INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 25, No. 6, p. 180-200, 2024

RESEARCH PAPER OPEN ACCESS

An Analysis of Land Use Land Cover Changes and Key Factors Enhancing Climate Change Adaptive Capacity in the Hadiya Zone, Ethiopia

Yohannes Horamo*[1], Munyaradzi Chitakira[2], Kowiyou Yessoufou[3]

[1*]*Department of Natural Resources Management Wachemo University, Ethiopia*

[2*]*Department of Environmental Sciences, University of South Africa, Florida, South Africa*

[3*]*Department of Geography, Environmental Management and Energy Studies, Auckland Park 2006, University of Johannesburg, South Africa*

Key words: Climate change, Adaptive capacity, Agroforestry practices, Land cover change, Ethiopia

http://dx.doi.org/10.12692/ijb/25.6.180-200 Article published on December 06, 2024

Abstract

Climate change negatively affects agricultural production, the natural resources base, and the livelihoods of communities. As such, adapting to climate change through agroforestry practices is important for sustainable agriculture. This study aimed to assess farmers' adaptation to climate change through agroforestry practices in the Hadiya zone, in Ethiopia. Stratified random sampling techniques were employed. Data were collected through Landsat images. Data were analyzed using SPSS version 23, ArcGIS10.3 and Participatory Learning Action tools. The land use and land cover change analysis indicated that over four decades, land under agricultural use increased throughout the period while land under shrubs decreased throughout the years 1991–2017. Similar findings with the historical timeline analysis of land use land cover change discussed with a focus group or key informants, which state that population pressure resulted in expansion of extensive agriculture, which caused the loss of vegetation cover, and it is the actual situation on the ground observed during the transect walk. The one-way within-subjects repeated measures ANOVA analysis revealed that the 22 factors significantly influence adaptive capacity, $F(13.93, 4052.46) = 299.21$, $p < .05$ and that the four major factors have a statistically significant difference in enhancing adaptive capacity to climate changes, $F(2.39, 695.59) = 4116.06$, $p < .05$. Agroforestry systems and practices should be encouraged in the study area to enhance adaptation to climate change by addressing food, wood, and income needs. Therefore, community should engage in tree planting activities and conservation of closure areas to ensure agroforestry systems and practices.

* **Corresponding Author:** Yohannes Horamo ✉ yohannesh2005@gmail.com

Introduction

Due to the high level of poverty, latitudinal position, considerable incomplete adaptation, and adaptive capacity or coping competence, Africa is considered one of the world's most susceptible regions to the existing and anticipated shocks of climate changes (Allen, 2003). Climate change and related failures generate a severe hazard to increased poverty and sustainable development on the African continent (De Wit, 2006). Furthermore, Africa faces many challenges at this critical point (Huq *et al.,* 2004). This may be due to the lack of attention in the countrywide growth plans, inadequate quality approach, and sectorial approaches in adaptation to climate changes (Thornton, 2015).

In Ethiopia, according to the woody biomass inventory strategic planning project (WBISPP), at one time occupied as much as 35% of the country, is now covering only about 3.6% (Inventory, 2004). This scenario is the same in the Hadiya zone (study area) as it is part of the country. From this source, one can easily understand the major problems: the annual deforestation rate that ranges between 163,000ha to 200,000ha, with a difference of 37,000ha. This was much higher than the annual average of planting, that is, 2000 hectares, and an acute lack of information about agroforestry practices, limited research and an absence of technical extension to support farm tree growing (agroforestry practices) which can contribute to climate change.

From the reviewed literature, one can understand that there is a great deal of variation in weather and climate from year to year (Connelly *et al.,* 2012). Furthermore, local temperatures do not inevitably follow globally averaged ones, possibly due to the specific local situations in particular areas. It is acknowledged that the first decade of the 21st century is the warmest on record and could continue in future (Field, 2014; Richard *et al.,* 2020). Since record-keeping of temperatures began, the years 2005 and 2010 recorded higher temperatures than previous global temperatures. Since the mid-1970s, the average global temperature has risen by about 0.6°C (1.1°F) and by almost 0.2°C per decade (Richard *et al.,* 2020). The rising temperatures are being experienced everywhere but it is more significant at high latitudes in the northern hemisphere (Srimake, 2015). It is predicted that global temperature could rise between 1.4°C and 5.8°C by the end of the 21st century (Field, 2014).

In relation to Land use land cover (LULC), Soil loss estimates indicate that Ethiopia's annual soil loss is about 1.5-3 x 10^9 tons (Adimassu *et al.,* 2012). About 50% of soil loss occurs in croplands, where soil loss has been reported to be very high (296't' $ha^{-1}a^{-1}$) on a 16% slope with a "teff" crop (*Eragrostis teff*) on nitosols (Hurni *et al.,* 2010).

This chapter focuses on land use land cover change analysis and factors influencing and enhancing adaptation to climate change. The chapter also addresses the objective relating to factors influencing the farmers' choice and decisions regarding adaptation to climate change. The problems are immense and different. Annihilation of the world's rain forests is just one of the problems that many researchers believe will reach serious magnitude in the coming decades (Srimake, 2015). All the problems mentioned above could openly or not openly be affected by climate changes. Increasing climate changes are the cause of practically all of the world's ecological inconvenience. Adaptation strategies that would not significantly alter lifestyles but would considerably lessen climate change impact are essential in the developing world (Pittock, 2013).

Atmospheric scientists have found that at least half of that temperature increase can be attributed to human activity. Plant and animal species are dying at an unprecedented rate. A large number of different species per year become extinct (Smith *et al.,* 2012).
To maintain health and be in a good physical state, good weather and climate are essential to life. It is imperative that humans should become skilled in utilizing natural resources in general and forests in particular. The study zone Hadiya has taken action to control or reduce climate changes through

agroforestry practices. In the zone, forestry development and climate change were established as a pilot project and to educate the community to support environmentally friendly activities. To this end, the land use land cover change analysis, factors influencing adaptive capacity, factors enhancing climate changes and the existing situation that will possibly continue happening in the future (that may contribute to climate changes) were investigated and presented.

This chapter focuses on land use land cover change analysis and factors influencing and enhancing adaptation to climate change. The chapter also addresses the objective relating to factors influencing the farmers' choice and decisions regarding adaptation to climate change. The problems are immense and different. Annihilation of the world's rain forests is just one of the problems that many researchers believe will reach serious magnitude in the coming decades (Srimake, 2015). All the problems mentioned above could openly or not openly be affected by climate changes. Increasing climate changes are the cause of practically all of the world's ecological inconvenience. Adaptation strategies that would not significantly alter lifestyles but would considerably lessen climate change impact are essential in the developing world (Pittock, 2013).

Atmospheric scientists have found that at least half of that temperature increase can be attributed to human activity. Plant and animal species are dying at an unprecedented rate. A large number of different species per year become extinct (Smith *et al.,* 2012).
To maintain health and be in a good physical state, good weather and climate are essential to life. It is imperative that humans should become skilled in utilizing natural resources in general and forests in particular. The study site (the Hadiya zone) has taken action to control or reduce climate changes through agroforestry practices. In the zone, forestry development and climate change were established as a pilot project and to educate the community to support environmentally friendly activities. To this end, the land use land cover change analysis, factors influencing adaptive capacity, factors enhancing climate changes and the existing situation that will possibly continue happening in the future (that may contribute to climate changes) were investigated and presented. The key findings or knowledge produced based on the critical issues mentioned above could assist the decision-makers, planners in the study area to fill the gaps regarding climate change.

Materials and methods

Description of the study area

The study location (the Hadiya zone), situated in South Nations Nationalities Peoples Regional State (SNNPRS), is one of Ethiopia's federal states. It is geographically located in 7°07'-7°92'N Latitude and 37°29'-38° 13'E Longitude (Fig 1). The zone is found in three traditional agro-climatic zones namely "Dega", "Woina Dega" and "Kolla" with an altitudinal range of 500-3200 meters above sea level with the variability of climate elements. According to Hurni *et al.,* (2010). The distribution of soil units in the Hadiya zone is eutric nitosols 61 percent, chromic luvisols 23 percent, cambisols 11 percent and eutric regosols 5 percent (DAaNRD, 2016).

Design of the research

The nature of the study determines the selection of the study design. The pragmatic (matter of-factual) world outlook or rational approach was suitable for this study since it is factual-world practice-oriented and problem-centered (Creswell, 2009). This approach is appropriate for a comprehensive search for answers to the research questions. In this study, mixed-methods (triangulation design), a mix of quantitative and qualitative approaches were employed to collect and analyze data. This was to enhance the research output using two approaches: quantitative and qualitative (Creswell, 2009).

According to Hesse-Biber and Leavy (2019) since the research used both quantitative and qualitative approaches through questionnaires and interviews thus, the mixed methods design was accepted for the study. The approach and assumptions of the research thereby allowed the convergence of research findings and hence boosted research integrity. For this reason, a concurrent mixed methods design was employed. The approaches were employed to get the greatest benefits from each technique while minimizing their inadequacy and triangulating the details and clarifying the results of quantitative data through discussions and narrations. Therefore, the study used the model:

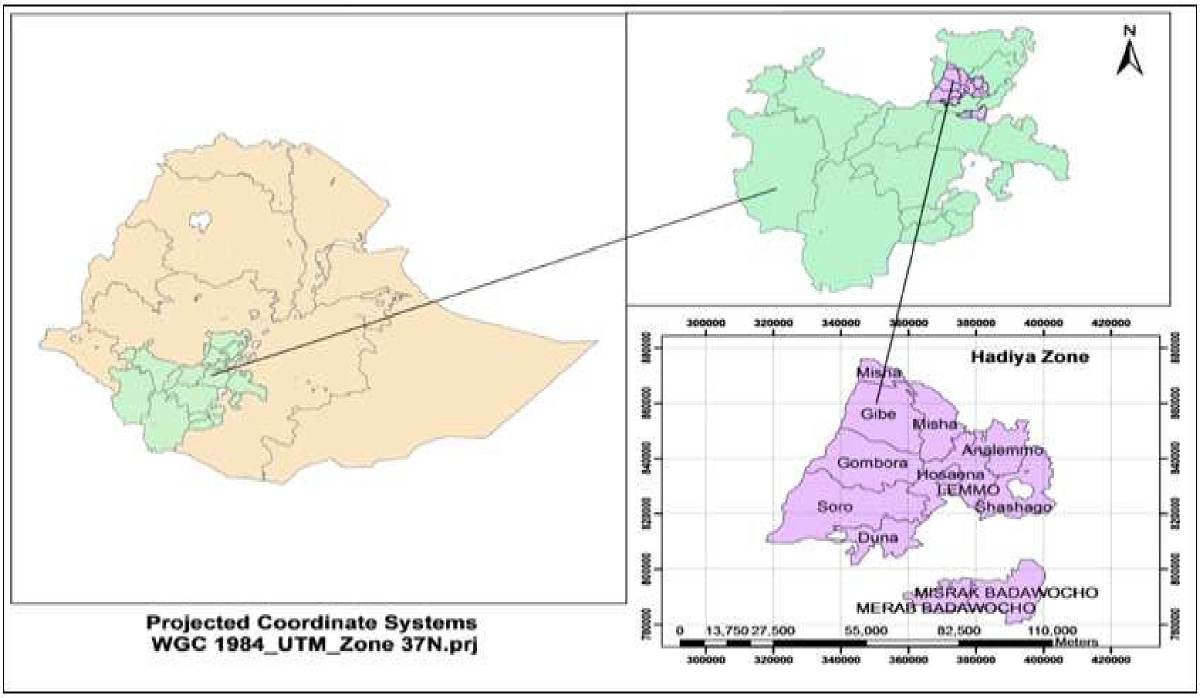


Fig. 1. Map of the Hadiya zone concerning Ethiopia and SNNPRS.
(Source: Survey of this study).

Agricultural crops and vegetation

In the Hadiya zone, all-natural vegetation and grazing lands have been converted into cultivated land. What remains in the area are the retained scattered trees in all land-use types. Farmers are already acquainted with plant tree species to replace the former natural vegetation to meet wood, construction, and fuel demands. These trees are predominantly made up of the exotic *Eucalyptus* species. The zone practices mixed farming, with complete integration of trees, crop and animal components. Farmers grow major crops like wheat, "teff", maize, potatoes, "enset" and "chat" during the "maher" season from mid-June to August. The minor crops in the study area are barley, sorghum, legumes, coffee, fruit, sugarcane and vegetables (DAaNRD, 2016).

Sample size determination

The sample size was calculated using the statistical application indicated below. The techniques for calculating the sample size and precision considerations were considered. Heads of households were listed based on wealth category. Proportional respondents were sampled randomly from each wealth category.

According to Daniel (1999), the following formula was used:

$$n = \frac{N}{1+N\,(e)^2}$$

Where, n= sample size, N = population size, e = the desired level of accuracy, where e equals 1– accuracy (0.05 level of tolerable error) point of accuracy = 95% (0.091 = a theoretical or statistical constant). n = 86,902/1+ 86,902 (0.091*0.091), n= 86,902 /719.635462 = 121. As shown above, the sample size calculated was 121 households. Though considering this fact, the researcher tried to take 292 households from purposively selected 4 Woredas and 12 kebeles/PAs (peasant associations) proportionally. The researcher aimed to achieve the statistical principle, which asserts that the more the population sizes, the more the precision is and to arrive at the level of idea saturation.

Source and methods of data collection

The primary data collections were carried out by employing a checklist and structured questionnaires, interviewing focus groups, and sample households. Twelve focus groups (consisting of six to eight members) of community strata (male, women and youth) from four locals were interviewed. The sample size of 292 households was proportionately from each wealth status (the poorest and poor, medium and better off) based on agroforestry systems and practices practitioners' categories were interviewed.

Moreover, transect walks that are the actual field observations by dividing the catchment into upper, middle and lower areas were used in data collection.

Data analysis

Data were analysed using Statistical Package for Social Science (SPSS) software version 23. Data were organised; results are presented as descriptive and inferential statistics showing the number of households corresponding to their answers, usually expressed as means and standard deviations. The focus group discussions using prioritizing techniques to identify critical issues, intervention points and implications on adaptation to climate change.

The (LULC) changes by ArcGIS-10.3 software to look for changes through time and its influences on climate change in the Hadiya zone. Spatial data analysis was performed to get important information from the acquired Landsat TM and ETM+ satellite images derived from the years 1991, 2000, 2010 and 2017 as it has been purposively designed to carry out study for the last four decades. To generate images, ENVI 4.7 was used at different stages. Image classification and analysis procedures were used to identify and classify pixels in the data digitally in the image pre-processing techniques used in the study. The classification was implemented on multispectral data sets, and the process assigns each pixel in an image to a particular class or theme based on spectral characteristics of the pixel reflectance values. Finally, the supervised classification method and maximum likelihood technique were carried out using training areas and test data for accuracy assessment to compare the changes in the spatial trends of land use and land cover. The classified land use and land cover were cross-checked with ground truth using a global positioning system. Land use and land cover classification accuracy were assessed to examine whether the classification result reflects the reality on the ground. The classified images were exported to ArcGIS 10.3, and land use and land cover maps of the years were produced. Moreover, the classified land use and land cover maps were used to detect or analyze change that occurred over the past 40 years.

Results and discussion

Land use and land cover change analysis

Historical timeline assessment of land use land cover change (LULC) in the Hadiya zone was investigated through focus group discussions. LULC change, agroforestry related physical components (livestock, crop and tree and forest cover), water resources, policy and political situations, land possession and infrastructure, were critically discussed, and the results are summarized in (Table 1). From these results, one can easily see that the historical background of vegetation cover results from focus group discussions and Landsat image analysis results are reasonably in agreement. The trend of vegetation cover assessed by the woody biomass inventory strategic planning project (WBISPP) (FAO, 2005) indicated that the vegetation cover of the Hadiya zone was falling from time to time, which was also in harmony with this study findings. The overall result (Table 1) agrees with the finding that states that human activities are responsible for the global warming observed since the 1950s (Winkler, 2010).

Forms of land use land cover change

The primary eight lands use land cover change forms recorded during observation through transacting walk (Table 2) were also in agreement with Landsat image classification forms (Table 3).

Table 1. Analysis of land use land cover change and related issues.

In the past four decades, from 1950 to 1990	In the last two decades, from 1991 to now
The livestock component:	The livestock component:
* There were high livestock numbers. This may be due to gazing land and fodder availability. * There were several different types of livestock diseases in the area that led to associated low livestock productivity. * Water and adequate grazing land and fodder were available; hence livestock numbers were high, but there were no domestic animals' health services. * There were a high number of equine animals like horses, donkeys and mules and this assisted farmer with labour availability. This is mentioned in the relative term.	* There is a decline in livestock records due to the drop in grazing land leading to unavailability of animals feed or fodder. * There is decline in the number of bees - due to scarcity of bee forage due to considerable forest losses; and extensive use of pesticides and herbicides. * There is increased livestock productivity per unit through existing improved and easily accessible veterinary and related services. * The low number of non-ruminant (draught) animals or equines (horses, donkeys and mules) challenged labor availability for farmers, which adds labor costs.
The crop component:	The crop component:
* Lack of fertilizer, related agricultural inputs and professional support influenced farmers to cultivate limited land, thus resulting in less crop production and productivity. * Limited access to a market for their farm products was one of the main reasons not to allocate more land for crop cultivation. * Farmers did not grow a wide variety of crops thus there is no improved seed supply hence low productivity. * There was enough cow dung to use as a source of fertilizer for the land they put under crop cultivation. * Households had large land holding, so farmers practiced fallow phases, which assisted in maintaining and sustaining the soil productiveness of land.	* An increasing crop production plus productivity due to the adoption of modern farming techniques by farm community and professionals follow-up. * Relatively farmers had more right to use farm inputs like better seeds, inorganic fertilizer plus herbicides and pesticides, increasing crop production and productivity. * Increasing a wide range of trees, livestock, and crop types by farmers implies diversified and strengthened farming systems. * A more significant amount of fragmented land resulted in a decrease in land holding, thereby less land under crop farming and production. * Due to fragmented households' land holding, farmers practiced continuous farming, depleting soil fertility, leading to agroforestry adoption.
The forest and tree cover and water resources:	The forest and tree cover and water resources:
* These decades have a high proportion of the land covered with natural forests and no population pressure that led to no need to look for conversion of forest land to cultivation. * There were a high river water flow and more springs. These may be due to the presence of high forest and tree cover that availed enough tree products and services * Rainfall was high, regular and evenly distributed in the area and permanent flow of rivers, streams, and springs because of available forest cover and moderate climate. * In these decades, there was a harsh drought in 1983 that caused the death of humans, domestic and wild animals. * There were uniform flow and volume of rivers, no flooding. This may be due to high forest/tree density. * Wild animal numbers were high, which enhanced soil fertility through their dung, but wild animals destroyed crops. * High availability of forest resources due to this there was fruits, fodder and fuel-wood. * There were high densities of trees, many springs, a high volume of river water flow, and better rainfall distribution, more prolonged period, high intensity.	* There was a decrease in forest cover due to population pressure, which led to the alteration of forest land into built-up land and land for crop cultivation. * Deforestation led to tree product scarcity, thereby leading to planting trees on farmland (agroforestry) farmers wanted tree products and services. * Irregular flow of rivers and varying volume, the disappearance of tributaries may be due to deforestation. The majority of the permanent and primary water sources become seasonal, and some vanished utterly. * There are a reduced number of springs, and its discharge is known to decrease from time to time. * There is flooding and a sharp reduction in the volume and seasonality of rivers flow. This may be because of deforestation. * The decline of wildlife decreased rainfall intensity, distribution and duration. * Forest resources become depleted, but on-farm availability of fruits, fodder and fuel-wood increased. * Less number of sprigs, rivers flow becoming seasonal, variable rainfall with shorter duration and low intensity may be because

* There was a severe drought in 1983; the initiative of on-farm tree planting began in this era.	of no forest and low tree density. * The area's drought is cycling at every ten years is quite undeniable by all focus group members.
The political situation:	The political situation:
* Political insecurity and war were quite common. * Farmers decided settlements on their possession with no freedom of movement, which led to villagization. * In this time, main roads were constructed through joint efforts of both the government and the community participation: only a few primary schools and few farmers' co-operatives.	* Relative peace and political stability. * People living where they have got land, freedom of movement, settlement and no villagization. * Minimum of one school in each peasant associations and better roads improved accessibility through genuine participation and effort of both government and local communities.
Land possession and infrastructure:	Land possession and infrastructure:
* This era marked the end of 'landlord-tenant system by introducing privacy to use; promoted land tenure security encouraged farmers. * There were no improved infrastructures, schools, and water supply and communication facilities. * Few infrastructures and few schools (particularly grade 1 to 6) which is insignificant.	* Through the building of rural feeder roads, there was the ease of market access to agricultural products. Thus, the farmers' income increased and led to better livelihoods. * Improved infrastructures like more schools, communication and facilities of water supply scheme. * Community access to social services facilitated through rural roads that linked various "kebeles."
The policy issues	The policy issues
* The low-price disparity between crops with its low production potential. * A policy of channeling inputs to only certain areas that are focused on excess producing areas which is unfair. * There were no overall comprehensive formulations of sectoral and cross-sectoral concern into the policy. * Inconsistent sectoral and cross-sectoral policies and the concerned issues. * Generally, undeveloped comprehensive policy on forest resources and related issues.	* The relatively high price disparity between crops with its high production potential. * A policy of providing inputs to all areas that engaged in agricultural production which is fair. * There are overall comprehensive formulations of sectoral and cross-sectoral concern into the policy. * Consistency of sectoral and cross-sectoral policies and the concerned issues. * Developed a comprehensive policy on natural resources and the environment.
Summary	Summary
* Livestock: high in number but low productivity per capita * Crop: low production and productivity * Natural resources: high potential * Political issues: corrupt governance/democracy * Land ownership: not secured * Climate: predictable and relatively good	* Livestock: low number but high productivity per capita * Crop: high production and productivity * Natural resources: low potential * Political issues: better governance/democracy * Land possession: more or less secured * Climate: unpredictable and relatively bad

(Source: Survey results)

Land use and land cover change classification from landsat image

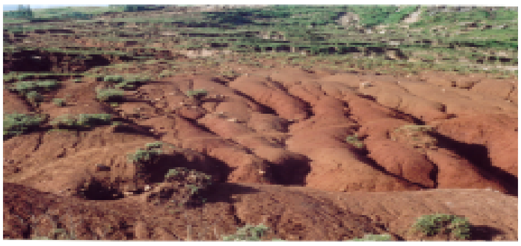
It is known that land use land cover maps offer processed data to identify with the existing landscape. To see change over time, land use land cover maps of four decades were used.

Land use and land cover categorization from ETM+ images of a satellite using supervised classification method with recoding when change is indispensable (Table 3) showed that the greater part of the Hadiya zone in 1991 was under agriculture or cropland accounting for 192,868 hectares (53.67%) and shrub land accounting for 76,818 hectares (21.38%).

Built-up area was 495.63 hectares (0.14%), grassland 57,661 hectares (16.05%), wetland 18,655 hectares (5.19%), forest land 9,021.9 hectares (2.51%), water body 1,327 hectares (0.37%) and bare land amounted to 2,487.05 hectares (0.69%).

Table 2. Major land use land cover forms in the Hadiya zone.

S/N	Land use land cover classes or type	Narrative of each land use land cover classes or types.	Pictorial presentations of each land use and land cover types
1	Crop lands 	Land under both annuals and perennials crop production, mainly of cereals in subsistence farming and the scattered trees and country built-ups incorporated within the farm fields. 	
2	Forest cover 	A forest appearance closed or nearly closed canopies and more than 0.5 hectares and the height greater than 7 to 30 meters. 	
3	Shrub lands 	Areas with short vegetation usually less than two meters tall often interspersed with grasses. 	
4	Grass lands 	Land or areas covered by grasses to mean it is land for grazing as indicated on the plate. 	
5	Water bodies 	Land covered with water like rivers, lakes, dams and public and family ponds.  	

6	Wetland 	Land that is enclosed by water at least some of the time and that ropes plants tailored to water-saturated soil. Wetland became 	
7	Built-up land 	Land that has been occupied with business, manufacturing and transportation services. . 	
8	Bare land 	Land almost without vegetation, grasses and crops which are almost denuded. 	

(Source: survey results).

The land use land cover categorization from ETM+ image of satellite for about four decades (Table 3) indicated that agricultural or cropland use land cover accounting for 192,866 hectares (53.67%) in 1991 was increasing throughout and shrub land use land cover accounting for 76,818 hectares (21.38%) in the year 1991 was decreasing throughout.

This indicated that cropland use land cover was increasing, and shrub land use land cove decreased throughout 1991, 2000, 2010 and 2017. This implies the removal of vegetation cover for the expansion of land for the cultivation of crops.

These findings agree with the focus group discussions, which state that population pressure resulted in expansion of extensive agriculture, which caused the loss of vegetation cover. While the built-up land cover is increasing throughout, the roads and built-up areas should be carefully planned and minimized because such developments may negatively impact biodiversity (Chitakira *et al.,* 2018), grassland decreases throughout.

However, forest land cover decreasing from 1991, 2000 and 2010 while increasing in 2017 may be because of the millennium plantations and shrub land grown or improvement through plantations management. The water body is increasing slightly throughout; this also might be due to constructed water harvesting structures like public and family ponds, constructed dams, lake spreading out caused by siltation and the flood and dams that increased the area of rivers. For example, it has been observed that Gibe River increased the area of land cover due to a dam constructed for hydropower generation (Fig 3).

Table 3. Land use land cover change in the Hadiya zone.

S/N	LULC Types	1991		2000		2010		2017	
		ha	%	ha	%	ha	%	ha	%
1	Built-up area	495.63	0.14	785.81	0.22	2450.8	0.68	4925.5	1.37
2	Bare land	2487	0.69	2673.4	0.74	2538.9	0.71	3545.4	0.99
3	Forest	9021.9	2.51	7602.5	1.72	5737.6	1.6	8243.4	2.29
4	Water body	1327	0.37	1473.3	0.41	1650.3	0.46	2857.4	0.8
5	Grass land	57661	16.05	40818	11.44	39655	11.36	36973	10.29
6	Crop land	192866	53.67	228013	63.45	230972	64.28	235100	65.43
7	Wetland	18655	5.19	12194	3.39	10256	2.85	10177	2.83
8	Shrub land	76818	21.38	66934	18.63	64907	18.06	57509	16
Total		359331	100	359331	100	359331	100	359331	100

(Source: Research results)

The wetland land cover is decreasing all the way through; this may be because of the erratic rainfall and droughts occurring almost every ten years. The fact that water-saturated land cover is changing from wetland to grazing land was discussed and identified within a focus group and also observed during the transect walk. McKee (2008) agrees and states that in general Ethiopian history is punctuated by drought and famine, which affected large parts of the country, covering hundreds of thousands of square kilometers and millions of households.

The bare land amounted to about 0.69% in the year 1991 and is increasing throughout in years 2000 and 2017 except a minor decrease in 2010. This indicated that bare land is generally increasing, which is contributing to desertification (the degradation of productive land to bare land).

Table 1. LULC change accuracy analysis result of 1991, 2000, 2010 and 2017.

LUCC change types	Reference Totals	Classified totals	Number correct	Producers accuracy	Users accuracy
Bare land	0	0	0	---	---
Crop land	38	36	35	92.11%	97.22%
Shrub land	8	11	7	87.50%	63.64%
Forest land	1	2	1	100.00%	50.00%
Water body	0	0	0	---	---
Wetland	5	3	3	60.00%	100.00%
Built-up area	0	0	0	---	---
Grass land	6	6	5	83.33%	83.33%
*1991, Overall Classification Accuracy = 87.93% and Overall Kappa Statistics = 0.7811					

LULC change types	Reference totals	Classified totals	Number correct	Producers accuracy	Users accuracy
Forest land	4	3	3	75.00%	100.00%
Grass land	4	2	2	50.00%	100.00%
Bare land	2	2	1	50.00%	50.00%
Wetland	4	2	2	50.00%	100.00%
Built-up area	0	0	0	---	---
Shrub land	12	17	12	100.00%	70.59%
Crop land	32	32	30	93.75%	93.75%
Water body	0	0	0	---	---
*2000, Overall Kappa Statistics = 0.7795 and Overall Classification Accuracy = 86.21%					

LULC change types	Reference total	Classified totals	Number correct	Producers accuracy	Users accuracy
Bare land	0	0	0	---	---
Wetland	5	3	2	40.00%	66.67%
Shrub land	33	36	32	96.97%	88.89%
Grass land	8	11	8	100.00%	72.73%
Crop land	25	22	22	88.00%	100.00%
Built-up area	1	1	1	100.00%	100.00%
Water body	1	1	1	100.00%	100.00%
Forest land	1	1	1	100.00%	100.00%
*2010, Overall Classification Accuracy = 89.33% and Overall Kappa Statistics = 0.8413					

LULC change types	Reference totals	Classified totals	Number corrected	Producers accuracy	Users accuracy
Wetland	4	2	2	50.00%	100.00%
Built-up area	20	23	20	100.00%	86.96%
Shrub land	4	4	3	75.00%	75.00%
Water body	0	0	0	---	---
Grass land	14	9	9	64.29%	100.00%
Crop land	72	77	69	95.83%	89.61%
Forest land	3	3	3	100.00%	100.00%
Bare land	2	2	2	100.00%	100.00%
*2017, Overall Classification Accuracy = 90.00% and Overall Kappa Statistics = 0.8251					

(Source: Research results).

Moreover, the land use and land cover change categorization from the Landsat image (Table 3) illustrated that cropland cover plus shrub land cover are the dominant classes in the Hadiya zone. The shrub land is still decreasing from 76,818 hectares (21.38%) to 57,509 hectares (16%) in 2017, and agricultural land or crop cover is still increasing from 192,866 hectares (53.67%) to 235,100 hectares (65.43%). However, the cropland cover change of the year 2000, 2010 and 2017 is insignificant, indicating that the land is almost near to fully occupied or towards not having more land to be used except the bare land for rehabilitation. This agrees with the historical timeline analysis of land use land cover change discussed with a focus group or key informants, and it is the actual situation on the ground observed during the transect walk.

Remarkably what has been observed in the Hadiya zone is the ‘’enset” *Enset ventricosum* based complex agroforestry system and practice as the area is covered by forest or grown or developed shrubs. Even for those who know the area very well, the horizontal view bears a resemblance to a forest. For this matter, the interpretation of the satellite image is difficult for those who do not know the real location of the Hadiya zone without checking the coordinates. However, the interpretation of LULC change analysis is based on the result of Landsat image analysis, the researcher and the enumerators' knowledge, plus Google earth (Fig 3). Even though the shrub land was decreasing, the bare land was increasing; the bare land as a closure area, contributed to shrub land not being diminished. However, when this research was conducted, bare land was an issue to be considered. This is particularly in the low lands like Gibe valley to some extent, pastoralists' living with many livestock.

The significant reasons for land use land cover change in the Hadiya zone were clearing vegetation or deforestation for different functions. Landsat image analysis and focus group results revealed that land use land cover change in the Hadiya zone is changing. The major causes for the alteration were extensive cultivation, settlement, illegal cutting of forest for different functions, and overgrazing.

Accuracy assessment of LULC change

Classification accuracy can be affected by the lack of high resolution of images used and lack of previous knowledge of the area. To assess the change accuracy image to image accuracy assessment with random point generation method and Google earth was used to indicate the nature of the classification error. As shown in (Table 4*) the overall accuracy for 1991 is 87.9%, for 2000 is 86.2%, for 2010 is 89.3% and for 2017 is 90%. The kappa coefficient for 1991 is 0.7811, for 2000 is 0.7795, for 2010 is 0.8413 and for 2017 is 0.8251. This shows that classes of land use land cover of each ten years are acceptably classified. Based on assessment made, producer and user accuracy of all land use land cover classes are indicated in (Fig 4).

Table 5. Analysis of factors influencing adaptation to climate change.

Factor	Mean	Standard Deviation
Access to training	3.80*******************	.60
Extension service	3.84*******************	.43
Land use land cover	3.90*******************	.41
Access to credit	2.92*****************	.50
Access to media	2.92*****************	.53
Technology	2.73**********	.66
Environment	2.60****	.49
Family size	2.62***	.67
Land holding	2.60***	.65
Farm income	2.62***	.68
Livestock quantity	2.61***	.69
Credit facilities	2.60***	.69
Government policies	2.62***	.65
Literacy status	2.53**	.66
Farming experience	2.55**	.64
Off/non-farm income	2.50**	.70
Economic conditions and market distance	2.53**	.66
Distance from nurseries	2.48**	.68
Tree management practices	2.53**	.78
Private insurance	2.40**	.68
Farmer to farmer extension	1.78	.69
Sex	1.69	.64

N=292, *p< .05 (Source: Survey results).

Impacts of land use and land cover change

The farmers in the Hadiya zone reported high variability of rainfall and rainy season recently compared to two decades ago. Also, the data obtained from NMA indicated that the mean annual temperature of the Hadiya zone increased from 16.72°C in the year 1991 to 17.6°C in 2017.

The trend of increasing temperatures (almost an average of 0.22 °C in every decade) is in agreement with the study of Getachew and Geta (2014). The study indicated that the average annual minimum temperature over the country has increased by about 0.25 °C every ten years, while the average annual maximum temperature has increased by about 0.1°C every decade. Furthermore, the warming is occurring everywhere but is more significant at high latitudes in the northern hemisphere (Srimake, 2015).

With regard to rainfall the total rainfall of the zone varies (fluctuating or increasing-decreasing fashion) in the years 1991 to 2017.

Table 6. Analysis of factors enhancing adaptation to climate change.

Factors	*M	*SD
Weather and climate information systems	3.78***	.11
Resource management	3.39**	.17
Farm production practices	2.97*	.15
Farm financial management to reduce the risks of climate-related income loss	2.56	.16

n=292, *p< .05 *M (Mean) *SD (standard deviation)

(Source: Survey results).

One of the reasons for these climate changes may be land use land cover change, which is statistically significant (Table 5) which will contribute to a lesser amount of agricultural efficiency since the agricultural system of the Hadiya zone is hugely reliant on rainfall or rain-fed agriculture. Thus, it is probable to confirm that climate change is due to change in land use and land cover. As revealed by Landsat image analysis results on land use land cover change and focus group discussions, climate changes showed an increase of agricultural land in the Hadiya zone. The total cropland was higher than in the past four decades (1991, 2000, 2010 and 2017) as shown in (Table 3).

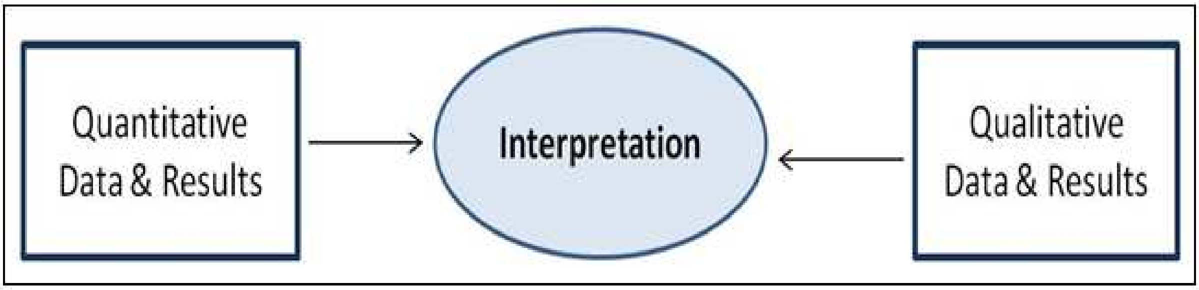


Fig. 2. Coexisting mixed design of the research.

(Source: Creswell and Clark, 2011).

Moreover, focus groups, or critical informants, described that after the year 2000, farming practice changed from sole crop growing to the mixed farming system because of the beginning of agroforestry systems and practices in the Hadiya zone that reduced the possibility of sole crop cultivation. It is possible to substantiate that land use and land cover change may be one of the cases that cause climate changes mainly (increase in temperature and variation in precipitation). The findings from focus group discussions and the Landsat image analysis for land use land cover change results are the same as that of Jose (2009); Smith *et al.* (2012) and James, (2014). Agroforestry systems and practices (establishing trees alongside crops and pastures in a mix) as a land management approach can assist in keeping the balance between farming production, ecological strengthening and carbon confiscation to counterbalance releases from the sector. Agroforestry may improve productivity and improve the quality of air.

In summary, land use and land cover changes degrade the vegetation capability for continued use and retrieval of its original cover. Notably, changes in land use and land cover have considerable pressure on the environment. This is because SPSS based data analysis revealed that land use land cover change is a highly statistically significant influencing factor (M = 3.90, SD =.41) in adaptation to climate change (Table 5).

Agroforestry is a critical habitat that has the potential to provide farmers, communities and society at large with a wide array of tree-related goods and services. Agroforestry is now being recognized as an integrated land use that can immediately enhance plant variety while reducing habitat loss and disintegration (Ong *et al.,* 2015). Based on the findings stated above, land use land cover change has an impact on adaptation to climate change through agroforestry systems and practices in the Hadiya zone since agroforestry is an integrated land-use system.

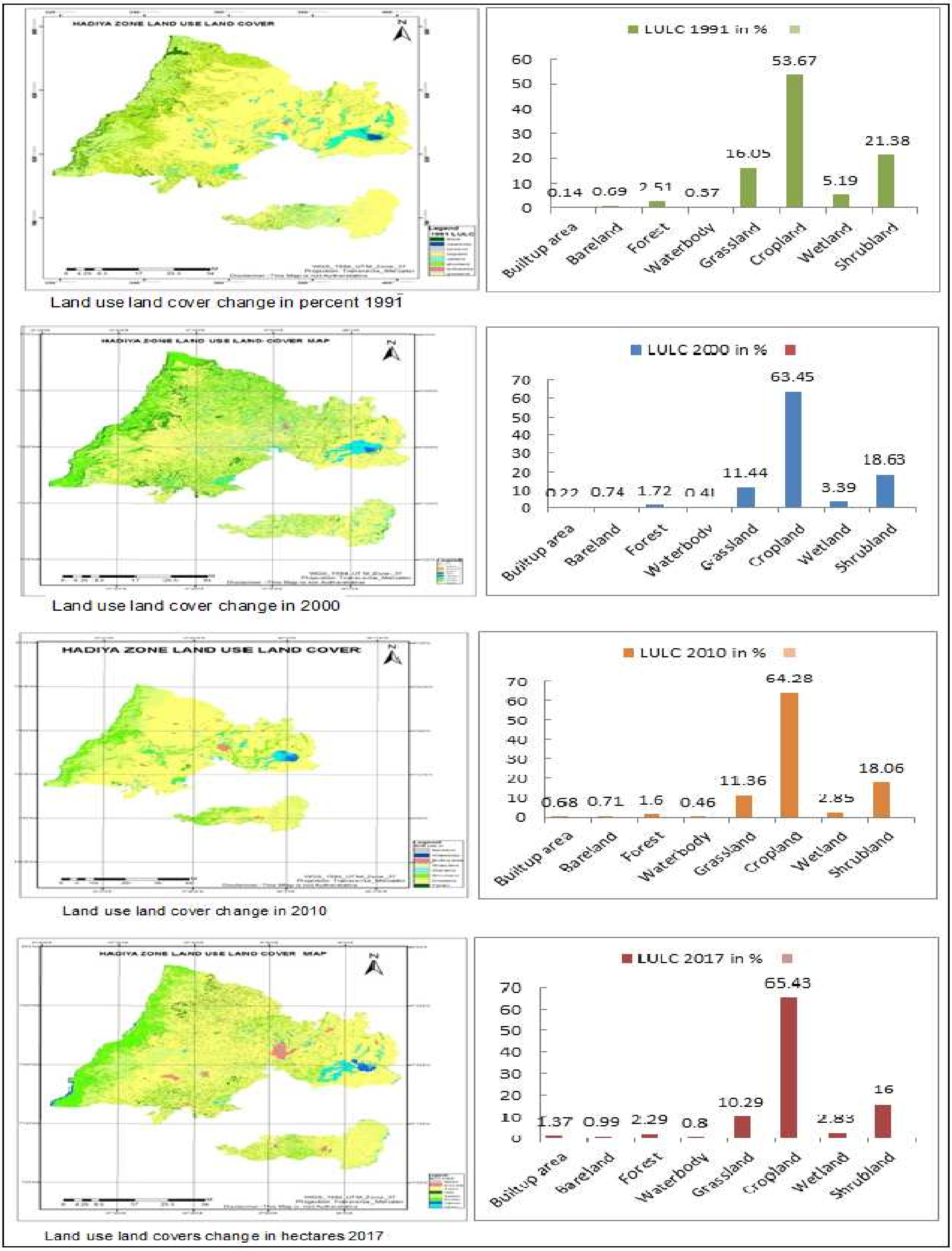


Fig. 3. Land use land covers changes of 1991, 2000, 2010 ad 2017 in hectares.
(Source: Research results X= LULC types and Y=Percent)

Factors influencing adaptive capacity

The respondents rated 22 items to investigate the factors influencing adaptive capacity (Table 5). The factors identified were sex, literacy status, farming experience, family size, landholding, access to credit, access to training, access to media, extension service, farmer to farmer extension, farm income, off/non-farm income, livestock quantity, economic conditions and market distance, credit facilities, distance from nurseries, tree management practices, land use, private insurance, technology, government policies and environment (soil, water, pests). The totality of the surrounding physical or biological and abiotic or biotic factors may positively or negatively influence climate changes. The negative influences have to be minimized through adaptation and mitigation and the positives influences have to be enhanced as much as possible to tackle the problems caused by climate change, which is a global problem. After doing different analysis and presentation options exhaustively, the analysis below was regarded as fit for the purpose.

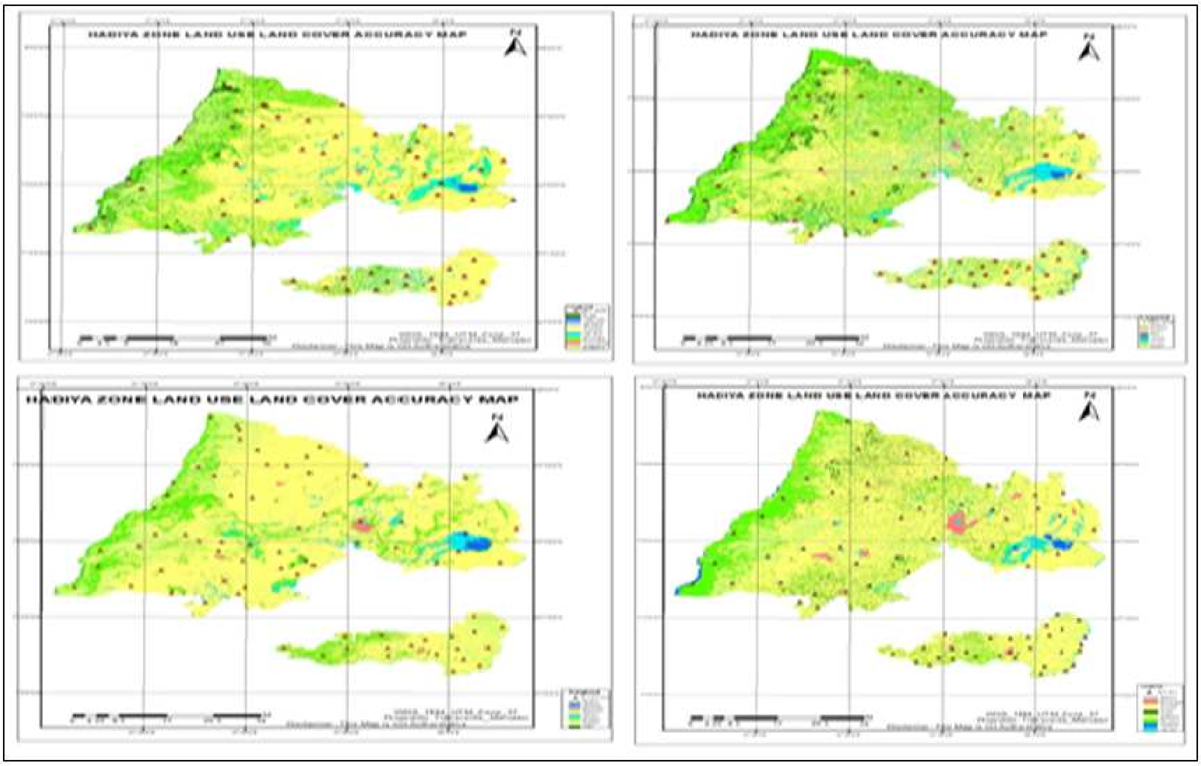


Fig. 4. Maps of accuracy analysis.

(Source: Research results)

These factors were selected and investigated by the researcher. This is because the researcher's assumption was related to adaptation to climate change, specifically in the study location (the Hadiya zone) and generally in South Nations Nationalities Regional State and the country (Ethiopia). Conceptually, one can see that the following factors play an important role in adaptation to climate change through agroforestry practices (an integrated operation of farm practices with trees being the pillar component): Access to natural resources, credit, training, media, nurseries and market; Facilities like insurance and credit; Farm experiences like extension services, farmer to farmer extension, land use land cover change manipulation and tree management practices; Economic capacities like farm income, off/non-farm income, and Livestock production, literacy, technology and environment (water, soil and pests, *etc.*) in operation by households (male and female-headed family members).

The one-way within-subjects repeated measures ANOVA analysis was used to observe the significance of these 22 factors in influencing adaptive capacity.

The one-way within-subjects repeated measures ANOVA analysis revealed that the 22 factors significantly influence adaptive capacity, $F(13.93, 4052.46) = 299.21$, $p < .05$.

Findings by different researchers on factors influencing adaptation to climate changes revealed that the impacts of climate changes on people or communities depend not just on how the climate changes but also on multiple socio-economic factors related to (i) where and how people live, (ii) how rich or poor they are (wealth status), (iii) how they earn their livings, (iv) what technologies and natural resources they rely on, and (v) what institutions, cultural practices, and policies govern them. As a result, impacts will vary among people and places, not just because they are experiencing different climate changes but also because they differ in their sensitivity to specified factors. Particular people, places and activities are responsive to specific aspects of climate in particular ways (Dessler and Parson, 2010). The impact of climate changes in the agriculture sector of moist and sub moist tropics (like Ethiopia) have negative consequences. Agriculture, mainly in the sub-moist areas, is susceptible to many biological factors, including recurrent overflow, famine, and high heat, Rao (2010) supports these thoughts.

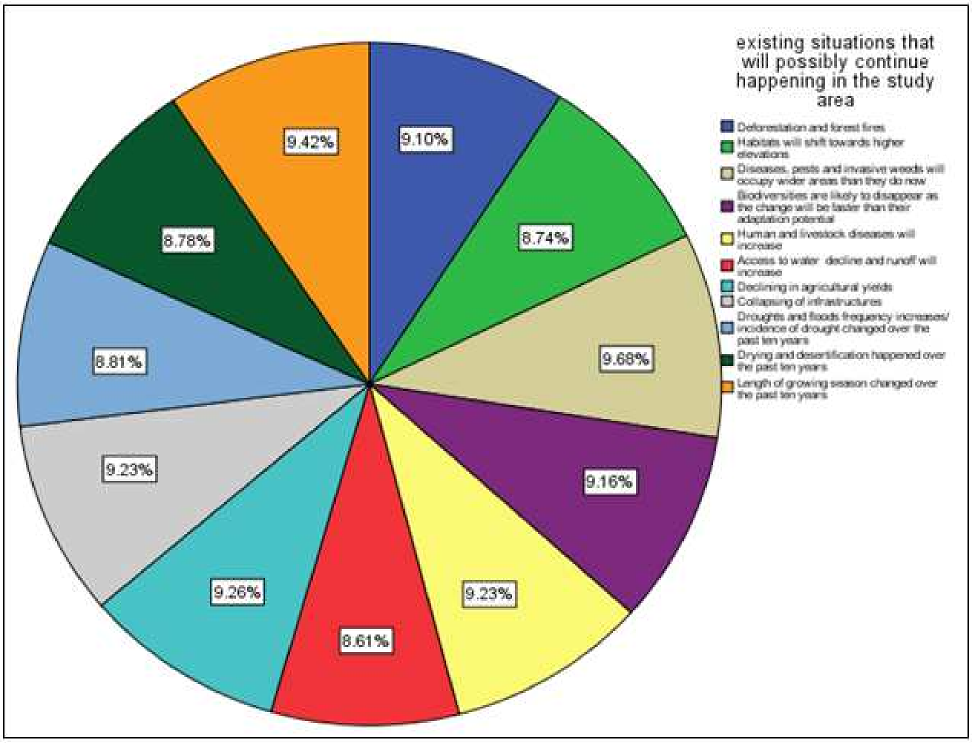


Fig. 5. Existing situation that could continue happening.
(Source: Survey results)

As can be seen from (Table 5), the related samples t-test result with Bonferroni adjustment for the number of comparisons revealed that the first five factors like access to training (M = 3.80, SD = .60), extension service (M = 3.84, SD = .43), land use land cover (M = 3.90, SD = .41), access to credit (M = 2.92, SD = .50) and access to media (M = 2.92, SD = .53) had the highest statistically significant influence on adaptive capacity of households as compared to others. The following fifteen factors had statistically significant influence on adaptive capacity of households: Technology (M = 2.73, SD = .66), Environment (M = 2.60, SD = .49), Family size (M = 2.62, SD = .67), Land holding (M = 2.60, SD = .65), Farm income (M = 2.62, SD = .68), Livestock quantity (M = 2.61, SD = .69), Credit facilities (M = 2.60, SD = .69), Government policies (M = 2.62, SD = .65), Literacy status (M = 2.53, SD = .66), Farming experience (M =

2.55, SD = .64), Off/non-farm income (M = 2.50, SD = .70), Economic conditions and market distance (M = 2.53, SD = .66), Distance from nurseries (M = 2.48, SD = .68), Tree management practices (M = 2.53, SD = .78), and Private insurance (M = 2.40, SD = .68). On the other hand, sex (M = 1.69, SD = .64 and farmer to farmer extension (M = 1.78, SD = .69) were found to be statistically insignificant or the least influencing factors.

The results from the investigation are similar to various researchers' findings. Hazell *et al.* (2007) state that for any enhancement of farming practices, the indispensable public goods funded by the state, like literacy status, agricultural research and extension, and the maintenance of rural roads, should be in place. Transportation of better planting material, fertilizers, tools, and extension services to remote fields requires well-maintained roads in good condition.

The inaccessibility of services like credit facilities takes time and consumes money and reduces the availability of a workforce for farming (Watanabe, 2014). Furthermore, Thomas (1990) cited by Garrity (2012) argue that considerations concerning social (demographic factors, land ownership, availability of markets, infrastructure), economic (financial incentives, economic benefits) and environmental (soil erosion, water quality, worldwide climate change) limitations are indispensable to the success of agroforestry systems and practices programmes. Watanabe (2014) also stated that inadequate access to capital and credit is commonly considered as a significant constraint for increasing household production and income to invest in more efficient land use.

Factors enhancing adaptive capacity

To investigate the factors enhancing adaptive capacity 25 items categorized under four themes (Table 6) based on their similarity that refer to the factors enhancing adaptive capacity were rated by the respondents. The four themes are resource management, farm production practices, farm financial management to reduce the risks to climate-related income loss and weather and climate information systems. For the 25 items, the higher the rating scores for the themes, the higher their value in enhancing adaptive capacity.

The one-way within-subjects repeated measures ANOVA analysis was used to observe the difference between the four significant factors or themes enhancing adaptive capacity. The one-way repeated measures ANOVA revealed that the four major factors have a statistically significant difference in enhancing adaptive capacity to climate changes, $F (2.39, 695.59) = 4116.06$, $p< .05$.

As can be seen from (Table 6), the related samples t-test result with Bonferroni adjustment for the number of comparisons revealed that weather and climate information systems (M = 3.78, SD = .11) are found to be the essential factor in enhancing adaptive capacity followed by resource management (M = 3.39, SD = .17).

The farm production practices (M = 2.97, SD = .15) and farm financial management to reduce the risks to climate-related income loss (M = 2.56, SD = .16) are the third and fourth vital factors rated by the respondents as enhancing the adaptive capacity to climate changes.

These findings are quite similar to findings which state that the ability to adapt to climate changes depends on the stage of development. Under-development limits adaptive capacity because of a lack of resources to respond to severe but expected proceedings. Thus enhancing adaptive capacity requires similar action as an endorsement of sustainable development (Pittock, 2013).

It is also compatible with Erickson *et al.* (2012) who argue that evident farming productivity is susceptible to two broad classes of climate-made issues and similar to low-revenue of rural populations that rely on traditional farming systems or on marginal lands more susceptible (Rao, 2010).

The existing situation that could possibly continue
An investigation of existing eleven critical situations (Fig 5) which could cause or affect climate changes (that may have sound effects on temperature increment and rainfall variations) in the future was carried out. From this investigation, the pie chart results (Fig 5) indicated that diseases, pests and invasive weeds could have the highest chance (9.68%) of continuing to happen in the future followed by a change of crops growing season (9.42%), and the third is declining of agricultural yield (9.26%).

The fourth is an increase in human and livestock diseases (9.23%) in comparison to other factors. According to the results, declining access to water and an increase in runoff have the least chance (8.61%) of continuing in the future. Almost all situations will occur, but those with the highest chance are diseases, pests and invasive weeds (9.68%). The least chance is declining access to water and an increase of runoff (8.61%) with a range of 1.07%. From the results, one can conclude that all situations are reasonably critical to the climate changes in the Hadiya zone.

Conclusions
Ethiopia in general and the study area in particular is experiencing change at many levels (climatic, agricultural, socioeconomic), which have an impression on the land surface that a range of long-term satellite observations can characterize. Land use land cover change analysis of the Hadiya zone showed how much of the zone is covered by cropland, shrub land, grassland, forest land, wetland, water body, built-up land and bare land. Land use shows how people use the landscape for development or diverse uses. The different types of land use land cover can be dealt with or used quite differently in the Hadiya zone. These have been investigated facts through Landsat image analysis and observation through transect walk.

Land use land cover change information can assist the planners or landscape managers to understand the current landscape condition. To witness variation over time, data about land use land cover change for several different consecutive decades are required. Maps of the LULC changes can assist executives in assessing built-up land, map loss of wetland and water body and potential bare land to prioritize areas for protection. It has been revealed that land use land cover analysis results in agricultural expansion progressively put pressure on the environment in the Hadiya zone. Over the past four decades, ever-increasing extents of land were converted into agricultural production areas and towns were built up, often targeted to be used at local, and zone levels for farming purpose caused clearance of vegetation in the Hadiya zone. Such human interferences affected land uses land cover at a high level in the Hadiya zone. An assessment shows that land conversions related to environment and climatic conditions were not studied before, despite its importance in the development of agriculture. Hopefully, this research may assist in filling the gap in the Hadiya zone.

The current trends in land use and land cover change must be improved towards the proper management and protection of the existing natural resources in the Hadiya zone through community involvement and sustainable land use management. This will assist in increasing tree planting that enhances or improves agroforestry systems and practices and, in turn, adaptation to climate changes. Also, the most important constraints expressed by farmers were: (i) Shortage of livelihood assets (natural, financial, human, social and physical) which is directly related to adaptive capacity and adaptation to climate change. (ii) Shortage of quality planting materials is most important in the Hadiya zone and has to be improved as it plays a significant role in the expansion of tree planting. Moreover, the needs for tree planting may change through time; hence needs assessments may need to be carried out regularly.

In the wake of the increasing population pressure on natural resources in general, land scarcity and rising amounts of youths without land, other streams of job like manufacturing and service provision and interrelated actions should be developed by the government in the study area so that pressure on the remaining natural forest will be reduced. The Agriculture and Natural Resources Development Department of the Hadiya zone and other stakeholders (governmental and non-governmental organizations) should help in resolving the confrontation associated with livelihood assets (which are directly related to the adaptive capacity to climate change) and properly manage them in such a way to have a substantial influence on adaptation to climate change.

Data availability statement

The datasets presented in this article are not readily available because Ethical clearance given may not permit sharing of datasets with a third party. Requests to access the datasets may be directed to *john@wcu.edu.et* yohannesh2005@gmail.com

Ethics statement

The studies involving human participants were reviewed and approved by College of Agriculture and Environmental Science Ethics Review Committee, University of South Africa. The participants provided their written informed consent to participate in this study.

Author contributions

Yohannes Horamo (YH) (Ph.D.) and Munyaradzi Chitakira (MC) (Professor): project conception. YH, MC and Kowiyou Yessoufou (KY) (Associate professor): draft and final manuscript. MC and KY: manuscript quality control and supervision. YH: data collection and analysis. All authors contributed to the article and approved the submitted version.

Funding

The logistical support by the University of South Africa and Wachemo University (particularly office of research and community services) is greatly appreciated.

Acknowledgments

Researchers are grateful to the farmers of Misha, Sorro, Badawacho and Lemo Woredas who devoted their precious time to share their immense locally adapted knowledge and their experience during my study period. Many thanks to the enumerators (who assisted in data collection, as well as the staff of Hadiya zone and four Woredas (Misha, Sorro, Badawacho and Lemo) office of agriculture and natural resources for their unreserved cooperation and support in this study.

Conflict of interest

We all authors assure that it is our original work. So that, we all authors would like to confirm that no conflict of interest.

References

Adimassu Z, Kessler A, Hengsdijk H. 2012. Exploring determinants of farmers' investments in land management in the Central Rift Valley of Ethiopia. *Applied Geography*, **35(1-2),** 191-198 p. http://dx.doi.org/10.1016/j.apgeog.2012.07.004

Allen K. 2003. 11 Vulnerability reductions and the community-based approach. *Natural disasters and development in a globalizing world*, 170 p.

Chitakira M, Torquebiau E, Ferguson W, Mearns K. 2018. Analysis of landscape performance assessment by key stakeholders in a transfrontier conservation area. Landscape Research **43(5),** 665-678. https://doi.org/10.1080/01426397.2017.1355052

Connelly J, Smith G, Benson D, Saunders C. 2012. Politics and the environment: from theory to practice. Routledge. https://doi.org/10.4324/9780203135495

Creswell JW. 2009. Editorial: Mapping the field of mixed methods research. Journal of Mixed Methods Research *3***(2),** 95-108 p. https://doi.org/10.1177/1558689808330883

Creswell JW, Clark VP. 2011. Designing and conducting mixed methods research. Retrieved on July *25*, 2014 p.

Daniel WW. 1999. Probability and t distribution biostatistics: A foundation for analysis in health science. 83-123. John Wiley and Sons.

DAaNRD (Department of Agricultural and Natural Resources Development) 2016. Five Years Development Report.

Dessler A, Parson EA. 2010. *The science and politics of global climate change: A guide to the debate*. Cambridge University Press.

De Wit M. 2006. Climate change and African agriculture. *Policy Note, 27*.

Erickson P, Thornton P, Notenbaert A, Cramer L, Jones P, Herrero M. 2012. Mapping Hotspots of Climate change and Food Insecurity in the Global Tropics| CGIAR Climate.

FAO. 2005. *Global Forest Resources Assessment*. Food and Agriculture Organisation of the United Nations, Forestry Department. Country Report, Ethiopia.
https://doi.org/10.1007/978-3-642-32292-1_19

Field CB. ed. 2014. *Climate change 2014–Impacts, adaptation and vulnerability: regional aspects*. Cambridge University Press.

Garrity D. 2012. Agroforestry and the future of global land use. In *Agroforestry-The future of global land use* (21-27 p). Springer, Dordrecht. https://doi.org/10.1007/978-94-007-4676-3_6

Getachew R, Geta E. 2014. *Climate change Adaptation Strategies of Agropastoral Households: The Case of Babile Woreda, Somali Regional State, Ethiopia* (Doctoral dissertation, Haramaya University).

Hazell PB, Poulton C. Wiggins S, Dorward A. 2007. *The future of small farms for poverty reduction and growth* **(42),** Intl Food Policy Res Inst.
https://dx.doi.org/10.2499/97808962976472020vp42

Hesse-Biber SN, Leavy P. 2019. "Focus group interviews." The practice of qualitative research 163-192.
https://dx.doi.org/10.4135/9781526421036821959

Huq S, Reid H, Konate M, Rahman A, Sokona Y, Crick F. 2004. Mainstreaming adaptation to climate change in least developed countries (LDCs). *Climate Policy*, **4(1),** 25-43 p.

Hurni H, Abate S, Bantider A, Debele B, Ludi E, Portner B, Yitaferu B, Zeleke G. 2010. Land degradation and sustainable land management in the highlands of Ethiopia.

Inventory WB, Strategic Planning Project (WBISPP) 2004. Forest Resources of Ethiopia. Development Report.

James Ford D, Lea Berrang-Ford, Anna Bunce, Courtney McKay, Maya Irwin. 2014. The status of climate change adaptation in Africa and Asia. Springer, Netherlands.
https://doi.org/10.1007/s10113-014-0648-2

Jose S. 2009. Agroforestry for ecosystem services and environmental benefits: an overview. Agroforestry systems **76(1),** 1–10 p.
https://doi.org/10.1007/s10457-009-9229-7

McKee J. 2008, October. Deconstructing some myths about climate change adaptation and mitigation. In *Climate change–a burning issue for Ethiopia: Proceedings of the 2nd Green Forum Conference held in Addis Ababa* **31.**

Ong CK, Black C, Wilson J. eds. 2015. *Tree-crop interactions: agroforestry in a changing climate*. CABI.
https://doi.org/10.1079/9781780645117.0000

Pittock AB. 2013. *Climate change: the science, impacts and solutions*. Routledge.
https://doi.org/10.4324/9781315870359

Rao PK. 2010. Institutions and Policy Design. In *The Architecture of Green Economic Policies* 65-86. Springer Berlin Heidelberg. https://doi.org/10.1007/978-642-05108-1

Richard T, Wright B, Dorothy F. 2020. *Environmental science: Toward a sustainable future*. PEARSON.

Smith JP, Pearce BD, Wolfe MS. 2012. Reconciling productivity with protection of the environment: is temperate agroforestry the answer? Renewable Agriculture and Food Systems **28(1),** 80–92 p. https://doi.org/10.1017/S17421705110005.85

Srimake Y. 2015. PBT 210 Introduction to Environmental Science syllabus.

Thornton PK, Boone RB, Ramirez-Villegas J. 2015. Climate change impacts on livestock. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Working Paper No. 120.

Watanabe T, Shibata H, Ishihara M, Yoshimura N, Kohyama T. 2014. Global Land Project Sapporo Nodal Office addressing land system studies on resilience, sustainability and vulnerability in Asia. *Glob Environ Res*, **18(2),** 105-112 p.

Winkler H. 2010. *Taking action on climate change: Long term mitigation scenarios for South Africa*. Juta and Company Ltd.