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Land Use Patterns and its Implication for Climate Change: The Case of Gamo Gofa, Southern Ethiopia

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ABSTRACT

Land is one of three major factors of production in classical economics (along with labor and capital) and an essential input for housing and crop production. Land use is the backbone of agriculture and it provides substantial economic and social benefits. Assessing past-to present land use patterns associated with the crop production helps to understand which climatic effects might arise due to expanding crop cultivation. This study was conducted to evaluate the land use pattern and its implication for climate change in Gamo Gofa, Southern Ethiopia. For evaluation, correlation and time series trend analysis were used. Results revealed that a significant reduction in cultivable land, which was converted into cropland and might increase deforestation and greenhouse gas emission, in turn induce climate change. The correlation between cropland and fertile (cultivable) land (r=0.22674) in 2005 improved to (r=0.75734) in 2012 indicating major shift of fertile land to cropland in seven years interval. On other side, twelve years (1987-1999 and 2000-2011) average maximum temperature difference in Gamo Gafa was increased 0.425^{o}C with standard deviation 0.331. It is statistically significant (t =1.284, alpha=0.10) at 10% level of error. Moreover, the spatial differences in climate change are likely to imply a heterogeneous pattern of land use responses. Agro-climatic features make agricultural activities less vulnerable to climate change. It should be remarked that findings indicate the conversion of cultivable lands into cropland mainly restricted to the resettlement areas, which is in line with our predicted land use patterns. However, forest and bush land areas were generally maintained in most studied Woredas due to the implementation of Green Economy Program in the country that is fundamental importance to offset population and deforestation pressures.

KEY WORDS: Climate change, land use pattern, regression analysis and time series trend analysis.

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INTRODUCTION

Primary Development Goal of the Ethiopian Government is to achieve food security and sustain high economic and export growth levels with the aim ending poverty. Agriculture is the dominant economic sector in Ethiopia, particularly, smallholder farming provides over 85 % of the total employment[1]. Since the smallholders' agriculture is the primary stimulus to generate employment and income, reduce poverty, promote industrialization and ensure a dynamic and self-sustaining growth. Crops in general contribute 60% of the zonal economic share while the contribution of livestock and forest are 30% and 7%, respectively[2].

Land is one of three major factors of production in classical economics (along with labor and capital) and an essential input for housing and food production. Thus, land use is the backbone of agricultural economies and it provides substantial economic and social benefits. Sustainable land management (SLM) can be defined as the use of land resources such as soils, water, animals and plants for the production of goods - to meet unlimited human needs – while assuring the long-term productive potential of those resources, and the continuation of their environmental functions. The government of Ethiopia well recognizes the impeding nature of climate and land use changes. Since soil, land, water and forests are the foundations of Ethiopia's economic development, food security and livelihood sustenance and each of them faces additional pressures through climate shocks and stresses[3]. Among other adverse effects, climate change results in a sharp increase in Green House Gas Emissions and unsustainable use of natural resources. Climate change is expected to increase the area of drylands and hence reduce the area suited to intensive agriculture in Sub Saharan Africa (SSA). According to[4] past soil erosion in SSA might have generated yield reductions from 2-40 percent, compared to a global average of 1-8 percent. If nutrient depletion continues in SSA, about 950,000 km^2 of land is threatened by irreversible degradation. Land degradation is the principal environmental factor behind declining per capita food production. Rising population pressure often obliges farmers to utilize vulnerable, sloping land with aggravated erosion and degradation. Land use management is a continuous process, besides addressing current nutrient deficiencies, understanding measures that are needed to ensure sustainable land productivity. Because of the complexities of processes, management and inter-relationships of land use within a farm, studies on land use patterns require a holistic approach[5].

Climate change projections for Ethiopia have been generated for three periods centered on the years 2030, 2050 and 2080[6]**.** Such scenario indicate that, the mean annual temperature will increase in the range of 0.9 -1.1 °C by 2030, in the range of 1.7 - 2.1 °C by 2050 and in the range of 2.7-3.4 °C by 2080 over Ethiopia compared to the 1961-1990 norm. A small increase in annual precipitation is also expected over the country. According to[6], climate related hazards in Ethiopia include drought, floods, heavy rains, strong winds, frost, heat waves (high temperatures), etc. Causes for vulnerability of Ethiopia to climate variability and change include very high dependence on rain fed agriculture which is very sensitive to climate variability and change, under-development of water resources, high population growth rate, low economic development level, low adaptive capacity of technology, inadequate road infrastructure in drought prone areas, weak institutions, lack of awareness, etc. Though the small household land use change impacts on climate change are not well studied and documented.

The topography of the land characterizes an undulating feature that favors for the existence of different climatic zones in the study area. It is a zone of immense ecological and cultural diversity ranging from arid and semi–arid conditions to cool temperate zones. Using the traditional agro–climatic classification, 28.4% of the zone falls under the Kola (lowland), 41.4% under Woina Dega (mid-altitude), 30.1% under Dega (high altitude) and 0.5% Wurch/cold temperate. The mean annual temperature ranges between 20–25^{0}C; whereas the mean annual rainfall ranges from 200-2000 mm.

At present, about 343,369 hectares of land, 35% in the study area is under cultivation (by annual and perennial crops) per a year, as people mainly depend on agriculture to meet their basic needs. Grains are the most important field crops mostly maize in croplands, occupying considered percent of area planted and being the chief element in the diet of most peoples. On the other hand, about 16% is covered by shrubs, bushes and dense forests, and 14% is grazing land. Two National Parks are considered as part of forest land in this zone. It was found to be of paramount importance to assess land use pattern and its implication for climate change. Because, understanding land use patterns help to identify practical options that fit different farming systems[7, 8]. Therefore, the objective of this study was to understand the land use pattern and its implication for climate change, and to sustain the land use system.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted in Gamo Gofa Zone of Southern Nations, Nationalities and Peoples` Regional State (SNNPR), Southern Ethiopia. The study area is found at 5^0 57 - 6^0 71’ N and 36^0 37’- 37^0

98' E and altitude of 680 to 4207 masl. The highest point is called Mount Gughe, which is 4207 meters above sea level and the highest Mountain peak in the zone as well as in the SNNPR.

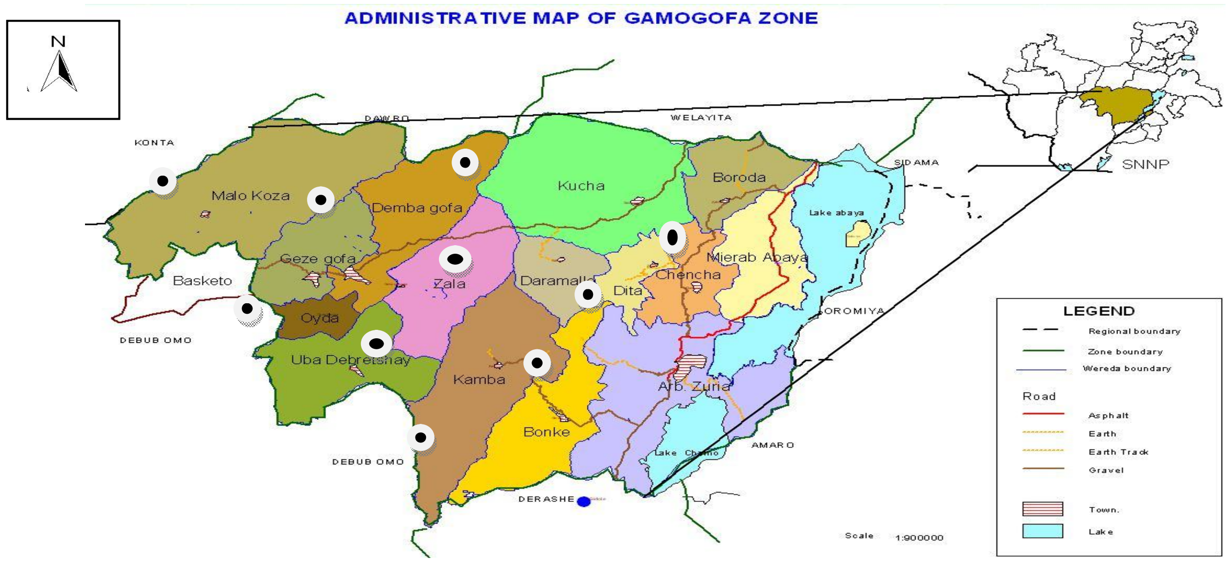


Figure 1: Map of Gamo Gofa Zone (• Sampled Representative Woredas in the Zone)

Source: Department of Finance and Economic Development of Gamo Gofa Zone

There are five indigenous ethnic groups in Gamo Gofa Zone with distinct languages and cultural base. The largest ethnic groups reported in the zone Gamo (70%), the Gofa (23%) of the population[9]. As a result, Gamo Gofa is named for the Gamo and Gofa peoples, whose homelands lie in this zone. They line in relative harmony and peacefully. The zone has a total area of 12,581.4km^2 and administratively consists 15 rural woredas namely, Arba Minch Zuria, Mirab-Abaya, Boreda, Chencha, Dita, Kucha, Daramlo, Bonke, Kemba, Zala,Ubadebretsehay, Oyida, Demba Gofa, Geze Gofa and Melakoza; and two reform towns called Arba Minch and Sawla. Arba Minch town is the administrative and trading center of the zone, located at 505 km from Addis Ababa and 275 km south west of Hawassa. The general elevation of the Gamo Gofa zone ranges from 680 to 4207 meters above sea level. The highest point is called Mount Gughe, which is 4207 meters above sea level and the highest Mountain peak in the zone as well as in the SNNPR. The total population of the Gamo Gofa zone is estimated about 1593104[9], with a population density of 144.68 inhabitants per kilometer square. While 157,446 or 9.88% are urban inhabitants, a further 480 or 0.03% are pastoralists. A total of 337199 households were counted in this Zone, which results in an average of 4.72 persons to a household, and 324919 housing units.

Data Source

For the purpose of this study, data were obtained from secondary sources on the land use systems, meteorological, and human population. The base land use data (cropland, grazing land, forest and bush land, cultivable, uncultivable and others) had been collected since 2005 for the Rift Valley and Omo-Gibe Catchments Study. The current land use data have been collected and updated by the Department of Agricultural Division of each sampled woredas. The meteorological data (average annual: maximum and minimum temperature, rainfall, and relative humidity) have been taken from National Meteorology Agency- Awassa Branch. The population data is taken from 2007 population census result which is conducted at national level. To support the data and get a closer look at the current status of the land use system, a survey has been conducted on land use system. This is expected to document the land use status for further studies of the area and helpful to evaluate projects which may implement on the area.

Statistical Analysis

Data analysis was carried out using Microsoft Excel to describe the pattern of land use in two timings. It applied radar chart and line chart to display the land use shift pattern in the sampled woredas of Gamo Gofa zone. In addition to this, line charts used to display the trends of meteorological data over years. Also SAS System for Windows V8 is employed to analyses of correlation within land use variables, and meteorological variables.

RESULTS

Allocation of Land Use Patterns

Land allocations/land use patterns: cropland was defined as the sum of temporary and permanent crop areas, while grazing land was computed as the sum of natural and planted pastures. Forest areas correspond to the sum of natural forest, planted forest and bush land. Assessing past-to present land use patterns associated with the crop cultivation helps to understand which agricultural effects expanding crop production. The study showed a progressive shift among land use patterns in seven year time interval, and provided information on major changes in crop cultivation (Table 1, 2; Figure 3, 4, 5) in Gamo Gofa. Most of natural forests and cultivable lands were converted into crop cultivation (Table 1, Figure 2) whereas smallholders' cultivation was progressively increased and influenced by resettlement expansion of human population. Parts of mountain tops that were previously covered by grass and bushes were deforested because of shortage of farmland in the highlands, absence of other alternative livelihood diversification strategies to rural-urban migrants, and rampant rural poverty and unemployment.

Table 1: Land Use Patterns of Gamo Gofa Zone 2005 Vs 2012 (in Hectare)

Woreda	Cultivated Land		Grazing Land		Forest & Bush		Cultivable		Uncultivable		Others	
>>>Year	2005	2012	2005	2012	2005	2012	2005	2012	2005	2012	2005	2012
Kucha	30566	36387	43914	41574	33783	34724	16894	12572	13726	13726	7277	7177
Melokoza	34690	73420	8463	6880	50456	42432	55086	26782	9047	9017	10437	9649
D/ Gofa	31163	34997	9794	10040	13356	12525	4452	3290	10684	8597	19588	19588
Oyida	5481	7112	1218	524	731	1527	609	784	1583	175	2558	280
Chencha	20648	21818	3158	2578	3585	4166	2203	2404	6609	6052	1157	324
Kemba	20661	21832	25716	23937	26707	29297	26595	15577	6265	6267	4945	10980
Bonke	43548	48122	8068	8492	7266	6519	10385	10000	7305	7000	8498	4937
Daramallo	13668	15677	4482	3975	10371	10228	5334	4975	2000	1355	1185	828
A/M Zuria	17824	32567	4433	2713	5603	10058	23319	11421	53668	50668	58983	56403
M/Abaya	49672	51437	25955	30142	5718	4247	13908	9944	3375	2452	22522	22928

Source: Omo Gibe Catchments Study and Gamo Gofa Zone Agriculture and Rural Development (2005); Department of Agricultural Division of each Woreda (2012)

In Gamo Gofa, the 2005 data of land use patterns (LUPs) were partitioned as cultivated (28%), grazing (14%), forest and bush (16%), fertile/cultivable (16%), not cultivable (12%), and others (14%) land use systems (Table 1, Figure 2). Similarly, the 2012 data of LUPs were partitioned as cultivated (35%), grazing (14%), forest and bush cover (16%), fertile/cultivable (10%), not cultivable (11%), and others (14%) (Table 1, Figure 2). Table 3 shows the correlation between land use variables. Since 2005 and 2012 data were used, the forest and bush land area positively correlated, 0.83045 (p-value <0.003) with fertile land area. After seven years later we observed same correlation in 2012. On other side the 2005 and 2012 data of cropland conversion was positively (r= 0.2694, 0.75734*) correlated with fertile land, respectively. The impressing result of the correlation between cropland and fertile land in 2012 has been improved from 0.2694 to 0.75734 (p-value <0.012) in seven year time period. This at least in part, and explains the significant reduction in cultivable land and expansion of cropland in the study area. These changes were being driven by population pressure (Table 3 and 4) and development programs, which is in line with[10] but, in comparison to other drivers, it is unlikely that climate change will affect land use change significantly. Thus, this study indicated that most of cultivable land was converted into cropland in all woredas (Table 1, Figure 2), and the increase in relative human and cattle population (Table 3,

Table 4) lead to expansion of cropland, and also associated with grazing land. This is due to the increasing demand for crop and grazing land, and wood for fuel and construction[11]. The allocation/distribution of the land use in Gamo Gofa has been changing greatly over time because of subsequent cultivation after deforestation due to high population and economic pressures, and infrastructure and irrigation development[2].

Apart from the degradation, the study area was remarkably well covered by recently introduced fruit trees and crops. There was a breakthrough in production and transforming the livelihoods of the inhabitants from survival level to elevated way of life at lowlands in the irrigated Woredas; fast changes are taking place now in farming systems, peoples' lifestyles, breaking of traditional systems. For example, improved farming methods such as mulching, intercropping, and shifting cultivation were also well practiced. For example, enclosures of hillside and degraded areas were also maintained the land available for livestock production, grazing and browsing (Personal Communication). Although such enclosed hillsides recover vegetation very quickly, protecting soil, the introduction of cut and carries systems for grass on these hillsides for livestock use. This is in agreement with[12] that farmers shape the distribution and degree of diversity for the crops both directly through selection, and indirectly, through management of biotic and abiotic agro-ecosystem components.

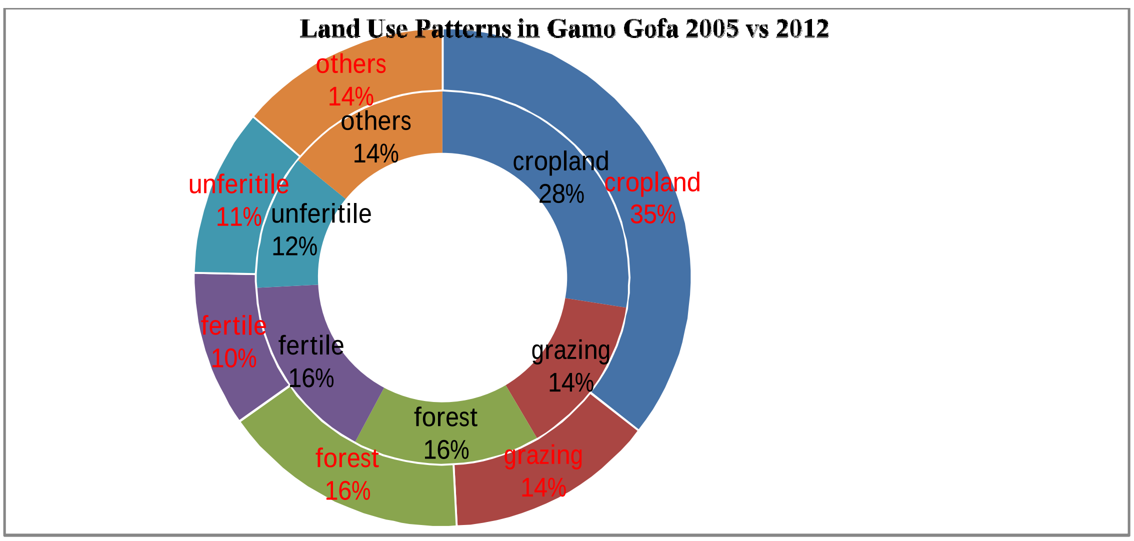


Figure 2: Doughnut Chart of Land Use Partition System of Gamo Gofa 2005 vs. 2012

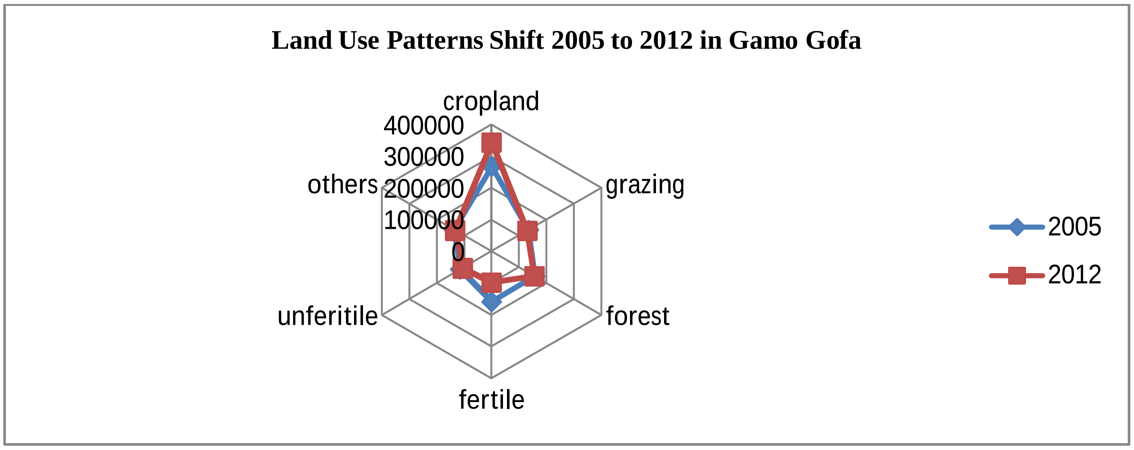


Figure 3: Radar Chart Depicts the Land Use Shift Fertile (2005) to Cultivation (2012) in Gamo Gofa.

Specifically, in Melokoza Woreda, most of the forest land was converted into crop and grazing lands (Table 1, Figure 4), which is in line with our predicted LUPs, that the higher vulnerability of the agricultural activities in the Melokoza Woreda. In Melokoza Woreda remarkable resettlement program was implemented in 2006-2009 by Gamo Gofa Zone Department of Agriculture. Farmers´ adaptation to climate change; deforestation pressure and greenhouse gas emissions may progressively increased or maintained by forest and watershed management. This pattern is in line with previous studies that agricultural productivity will be severely affected by climate change[13, 14], higher temperatures would reduce the productivity of most crops, and further farmers would convert land use systems to cropland.

Table 2: Simple Statistics (N= 10 Selected Woredas of Gamo Gofa)

Land use	**Mean**		**Std Dev**		**Sum**		**Minimum**		**Maximum**	
>>>>**Year**	2005	2012	2005	2012	2005	2012	2005	2012	2005	2012
Cropland	26792	34337	13671	19494	267921	343369	5481	7112	49672	73420
Grazing land	13520	13086	13822	13936	135201	130855	1218	524	43914	41574
Forest & bush	15758	15572	16102	14462	157576	155723	731	1527	50456	42432
Cultivable land	15879	9775	16345	7701	158785	97749	609	784	55086	26782
Not-fertile	11426	10531	15323	14662	114262	105309	1583	175	53668	50668
Others	13715	13309	17502	17028	137150	133094	1157	280	58983	56403

Other land use categories did not show a significant shift of land use system in zonal level as well as Woredas level (Table 2, Figure 5). Furthermore, Figure 3, 4, 5 display the status of cultivated, cultivable, and forest lands in two timings. Expansion of cultivated land has been observed significantly in Melokoza and Arba Minch Zuria Woredas. Forest and bush land expansion is permissible in Arba

Minch Zuria and Kemba but it is the discouraging practice in Melokoza. The cultivable land was speedily reduced in seven year length at Melokoza, Kemba, and Arba Minch Zuria woredas (Table 1; Figure 3, 4, 5). This is in agreement with information obtained from field survey that in the mountains and escarpments between lowland catchments and highland areas, previously covered by grass, bushes and trees were also disappearing from those places. Particularly, in Arba Minch Zuria Woreda parts of the border areas near Lake Abaya and Chamo which was previously covered with forest was cleared.

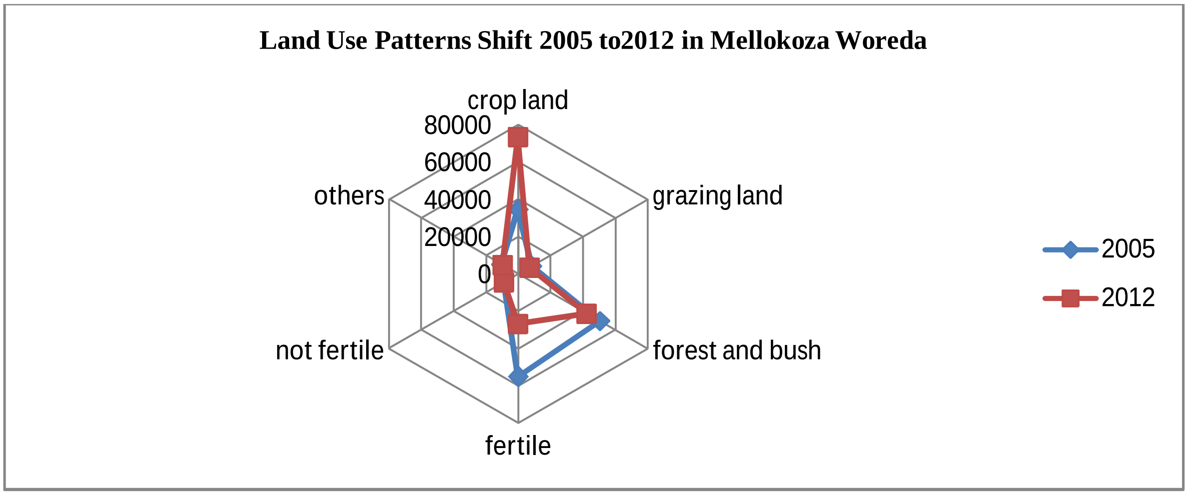


Figure 4: Radar Chart Display the Land Use Shift Fertile and/or Forest (2005) to Cultivation (2012) in Melokoza Woreda, Gamo Gofa.

On the other hand, climate change can offer new opportunities for productive and sustainable land management (SLM) practices, such as reforestation, improved water management, integrated soil fertility management, conservation agriculture, agroforestry, improved rangeland management and others as a result of changing biophysical conditions. SLM can also reduce vulnerability and help people adapt to climate change. For example, farmers in Gamo Gofa were reported investing in soil and water conservation measures as their most common response to maintaining forestland. Many SLM practices can increase soil organic carbon, and reduce the need for coping measures, like changing crops and livelihoods, clearing new lands for agriculture and migration.

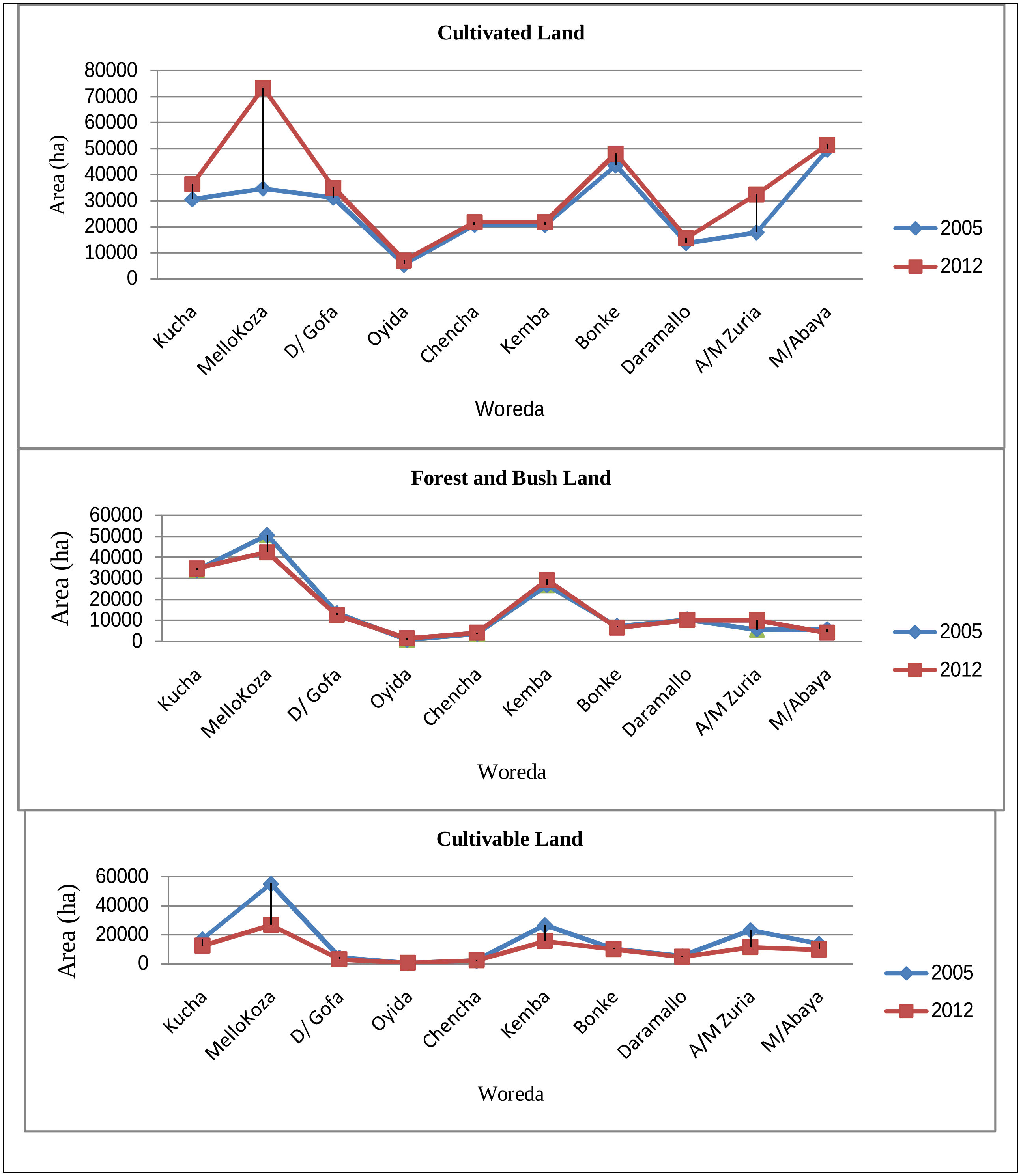


Figure 5: Land Use Status of Different Woredas of Gamo Gofa in Two Timings 2005 vs 2012

The SLM practices reduce the variability of agricultural production (for example, soil and water conservation and organic practices that improve soil moisture holding capacity or integrated pest management practices that reduce vulnerability to pests), while others can help to diversify agricultural income (for example, agro-forestry or crop rotations).

Table 3: Pearson Correlation Coefficients(r) of Land Use Variables with P-Value in 2005 vs 2012

Land Uses	Forest & bush land		Fertile land		Not-fertile		Other land uses	
	r-value	p-value	r-value	p-value	r-value	p-value	r –value	p-value
Land use patterns of 2005								
Cropland	0.227	0.529	0.269	0.452	-0.133	0.714	0.101	0.782
Grazing land	0.443	0.199	0.181	0.616	-0.096	0.791	-0.092	0.800
Fertile land	**0.830**	0.003**	1.000	-	0.235	0.513	0.204	0.571
Not -fertile	-0.068	0.851	0.235	0.513	1.000	-	**0.905**	0.000***
Land use patterns of 2012								
Cropland	0.485	0.155	**0.757**	0.011*	0.098	0.789	0.201	0.578
Grazing land	0.434	0.210	0.285	0.424	-0.118	0.745	-0.013	0.972
Fertile land	**0.831**	0.003**	1.000	-	0.202	0.576	0.178	0.623
Not -fertile	0.061	0.868	0.202	0.576	1.000	-	**0.878**	0.001***

Pearson Correlation Coefficients, Prob > |r| under H0: Rho=0; Correlation is ** 1% highly significant * 2% significant.

Human and Livestock Population

The total human population of Gamo Gofa zone is about 1593104[9]. In the study area, land use pattern has been changed greatly over time because of high human and livestock population pressure (Table 4, Table 5). As a result, growth in food production has not kept pace with the population growth leading to increased domestic demand and shortages of food.

Table 4: The Human Population of 10 Selected Woredas of Gamo Gofa

Year	Human population of 10 selected woredas in Gamo Gofa									
	Melokoza	D/Gofa	Kucha	M/Abaya	A/Zuria	Chencha	D/Malo	Kemba	Bonkie	Oyida
2007	120398	81165	149287	74967	164529	111686	81025	155979	159089	33310
2012	139180	93827	172576	86662	190196	129109	93665	180312	183907	38506

Source: CSA, 2007 and projection by 2.9% Growth Rate

According to farmers, livestock production in Gamo Gofa are currently subsisting on crop residues in the most drought affected parts of the zone, but there was little natural grazing land available in some parts of the study area, due to a succession of dry years. Enclosure of hillsides that used for grazing and browsing has also maintained the amount of land available for livestock production. Although such enclosed hillsides recover vegetation very quickly, protecting soil, the introduction of cut and carries systems for grass on these hillsides for livestock use has not yet been properly managed by local authorities. Small ruminants have a number of advantages as an integral component of the agricultural production systems.

Table 5: The Livestock Population of 10 Selected Woredas in Gamo Gofa

Year	**Livestock population of 10 selected Woredas in Gamo Gofa**							
	Cattle	Sheep	Goats	Horse	Donkey	Mule	Poultry	Beehives
2007	914983	527631	202174	36716	13378	10698	594948	46777
2012	1438752	800704	374153	76654	44644	72645	1050744	116942

Source: Gamo Gofa Zone Department of Agriculture, 2012; CSA, 2007

Trend of Temperature

The observed climatic data from 1987 to 2011 indicate that the temperature is shown decreasing trend in the Meher season (June, July and August).

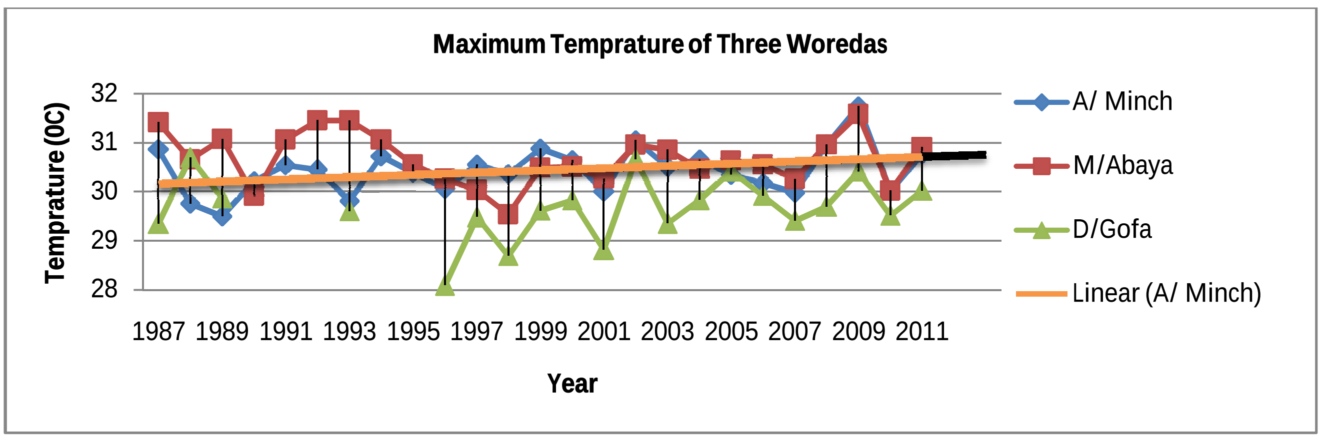
Table 6: Average Maximum Temperature of Four Meteorological Stations of Gamo Gofa

Year	**A/Minch**	**M/Abaya**	**G/Gofa**	**D/Gofa**	***Year***	**A/Minch**	**M/Abaya**	**G/Gofa**	**D/Gofa**
1987	30.9	31.4	19.8	29.3	***2000***	30.6	30.5	21.7	29.8
1988	29.8	30.7	20.7	30.7	***2001***	30.0	30.3	21.3	28.8
1989	29.5	31.1	19.6	29.9	***2002***	31.1	31.0	22.0	30.7
1990	30.2	29.9	-	-	***2003***	30.5	30.9	21.2	-
1991	30.5	31.1	20.4	-	***2004***	30.7	30.5	22.0	29.8
1992	30.4	31.5	20.1	-	***2005***	30.3	30.6	22.4	30.4
1993	29.8	31.5	20.3	29.6	***2006***	30.2	30.6	21.9	29.9
1994	30.7	31.1	21.1	30.9	***2007***	30.0	30.3	20.8	29.4
1995	30.4	30.6	21.4	-	***2008***	31.0	31.0	21.9	29.7
1996	30.1	30.3	20.7	28.1	***2009***	31.7	31.6	20.0	30.4
1997	30.6	30.0	21.3	29.5	***2010***	30.0	30.0	22.2	29.5
1998	30.4	29.5	20.6	28.7	***2011***	30.8	30.9	22.6	30.0
1999	30.9	30.5	21.5	29.6					
Average(max)	**30.3**	**30.7**	**20.6**	**29.6**		**30.6**	**30.7**	**21.7**	**29.9**
Difference(max)	0.3	0.0	1.1	0.3	Average difference = **0.425 °C** with SD=0.331				
Average(min)*	**17.5**	**17.5**	**11.1**	**17.6**		**17.3**	**18.3**	**10.8**	**17.3**
Difference(min)	-0.2	0.8	-0.3	-0.3	Average difference = **0 °C** with SD=0.535				

* **The minimum temperature data are not displayed in the table, but averages and average differences are displayed.**

The 25 years maximum and minimum temperature trends of the study area were displayed in Figure 5. The twelve years (1987-1999 and 2000-2011) average maximum temperature difference in Gamo Gafa was 0.425 °C(Table 6) with standard deviation (SD) 0.331. It is statistically significant (,) at 10% level of error. But by similar analysis yield, the average minimum temperature difference in Gamo Gofa was 0°C with SD 0.535, which is statistically not significant. However, there is tendency to average decline at second decade (1987-1999) than first (2000-2011) except Mirab Abaya Station.

The minimum temperature trends (Figure 6) were shown variation before and after 1996. Before 1996 minimum temperature trends of woredas were shown gradual decline until 1996. At that point the trends were shift up takedown and down take up positions. High temperature can cause increased evapotranspiration, shorter growing periods, drying of the soil, increased pest and disease pressure. Climate change is also expected to cause increased variability of temperature and rainfall, increased intensity and frequency of extreme events, including droughts, floods, and storms.



Positively sloping line in the chart is linear trend (orange color) and its extension is linear forecast (black color) for next time over Arba Minch Meteorological Station.

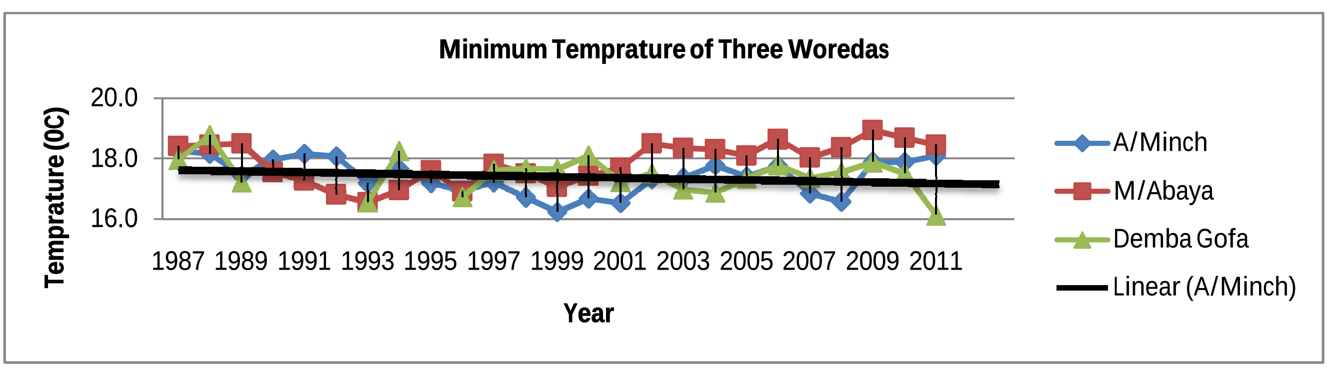


Figure 6: The Maximum and Minimum Temperature of Selected Stations in Study Area Together with Linear Trend Lines

Trends of Rainfall

The rainfall data from 1987 to 2011 of 4 stations found that only 2 stations showed gradually increasing trend, while 2 stations showed constant trend of rainfall (Figure 7).

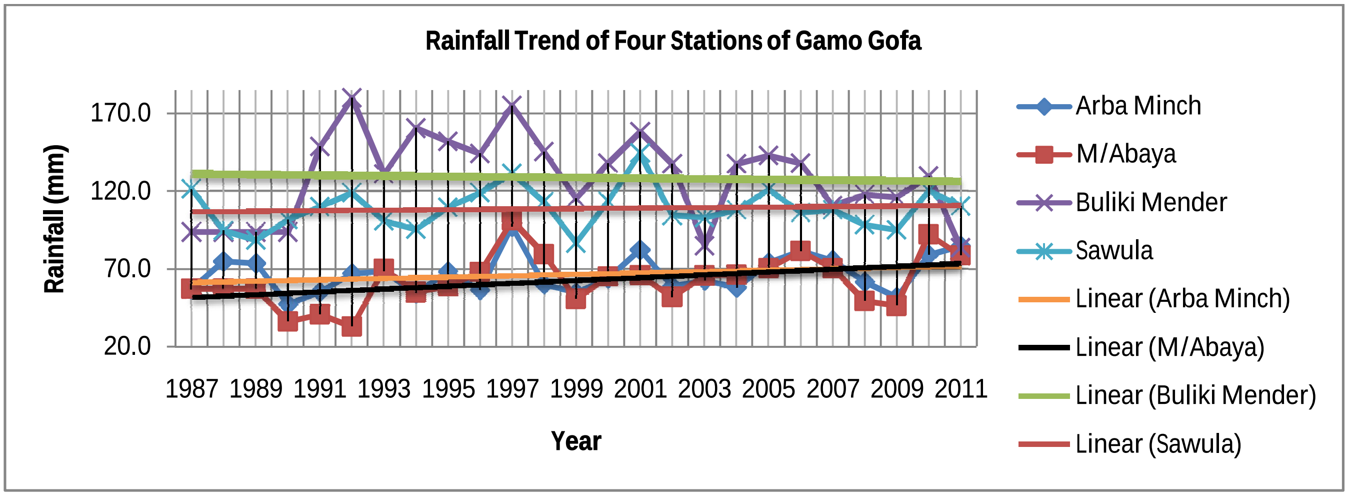


Figure 7: Rainfall Distribution and Trend of Four Stations of Gamo Gofa Zone.

The rainfall trends of Arba Minch Zuria and Mirab Abaya Woredas were shown the same trend over time (Figure 7). There are diverse ranges of factors that limit the smallholders' agricultural production in Gamo Gofa Zone (Personal Communication): amongst these most mentioned agricultural production problems in the study area are rainfall variability- amount and distribution which cause drought/moisture stress, delayed planting date and end season drought; extreme weather phenomena, dry spells and heavy rains– causing flooding, water logging and siltation of sediments in lower watercourses; low level of technology adoption; declining soil fertility, etc. However, as indicated in Figure 7, the average rainfall distribution of Gamo Gofa was nearly constant every 25 years.

Correlation of Meteorological Variables

Four meteorological variables (maximum temperature, minimum temperature, rainfall and relative humidity) of sampled woredas were correlated. Maximum temperature of Arba Minch and Mira Abaya Stations were negatively and significantly correlated (r= -0.61985**,-0.58753*) with relative humidity while maximum temperature was negatively and significantly correlated (r= -0.69089**, -0.4032*) with rainfall (Table 7).

Table 7: Correlation (r) between Meteorological Variables of Araba Minch and Mirab Abaya Stations Together with P-Value

Meteorological variables	**Minimum Temperature**		**Rainfall**		**Relative Humidity**	
	r-value	p-value	r-value	p-value	r-value	p-value
Arba Minch Station						
Maximum temperature	0.0426	0.8397	**-0.4032**	0.0457*	**-0.61985**	0.0010**
Rainfall	-0.0432	0.8375		-		
Relative humidity	-0.2457	0.2365	0.38959	0.0542		-
M/Abaya Station						
Maximum temperature	0.35533	0.1479	**-0.6909**	0.0015**	**-0.58753**	0.0103*
Rainfall	0.10549	0.6770		-		
Relative humidity	-0.39965	0.1004	0.55974	0.0157		-

Most of the temperature and precipitation coefficients are statistically significant, and suggest that variations in temperature and precipitation in different seasons may have a distinct impact in terms of land allocations. This finding also highlights the importance of using climate data sufficiently with regard to time. Thus climate factors are an important determinant of farmers´ decisions regarding land allocation choices.

DISCUSSION

Assessing past-to present land use patterns associated with the crop production helps to understand which climatic effects might arise due to expanding crop cultivation. Unsustainable land use has been driving land degradation. The result is a loss of land productivity with impacts on livelihoods and an economy. This may lead to conversion of forest, grazing, and fertile lands to crop lands. This section describes the discussions of land use shifts and trends of temperature and rainfall over past 25 years (1987-2011). The major land use and land cover types shown by doughnut charts of 2005 and 2012 include cultivated land, grazing land, forest land, and fertile (cultivable) land. As indicated in Figure 2, the greatest share of land use was cultivated (crop) land, which covers an area of 267,921 hectares, contributes 28% of the total sampled area in 2005. But it has been increased to 343,369 hectares, contributes 35% of the total sampled area in 2012. It has been shown 7% change in past 7 years. The fertile land area (16% of total) in 2005 was shifted to crop land (approximately 6% of total) in 2012 to secure sustainable food security of farmers. It derived fertile land area from 16% in 2005 to 10% in 2012. As indicated in Figure 4, the good example of major expansion of crop land or major decline of cultivable land and forest land is Melokoza. The large expansion of crop land or decline of forest and cultivable land in Melokoza was due to notable resettlement around 2006-2008. Land use pattern– especially conversion of natural vegetation to cropland – can result in a range of environmental impacts, and the land use consequences of crop cultivation is a topic that attracts much attention. The correlation between cropland and fertile (cultivable) land (r=0.22674) 2005 improved to (r=0.75734) in 2012 indicating major shift of fertile land to cropland in seven years interval. And unchanged correlation (r=0.830) between fertile land and forest land shows forest land did not converted to any other in average at study area. A decrease in the rate of forest conversion contributes a dampening effect on CO_2 emissions; a decrease in CO_2 emissions moderates climate change. [15]showed that choice of farm type are very sensitive to climate: Farmers tend to choose mixed crop-livestock farms and livestock-only farms in warmer locations, while crop-only farms are more likely to be found in cooler locations. [13]showed that a combined increase of 1°C and 3 percent rainfall will lead to a 1.84 percent reduction in natural forest and an increase of 2.76 percent in natural pasture. Their analysis suggests that increased investments in research and development would partially mitigate the loss of natural forest due to climate change. The Green Economy Program of the Ethiopian Government particularly in the study area, maintained forest coverage and minimize greenhouse gas emissions. However, as indicated in[16] at the national level study in Brazil, suggests that climate change may induce a significant reduction in forestland. Depending on the time horizon, deforestation ratios are ranged between 15 percent and 20 percent of total forest area of rural establishments.

The spatial differences in climate change are likely to imply a heterogeneous pattern of land use responses that vary by woredas. Such agro-climatic conditions make agricultural activities less vulnerable to climate change. Actually, agronomic studies point out that rising temperatures may ease the introduction of tropical crops in the woredas. Climate change will not only affect crop yield, but total farm-level production through effects on altered carbon, rainfall distribution and nitrogen flows resulting from changed crop and residue quality, crop resource use, or mineralization of soil organic matter[17]. This same mild climate change is predicted to reduce land values by 1.23 percent in Brazil as a whole. Finally, [16] suggested that the overall impact of climate change will be quite modest for agriculture in the medium term, but these impacts are considerably more severe in the long term.

Climate variability can contribute to land degradation by exposing unprotected soil to more extreme conditions and straining the capacity of existing land management practices to maintain resource quality, contributing to de-vegetation, soil erosion, depletion of organic matter and other forms of degradation. These changes can cause land management practices that are sustainable under other climate conditions to become unsustainable, and induce more rapid conversion of forest or rangeland to unsustainable agricultural uses. At the same time, land degradation increases the vulnerability of agricultural production and rural people to extreme weather events and climate change, as the fertility of the land and livelihood assets are depleted. Increased maximum temperature (0.425^{o}C) and fixed average rainfall trends indicate existing impacts on climate unpredictability and change. These two variables are negatively correlated (r = -0.6909) and it indicates that increase in average maximum temperature lead to limited rainfall distribution and amount. The stallholder farmers' crop productivity may decline due to limited rainfall distribution and increased temperature. In addition to this maximum temperature of the study area is negatively correlated with relative humidity.

CONCLUSION

This study was aimed at evaluating the land use patterns and its implication for climate change in Gamo Gofa Zone. To this purpose, correlation and time series trend analysis was used to assess how land use patterns affect climate variables. At the local level, results suggest that crop land expansion may induce a significant reduction in fertile land. Most of the fertile land would be converted into cropland from 2005 base to 2012. In particular, it should be remarked that this conversion pattern is observed, where the resettlement programs are implemented. This means that farmers´ adaptation to climate change may increase the deforestation pressure in the resettlement programs implemented areas and therefore it contributes to an increase in greenhouse gas emission. Thus land use pattern and climate variables are structurally correlated and the land use pattern change effects are implied on climate variables- average maximum temperature difference was increased 0.425^{o}C in two decades (1987-1999) to (2000-2011); and average minimum temperature was 0^{o}C, showing declining trend(Figure 6) over 1987-2011 in Gamo Gofa, southern Ethiopia.

Moreover, the spatial differences in climate change are likely to imply a heterogeneous pattern of land use responses. Agro-climatic features make agricultural activities less vulnerable to climate change; farmers may convert pasture into cropland. This pattern is in line with previous studies that show that agricultural productivity will be severely affected by climate change. It should be remarked that our findings indicate that deforestation pressure would not be restricted to the resettlement implemented areas only. Forest area would be maintained in all studied areas of the zone. These findings suggest that policymakers should reinforce monitoring and control activities regarding rural land use regulations. In particular, the enforcement of legal forest reserve requirements and economic-ecologic zoning restrictions or area closures seem of fundamental importance to offset deforestation pressures.

Climate change, population growth, environmental degradation and lack of harmonized intervention have also been affecting land resources adversely. This is actually the challenge we face and hence need immediate intervention from all stakeholders including government, external support, non-governmental organizations (NGOs) and others.

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REFERENCES

1. Tuma A, Potassium Availability under Banana- Based Land Use Systems in Abaya Chamo Lake Basin, South-west Ethiopia. *IJSRR.* 2013; *2(2): 94-10.,*
2. Tuma A, Effect of Fruit Based Land Use Systems on Soil Physicochemical Properties: The Case of Smallholders Farming Systems in Gamo Gofa, Southern Ethiopia; MSc thesis, *Hawassa University, Hawassa*, Ethiopia, 2007.
3. CRGE (Climate- Resilient Green Economy), Ethiopia's Climate- Resilient Green Economy Strategy, Addis Ababa, Ethiopia, 2011.
4. Nellemann C., M. MacDevette T. Mander, B. Eickhout, B. Svihus, A. G. Prins, and B. P. Kaltenborn, The Environmental Food Crisis. The Environment's Role in Averting Future Food Crises. A UNEP rapid response assessment. United Nations Environment Programme, GRID-Arendal, 2009.
5. Rivington M., K.B. Matthews, G. Bellocchi, K. Buchan, C.O. Stöckle, M. Donatelli, An integrated modelling approach to conduct multi-factorial analyses on the impacts of climate change on whole-farm systems. Environ. Model. Software. 2006: 22: 202-210.
6. NMA (National Meteorology Agency), Final Summary Report on Synergy Assessment prepared by B and M Development Consultants for NMA. Addis Ababa, Ethiopia, 2007.
7. Bierman, P.M. and C.J. Rosen, Nutrient cycling and maintaining soil fertility, fruit and vegetable crop systems. University of Minnesota Extension service, 2005.

8. FAO (Food and Agricultural Organization, Rural House Holds and Sustainability: Integrating environmental and gender concerns in to home economics curricula of the United Nations, Rome, 1994.
9. CSA (*Central Statistics Authority*), The 2007 Population and Housing Census of Ethiopia. statistical Data of SNNPR, Addis Ababa, Ethiopia, 2007.
10. Rod L., Laure C. and Christian G, Study on Potential Impacts of Climate Change on Land Use in the Lao PDR. International Center for Tropical Agriculture (CIAT Asia), NAFRI-Lao PDR, Pheng Sengxua, 2010.
11. Taye Bekele, Getachew Berhan, Elias Taye, Matheos Ersado, and Kumilachew Yeshitila, Regeneration Status of Moist Mountain Forests of Ethiopia: Consideration for Conservation. *Journal of the Ethiopian Wildlife and Natural History Society*. 2002; 22: 45-60.
12. Jarvis, D. and T. Hodgkin, Farmer decision making and genetic diversity linking multi-disciplinary research to implementation on–farm. pp. 261-278 in Genes in the field: on – farm conservation of crop diversity Lewis publishers, Boca Raton, FL. USA. 2000; 261-278.
13. Evenson, R.E. & D.C.O. Alves, Technology, climate change, productivity and land use in Brazilian agriculture. *Planejamento e Políticas Públicas*, 1998; 18:
14. EMBRAPA, *Aquecimento Global e a Nova Geografia da Produção Agrícola no Brasil*. Campinas: EMBRAPA/UNICAMP, 2008.
15. Menselsohn, R. And N. Seo, Changing farm Types and Irrigation as an Adaptation to Climate Cahnge in Latin American Agriculture. World Bank Policy Research Working Paper Series No. 4161, 2007.
16. Anderson, K and E. Reis, The Effects of Climate Change on Brazilian Agricultural Profitability and Land Use: Cross-Sectional Model with Census Data. WHRC/IPAM for LBA project *Global Warming, Land Use, and Land Cover Changes in Brazil*, 2007.
17. Dueri S., P.L. Calanca, J. Fuhrer, Climate change affects farm nitrogen loss - A Swiss case study with a dynamic farm model. Agric. Syst. 2006; 93:191-214.