like barely and potatoes. Such a drastic reduction in the level of rains will be likely to have an effect on the production levels of these two crops. A study conducted by USGS et.al., (2012) indicated that the areas receiving sufficient precipitation during the Belg season in Ethiopia have contracted by 16% since 1990, exposing densely settled populated areas in SNNPR, among other areas, face near-chronic food insecurity (FEWS NET, 2012). The research further indicated that through 2010-

2039, based on an assumed persistence of the observed trends for the Belg rains, rainfall declines range from -150 to -50 mm across the south-central and eastern parts of the country, and will be associated with lower Belg harvests (ibid).

The result further revealed that the yearly reduction of Belg rain at Areka station (Ginger LZ) indicated that there is annual reduction of -3.6527 mm of rain, which directly affects ginger production. Locally named as ***Janjebelu*** in Kembatisa, Hadero Ginger LZ is one of the ginger producing belts in Ethiopia, which attitudinally fall within weyina dega agro-ecology (midland), is reported as very suitable agro-ecology for production of ginger. The crop is sensitive to water stress, frost and salinity. Hence, the reduction of Belg rain and its erratic distribution directly affects the production of the crop, as the traditional season for ginger planting fall in Belg season (usually from late January to March).

Similarly, the decadal Belg season trend shows a reduction of -19.875 mm of rainfall, as the crop prefers humid climate with moist soils that have proper water holding capacity and aeration. With the trend of decreasing -3.6527 mm of annual and -19.875 mm of decadal rainfall, the crop suffers moisture stress during its planting season, leading to decline of production and enhances its exposure for disease (see fig. 9 below).

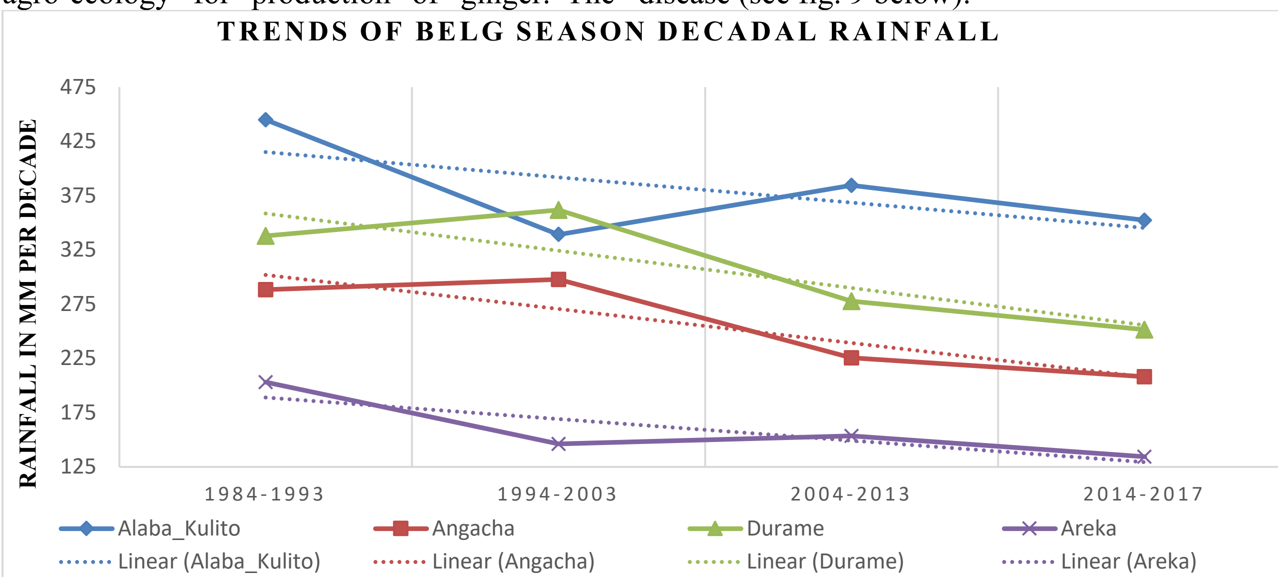

Figure 9: Historical Trends of Decadal Belg Season; **Source:** Computed based on raw data from the National Metrological Agency (NMA) of Ethiopia.

During the FGD held in Ginger LZ, participants underscored that in 2012 and 2014, production of the crop had been devastated almost 90% because of ginger bacterial wilt disease. This is mainly because of the annual and decadal reduction in precipitation, prevailing ideal weather condition for the occurrence of ginger bacterial wilt disease.

Looking the trend in the context of Alaba station (Maize and Pepper LZs), there is a reduction of -2.339 mm and -23.3 mm of annual and decadal rainfall, respectively. Maize and Pepper LZs fall in the altitudinal range of 1400 to 1800 masl, and Belg season plays critical role in both LZs for growing early maturing crops like soya bean, animal forage. Greatest decrease in grain yields of maize is caused by water deficient during the flowering period. Water deficient during the yield formation period may also lead to reduced yield due to a reduction in grain size.

In Pepper LZ, the Belg season helps in the preparation of seedbeds for growing seedlings of pepper crop to plant during kiremt season. According to a study conducted by Regassa et.al., (2010), if Belg rains reduce, central, south and east Ethiopia lose one of their main growing seasons; long-cycle crops (maize, sorghum, millet) will have to be planted later and may not mature; the preparation of seedbeds for kiremt season (June-September) crops will be difficult or impossible; pastures and drinking water places for livestock will lack not be replenished after the dry season.

In the context of Coffee LZ (Durame station), like other stations, there is a reduction trend of both annual and decadal Belg season rainfall, registering about -3.287 mm and -34.255 mm of rainfall, respectively. Variation of rainfall distribution within a season has significant impact on coffee production and lower rainfall will result in shifts in livelihood zones. In general, Belg rains are short in duration, as compared with Meher season, and the annual crops that grow during belg season are mostly used for consumption during the Meher season. In connection with annual and seasonal rainfall trends, analysis of secondary data on annual and seasonal precipitation concentration index (PCI) is undertaken to investigate heterogeneity of monthly and seasonal rainfall using:

$$PCI = \frac{(\sum_{i-1}^{12} Pi^2)}{(\sum_{i-1}^{12} Pi)^2} * 100$$

Where pi is the monthly rainfall in month i. The seasonal scale of Precipitation Concentration Index was calculated using the equation:

$$PCI = \frac{(\sum_{i-1}^{3} Pi^2)}{(\sum_{i-1}^{3} Pi)^2} * 25$$

The main aim of analysis of annual and seasonal Precipitation Concentration Index (PCI) is to characterize spatial and temporal distribution of rainfall. In this regard, analysis of annual and seasonal rainfall concentration index provides good information for suitability analysis of crops. According to Oliver, (1980) classification, annual and seasonal rainfall concentration index is: i. PCI < 10 indicates uniform rainfall distribution (low rainfall concentration), ii. PCI >11 and <15 indicates moderate rainfall concentration; iii. PCI >16 and < 20 indicates irregular distribution, iv. PCI > 20 indicates a strong irregularity (that is, high rainfall concentration).

Table 8: Annual and Seasonal Rainfall Index

Stations	Annual and Seasonal PCI					
	< 10	**< 16**	**>16**	**% of years above 16 PCI**	**Keremt PCI**	**Belg PCI**
Alaba_Kulito	0	29	5	14.7	8-16	8-13
Angacha	0	29	5	14.5	8-14	8.4-15.5
Areka	0	5	29	85.3	8-11.7	8.5-19.5
Durame	0	30	4	11.8	8-13	8.5-18.6

Note: Kiremt and Belg PCI Values indicate the Min. and Max. values.

Source: Computed based on raw data from the National Metrological Agency (NMA) of Ethiopia.

From the table indicated above, the result revealed that there is high variability of annual and seasonal rainfall concentration in all stations. The PCI variability is more pronounced during the Belg season, ranging from 8 (Minimum) to 19.5 (Maximum), with the highest value for Areka station (19.5), indicating that there is irregular distribution of Belg season rainfall distribution. Funk et.al., (2012) indicated that Belg rains are increasingly unpredictable, leading farmers to make risk-averse planting decisions that produce below average yields and loss of income.

However, the Kiremt season PCI magnitudes show significant variability for Alaba, Angacha and Durame stations, indicating that major crops of Barley, Maize, Pepper and Coffee fall under stress of moderate and high rainfall irregularity, leading to creating unsuitable moisture conditions for growth. This result is in coincidence with Wagesho and Yohannes (2016) conducted in Southern Ethiopia, including for rainfall analysis of Durame station. The rainfall concentration index result further revealed that 85% of years with values of PCI >16 in Areka station indicates strong irregularity of annual rainfall distribution, which indicates that suitability for production of Ginger is under a critical condition. Findings from national and regional level rainfall trends analysis in Ethiopia reported both increasing and decreasing trends (Wing et al., 2008; Belay, 2014; Kebede and Adane, 2011; and Rao and Solomon, 2013). However, the trend analysis of annual rainfall showed that rainfall remained more or less constant when averaged over the whole country for 1951 to 2006 (NMA, 2007). Parry et al. (2007) confirmed that regional variations can be much larger, and considerable spatial and temporal variations may exist between climatically different stations.

Variability of rainfall was computed using Standardized Rainfall Anomaly (SRA) method. SAI is used to demonstrate the intensity and frequency of drought and inter-annual variation at various time scales in the study area. SRA indicators allow for estimating different potential impacts of a meteorological drought. Standardized Rainfall Anomaly (SRA) was computed as the difference between the annual total of a particular year and the long term average rainfall records divided by the standard deviation of the long term data. SRA is given as:

$$\text{SRA} = \frac{(X - \mu)}{\delta}$$

Where, SRA is Standardized Rainfall Anomaly; X is the annual rainfall total of a particular year; μ is long term mean annual rainfall over a period of observation; and δ is the standard deviation of annual rainfall over the period of observation. Standardized anomaly index value was categorized according to McKee (1993) classification. The result revealed that negative anomaly index (dry) was observed in all stations.

Table 9: Standardized Rainfall Indices of Belg Season (1984- 2017).

		Percentage and frequency of occurrence (Years)							
		Alaba Kulito		**Angacha**		**Areka**		**Durame**	
Drought Category	**SAI value range**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
2.0+	Extremely wet	3	8.83	1	2.94	1	2.94	1	2.94
1.5 to 1.99	Very wet	0	0	3	8.83	1	2.94	2	5.88
1.0 to 1.49	Moderately wet	3	8.83	4	11.94	4	11.76	1	2.94
-0.99 to 0.99	Near normal	21	67.76	18	52.94	21	67.76	23	67.65
-1.0 to -1.49	Moderately dry	6	17.65	8	23.53	5	14.7	7	20.58
-1.5 to -1.99	Severely dry	1	2.94	0	0	2	5.88	0	0
-2 and less	Extremely dry	0	0	0	0	0	0	0	0

Source: Computed based on raw data from the National Metrological Agency (NMA) of Ethiopia.

This study indicated that standard anomaly values of (-2 or less) categorized as extremely drought condition has not been occurred in all stations during the last 33 years. However, severely dry condition has occurred twice in Areka and once in Alaba Kulito stations, respectively (see figure 5.13 and 5.14 below). The negative anomalies of Alaba station was 20.59% during the period of 1984 to 2017.

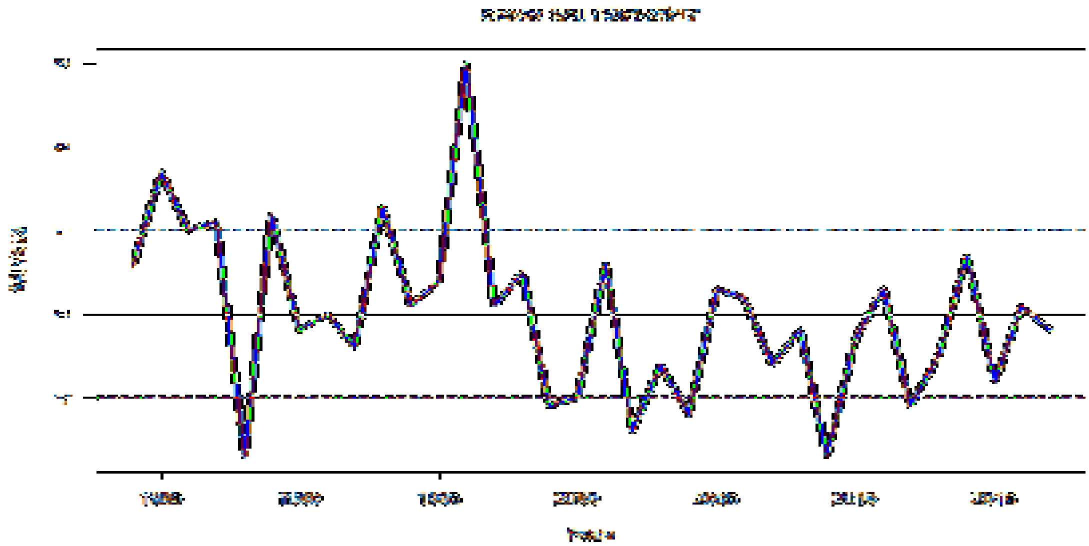

Figure 10: Belg Season Standard Anomaly Index of Areka Station; **Source:** Computed based on raw data from the National Metrological Agency (NMA) of Ethiopia.

This indicates the possibility of the occurrence of crop failure in ginger, maize and pepper production. The highest frequency of moderately dry condition is registered in Durame station indicating that predominantly coffee production is seriously affected by shortage of water; whereas extremely wet condition is registered in Alaba station, which tends to cause production decline in maize and pepper, leading to various diseases.

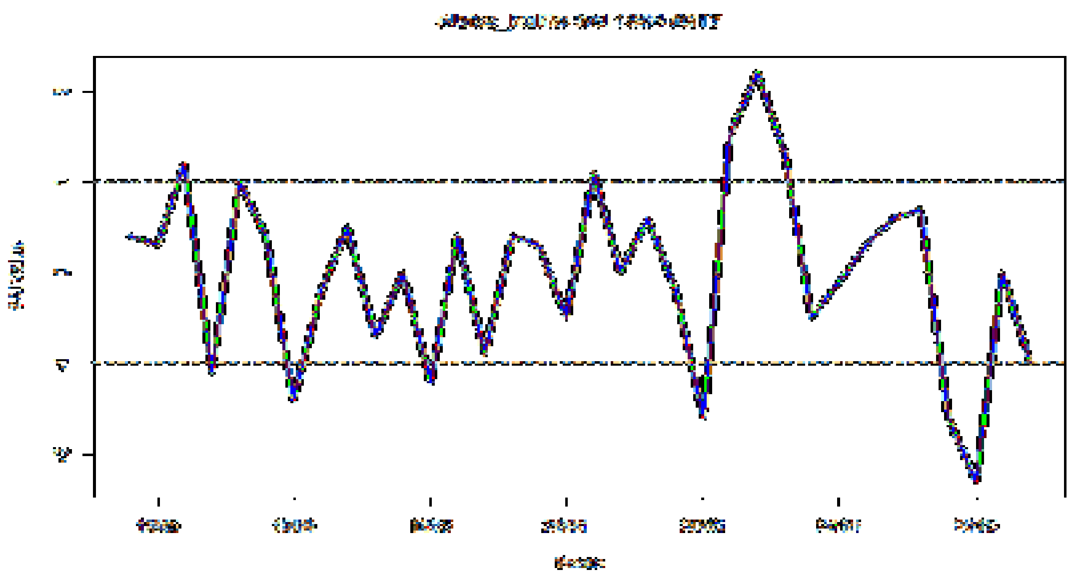

Figure 11: Belg Season Standard Anomaly Index of Alaba Station; **Source:** Computed based on raw data from the National Metrological Agency (NMA) of Ethiopia.

These calls for the need to use technologies which allow regulating moisture requirements of crops as per the relative required level. On the other hand, the highest percent (more than 50%) of stations experienced near normal condition during the last 33 years, indicating that more or less normal weather condition was happening in most years.

3.8 Impacts on Land Suitability for Selected Major Crops

Another evidence of the impact of climate change in the study area is observed through relocation of suitable area of production of some types of crops. Suitability analysis has a particular importance to guide the dissemination of new crops and cultivars released from the research system. Soil types, rainfall, temperature, elevation and other environmental factors have ranges in which a favourable, and out of which unfavourable influence on the development, growth and yield of crops is experienced. The suitability map in this research is a combined result of soil types, rainfall, temperature, slopes, elevation and LULC changes. These data layers were assigned weights to account for their relative influence on crop growth. One of the crops which observed in relocation of suitable area is experienced by coffee. It is known that coffee plants are fragile and often acutely sensitive to temperature changes, particularly those belonging to the Arabica species (*Coffea arabica*), which is the dominant coffee species in Ethiopia and the source of the world's most popular coffee variety. Studies conducted by Ovalle-Rivera, et.al., (2015) and Bunn, et.al., (2014) indicated that climate change impact assessments suggest a significant reduction, up to 50% in the global area suitable for coffee farming by mid-century. This effect has not been examined in coffee climate studies.

Looking the yearly maximum temperature of Belg season trend analysis, there is an increasing trend in all stations, particularly observing the trend in Durame station (which represents Coffee LZ), the temperature has increased from about 26ºC during the early 1984 to about 28°C in 2017.

Mekasha et.al., (2013) indicated that under warming scenarios, plant species are forced to relocate growing areas to remain within optimal thermal zone.

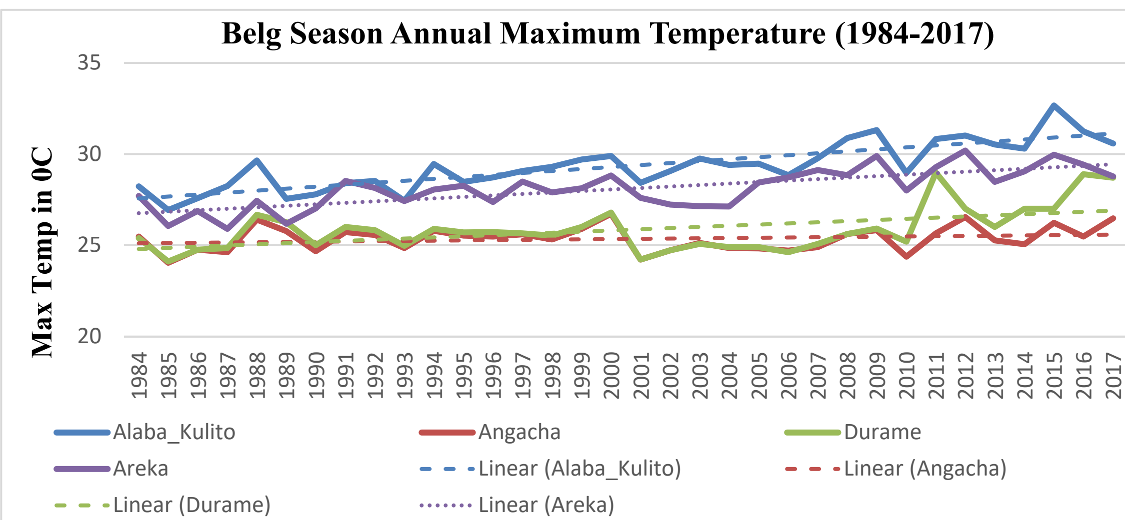

Figure 12: Belg Season Annual Maximum Temperature; **Source:** Computed based on raw data from the National Metrological Agency (NMA) of Ethiopia.

More specifically looking the decadal trend, from 1994 to 2017, there is an increasing trend of maximum temperature exceeding 25 ºC from 1994 to more than 27°C in 2017, indicating an increasing trend of 0.69 ºC decadal temperature. There is on average 0.0636 °C annual Belg season increase in temperature; looking the trend specifically, from 2007 onwards (last ten years), there is fluctuations of temperature in between 25°C and 29°C.

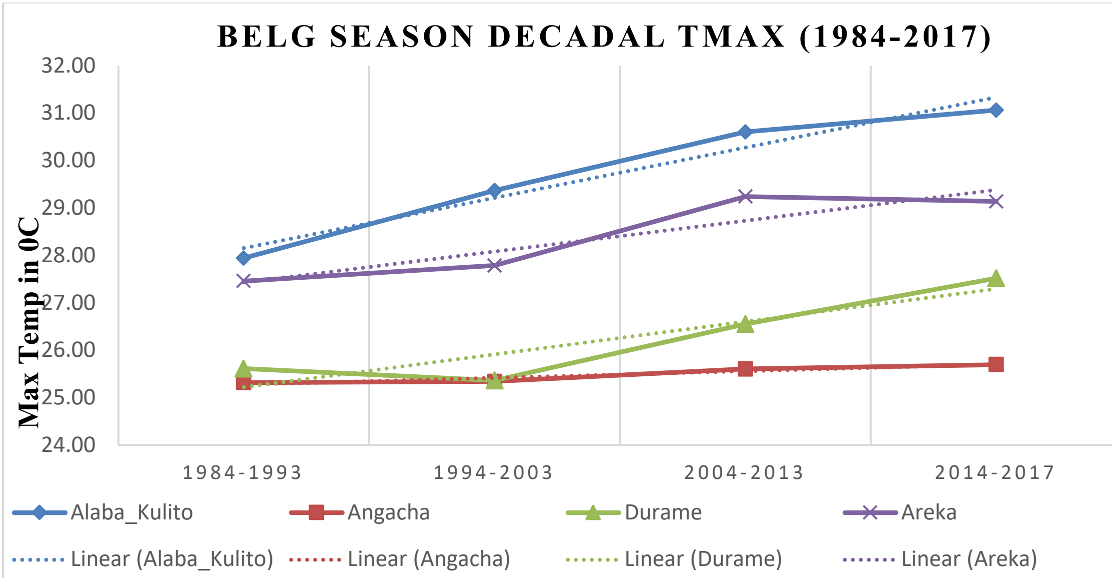

Figure 13: Belg Season Decadal Maximum Temperature; **Source:** Computed based on raw data from the National Metrological Agency (NMA) of Ethiopia.

Coffee will become increasingly stressed as the air temperature increases and soil moisture decreases (due to lack of rainfall), and vice versa. The best time to observe and assess stress in coffee plants is towards, or at the end of, the dry season in February and March (belg season), although observations throughout the year are also worthwhile and sometimes unexpected. Belg season is the main period for coffee flowering, fruit initiation and early development. The Coffee Research Institute says Arabica coffee needs year-round temperatures of between 15°C and 24°C in order to maintain high production levels and good quality.

According to ECFF (2017), climate change will negatively impact much of the current coffee farming landscape of Ethiopia. However, substantial areas which were previously unsuitable for coffee will become suitable as the century progresses. This is due to the upslope shift of coffee growing suitability (the niche) as higher altitude areas (e.g. above 2000 m) improve and lower altitude areas worsen, as the climate changes.

Some of Ethiopia's coffee growing areas are already poorly suited for growing coffee, and it is mainly these areas that have been impacted by climate change and will continue to be so in the future. It has been suggested that higher temperatures adversely affect yields in current coffee areas, especially in the south, because coffee plants require temperatures below 22°C (ibid).

According to FGD participants in Coffee LZ, the occurrence of high heat wave especially during the flowering time of coffee is severely affecting the crop, spoiling the coffee berry and leading to ***Coffee Berry*** disease. The participants' perception of the occurrence of high temperature and variation of extremity during its flowering period strictly coincides with the trend analysis of annual average maximum temperature of the study area from 1984-2017, as sourced from National Meteorological Agency (see Figure 5.13). And the repeatedly occurrence of the disease prevention is difficult to manage with the available local knowledge and skills, seriously affecting the farmers' livelihood system. According to Imbach et.al., (2017), coffee production will likely be affected by climate change in two ways: directly, through the effects of changes in temperature, rainfall, or extreme events on coffee production, and indirectly, through changes in pollination services. Hence, assessing the annual maximum and minimum temperature trend offers insights on the level of stress the perennial flowering crop system suffers from climate variability and extremes.

Climate change will continue to impact and alter coffee growing areas in Ethiopia over the coming decades as temperatures are expected to increase in all seasons with on average 1°C by 2030, 2°C by 2050, and 3°C by 2080 (compared to 1975) (Eshetu et.al., 2014; Aragie, 2013). Most models indicate substantial increases in the frequency of hot days and nights, with up to 93% of days and 99% of nights considered 'hot' in the July-September season by the 2090s, compared to 10% of days and nights in the same season in the 1960s (McSweeney, et.al., 2010). If recent warming trends continue, most of Ethiopia will experience more than a 1.0° Celsius (°C) increase in air temperature, with the warming tendency projected to be greatest in the south-central part of the country. This warming will intensify the impacts of droughts, and could particularly reduce the amount of productive crop land for coffee, since coffee plants typically prefer temperatures cooler than 22°C (FEWS NET, 2012). Higher temperatures will increase evapo-transpiration so that there will be increased loss of water, exacerbating drought phenomenon by offsetting advantages of increasing rainfall in some areas (Ethiopian Panel on Climate Change, 2015).

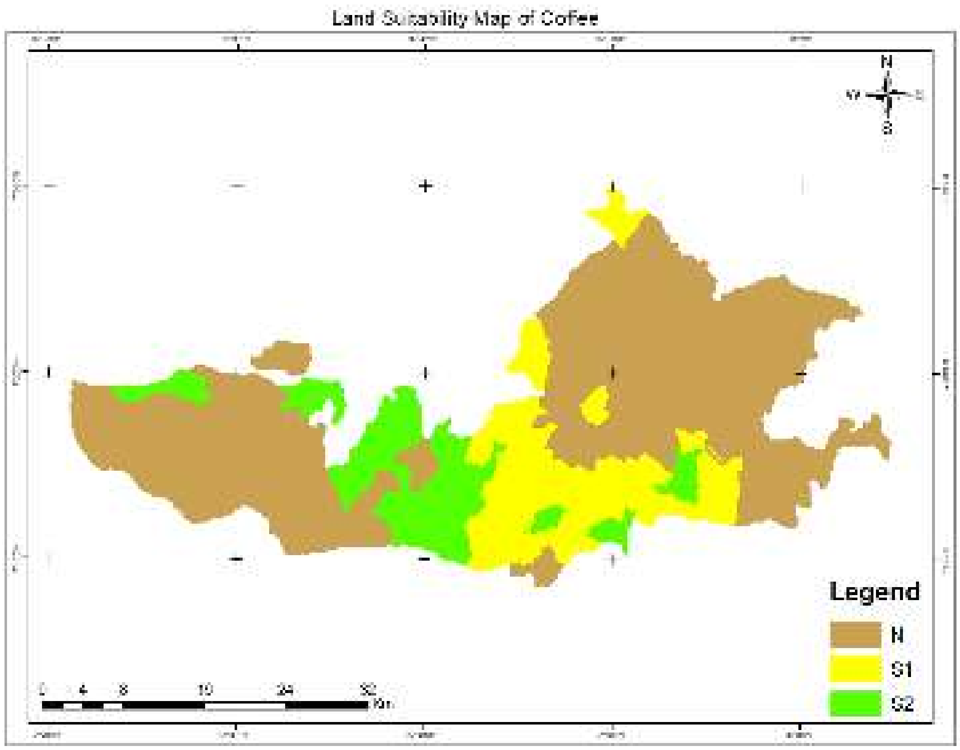

Figure 14: Land Suitability map of Coffee; **Source:** Based on GIS and FAO data

In addition to Coffee, FGD participants in Coffee LZ discussed that root crops like taro and sweet potato which are suited to grow in the LZ are also reducing in their productivity due to increase in temperature.

Impacts of climate change were clearly visible in allocating farm land for growing various crops. For instance, in Cereal and Enset LZ, specifically in Hobicheka and Doreba kebeles, there is an adoption of new crop types which formerly were unable to grow, like coffee, taro, sweet potato, and to some extent ginger in few areas that border Ginger and Cereal and Enset LZs. This leads to get the knowledge and skill of managing the process of change from growing annual crops (like wheat and barley) to perennial crops, like coffee. This change of cropping pattern is also observed with allocating more size of crop land for new crop types. This is reflected in Cereal and Enset LZ, where formerly production of coffee was impossible, but in recent years, more size of crop land is being allotted to grow the crop.

Accordingly, the trend analysis shows that the Belg season maximum temperature is increasing in all stations, indicating that temperature change sensitive crops tend to decline their productivity. The highest rate of change is registered in Halaba Kulito station, from its maximum temperature of about 28 ºC in 1984, reached about 33 ºC in the recent drought year of 2015/16, and 31 ºC in 2017. Evangelista et.al., (2013); cited in Ethiopian Panel on Climate Change, (2015) indicated that by 2020, the major cereal crops of Ethiopia such as maize, tef, sorghum and barley will loss over 14, 11, 7 and 31% of their current suitable area of production, respectively. For maize, tef and barely this will be expected to increase to over 18, 11 and 37% by 2050, respectively.

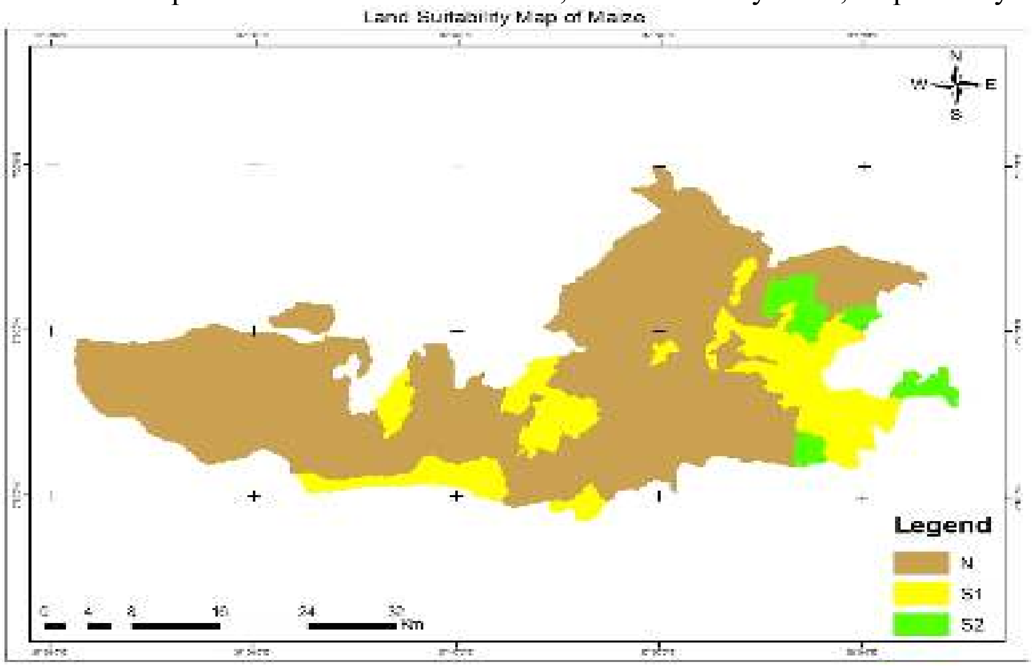

Figure 15: Land Suitability map of Maize; Source: Based on GIS and FAO data

This indicates that C4 species (maize, sorghum, millet and tef), (widely grown in both Maize and Pepper LZs), which are originated in warm tropical environments, will reach near to their upper limit of maximum temperature tolerance and a small increase in temperature over the present maxima will displace them from their current adaptation area.

Mumo et.al., (2018) discussed that maize plant is highly sensitive to any slight increase in temperature. Apart from C4 crops, C3 species, which area adapted to cool temperature, will be most affected by projected climate change because of loss of suitable area as a result of conversion of current cooler environments to warmer conditions (Tesfaye et.al., 2015a). If heat stress occurs during flowering and grain filling stages, it reduces the quantity and quality of the yield by shortening the ripening period (Bita and Gerats, 2013). In most cases, heat stress is usually accompanied by water stress which leads to dehydration of the plant tissues leading to overheating, and these combined effects are devastating to the crop as compared to the individual occurrence (Porter and Semenov, 2005). FGD participants conducted in

Maize LZ stressed that all those seed stocks that they use traditionally for sowing maize crop are almost incompatible with the existing changed climate, which created stress to the extent of threatening their livelihoods, leaving them economically in secured.

It is known that climate is a major factor in soil variation. Temperature affects the activity of soil microorganisms, the rate of chemical reactions that take place in soil, and the nature of vegetation that develops in a particular area. With the extreme variation in temperature from year to year, the process of soil formation occurs with various in degrees in different LZs, causing disruption in soil fertility, causing crop disease and eventually causing unsuitable land for crop growth, though the impact varies in different LZs.

Adverse impacts of climate change were also observed in changing the suitability for pepper crop production in the study area. In FGD held in Pepper LZ with elderly farmers who lived in the area for more than thirty years mentioned that before fifteen years ago, the land was highly suitable for the production of Pepper. But through time, with the continuous change of climate, it has reduced its productivity, leading to repeated crop failure in recent years. Negative effects of increasing temperature and rainfall variability on pepper crop has been repeatedly reported, and it has been also indicated that there is a climate-related expansion of crop diseases that affect the crop (Kembata Tembaro Zone, 2016).

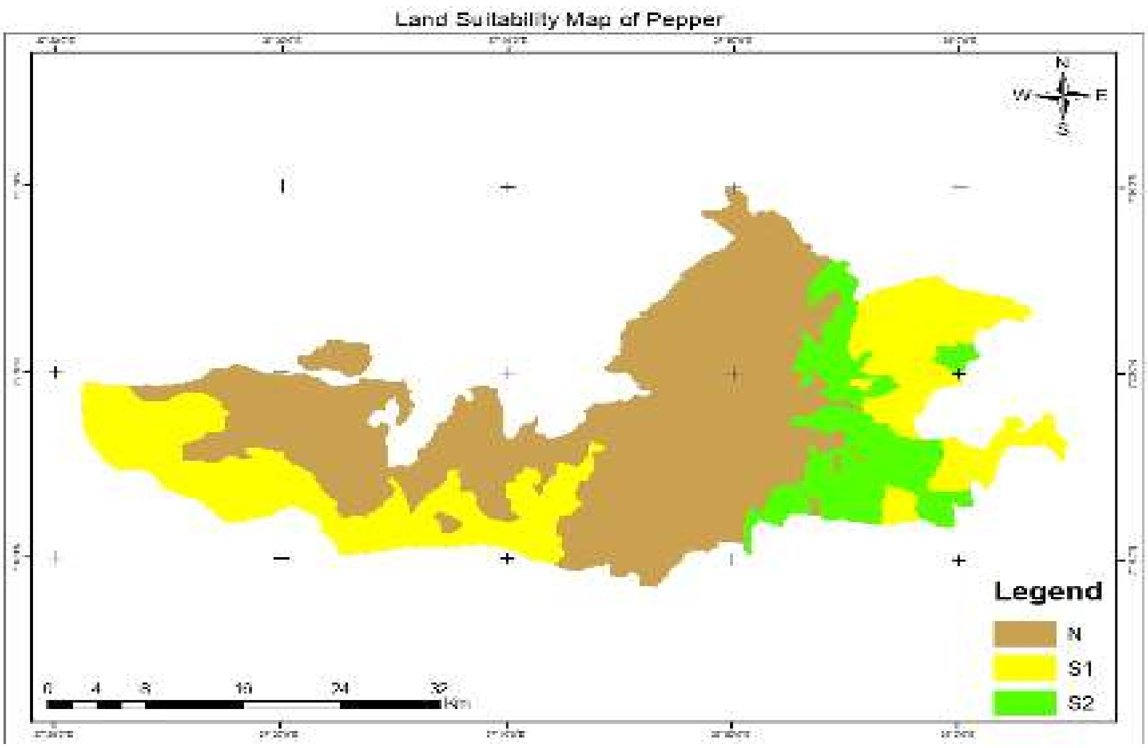

Figure 16: Land Suitability map of Pepper, **Source:** Based on GIS and FAO data

As shown in the map above, land suitability of pepper crop is moving from its widely grown areas, making it moderately suitable to areas formerly used to grow highland crops like barley and wheat being highly suitable, and ginger crop land being moderately suitable, indicating that mainly the temperature and rainfall, in addition to soil type and slope have contributed for the change.

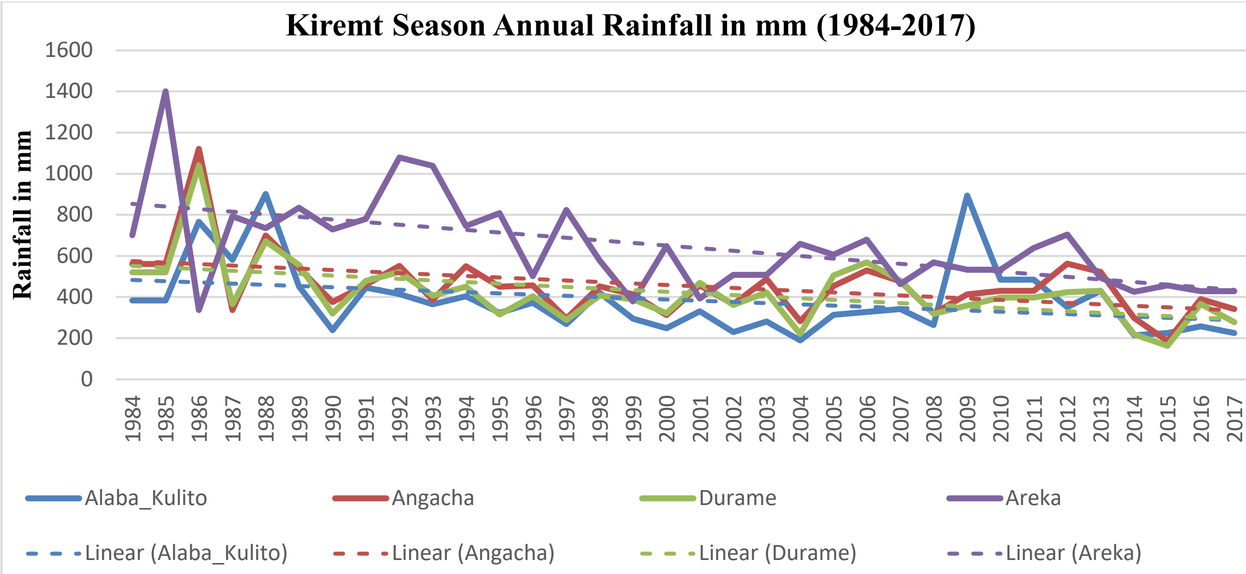

Figure 17: Kiremt Season Annual Rainfall, **Source:** Computed based on raw data from the National Metrological Agency (NMA) of Ethiopia.

Looking at both annual and decadal rainfall distribution for Areka station, the result indicates annual extreme variability in distribution and a decreasing trend. The result further indicates that there is on average -12.695 mm and -106.48 mm rainfall reduction in both annual and decadal distribution, creating difficult condition for ginger production as the annual rainfall distribution is getting less than 600 mm, especially from 2004 to 2017.

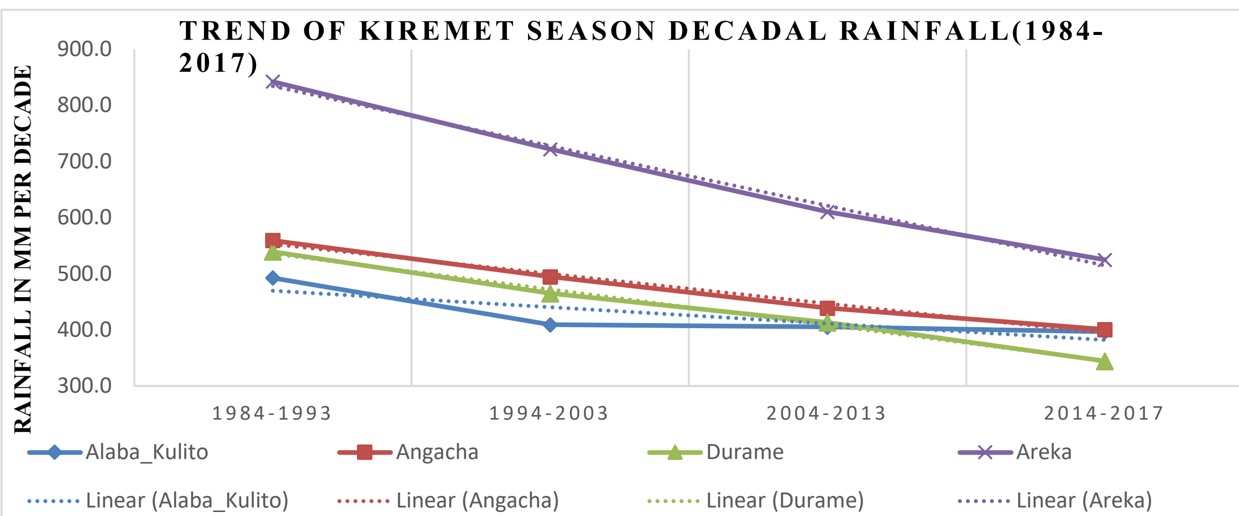

Figure 18: Kiremt Season Decadal Rainfall, **Source:** Computed based on raw data from the National Metrological Agency (NMA) of Ethiopia.

According to Jansen, (1981), in Ethiopia, ginger needs a rainfall often less than 1500 mm per year, indicating that the last thirteen years, production of ginger has been affected by the changing climate, creating suitable conditions for the occurrence of ginger wilt disease.

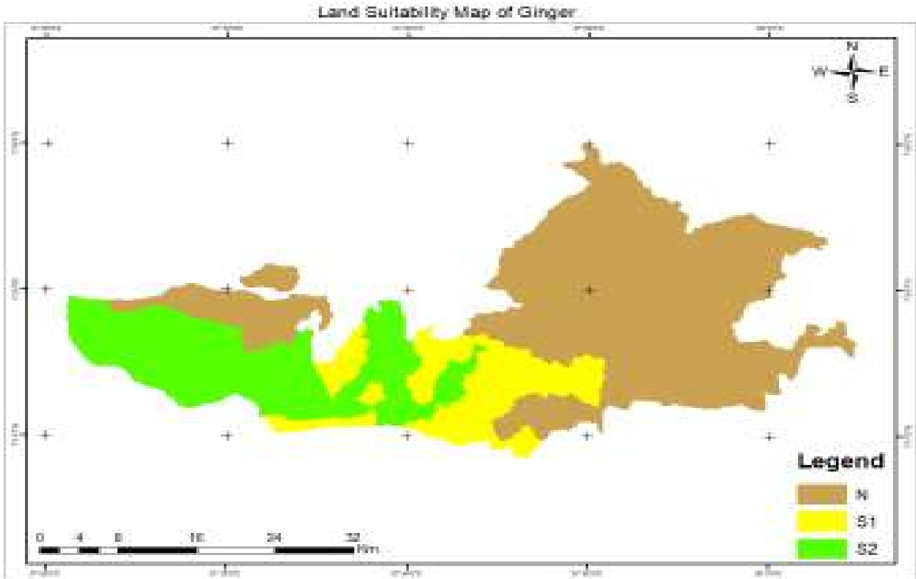

Figure 19: Land Suitability map of Ginger, **Source:** Based on GIS and FAO data

As a result, farmers are diversifying their cropping pattern to tropical fruits, like banana, mango and avocado. Barnabás et.al., (2008) argue that precipitation variability leads to water stress which shortens crop life by reducing leaf area as the stomata close to minimize water loss and increases pollen sterility hence poor/low-quality yields. Overall, rainfall reduction trend and poor distribution were the problems that happened during the 1984 to 2017 kiremt seasons in all LZs.

Looking the decadal trend of maximum temperature for kiremt season, there is a decreasing trend of maximum temperature for Areka, Durame and Angacha stations for the first decade (1984 to 1994), except results of Alaba station, which shows an increasing trend for the first two decades (1984 to 2004), and nearly constant trend for the last decade (2005-2017). An increasing trend of maximum temperature indicates that crops that mature during kiremt season are highly expose for gradual increase in temperature. This leads for decline in productivity and spread of crop disease, depending on the nature of specific production systems.

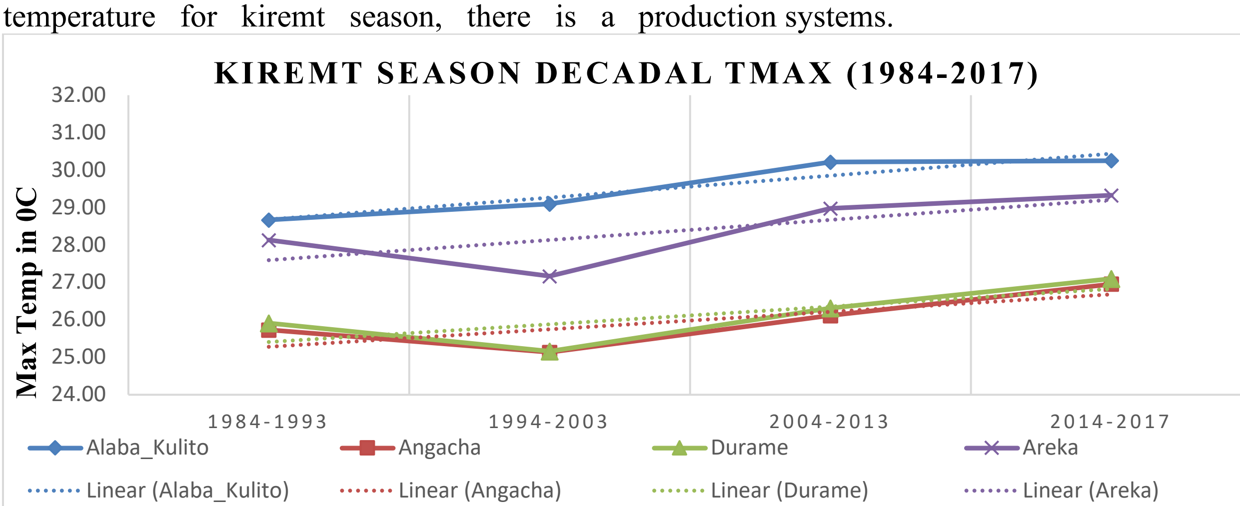

Figure 20: Kiremt Season Decadal Maximum Temperature; **Source:** Computed based on raw data from the National Metrological Agency (NMA) of Ethiopia.

In many cases, temperature increases are predicted to lead to the geographic expansion of pathogen and vector distributions, bringing pathogens into contact with more potential hosts (Baker, et.al., 2000; Olwoch, et.al., 2003) and providing new opportunities for pathogen hybridization (Brasier, 2001; Brasier, et.al., 1999).

In connection with the impact analysis in relation with change of crop types, farmers were asked to fill their perceptions about the negative impact of climate change on crop types. The result revealed that more than 50% of farmers perceived that the impact of climate change on crop types is increased.

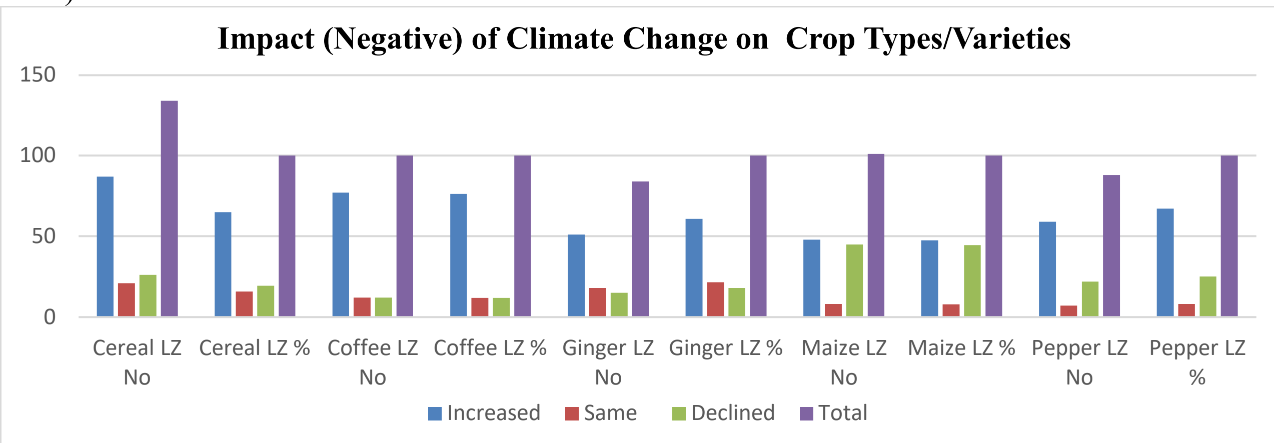

Figure 21: Farmers' Perception of Impact of Climate Change on Crop Types, **Source:** Household survey (2021)

At a global scale, pests and diseases attribute to an average yield loss of 18% and 16%, respectively in major crop species (IPCC, 2014). Although, evaluation of climate change impacts on crop pests and diseases is difficult, owing to lack of long-term data sets, some studies highlight the potential impact of climate on crop diseases and pests. Climate change will alter potential losses to many pests and diseases as changes in temperature can result in geographic shifts through changes in seasonal extremes. To date, studies on the impacts of climate change on crop diseases, pests and weeds are not available in Ethiopia (Ethiopian Panel on Climate Change, 2015). However, there is evidence that climate change will affect the geographic range of specific species of insects and diseases for a given crop growing region and increase crop losses (IPCC, 2014). Climate change may also influence the migration of agronomic and invasive weeds species which possess characteristics that are associated with long-distance seed dispersal, and it has been suggested that these species may migrate rapidly with increasing surface temperatures (ibid).

3.9 Observed Impacts of Climate Change

Negative impacts of climate change can be observed through a number of arrays that can directly or indirectly contribute in threatening the livelihood system of farmers built for many decades. Specifically, in the last ten years, there was repeated occurrence of drought registered both at national and local levels. In this connection, farmers were requested to fill their observed impact of climate change for various conditions in the last ten years across the five LZs. In relation with the impact of climate change on crop yields, the highest percent (71.29) of farmers in Coffee LZ observed that there was a reduction of crop yields significantly, mainly of coffee. In addition, 68.18% of farmers in Pepper LZ reported that they observed the impact of climate change in reducing pepper crop yield in the last ten years. More specifically, the negative impact of climate change on crop types and varieties is observed by 76.24% of farmers in Coffee LZ. Incompatibility of local coffee plant varieties adopted for many decades are becoming less productive and easily susceptible for disease.

In relation with the observed negative impact of climate change in reducing water availability, more than 60% of farmers in all LZs reported that due to the occurrence of recurrent drought, access to water is decreasing, which affects their overall agricultural production. Water availability is very critical for both crop production and animal husbandry, especially for crop-livestock mixed farming system. Specifically, with the trend of increasing temperature, water will get stress and overall production of different crops will get difficulty. Looking the overall income from agriculture, more than 57% of farmers observed that their income from agriculture in the last ten years is decreasing; implying that observed impacts of climate change is affecting their overall livelihood system.

Table 10: Observed Impact of Climate Change across LZs

	Livelihood Zones								
		Cereal LZ	**Coffee LZ**	**Ginger LZ**	**Maize LZ**	**Pepper LZ**	**Total**	**Pearson chi2(8)**	**Pr**
Observed impact (negative) of climate change on crop yields in the last ten years	Increased	59.70	71.29	67.86	43.56	68.18	61.61	26.8819	0.001
	Same	14.18	13.86	17.86	17.82	12.50	15.16		
	Declined	26.12	14.85	14.29	38.61	19.32	23.23		
	Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**		
Observed impact (negative) of climate change on crop types and varieties in the last ten years	Increased	64.93	76.24	60.71	47.52	67.05	63.39	43.0182	0.000
	Same	15.67	11.88	21.43	7.92	7.95	12.99		
	Declined	19.40	11.88	17.86	44.55	25.00	23.62		
	Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**		
Observed impact (negative) of climate change on crop pests and diseases in the last ten years	Increased	83.58	70.30	79.76	75.25	73.86	76.97	11.7547	0.162
	Same	8.96	18.81	17.86	14.85	18.18	15.16		
	Declined	7.46	10.89	2.38	9.90	7.95	7.87		
	Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**		
Observed impact (negative) of climate change on reducing water availability in the last ten years	Increased	64.18	52.48	65.48	62.38	65.91	62.01	19.5385	0.012
	Same	20.15	31.68	16.67	13.86	10.23	18.90		
	Declined	15.67	15.84	17.86	23.76	23.86	19.09		
	Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**		
Observed impact (negative) of climate change on soil erosion in the last ten years	Increased	79.10	70.30	73.81	79.21	70.45	75.00	23.1821	0.003
	Same	10.45	17.82	15.48	13.86	4.55	12.40		
	Declined	10.45	11.88	10.71	6.93	25.00	12.60		
	Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**		
Observed impact (negative) of climate change on income from agriculture in the last ten years	Increased	17.16	17.82	15.48	26.73	26.14	20.47	17.1932	0.028
	Same	23.13	15.84	8.33	15.84	11.36	15.75		
	Declined	59.70	66.34	76.19	57.43	62.50	63.78		
	Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**		

Source: Household survey

4. Conclusion

Understanding the context of changes is very helpful to design context specific policies and strategies for appropriate adaptation mechanisms. The result showed that cultivated land has showed an increasing trend, while forest land doesn't show any improvement, rather a trend of significantly decreasing in size. Impacts of climate change on LULC change varies across various LZs, in the form of adopting new crop types, change of local crop types and change of land suitability of crops in other LZs, influencing land allocation decision behaviour of farmers. This shows that climate variability and change, change in LULC and geographical settings like slope and altitude are important components in influencing production system of local communities. Hence, continuous assessment understanding local level land use land cover changes is very helpful to facilitate livelihood zone based specific support needs. This calls for the need to search for alternative solutions through integrating LULC policies and strategies to reduce the impact of climate change in the context of densely populated mixed smallholder farming system.

Author Contribution

The manuscript was written through contributions of the author. The author has given approval to the final version of the manuscript.

Consent

There is no conflict of interest on this article

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5. References

Alemayehu, M. 2010. Synthesis of research on land use and land cover Dynamics in the Ethiopian highlands. UNU-Land Restoration Training Programme. Final project 2010 Keldnaholt, 112 Reykjavik, Iceland

Amare Sewnet (2016) Land use/cover change at Infraz watershed by using GIS and remote sensing techniques, Northwestern Ethiopia, Intl. J. River Basin Management 14(2), pp. 133–142.

Ashebir WoldeYohannes, Marc Cotter, Girma Kelboro and Wubneshe Dessalegn (2018). Land Use and Land Cover Changes and Their Effects on the Landscape of Abaya-Chamo Basin, Southern Ethiopia. Land 2018, 7, 2. doi:10.3390/land7010002

Berhan G (2010). The role of Geo-information technology for predicting and mapping of forest cover spatio-temporal variability: Dendi district case study, Ethiopia. Journal of Sustainable Development in Africa, 12(6): 9-33.

Binyam Alemu (2015).The Effect of Land Use Land Cover Change on Land Degradation in the Highlands of Ethiopia. Journal of Environment and Earth Science ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online) Vol.5, No.1, 2015 https://www.researchgate.net/publication/324845329

Bürgi, M.; Bieling, C.; von Hackwitz, K.; Kizos, T.; Lieskovský, J.; Martín, M.G.; McCarthy, S.; Müller, M.; Palang, H.; Plieninger, T.;(2017). Processes and driving forces in changing cultural landscapes across Europe. Landsc. Ecol. 2017, 32, 2097–2112.

Central Statistical Agency of Ethiopia, (2010). Population and Housing Census Report-Country – 2007. Addis Ababa: CSA.

Central Statistical Agency of Ethiopia, (2013). Population Projection of Ethiopia for All Regions at Wereda Level from 2014 – 2017. Federal Democratic Republic of Ethiopia, Addis Ababa: Central Statistical Agency.

Moges, D. M., & Bhat, H. G. (2018). An insight into land use and land cover changes and their impacts in Rib watershed, north-western highland Ethiopia. *Land degradation & development*, *29*(10), 3317-3330.

DPPC (Disaster Prevention and Preparedness Commission) (2005b) *SNNPR Livelihood Profile: Hadiya-Kambata Cereal and Enset Zone Report*, Addis Ababa: LIU.

DRMFSS (Disaster Risk Management and Food Security Sector) (2010) *An Atlas of Ethiopian Livelihoods*, Addis Ababa: MOARD.

Eleni, Y., Wolfgang, W., Michael, E.K., Dagnachew, L. and Günter, B. (2013) Identifying Land Use/Cover Dynamics in the Koga Catchment, Ethiopia, from Multi-Scale Data, and Implications for Environmental Change. ISPRS International Journal of Geo-Information, 2, 302-323. ttps://doi.org/10.3390/ijgi2020302

Emily Schmidt and Timothy S. Thomas (2018). Cropland expansion in Ethiopia: Economic and climatic considerations for highland agriculture. STRATEGY SUPPORT PROGRAM. WORKING PAPER 127, IFPRI)

FAO. 1987. Agriculture: Towards 2000. (Revised Version). FAO, Rome.

Gebresamuel G, Singh BR, Dick O (2010). Land-use changes and their impacts on soil degradation and surface runoff of two catchments of Northern Ethiopia. Acta Agric. Scand, Section B. Plant Soil Sci. 60, 211-226.

Hassen, M. Y., Mohammed, A., Assefa, M., & Tena, A. (2015). Detecting land use/land cover changes in the Lake Hayq (Ethiopia) drainage basin, 1957–2007. Lakes Reserv, 20, 1–18. https://doi.org/10.1111/lre.12082

Hurni H. (1993). Land degradation, famine, and land resource scenarios in Ethiopia. In: Pimentel D, editor. World Soil Erosion and Conservation. Cambridge, UK: Cambridge University Press, pp 27–61.

IPCC, (2018). Impacts of 1.5°C Global Warming on Natural and Human Systems. In: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Portner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Pean, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]. In Press.

Kothari CR., (2004). Research methodology: methods and techniques. New age international (P) Ltd, New Delhi.

Lobell, D. B., & Field, C. B. (2007). Global scale climate–crop yield relationships and the impacts of recent warming. *Environmental research letters*, *2*(1), 014002.

Kindu, Mengistie, Schneider, T., Teketay, D., & Knoke, T. (2015). Drivers of land use/land cover changes in Munessa-Shashemene landscape of the south-central highlands of Ethiopia. *Environmental monitoring and assessment*, *187*(7), 452.

Mesfin, F., Demissew, S., & Teklehaymanot, T. (2009). An ethnobotanical study of medicinal plants in Wonago Woreda, SNNPR, Ethiopia. *Journal of Ethnobiology and Ethnomedicine*, *5*(1), 28.

Narumalani, S., Mishra, D. R., & Rothwell, R. G. (2004). Change detection and landscape metrics for inferring anthropogenic processes in the greater EFMO area. *Remote Sensing of Environment*, *91*(3-4), 478-489.

Smith, B. D., & Zeder, M. A. (2013). The onset of the Anthropocene. *Anthropocene*, *4*, 8-13.

Southworth, J., Munroe, D., & Nagendra, H. (2004). Land cover change and landscape fragmentation—comparing the utility of continuous and discrete analyses for a western Honduras region. *Agriculture, ecosystems & environment*, *101*(2-3), 185-205.

Tolessa, T., Senbeta, F., & Kidane, M. (2017). The impact of land use/land cover change on ecosystem services in the central highlands of Ethiopia. *Ecosystem services*, *23*, 47-54.

Van De Steeg, J., Verburg, P. H., Veldkamp, A., & Willemen, L. (2009). From land cover change to land function dynamics: a major challenge to

improve land characterization. *Journal of environmental management*, *90*(3), 1327-1335.
Bewket,W.; and Abebe, S. (2013). Land-use and land-cover change and its environmental implications in a tropical high land water shed, Ethiopia. Int. J. Environ.Stud.70, 126–139, doi:10.1080/00207233.2012.755765.
Takala, W., Adugna, T., & Tamam, D. (2016). Land use land cover change analysis using multi temporal Landsat data in Gilgel Gibe, Omo Gibe Basin, Ethiopia. *International Journal of Science and Technology*, *5*(7).