

**SPATIOTEMPORAL ENVIRONMENTAL DYNAMICS AND ITS IMPLICATIONS ON RURAL LIVELIHOODS IN WASARBI-GARBA  
GURACHA WATERSHED, CENTRAL ETHIOPIA**

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***Abstract***

The overriding objective of this study was to assess the spatiotemporal environmental dynamics and its implications to rural livelihoods in Wasarbi-Garba Guracha Watershed, Ethiopia. The major data for this study were obtained from three series of LANDSAT images (1986 TM, 2000 ETM+ and 2010 ETM+), GPS-based ground works, large scale topographic map and socio-economic survey. The important laboratory works performed for the study were digitization of topomaps, geo-referencing, delineation, satellite image enhancement, land use classification and change detection statistical analysis. Farmland was found to be the most expanding land use type in the watershed. It increased from 6.4% (in 1986) to 29.6% (in 2010) at the rate of about 15.3% per year. The area covered by shrub, grazing and wetland has been alarmingly reduced with the annual average conversion rate of 0.44%, 3.46% and 3.90%, respectively. Therefore, integrated rural development planning and enhanced environmental protection practices are hurriedly required so as to stabilize the environmental degradation processes and reduce its unfavorable impacts on socio-economic development in the watershed.

**Keywords:** Land-use, land-cover, spatiotemporal, watershed, Dayi-G/Guracha, Ethiopia

## INTRODUCTION

Ecologically, Ethiopia is characterized by abundant, but shrinking, diversity in biological resources: forest, woody and grassy lands, shrubs and varied wildlife. It is also renowned for its massive mountain ranges, high flat plateaus, deep gorges, river valleys, lowland plains, extensive wetlands and deserts. About 45 percent of the country is highland in which about 88% of the country's population is living. The geographical setting of the country is generally distinguished by the highlands in the central part, circumscribed by the flat lowlands. Overpopulation, extensive croplands and frequent incision by ravines and gullies characterize the highlands (EMA, 1988; Messay, 2011).

Ethiopia is also noted by severe environmental degradation of which the most notable ones are soil erosion, deforestation, water depletion and shrinking wetlands. Historical documents show that forest and woodlands covered over 40% of the total area of the country only a century ago (Badege, 2005). Presently, this figure is estimated to be less than 10% (Bane, et. al., 2008). As Woldeamlak (2009) cited FAO (1986, 1999), the country's annual deforestation rate is estimated to be about 62,000 hectares, attributed primarily to the increased demand for farmland, fuelwood, and settlement sites. This has resulted in severe soil degradation (about 2 billion tons per year), alteration of hydrologic regimes, disturbance of local and/or regional climates, loss of biodiversity and expansion of desert ecological conditions.

These environmental problems call for an accurate investigation in the status, causes, processes, and rate of land use/cover dynamics in a given area. Such inquiries enable researchers, policy/strategy formulators, environmentalists, and aid agencies to have accurate data related to the subject and proceed accordingly. In fact, some studies (Negash, 1987; Belay, 2002; Woldeamlak, 2002; Olson *et.al*, 2004; Badege, 2005) have shown that the land use/cover has been rapidly changing in Ethiopia, owing to population pressure, resettlement programs, climate change, and other human- and nature-induced driving forces. Particularly, anthropogenic activities are the most significant factors adversely altering the natural status of the Ethiopian landscape. This resulted in impressive changes in the land-use/cover patterns of the country over time. Hence, as precisely noted in Belay (2002) and Mausel, Brondizio and Moran (2003), well-timed and accurate change detection of the natural resources (such as vegetation cover, water, and soil) provides a foundation to clearly comprehend the prevailing interactions between people and the environment. This, in turn, enables the people to manage and use the resources sustainably.

As indicated in Belay (2002), land-use/cover change analysis is one of the most precise techniques to understand how land was used in the past, what types of changes are to be expected in the future, as well as the forces and processes behind the changes. It also yields valuable information for the analysis of the environmental impacts of population pressure, agriculture, urban expansion, resettlement program, climate change, and others. Such analysis is of great use to natural resources managers, development agents, fund agencies, socio-economic development planners, public administrators, and environmentalists because it provides accurate information related to land-use/cover changes.

Nevertheless, there is no such critically investigated land-use/cover change study carried out in and around Wasarbi-Garba Guracha Watershed so far. The watershed represents central Ethiopian plateau, where crop cultivation and human

inhabitation have taken place since time immemorial. It is characterized by distinct dry and wet seasonal climatic conditions, expanding farming activities, and ever-increasing population settlements, making this study realistic.

### **Objectives and Research Questions**

The purpose of this study is to assess the spatiotemporal environmental dynamics and its implications on rural livelihoods in Wasarbi-Garba Guracha Watershed, Central Ethiopia. More specifically, the study addresses the following four major questions:

- What does the spatiotemporal environmental dynamics look like in Wasarbi-Garba Guracha Watershed?
- What are the major land use/cover types in in Wasarbi-Garba Guracha Watershed?
- What are the causes of the existing spatio-temporal environmental dynamics in Wasarbi-Garba Guracha Watershed?
- What is the implication of the spatiotemporal environmental dynamics to rural livelihoods
- What should be done to maintain environmental sustainability in Wasarbi-Garba Guracha Watershed?

### **METHODS AND MATERIALS**

The most important data for this study are satellite images, GPS-based ground survey, large scale (1:50,000) topographic map (0938A2), long-term climatic data (rainfall and temperature) and firsthand socio-economic data that were obtained through Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs). The most important laboratory works for this study were accomplished in GIS laboratory setup located in Addis Ababa University Main Campus Department of Geography and Environmental Studies. The important laboratory works required for the study were scanning, digitization of topomaps, geo-referencing, delineation, clipping, satellite image enhancement, land use classification and change detection statistical analysis.

Three series of LANDSAT images (1986 TM, 2000 ETM+ and 2010 ETM+) were acquired from Ethiopia Mapping Agency (EMA). The selected images were all cloud free since they were captured during the dry period. In addition, ASTER image was also acquired for the same season to use as base map in field survey and reference for accuracy assessment. The ASTER image was first georeferenced using ground control points with a root mean square error (RMSE) of less than 1 pixel. The TM and ETM+ images were then geo-referenced using the ASTER and the topomap as a master sources. The Universal Transverse Mercator (UTM) geographic projection, WGS 1984 spheroid and datum, zone 37 North, were used in geo-referencing the images.

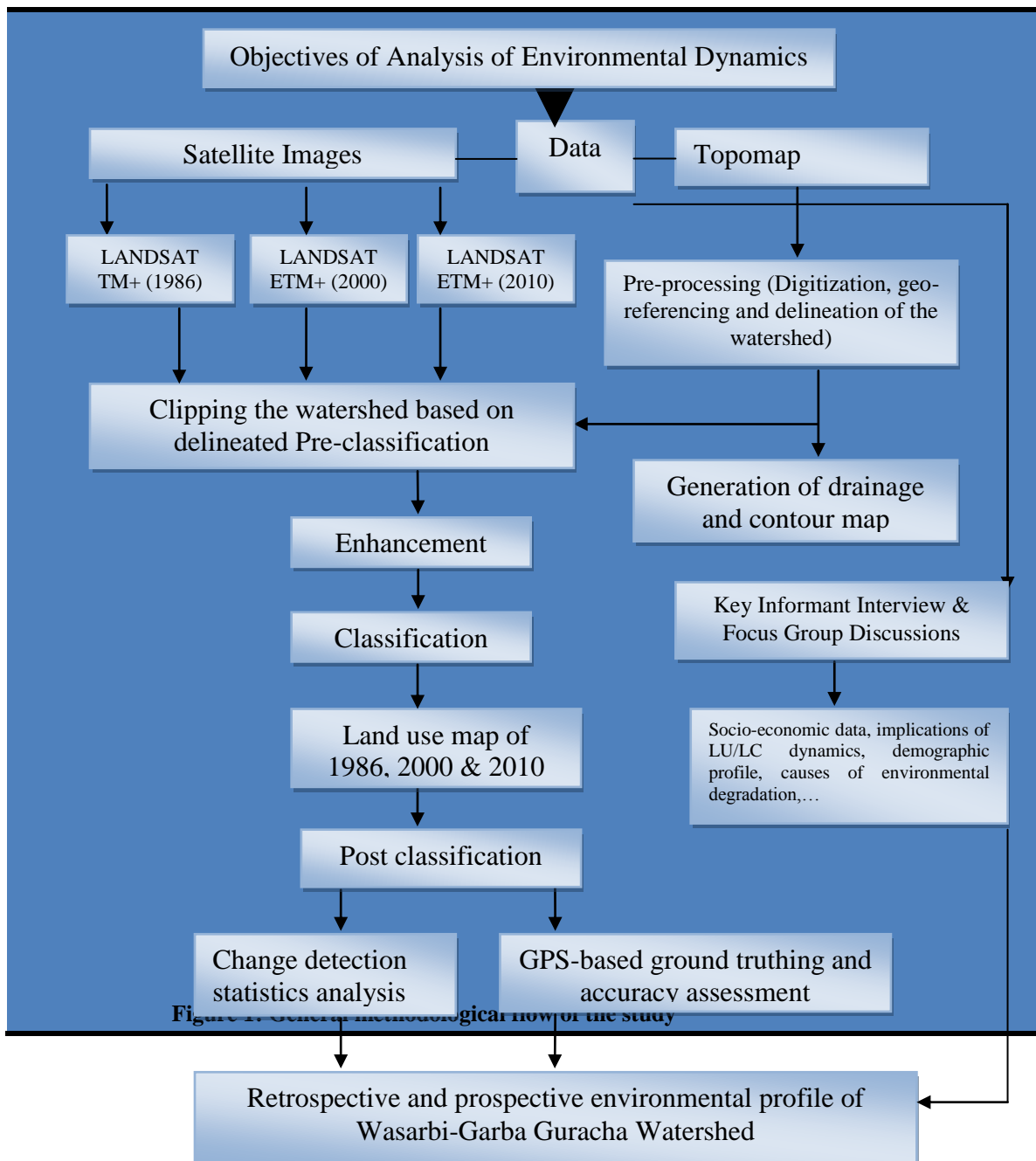


Figure 1: General methodological flow of the study

### Location of Wasarbi-Garba Guracha Watershed

Wasarbi and Garba Guracha are the two major tributaries of Mogor River, which in turn, is one of the major tributaries of Abay River. The study area is, therefore, named after these two rivers originating from Kuyu District, North Shewa Zone of Oromiya National Regional State. Astronomically, the watershed is located at  $9^{\circ}45'00''$  -  $9^{\circ}49'45''$ N latitude and  $38^{\circ}22'24''$  -  $38^{\circ}38'00''$ E longitude.

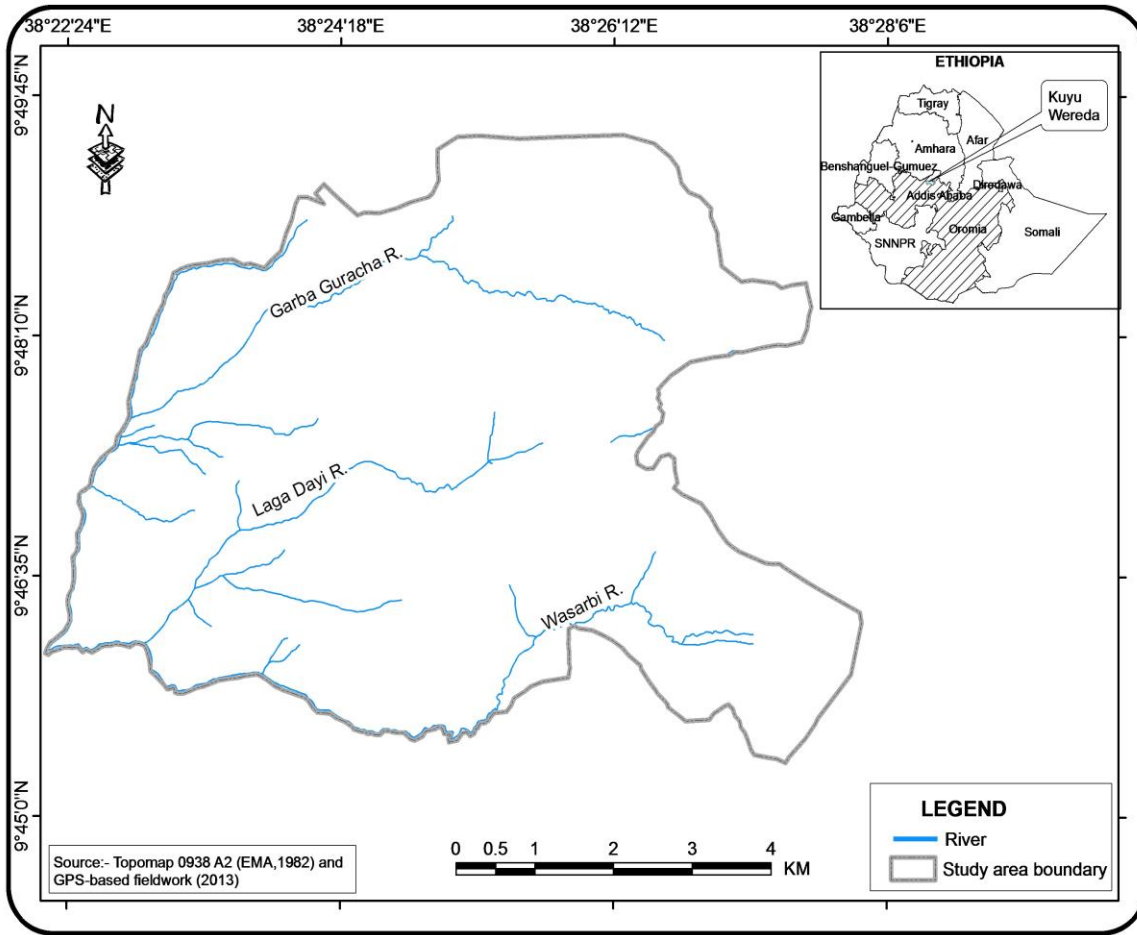


Figure 2: Location of Wasarbi-Garba Guracha Watershed in its national and regional settings

### Topography of Wasarbi-Garba Guracha Watershed

The spatial coverage of the watershed is about 50,356 hectares with altitudes ranging from about 1,780m amsl at Wasarbi-Garba Guracha Confluence to about 2,640m amsl at Muka Chita Hill. The northern, eastern and southeastern portion of the watershed are characterized by a flat terrain milieu; whereas the western portion is characterized by steep topography such as Chari, Ambacha and Dargu escarpments. The escarpments are found to be prone to severe soil erosion, degradation of vegetated lands and land slides. Chari Escarpment, for instance, is frequently hit by land slide disasters owing to the sloping nature of the area.

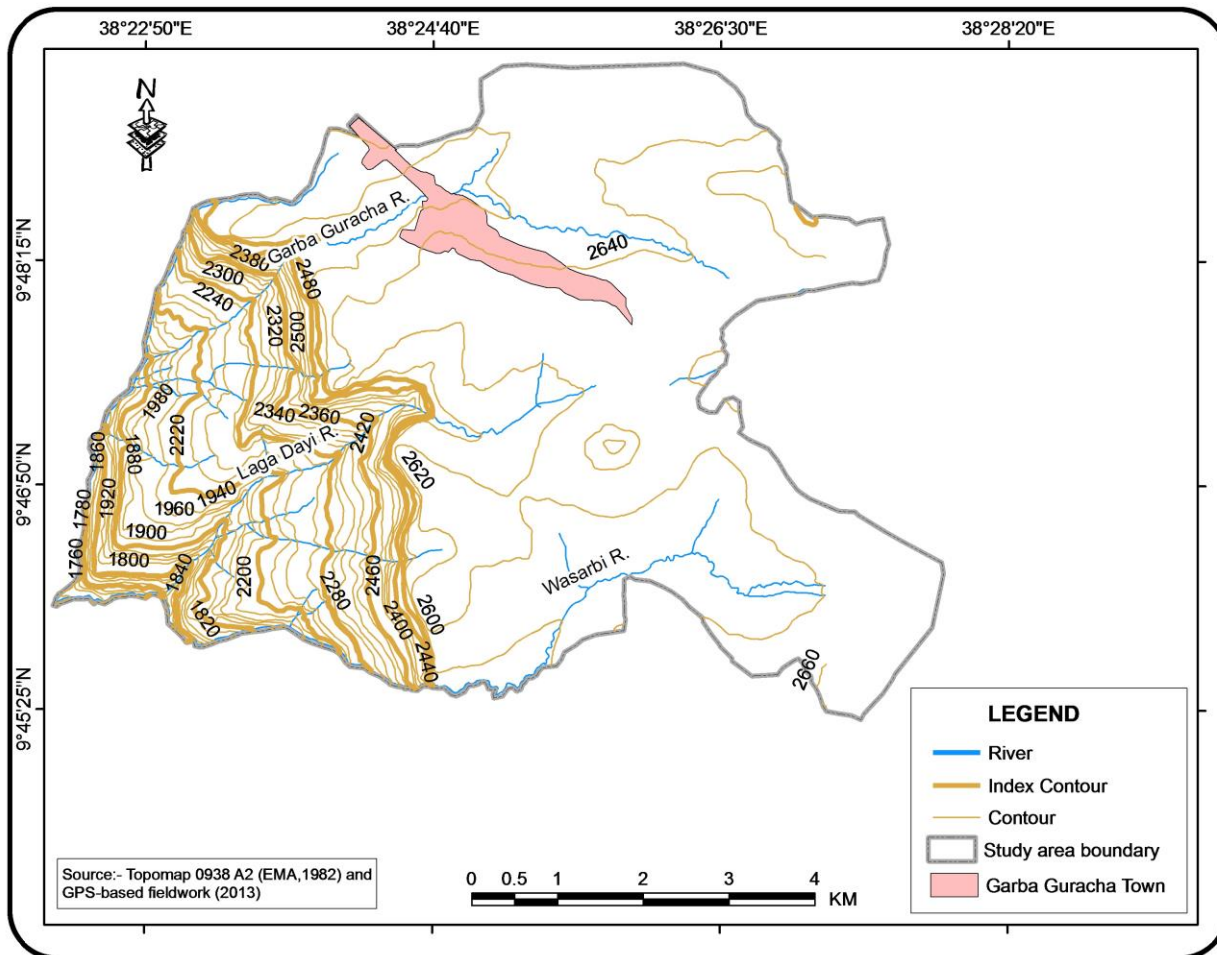


Figure 3: Topography of Wasarbi-Garba Guracha Watershed

## RESULTS AND DISCUSSIONS

### Climatic condition of Wasarbi-Garba Guracha Watershed

As briefly discussed above, the watershed is located in Shewan Plateau that receives maximum rainfall in summer (*ganna* in *Afan Oromo* Language) season (June, July and August). It is characterized by high seasonal concentration and variation of rainfall amounts. Autumn (March, April and May) /*Arfasa* in *Afan Oromo*/ is the short rainy season in the area.

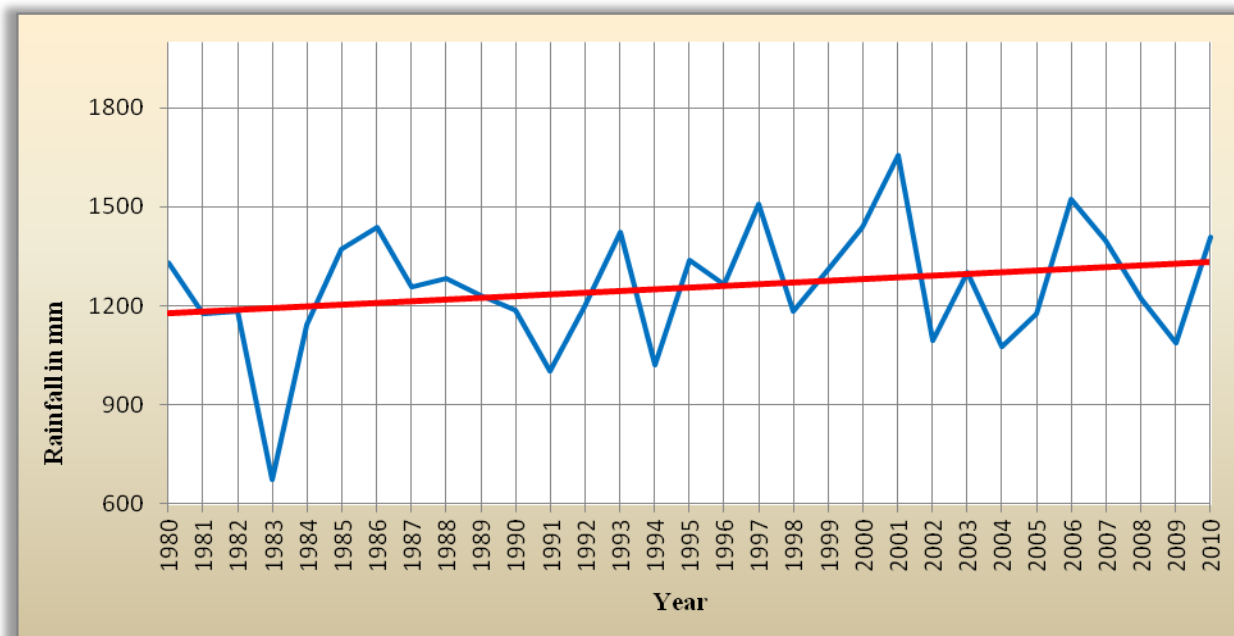
The analysis of long-term (*i.e.* 31 years) rainfall data obtained from National Meteorological Agency (NMA) of Ethiopia indicates that the mean annual rainfall of the area is about 1258 mm. Summer rain accounts for 79.3% of the total amount of rainfall; whereas spring rain accounts for 14.6% of the total annual amount of rainfall of the area. The detailed analysis is indicated in the table below showing the mean annual rainfall, standard deviation (SD) and coefficient of variation (CV) of the rainfall pattern in the area.

Table 1: Annual rainfall distribution of Garba Guracha Meteorological Station (1980-2010)

	Months												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
$\bar{X}$ total (mm)	11.3	13.4	40.4	71	72.5	158.3	344.9	338.9	154.9	31.8	13.9	10.3	1257.4
SD	12.9	14.2	31.3	39.5	47.6	79.1	93	72.5	69.2	39.7	40.8	13.9	186.4
CV	114.2	106	77.7	55.8	65.7	49.9	26.9	21.4	44.7	125	293	135	14.8

Source: Computed based on raw data from NMA

The coefficient of variation (CV), which shows by how many percent the monthly rainfall for the year 1980 to 2010 deviates from the mean, is 14.8 percent. The value of the coefficient of variation is found to be the highest during the drier months of a year such as in October, November, December, January and February. The lowest value is registered during the rainy season that encompasses the months June, July, August and September. But the highest and the lowest coefficient of variation values are registered during the months of November and August, respectively. This fluctuation in rainfall pattern has implication on agricultural production (crop and livestock). It causes poor harvest and livestock loss which again causes food shortage and loss of assets that exacerbate the vulnerability of the people even to a slight shock. Failure in spring rain severely affects the production of sorghum in particular. Fluctuation in autumn rain has also impacts on main season crop production activities. It causes extreme shortage of pasture which consequently causes death of livestock as well as either total losses or reduction of dairy products (milk and butter) and traction power as oxen are the dominant drought power used for farmland preparation similar to other parts of the country.



Figure

4: Annual total rainfall at Garba Guracha Meteorological Station (Source: Computed based on the raw data obtained from NMA)

The long-term (1980-2010) annual average rainfall at at Garba Guracha Meteorological Station (located in the watershed) is computed to be about 1254.88mm. The annual total rainfall seems somewhat constant over years in the area. The anomalous year is 1983 when the total annual rainfall was only about 670mm. The maxim annual total rainfall occurred in 2001 (i.e. 1657mm). Generally, the watershed receives good amount of total annual rainfall in view of the characteristics of most Ethiopian highlands. At this juncture, one can raise a question regarding what the critical problem is in this area in case of rainfall. The problem is, therefore, not the amount; rather the temporal variability *.i.e.* inconsistencies in onset and offset of the rains as confirmed by FGDs and KIIs.

As indicated in Figure 4, the general trend of rainfall in the area seems increasing over years. The solid red line in the figure indicates an increasing annual total rainfall between 1980 and 2010. This could be one of the opportunities for the overall agricultural (both crops and livestock sub-sectors) development of the area as water is one of the crucial resources for these sectors. This could be an important input for the existing water resources whether it is underground or surface water. In fact, one can see the increasing trends of rainfall as an adversity as this may amplify the prevailing severe soil erosion in the area.

The coefficient of variation is computed to be only 0.15 indicating a slight inter-annual total rainfall variation in the area. In fact, 1983 is an anomalous as the total annual rainfall received in this year deviates significantly from the general rainfall situation in the area. As corroborated by FGD and KII participants, 1983 was the most devastating when almost the entire crops were lost to the drought and the animals were significantly harmed. The life of almost all the farming households was sustained by government aid which was in fact untimely and inadequate in distribution to the victims.





Figure 5: Long-term mean monthly rainfall at Garba Guracha Meteorological Station (Source: Computed based on the raw data obtained from NMA)

The summary of rainfall attributes in Table 2 indicates that rainfall in the watershed is extremely characterized by high seasonal rainfall concentration and fluctuation. The Precipitation Concentration Index (PCI) value for the watershed is about 0.1853 (18.53%). As argued by Woldeamlak (2009) values of PCI less than 10 indicate uniform monthly distribution while values between 11 and 20 signify high rainfall concentration. PCI values greater than 20 represent very high concentration of the attribute. Accordingly, rainfall patterns in this area is said to be highly concentrated in the three months of the summer season during which about 67 percent of the total annual rainfall is received. Only about 2.77, 14.37 and 16.02 percent is received in winter, spring and autumn seasons, respectively. The greater the value of PCI, the more the variable is the amount of precipitation, as noted in Zhao *et al.* (2011)

Table 2: Computation of PCI for Graba Guracha Meteorological Station

Months	Mean monthly rainfall in mm (Pi)	Pi <sup>2</sup>
January	10.65	113.42
February	14.04	197.12
March	43.35	1879.22
April	70.88	5023.97
May	72.12	5201.29
June	160.12	25638.41
July	345.73	119529.23
August	338.06	114284.56
September	154.73	23941.37
October	31.79	1010.60
November	14.51	210.54
December	10.08	101.61
$\Sigma pi = 1266.06$		$(\Sigma pi^2) = 297131.37$
$(\Sigma pi)^2 = 1602895.54$		
$PCI = \frac{(\sum Pi^2)}{(\sum Pi)^2} \quad PCI = \frac{297131.37}{1602895.54} = 0.1853 \text{ or } 18.53\%$		

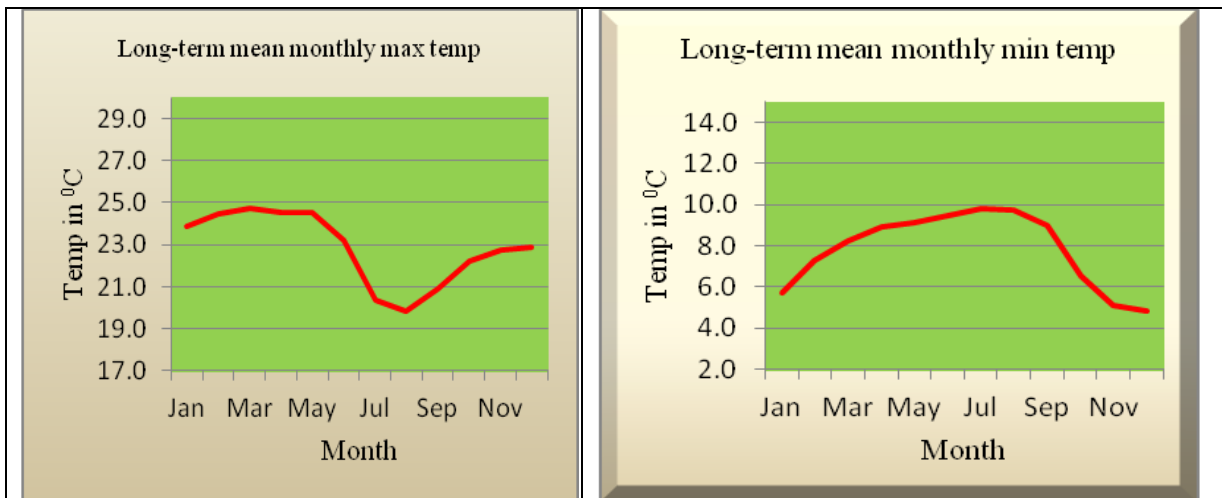
Source: Computed based on the raw data obtained from NMA

Table 3: Seasonal distribution of rainfall at Garba Guracha Meteorological Station

Seasons	Long-term total seasonal rainfall in mm	Percentage distribution of the rainfall
Winter (Dec., Jan., & Feb.)	34.8	2.77
Spring (Mar., Apr & May)	180.3	14.37
Summer (Jun., Jul. & Aug.)	838.7	66.84
Autumn (Sep., Oct. & Nov.)	201.0	16.02
<b>Total</b>	<b>1254.8</b>	<b>100.00</b>

Source: Computed based on the raw data obtained from NMA

The data from NMA indicates that the long-term (1980-2010) mean annual temperature of Garba Guracha Meteorological Station lay around 14.76°C. The long-term mean minimum monthly temperature is computed to be about 7.8°C, while the mean monthly maximum temperature is about 22.9°C. The warmest period in a year is from the months of February to May, while the lowest annual temperature occurs between the months of July and September. Though the sun is overhead between 23<sup>rd</sup> June to September 22<sup>nd</sup>, the area becomes very cold owing to the summer cloud cover and the high altitude of the area. Regarding this, FGD and KII participants confirmed that temperature highly drops particularly in October and the first week of November. This causes frost damage to crops that adversely affects crop productivity. Both farmers and the experts in Kuyu *Woreda* Agricultural Bureau disclosed that some crops such as wheat and *teff* are more vulnerable to the adverse frost actions in the area.



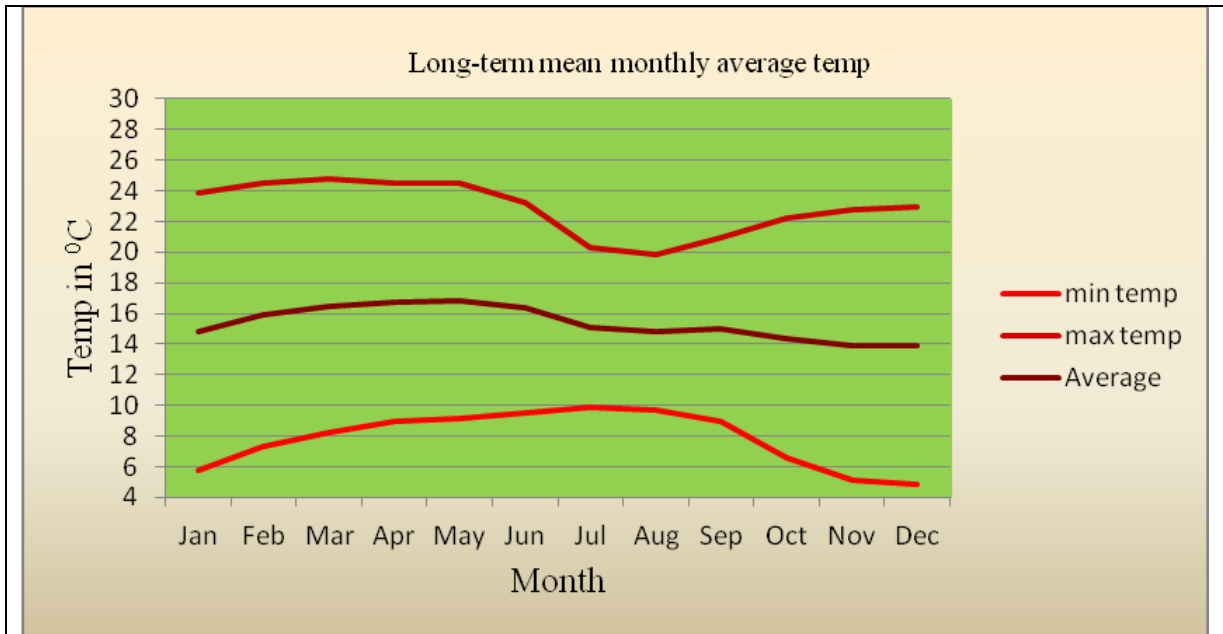


Figure 6: Long-term (1980-2010) monthly mean maximum, minimum and average temperature (Source: Computed based on raw data obtained from NMA)

#### Socio-economic Aspects of Wasarbi-Garba Guracha Watershed

The data from CSA (2011) reveals that the population density of Kuyu *Wereda* (where the watershed is located) is about 148 persons per square kilo metre. The overall picture of the watershed is also not different from the case of the *woreda*. Hence, it is safe to say that the area is densely populated in view of most areas in Ethiopia.

Mixed agricultural practices (crop production and livestock rearing) are the major means of livelihood of the study area. According to the information obtained from Kuyu *Wereda* Office of Agriculture, the productivity of both sub-sectors has remained below its potential owing to several biophysical factor like erratic rainfall, poor access to improved technologies and poor natural resource management and utilization.







Crop production is the dominant agricultural activity that most of the population of the study area engaged in and are earning their life. Majority of food crops grown in the area include *teff* (*Eragrostis tef*), wheat, barley, *nug* (*Guizotia abyssinica*), field pea and horse bean. These food crops are grown mostly by using rain water. Food crops like fruits and vegetables are grown using traditional small-scale irrigation schemes. Majority of the farmers in the area plough their land using pair of oxen.

The livestock sub-sector plays an important role in the livelihood of the rural people. It provides the people with alternative income sources, traction power and food items. However, only a limited number of farmers have been introduced to improved breeds of livestock which are either exotics or crossbreeds and also there are no selected breeds of small ruminants (sheep and goats) and equines (horse, donkey and mule).

### Characteristics of the land-cover units

Six major of land-usetypes have been identified in the watershed. These are farmland, grazing land, scrubland, wetland, urban area and degraded land. Farmland accounts for the vast majority (about 30%) of the total area followed by the bareland (degraded area) in the watershed at present. The land-use/cover types and their brief description is given in the Table 4.

Table 4: Brief description of land-use/cover types identified in the watershed

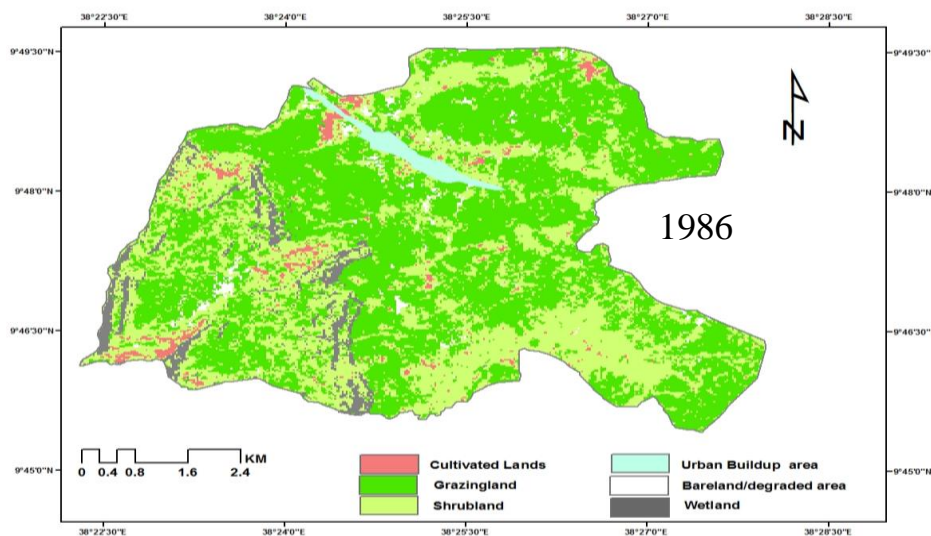
Types	Brief descriptions
<p>Farmland</p> 	<p>This land-use/cover category encompasses areas allotted for crops production (both annual/seasonal and perennial), dispersed rural settlements, and homesteads. Most cultivated lands are meant for seasonal subsistence rain-fed crops.</p>
<p>Grazing land</p> 	<p>This land-use/cover category is a field covered with grass/herbage suitable for grazing by livestock such as cattle, sheep and beast of burden. It can also be used to produce hay or fodder. The grasses are cut, dried and then used as fodder for animals.</p>
<p>Scrubland</p> 	<p>Area with a plant community, characterized by a mixture of shrubs, grasses and herbs. Here, grasses and shrubs are the most dominant vegetation type. The community uses this land-cover type mostly for grazing and browsing. It is also the source of firewood and thatch.</p>
<p>Wetland</p> 	<p>This is a land area that is saturated with water, either permanently or seasonally, such that it takes on the characteristics of distinct ecosystem. Primarily, the factor that distinguishes wetlands from other landforms is the characteristic vegetation that is adapted to its unique soil conditions.</p>
<p>Urban area</p> 	<p>Garba Guracha Town i.e. the capital of Kuyu <i>Woreda</i></p>
<p>Degraded area</p> 	<p>This land category refers to the area severely affected by natural or human-induced processes acting upon the land leaving it unproductive for crop and livestock production. It is the area severely eroded/deforested to almost bare-rock (rock-strewn and stony) and difficult rehabilitated so as to support agricultural practices.</p>

As indicated in Table 4, six land-use/cover classes were identified. A pixel based supervised image classification with maximum likelihood classification algorithm was used to map the land-use/cover classes. Accuracy assessment of the classification was performed for the LANDSAT ETM+ 2010 images, using the accuracy assessment tool available in ERDAS Imagine. The 2010 ETM+ image was selected for accuracy assessment because of availability of better resolution ASTER images for the same period. The samples overlaid with the classified images of 2010 ETM+ as well as ASTER

multi-spectral image and accuracy assessment of the single land-use/cover classes was carried out. Hence, the overall accuracy and Kappa Coefficient of the analysis were calculated to be 88.68 and 0.85, respectively.

Six major land-cover/use types were identified in all the satellite images (i.e. 1986, 2000 and 2010) of the watershed. Although an asphalted road passes through the area from east to northwest, it is found to be negligible in the spatial coverage in this analysis. It was also impossible to compute the area covered by each farmhouse because of the scattering nature of the settlements and the less resolution (30m x 30m) of the satellite images used for this study. In fact, one can safely guess that farmhouses could have occupied a significant proportion of the watershed since the area is one of the most densely populated parts of the country.

Grazing land and scrubland were the predominant types of land-use/cover in 1986. They covered about 46 & 35.5%, respectively. (See Table 5 and Figure 7). These two land-use/cover types covered about 80% of the watershed in 1986. Both grazing land and scrubland have been surprisingly reduced to 7.7% and 3% in 2010, respectively. Similarly, the spatial coverage of wetland has reduced from 3.8% (in 1986) to only 0.3% (in 2010). At this juncture, one may want to know what happened to these land-use/cover categories. Where did they go? A simple answer to these kinds of questions would be ‘they have been either converted to farmland or severely degraded to bare land (degraded land) over years.’



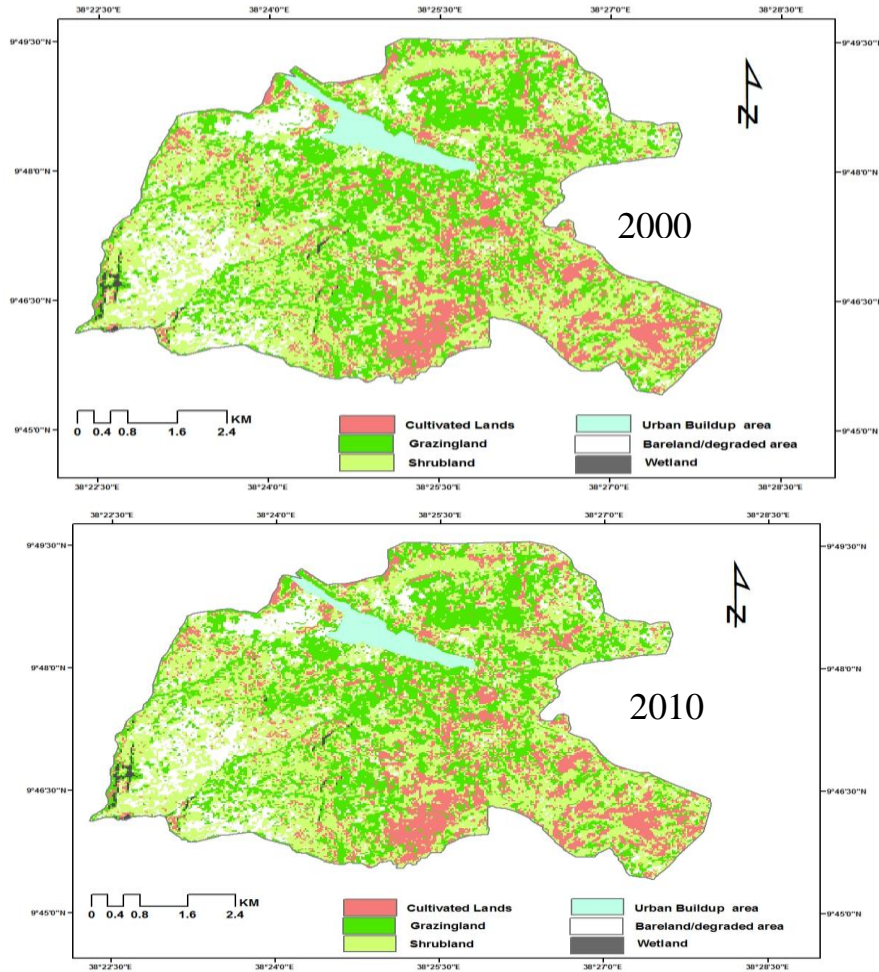


Figure 7: Land-use/cover types in Wasarbi-Garba Guracha Watershed in 1986, 2000 and 2010 (Source: Computed from LANDSAT images (1986, 2000 and 2010) and GPS-based fieldworks)

The two land-use/cover categories that amazingly reduced within the given years (1986-2010) were cultivated land and bare land (degraded land). The combination of both of them accounted only for 12.1% of the spatial coverage of the watershed in 1986. This increased to about 28.5% in 2000 and 50% of the area in 2010. (See Table 5) According to the firsthand data from key informants and focus group discussants, the watershed was covered by dense shrubs and scattered woods some two decades back. Particularly, the vast area of the western and southwestern part (Chari, Jib Gore and Hambacha escarpments) was densely vegetated according to the informants. In fact, the satellite image output in Figure 7 confirms this truth. Recently, most of these vegetated areas are severely deforested and converted to farmlands and settlement areas. Even community conserved areas (such as Jib Gore, Oddo Qerrensa, Hambacha, Dandi forests) as well as sacred areas (such as Adbari Warra Abba Magal and Burqa Kaka) are almost entirely devastated owing to agricultural expansion and human encroachment.

The finding of this study sharply contrasts with that of Belay (2002), who reported an insignificant increase of cultivated land in South Wello Zone (North Central Ethiopia) for the period of over 43 years. Woldeamlak (2002) also reported a shrinking of farmland by 2% between 1982 and 1998 in Chemoga Watershed, Ethiopia. This may be because these two areas might

have already gone beyond ecological limits hindering the spatial expansion of agricultural areas unlike the case in Wasarbi-Garba Guracha Watershed where farmland is still expanding in spatial extent.

Table 5: Land-use/cover units at different periods in the watershed

Land-use/cover categories	1986		2000		2010	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Cultivated land	319.4	6.4	777.6	15.4	1488.5	29.6
Grazing land	2313.7	45.9	1246.9	24.8	389.9	7.7
Scrubland	1688.6	33.5	1952.9	38.8	1511.8	3.0
Urban area	236.1	4.7	380.2	7.5	552.9	11.0
Bare land	284.3	5.7	657.2	13.1	1080.6	21.4
Wetland	193.8	3.8	21.1	0.4	12.2	0.3
<b>Total</b>	<b>5035.9</b>	<b>100</b>	<b>5035.9</b>	<b>100</b>	<b>5035.9</b>	<b>100</b>

Source: Computed from LANDSAT images (1986, 2000 and 2010) and GPS-based fieldworks

Recently, shrubs and woods are restricted to river valleys and streambanks as riverine plants. The diminishing of vegetation coverage is ascribed to the removal of plants for farmland preparation, fuel wood, construction, charcoal preparation, and traditional farm equipment.

The land-use/cover analysis for Wasarbi-Garba Guracha Watershed evidenced both modification and conversion types of changes. In case of modification, for instance, scrubs/shrubs (browsing areas) have been cut and the land has been modified to grazing land. In case of conversion, vast majority of the scrublands, wetlands and grazing areas have been converted to farmlands and settlement areas over years. Similarly, previous farmlands have been converted to bare (degraded) lands. These are rock-strewn and stony areas unable to support any agricultural practices at present.

The annual increment rate of farmland between 1986 and 2010 was 15.25% i.e the farmland has been increasing by 15.25% per year in the watershed. Similarly, degraded (bare) land has been increasing by 11.67% per year. Contrarily, the spatial coverage of wetlands, scrublands and grazing areas has been reducing in 3.9%, 0.44% and 3.46% per year over years. Particularly, it is shocking to see that wetlands (which covered about 194 hectares in 1986) are almost entirely used up/depleted at present (See Table 5 & 6) resulting in the crises of aquatic ecology in the area. The respondents also confirm that areas previously wetland and scrubland are alarmingly diminishing over the last few decades. Contrarily, degraded areas and farmlands stretched extensively according to the respondents. Amazingly, all the two vegetated land-use/cover types (grazing land and scrubland) and wetlands occupy a merely 11% of the spatial coverage of the watershed recently. It is very shocking to see the rapid conversion of the vegetated land into cultivated land within the 26-years period (1986 to 2010). For this reasons, the overall environmental situation of the watershed is shocking and horrifying. This is a dreadful and devastating episode that may result in irreversible environmental degradation and humanitarian disaster, unless appropriate actions are designed and implemented soon.

Table 6: Trends of land-use/cover changes in the watershed

Land-use/cover categories	1986-2000			2000-2010			1986-2010		
	Change in			Change in			Change in		
	Ha	%	% per yr	Ha	%	% per yr	Ha	%	% per yr
Farmland	+458.2	+143.4	+10.25	+710.9	+91.4	+9.14	+1169.1	+366.03	+15.25
Grazing land	-	-46.11	-3.29	-857	-68.73	-6.87	-1923.80	-83.15	-3.46
Scrubland	-	-15.65	-1.12	+441.1	+22.59	+2.26	-176.80	-10.47	-0.44
Urban area	+144.1	+61.03	+4.36	+172.7	+45.42	+4.54	+316.80	+134.18	+5.59
Bare land	+372.9	+131.1	+9.37	+423.4	+64.42	+6.44	+796.3	+280.10	+11.67
Wetland	-	-89.11	-6.37	-8.9	-42.18	-3.01	-181.6	-93.70	-3.90

Source: Computed from LANDSAT images (1986, 2000 and 2010) and GPS-based fieldworks

### Livelihood Challenges and Opportunities in Wasarbi-Garba Guracha Watershed

According to the data obtained from FGD and KII informants, the people living in the watershed are distinguished by various livelihoods challenges and opportunities. Land degradation, deforestation, soil loss, rainfall variability, agrochemical-induced soil acidification, overgrazing and landslide are the major detrimental biophysical factors threatening the livelihoods of the residents in the area. All the informants confirm that the area is under severe environmental degradation. Vegetated lands have been almost entirely removed and wild animals disappeared. Various areas have been affected by landslides of which the most considerable one is found in Halelu Chari *kebele*. In 2012, for instance, it damaged the croplands and farmhouses of several residents in areas called Horo, Hambacha and Dargu, displacing hundreds of farmers. The farmers are also living witnesses for persistent removal of soil from their farmlands. The overall consequence of these detrimental biophysical factors is decreasing agricultural productivity and livelihoods insecurity.

What is equally important in the area is the presence of opportunities for better agricultural production. One of such opportunities is the current better emphasis of the government to climate-resilient green economy strategy. This strategy gives emphasis to more agricultural production through environmentally friendly techniques and wise use of natural resources. As a result, currently one can observe larger public movement to protect the environment through reforestation, soil protection, rehabilitation of water bodies, and integrated watershed management in the area.

The nearness of the watershed to major market places such as Fiche (only about 50km of on asphalt road) and Addis Ababa (150km of asphalted road) is also a good opportunity for the community to produce and provide cash crops to the urbanites in these towns. Various cash crops (vegetables: onion, carrot, beetroot, garlic, pepper and cabbage) can be produced throughout the the area since it is rich in different agro-climatic zones and landscapes. In this regard, the existing perennial rivers (such



as Wasarbi, Garba Guracha, Yeyyi and Dayi rivers) and extensive irrigable lands can be good sources for the production of vegetables and fruits in particular.

### **Land-use/cover Dynamics in the Watershed: Causes, Nexus to Livelihoods and Its Implications**

The discussions earlier in this document indicate that the watershed is experiencing fast land-use/cover changes especially in recent years. Enormous extent of vegetated land uses have been converted to agricultural lands. Significant successive modifications amongst the vegetated land uses were also evidenced.

Regarding this the words of an elderly key informant is translated and presented below:

...I was born and grew up in Halelu Chari *Kebele*. The whole area of this watershed was covered by dense vegetation during my childhood. Scattered giant trees such as *zigba* [*Podocarpus falcatus*], *qerero* [*Anningeria adolfifredricii*], *shola* [*Ficus sur*] and *warka* [*Ficus vasta*] were plentiful in the area. I am a living witness that the forest coverage and wild animal flocks have been diminishing gradually all over my age. There were remarkable wetlands throughout the area such as *Haro Kaka*, *Haro Harbu*, *Haro and Abba Dame*. Currently, all these wetlands have dried up and converted to farmlands. As you can see almost all the wetlands and forested areas were converted into grazing and cultivated lands. Most vegetation areas are plummeted into almost bare land these days. The major cause of the problem, I think, is the existing poor livelihoods and lack of public awareness regarding environmental protection.

At this juncture, one may raise a question regarding the causes of land-use/cover changes in the watershed. As indicated in Belay (2002), land-use/cover changes are the result of a number of interacting variables and processes. Correspondingly, the series of interviews and discussions conducted with the community indicate that five interlinked major socio-economic and environmental driving forces appear to explain a large part of land-use/cover changes in the area. Amidst other causes, (1) land tenure arrangements, (2) livelihood strategies, (3) population growth, (4) overgrazing, and (5) access to market appear to play a major role.

The discussants for this study corroborated the fact that the first of these interacting land-use/cover changing variables in the area is the preceding land tenures. As noted in Olson *et.al* (2004), land tenure is one of the most significant driving forces of land-use/cover changes in East Africa. Tenure insecurity denies the right incentives to invest or make improvements in land and natural resources. A land tenure system that does not ensure the holders a more secure landownership position usually hinders environmental conservation practices which, in turn, shoot up the rate of land-use/cover changes.

The three most notable land tenure systems in Ethiopia are that of the Imperial Government (1930-1975), the Derg Regime (1975-1993), and the Federal Democratic Republic of Ethiopia (FDRE) (1993-recent). The land policy of the Imperial government, though varied spatially, was favoring individual landlords to amass and possess the land indefinitely. This might

have encouraged the landowners to take care of their land and the natural resources on it which, in turn, might have resulted in relatively stable land-use/cover changes for over longer period of time.

Contrarily, the Military Government (Derg) nationalized the land and the natural resources on it under the umbrella of the renowned motto, 'Land to the Tiller'. Consequently, the land was divided into pieces among peasants or smallholding farmers, which resulted in massive deforestation of vegetated lands meant for various purposes. This, in turn, might have resulted in dramatic land-use/cover changes throughout the country, in general, and the study area, in particular. The informants lamentably and regrettably confirmed that enormous amount of land was degraded during the *Derg* Regime in the area, owing to the dramatic change in land tenure arrangements.

Land remained a public property and was administered by the government since the 1975 radical land reform in Ethiopia. In fact, the land use policy of the FDRE has offered the rural community the right to use land indefinitely. Particularly, Oromiya National Regional State, where Wasarbi-Garba Guracha Watershed is located, in its Proclamation Number 130/2007 (the proclamation to amend the previous Oromiya rural land use administration) assures the rural people the right to use, lease/rent, and transfer the land and the natural resources that it encompasses. It also authorizes sale of perennial crops on the land for restricted periods. However, selling land or getting collateral arrangements against a loan is strictly forbidden by this law (ONRS, 2007). Although this land tenure arrangement appears to be better compared to the previous regimes, the respondent farmers are still lacking confidence to rehabilitate their land resources in fear of the possible confiscation. They feel as if they have no right over their land. Moreover, since the landholding per household is very small, the farmers are forced to encroach into vegetated lands for cropping, grazing and settlement.

The major livelihood strategy-induced driving forces towards the existing rapid land-use/cover changes in the area are the expansion of agricultural land, charcoal production, and firewood collection. The farmers are currently converting the land into plots of farmlands in order to increase their crop output and cope with the problems of food shortfalls. Meanwhile, some rural households are increasingly engaged in charcoal preparation and firewood extraction as lucrative livelihood strategies. Particularly, those 'economically unfortunate' households are highly dependent on charcoal and firewood sale to fulfill the livelihood requirements of their family. The combined effects of these factors certainly result in rapid conversion and/or modification of the land-use/cover in the area.

The existing high rate of population growth, mainly because of the high natural increase, also exerts immense pressure on land resources in the area. Agrarian population in Ethiopia, in general, and in the area, in particular, is experiencing high annual growth rate, exceeding 2.6 percent (CSA, 2011). This, undoubtedly, intensifies the conversion and/or modification processes of the land-use/cover types.

The preceding discussions indicate that the farmers in the watershed are encircled by various land-use/cover detriments to produce more agricultural outputs and improve their livelihoods. Both the FGD and KII informants strongly and emotionally demonstrate that various land-use/cover factors are playing against their endeavors to produce more and more over years.

One of the unfavorable conditions for their agricultural practices is the undeveloped irrigation practices in the area because of which they and their farmlands remain idle for longer dry periods. A vast irrigable land that could have been used to produce more and more crop outputs remains unused for an extensive period of a year, owing to the existing high seasonal concentration of rainfall in the area. The farmers have nothing to do during this dry period. Moreover, the amount of feed available for livestock is diminishing thereby resulting in the weight loss and/or death of animals during dry months of a year. In addition, the farmers could also be extravagant in towns spending their time and mere earnings unimportantly. This, no doubt, results in persistent poor livelihoods and food insecurity in the area.

Fragmented farmland, scarcity of water resources, long-dry season, poor land management system, adverse effects of agro-chemicals (on soils, animal population like bees) and low agricultural investment are also said to be determinant factors affecting agricultural production in the area. In case of land fragmentation the respondent farmers have the opinion that it is time consuming to move from one farmland to the other particularly during harvesting and sowing times. Though it seems advantageous to have different plots of land scattered here and there for diversity purposes, the time and energy the plowmen spend is quite significant as noted by the informants.

The problem of water resources (because of diminishing wetlands) for agricultural practices in the area seems immense. Agriculture is almost entirely rainfed in the area. Though perennial rivers are found flowing down the hills, almost none of them has been kept back for irrigation so far. They could have been used for agricultural practices during the long-dry periods. The farmers strongly elucidate that the ever-increasing application of the agro-chemicals to increase productivity has got adverse impacts in deteriorating soil quality. They also witnessed the reduction/extinction of some important animals like bee population and micro-organisms in soils.

### **Adaptive Responses to Land-use/cover-induced Challenges**

Adaptation is a necessity among poor people living in environmentally uncertain areas like Wasarbi-Garba Guracha Watershed. As noted in Maxwell and Frankenberg (1992), to cope with environmental dynamics and shocks of livelihoods, households typically adjust their consumption patterns and reallocate their resources to activities which are more insulated from the influence of those risks. For example, households may sell-out their livestock assets to ease overgrazing and to ensure continued food and cash supply for their family. They may also shift their resources from crop production to non-farm petty-income activities such as firewood and charcoal production, and labor rental. Sometimes destitute households may send-off some of their family members to well-off relatives living in urban areas. Others may request social support from the community. They may also adjust their production and consumption patterns accordingly. If environmental crises and the resultant resource shortfalls continued unabated, household responses will become increasingly costly which may lead to loss of productive assets (such as livestock, land and farm equipment).

Intensive group discussions and interviews were made with the informants to have better understanding regarding how they cope with climate and land-use/cover change-induced shock in the area. Female respondents were purposively given due attention in this regard. It is assumed that females were more knowledgeable informants concerning the coping strategies in

the resource allocation (such as preparation and rationing of meals) for the household member which is mostly the duties of women in the area.

In order to clearly understand their adaptive techniques, the respondents were asked 'what do they do in order to adapt to the ever-increasing adverse environmental dynamics in the area'. The basic idea is to draw attention to the severity level of the adaptive strategies to cope with the fast environmental changes in the area. The respondents provided 13 major adaptive strategies that the community performs to cope with the adverse environmental changes in the area.

The adaptive practices listed in Table 7 can be grouped into four severity categories: (1) very severe, (2) severe, (3) moderately severe and (4) least severe. All the respondents were consulted about their perceptions of the severity of each adaptive practice. This is because it is the fervent belief of the researchers that the community can appropriately weigh the severity of the practices depending on their previous experiences and perceptions. Each respondent for this study was therefore requested to rank the strategies from lowest (least severe) to highest (most severe). Out migration, for instance, was reported to be indicating a failure to adapt to environmental changes. The finding of the analysis revealed that households did not resort to extreme life-threatening survival coping strategies to meet their requirements so far.

Table 7: Local adaptive practices in the area as reported by the respondents

Out migration to urban or other rural areas
Rehabilitation of degraded (bare) lands
Minimization of family size
Reduction of livestock population
Agricultural intensification (more agrochemicals per unit area)
Change of agricultural tools from wood to non-wood made items
Change of livelihood sources (from agriculture-based to off-farm activities)
Developing traditional irrigation practices so as to produce crops during dry months of a year
Water harvesting for irrigation, domestic uses and livestock drinking
More dependence on dung for domestic energy sources
More dependence on stubble and chaff for animal fodder and domestic energy purposes
Planting woodlots mainly exotic trees (largely eucalyptus trees for construction, firewood, sale and agricultural tool making purposes)
Sharecropping

The adaptive strategy patterns of the community were modeled to show the sequence of responses that the community employs in order to cope with environmental dynamics in the area. As indicated in the model, the strategies at the lowest stage of the ladder, such as sharecropping and development of woodlots require little commitment of resources and are more environmentally friendly. At these stages, the community can adapt to adverse environmental dynamics easily. The adaptive practices at the lowest stage are environmentally friendly and commits lowest amount of resources to cope with shocks of

environmental dynamism. The worst problem occurs if the environmental dynamics persists and results in degradation. This stage demands pressing adaptive practices such as reduction of livestock population, agricultural intensification and shifting to non-wood made agricultural tools. Failure to adapt to the situation eventually results in out migration, miserable life or death. It also requires a greater commitment of resources to rehabilitate a severely degraded (bare) land.

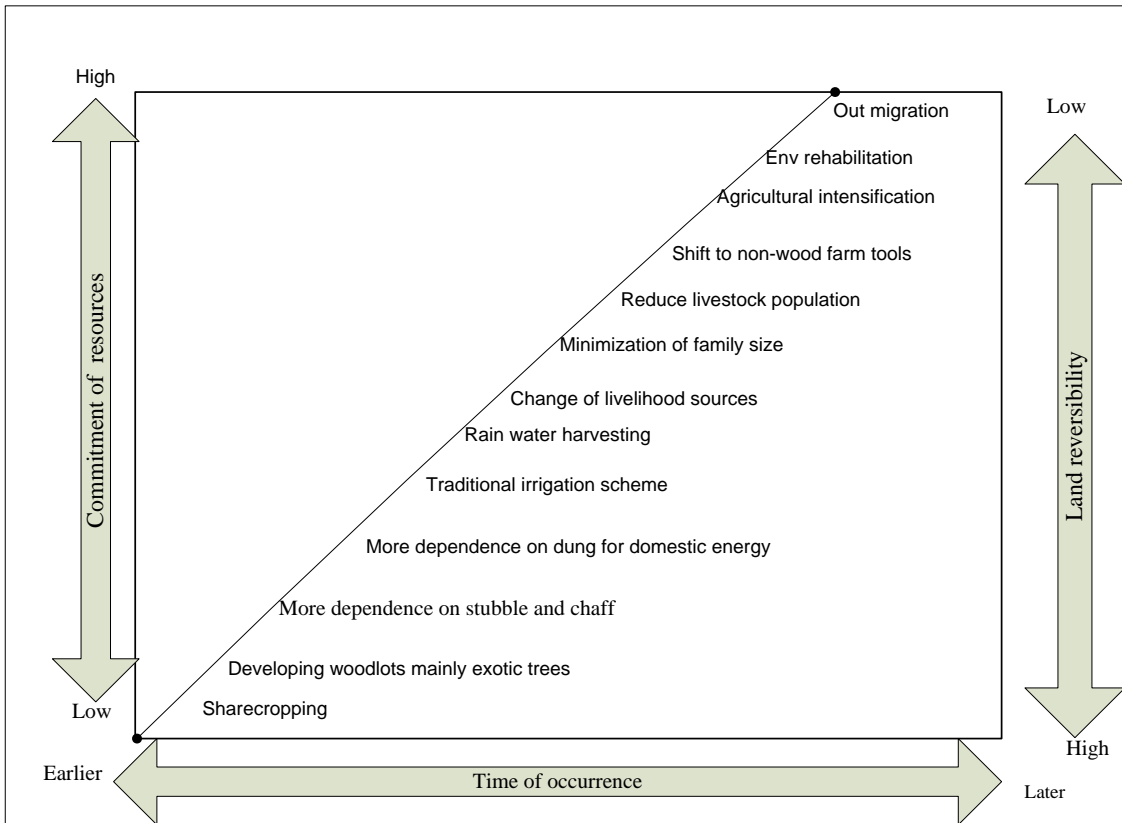


Figure 8: Model of adaptive strategies to environmental dynamics (Source: Modified to this study from Frankenberger (1992) and Messay (2012) based on Table 7)

### Concluding Remarks

Sequential satellite images and GIS technologies, in combination with GBS-based fieldworks, have been used to investigate the environmental dynamics in Wasrabi-Garba Gurcah Watershed, located in Kuyu *Woreda*, North Shewa Zone of Oromiya National Regional State. The study revealed both land-use/cover conversion and modification processes in the area. The grazing lands, which accounted for about 46% of the spatial coverage of the land-use/cover in 1986, shrank down to 24.8% in 2000, and further plummeted to 7.7% in 2010. Similarly, the spatial coverage of scrubland reduced from 33.5% in 1986 to only 3% in 2010. Grazing land was disappearing at the rate of 3.46% per year on the average. Wetland areas shrank to 0.3% of the spatial coverage of the area from 3.8% within the same span of time. Similarly, the scrubland dropped at the average rate of 0.44% per year. Contrary to the other two land-use/cover types, farmland broadened from 6.4% in 1986 to 29.6% in 2010, indicating the modification of an enormous size of vegetated land to agricultural land. These figures suggest that the area is under severe environmental degradation.

The expansion of farmland is primarily caused by vegetation clearing in search of adequate plot of land for agriculture and settlement. Of the total area of the watershed, the cropland accounted for 6.4%, 15.4%, and 29.6% in 1986, 2000 and 2010, respectively. These figures are excellent evidences for an alarming conversion of naturally vegetated land-use/cover types to cropland over the given span of time. Conversions of grazing lands and scrublands have contributed significantly to the expansion of the cropland. Wetland was also converted to agricultural plots.

The spatial coverage of degraded (bare) land increased alarmingly as a result of the fast conversion and modification of the land-use/cover units in the area. The coverage of bare land was only 193.8 hectares (3.8% of the total area) in 1986. It alarmingly increased to about 1080.6 hectares (21.4 of the total area) in 2010. The average annual expansion rate of the degraded land was about 11.67%. The area of urban settlement increased more than double over the investigated 24 years.

The overall consequence of these conversion and modification processes of the land-use/cover dynamics in the watershed is one of the severest degradation of its kind. Vegetated land-use/cover types in the area may entirely disappear within the coming 15 to 20 years if the situation continues unabated. Most parts of the area may be entirely degraded in to bare lands within the indicated span of time. This, coupled with the current frightening problems related to global warming, certainly leads to severe soil loss and deterioration of its nutrients, adverse micro-climatic changes, wildlife resources losses and depletion of wetlands. This, no doubt, may result in the appalling speculation of the Malthusian crises in the near future if the situation continues unceasingly. Hence, it is imperative to take all the necessary measures (such as establishment of area closure, encouraging community conserved areas, criminalization of firewood/charcoal production and indiscriminate cutting of trees, protection of forest fire, and discouraging human encroachment into vegetated areas) by the local government offices and other concerned bodies to impede the existing extensive destruction of the vegetated lands due to increased demands for farmland, charcoal, firewood, and settlement areas in the watershed and the environs.

## **ACKNOWLEDGEMENTS**

We, the authors, would like to express our sincerest thanks to Adama Science and Technology University (ASTU) Research and Publication Office (RPO) for its generous research fund.

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Annex 1: Rainfall in millimeter at Garba Guracha Meteorological Station (1980-2010)

Year	Months												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1980			23.7	133	64.3	161.9	416.5	392.7	102.5	22.8	0.6	0	1318
1981	0.0	0	67.0	136.5	28	87	361.1	289.5	180.4	24.6	0	0	1174.1
1982	16.0	24.3	1.2	23.4	110	66.4	289.1	397.2	132.8	73.6	41	8.7	1183.7
1983	0.0	25.7	77.0	74.3	48.3	88.4	20.3	86.5	193.4	26.4	33	0	673.3
1984	1.6	13.1	13.4	7.4	132	300.2	335.8	188.8	116.4	0	25.2	6.7	1140.6
1985	14.9	0	37.6	102.2	103	110.3	356	444.5	120.3	55.5	6.8	19.4	1370.5
1986	0.0	30.2	33.5	107.1	112.5	170.5	352.2	341.2	260.7	17.5	0	13.3	1438.7
1987	24.7	11.3	67.7	120.9	178	162.6	271.5	331.8	51.9	20.7	0	15.1	1256.2
1988	29.1	36.9	3.3	64.9	2.5	80.3	438.7	324.4	270	31.4	0	0	1281.5
1989	1.0	33.2	17.1	70.7	26.1	90.6	270.3	408.9	123.7	27	0	63.2	1131.8
1990	1.8	28.4	48.4	53.9	45	120.4	328.8	371.1	186.8	0.2	0.5	0	1185.3
1991	0.0	12.1	114.5	1.3	60.9	107.2	247.3	338.5	94.3	12.7	0	12.2	1001
1992	39.4	34.7	13.1	39.2	53.1	124.4	432.7	293.3	152.7	5.9	8.6	0	1197.1
1993	0.0	0	29.2	112.1	132.3	156.1	337.9	293	278.7	84.6	0	0	1423.9
1994	0.0	0	51.6	72.5	85.2	145.3	362.4	464.9	189	0	5.3	0	1376.2
1995	0.0	0	22.1	108.6	128.6	145.3	300.1	360.2	200.9	0	0	31.9	1297.7
1996	13.2	0	0.0	9.8	0	394.6	408.1	399.3	40	0	0	0	1265
1997	26.4	1	44.1	144.3	21.6	270.8	254.1	351.1	65.1	103.5	221	6.8	1509.8
1998	6.3	10.2	35.8	33.8	104.5	91.8	354	363.6	161.4	0	1.8	16.2	1179.4
1999	16.8	0	2.2	41.6	48	82.7	478.7	384.1	114	140.6	2.2	3.8	1314.7
2000	3.5	0	3.4	66.9	51.9	140.1	355	353.8	271.9	141.8	36	13.6	1437.9
2001	0	28.4	80.5	41.6	151.6	332.5	486.5	364.7	140.8	11.7	4.1	14.6	1657
2002		32.1	39.7	66.4	36.5	157.1	249.1	342.7	121.5	0	0	39.2	1084.3
2003	10.4	38	54.2	88.7	3	192.1	483.1	284.2	136.3	0.6	0.2	10.9	1301.7
2004	8.8	4.6	38.8	61	35.2	153.9	273.8	321	114.8	49.8	5.9	7.9	1075.5
2005	15.2	0.7	113.1	109.6	77.9	140.3	286.6	260.7	158.2	14.7	0	0	1177
2006	4.1	6.5	82.2	68.9	78.1	224.5	360.2	422.6	191	62.2	10.8	13	1524.1
2007	10.7	26.3	48.1	50	82	225.2	431.2	326.6	181.7	16	0	0	1397.8
2008	5.2	2.2	0.0		126.3	202.3	333.2	331.7	104	21.8			1126.7
2009	42.1	0.6	55.3	28.3	13.2	84.8	445.1	355.3	48.8	0	4.1	10.3	1087.9
2010	36.8	2.7	34.2	90.8	108.6	98.5	373.1	317.5	297.9	20	10.6	1.6	1392.3
AV	11.3	13.4	40.4	71.0	72.5	158.3	344.9	338.9	154.9	31.8	13.9	10.3	1257.4

Source: Computed based on the data from National Meteorological Agency of Ethiopia



Annex 2: Monthly mean minimum temperature in °C at Garba Guracha Meteorological Station (1980-2010)

Year	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	3.9	6.6	10.7	10.5	11.5	10.4	10.6	10.7	9.6	8.1	8.1	5.4
1981			11.1	11.4	11	11.7	11.3	11.5	12.1	9.9	7.7	3.9
1982	5.5	9.1	11.6	11.2	11.5	9.8	10.7	10.6	10.6	7.1	7.4	5.5
1983	6.5	11.8	11.8	11.1	13.1	14.7	14.2	13.3	14.9	16.7	16.9	16.8
1984	16.6	11.9	4.9	7.4	9.4	9.2	8.9	9.1	7.4	2.3	3.8	3
1985	3.7	4.4	8.2	8.4	8.1	8.1	8.9	9	7.5	5.5	2.9	3.3
1986	1.7	5.1	5.8	7.7	7.8	9	9	8.5	8.4	5.6	2.8	2.1
1987	1.2	6	8.8	8.1	8.7	9.2	9	9	8.5	4.9	1.9	3.8
1988	5.4	8.4	7.1	9.7	9.4	10.2	10.8	10.4	9.5	6.6	2.1	2.6
1989	2.8	5.8	8.2	9.4	8.2	8.6	9.9	10.1	9.7	6.9	2.8	7.1
1990	4.1	9.5	8.1	8.3	9.1	10.1	9.7	10	10	6.1	6	2.9
1991	8	9.2	10	10.5	11.1	10.2	10.7	9.6	9.3	5.9	5.9	3
1992	6.3	10	9.9	10.8	10.4	9.6	9.6	10.5	9.1	8.9	1.8	4.9
1993	9.9	10.5	10.2	10.1	9.8	10.6	10.3	9.1	9.1	8.3	9.4	6.4
1994	8.8	10.5	9.5	8.9	8.8	9.9	9.7	10.2	10.2	10.6	9.2	8.6
1995	9.1	8.3	8.7	7.6	7.7	9	10.9	10.6	12.2	12.5	12.3	11.9
1996	11.9	11.8	11.8	11.9	11.7	11.9	10	8.8	9	8.8	9.4	12.6
1997	9.7	3.1	3.3	3.3	3.1	3.6	3.8	6.4	4.2	2.7	2.9	2.8
1998	3.6	6.5	4.4	6.4	5.6	7.3	6.7	6	5.4	4.7	10.3	9
1999												
2000					8	9.4	9.4	8.3	8.2	7.6	3.2	1.9
2001	1.6	3.4	6.3	5.5	5.2	6.9	7.3	7.3	5.7	5.1	2.4	-0.4
2002		6.1	8.3	7.6	9.5	9	9.1	8.6	6.6	3.1	1.2	5.2
2003	2.9	3.7	6.2	7.5	8.2	7.6	9.4	9.9	8.3	3.9	2.7	1.8
2004	5.2	4.1	7.8	9.8	8.3	10.2	9.9	9.6	8.4	4.1	3.1	3.1
2005	4.4	6.2	8.3	9	9.6	9.4	10.1	10.2	9.3	4.5	2	-0.1
2006	3.9	6.6	9	9.8	9.3	9.9	10.7	10.2	8.6	6.2	4.7	5
2007	6.5	7.1	6.6	9.2	9.8	9.7	10.2	10.2	9.1	4.5	3.1	0.4
2008	3.2	4.1	5.8		9.1	9.3	10.1	9.8	8	5.5		
2009	5	5.7	6.6	8.3	9.1	9.4	10.5	10.4	8.5	5.5	2.8	6
2010	5.1	9.7	9.6	10.7	10.8	10.4	10.7	10.5	8.8	5.3	3.6	4.3
Average	5.8	7.3	8.2	8.9	9.1	9.5	9.7	9.6	8.9	6.6	5.3	4.9

Source: Computed based on the raw data from National Meteorological Agency of Ethiopia

Annex 3: Monthly mean maximum temperature in °C at Garba Guracha Meteorological Station (1980-2010)

Year	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980			24.3	26.3	25.8	22.2	18.7	19	20.2	21	22	22.2
1981	23.2	25.5	23.4	22.7	25	24.4	19.7	18.7	19.5	21.9	26.5	28.8
1982	28.9	28.9	29.3	28.4	23.2	24.7	20.1	18	19.5	19.3	20.7	21.4
1983	22.9	22.6	22.9	23.3	22.7	22.6	21.4	18.1	20.2	20.6	20.8	21.8
1984	22.4	23.6	24.1	25.3	22.9	20.1	18.9	19.6	19.8	21.4	22.3	21.4
1985	22.9	23.5	24.1	22.2	22	22.5	18.5	18.3	19.1	20.5	21.7	21.6
1986	22.6	22.9	22.8	22.3	23.6	20.5	18.8	18.6	19.5	20.7	21.3	21.9
1987	22.4	23.7	22.8	22.7	21.6	21.5	20.9	19.6	21.5	22.3	22.7	22.5
1988	23.6	23.4	25.5	24.6	25.9	23.4	17.7	18.1	19.3	20.4	21.1	22
1989	22.3	22.8	22.6	21.3	23.2	23	19.4	18.9	20	21.9	22.2	21.8
1990	23.4	23.4	23.7	24.1	25.1	24	19.9	20.6	21.2	21.9	22.1	22.5
1991	23.8	24.4	24.1	23.8	24.8	23.2	20.8	19.5	22.5	23	23.2	22.8
1992	21.8	22.6	23.8	23.8	24.6	22.6	20.9	20.4	21.2	22.7	22.9	23
1993	23.8	24.2	2.7	23	22.9	22.3	21.2	20.5	19.7	22.8	24.1	24.6
1994	24.7	24.8	24.1	23.9	24.1	24	22.7	22.7	23	23.3	23.1	23.9
1995	23.9	24.4	24	24	23.4	25.6	22.5	21.8	21.9	23.4	24.4	24.1
1996	23.5	24.3	24.7	25	24.6	24.1	22.3	21.4	21.3	22.3	23.1	21.3
1997	24.8	27.2	29.2	30.3	29.8	29.5	29.6	26.8	29.2	28	30.5	27.6
1998	29.9	29.6	29.6	29.4	29.2	28.8	28.7	28.5	28.4	29.2	28.5	28.5
1999												
2000					25.7	23.4	19.4	18.3	20.2	22.9	21.6	22
2001	23.1	24.3	22.9	24.5	23.4	21	20.3	20	19.9	19.5	19.7	
2002												
2003												
2004						22	19.8	19.6	20.8	21.4	22.6	23.1
2005	23.8	25.6	25.4	24.6	23.8	23.5	19.1	19.9	20.8	21.8	22.6	22.7
2006	24.3	25.3	24.2	23.4	24.2	22.6	19.5	19.5	20.5	22.3	22.2	22.2
2007	23.3	24.1	25.8	24.3	25.2	21.7	18.8	19.2	20.2	21.1	21.9	21.9
2008	23.5	24.6	25.8		23.6	21.6	19.6	19.6	21.1	21.9		
2009	23	24.2	25.2	25.6	26.8	26	19	19.7	21.8	21.5	22.6	22.2
2010	23.4	24.1	24.7	23.9	24.1	23.4	19.9	19.2	20.8	22.4	22.4	22.2
Average	23.8	24.6	23.9	24.51	24.49	23.36	20.65	20.15	21.18	22.2	22.92	23.08

Source: Computed based on the raw data obtained from National Meteorological Agency

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