

# Climate Change Impact and Adaptation in South Omo Zone, Ethiopia

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## Abstract

In Ethiopia rain-fed agriculture that is highly sensitive climate change and variability, accounts for much of the country's GDP. This study covered two parts-the first part assesses the impact of climate change on biophysical parameters such as temperature and precipitation in South Omo zone and the second part portrays an over view of adaptation mechanisms to climate change the region. A Statistical downscaling model was developed and validated using large-scale predictor variables derived from the National Centre for Environmental Prediction (NCEP) reanalysis data and observed station data that was achieved in order to establish a statistical relationship between large-scale NCEP reanalysis predictor variables and locally observed meteorological variables. The relationship obtained was then used to generate the possible future scenarios of meteorological variables such as temperature and precipitation using large-scale predictor variables obtained from the GCM, HadCM3 outputs for A2 and B2 emission scenario. The downscaling was done for intermediate (2021-2050) and far future (2070-2099) periods. The validation results of the SDSM revealed a good agreement between simulated and observed values for temperate. But the model underestimates simulated precipitation. The impact assessment over the south omo projects an increase in precipitation in both periods. Both the minimum and maximum temperature are projected to increase in a range of 0.5°C to 1.20°C for both intermediate and far future periods. For future period the potential evapotranspiration could also increase due to the rise of temperature that leads to more severe drought. Enclosed range land management was proposed by study for climate change adaptation, for this a capacity building training was given for the pastoralist community on range land management. Developmental activities by the government on that part of the area could be a treat and an opportunity for the pastoralist community for adaptation of climate change.

## Keywords: Climate change; SDSM; South Omo

## Introduction

Climate change is likely to happen with surface temperatures having increased by about 0.74°C from 1906 to 2005 [1]. Observations show that there are changes in precipitation, occurring in the amount, intensity, frequency and type of precipitation, as a result of direct influences of climate change. In both the developed and developing world, climate impacts are reverberating through the economy, threatening water availability, hydro-power generation, extreme weather impacts, sea level rise, amongst others [2].

Climate change and variability has potential impact in Africa in general and East Africa in particular on different natural resources, such as water availability, which in turn greatly influences agriculture, energy, ecosystems and many other sectors. Even in the absence of climate change, the present population trends and patterns of water use indicate that more Africa countries will exceed the limits of their economically usable, land-based water resources before 2025 [1].

A projected increase in rainfall in East Africa, extending into the Horn of Africa, is robust across an ensemble of models of which 18 out of 21 models project an increase in the core of this region, east of the Great Lakes [1]. Local and regional changes in the character of precipitation further depend on atmospheric circulations, which are in turn associated to climate change. For example, rainfall in east Africa is associated to the shift of the intra- tropical convergence zone (ITCZ), which is largely influenced by El Nino (ENSO Index), Indian Ocean Dipole in during some seasons (IOD), factors that are also influenced by chances in sea surface temperatures (SSTs) [3].

The underdeveloped and poor countries that are most vulnerable bearing the greatest impacts of climate change is [1] East Africa/N-East Africa is amongst the most vulnerable regions to climate change impacts since economic growth in these countries is strongly weather dependent, ranging from rain-fed agriculture, to pastoral activities. According to a UNDP report, agriculture accounts for around 60% of overall employment in some countries and more than 50% of GDP [4]. There have been notable droughts in Ethiopia throughout human history [5]. Previous droughts and the frequency of rainfall deviation from the average suggest that droughts occur every 3-5 and 6-8 years in northern Ethiopia and every 8-10 years for the whole country [5].

According to the Fourth Assessment Report released by the Intergovernmental Panel on Climate Change droughts have become longer and more intense, and have affected larger areas since the 1970s; the land area affected by drought is expected to increase and water resources availability in affected areas could decline as much as 30 present by mid-century [1].

Ethiopia is known to be highly vulnerable to drought, which is the single most important climate-related natural hazard impacting the country from time to time. Major droughts in Ethiopia in recent times were in the late 1950s (in northern parts), in 1972/73 (northeastern in Tigray and Wollo), in 1984/85 (in major parts of the country), 1994 (in the low land pastoral areas), in 2000 (in the southern lowland pastoral areas), in 2002/3 (in major parts of the country), and in 2007/8 (in many areas in the highland and lowlands) [6].

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The poor are likely to be hit hardest by climate change, and that capacity to respond to climate change is lowest in developing countries and among the poorest people in those countries. It is clear that vulnerability to climate change is closely related to poverty, as the poor are least able to respond to climatic stimuli. Furthermore, certain regions of the world are more severely affected by the effects of climate change than others. Generally speaking, vulnerability and adaptation to climate change are urgent issues among many developing countries. The objectives of this paper is to assess climate change impact and adaptation mechanisms for the pastoralist community in South Omo Zone, Ethiopia.

# **Climate Change in Ethiopia**

Ethiopia has made only a marginal contribution to global greenhouse gas (GHG) emissions.. The average Ethiopian is responsible for around one metric tons of CO<sub>2</sub> per year. According to the business-as-usual scenario outlined by the government, GHG emissions in Ethiopia are expected to increase from roughly 150 Mt CO<sub>2</sub>e, at present, to around 400 Mt CO<sub>2</sub>e in upcoming years [7]. This will be mainly the result of the expansions of agriculture, especially commercial farming and husbandry, and deforestation, which is influenced by the expansion of cropland and population growth. Despite this expected doubling of emissions, Ethiopia would still be a minor producer of GHGs by global standards. At the same time, a growing number of studies show that Ethiopia is likely to be one of the country's most severely affected by climatic changes associated with global warming. Ethiopia's high vulnerability is derived from the fact that its economy and the livelihoods of most Ethiopians are extremely dependent on agriculture. While the service sector has grown considerably in recent years, agriculture continues to account for nearly half of the country's GDP, more than 80 percent of its export revenues, and roughly 85 percent of employment. Although there is a growing trend towards modernised commercial farming, the majority of Ethiopia's agricultural production continues to be based on human and animal power, uses traditional tools and methods, and relies heavily on natural rainfall to feed crops.

## Climate variability and future projection

According to Solomon et al., [1], developing countries in general and least developed countries like Ethiopia in particular are more vulnerable to the adverse impacts of climate variability and change. This is due to their low adaptive capacity and high sensitivity of their socioeconomic systems to climate variability and change. Sensitivity and adaptive capacity also vary between sectors and geographic locations, time and social, economic and environmental considerations within a country. Abebe [8] has analyzed the annual minimum temperature and annual rainfall variability and trends observed over the country in the period 1951-2006. Annual minimum temperature is expressed in terms of temperature differences from the mean and averaged for 40 stations.

Climate change projection for three periods centered around the years 2030, 2050 and 2080 for the IPCC mid-range (A1B) emission scenario, the mean annual temperature will increase in the range of 0.9-1.1°C by 2030, in the range of 1.7-2.1°C by 2050 and in the range of 2.7-3.4°C by 2080 over Ethiopia (Figure 1) with reference to the 1961-1990 normal. A small increase in annual precipitation is expected over the country (Figures 2-4).

# Climate change and pastoralists in Ethiopia

In Ethiopia, pastoralists and agro-pastoralists live in the country's arid and semiarid rangelands of the south and east, and they compose nearly 13 percent of the population. Mobility is fundamental to pastoralists' strategies for coping with unpredictable rainfall, livestock diseases, and the sustainable use of scarce natural resources. Pastoralists in Ethiopia face a number of challenges that threaten the sustainability of their traditional practices. Trends indicative of climate change, such as increasingly recurrent drought, floods, erratic rainfall patterns, and high temperatures are adding significantly to these stresses.

Climate change has direct effects on livestock productivity as well as indirectly through changes on the availability of fodder and pastures. Climate determines the type of livestock most adapted to different agro-ecological zones and therefore the animals that are able to sustain rural communities. Drought-induced crop and livestock losses in north-eastern.

Ethiopia from 1999 to 2000, for example, were estimated at US\$266 per household, an amount greater than the annual average income of more than ¾ of the households in the region [9]. Climate change is expected to affect livestock at the species level [10]. In addition, climate change is likely to bring about even more erratic and unpredictable rainfalls and more extreme weather conditions such as longer and more frequent droughts. Where this happens, the delicate balance on which pastoral systems depend is undermined. The quality, quantity and spatial distribution of natural pastures are mainly shaped by rainfall. Predicted changes in rainfall patterns are bound to result in increasingly scarce, scattered and unpredictable pastures. The number, distribution



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Figure 4: Average projection of 19 GCMs for change (%) in rainfall relative to 1961-1990 normal for A1B emission scenario.

and productivity of permanent pastures and water points, which are so critical for livestock survival during the dry season, are bound to decline. Scarcer resources, coupled with current levels of demographic growth, are likely to lead to stronger competition between pastoral communities and between these and other groups possibly resulting in conflict and even violent clashes. As a result, access to pastures becomes more difficult, leading to loss of livestock and of livelihoods.

# Study Area Description and Demography

South Omo is a Zone in the Ethiopian Southern Nations,

Nationalities and Peoples Region (SNNPR). South Omo is bordered on the south by Kenya, on the southwest by the Ilemi Triangle, on the west by Bench Maji, on the northwest by Keficho Shekicho, on the north by Semien Omo, on the northeast by the Dirashe and Konso Special Woredas, and on the east by the Oromia Region (Figure 5). The administrative center of South Omo is Jinka. Based on the 2007 Census conducted by the Central Stastical Agency (CSA), this Zone has a total population of 573,435, of whom 286,607 are men and 286,828 women; with an area of 21,055.92 square kilometers. While 43,203 or 7.53% are urban inhabitants, a further 25,518 or 4.45% are pastoralists. A total of 125,388 households were counted in this Zone, which results in an average of 4.57 persons to a household, and 121,309 housing units. In the 1994 Census, South Omo had a population of 327,867 in 77,694 households, of whom 165,064 were men and 162,803 women; 22,084 or 6.74% of its population were urban dwellers. The six largest ethnic groups reported in this Zone were the Aari (42.94%), the Male (13.49%), the Hamer (12.89%), the Daasanach (9.77%), the Amhara (5.59%), and the Nyangatom (4.33%); all other ethnic groups made up 10.99% of the population. Aari is spoken as a first language by 43.33%, 13.7% speak Male, 13% Hamer, 9.76% Daasanach, 6.19% Amharic, and 4.32% speak Nyangatom; the remaining 9.7% spoke all other primary languages reported [2].

According to 2004 memorandum, 4% of the inhabitants of South Omo have access to electricity, this zone has a road density of 22.7 kilometers per 1000 square kilometers (compared to the national average of 30 kilometers) the average rural household has 0.4 hectare of land (compared to the national average of 1.01 hectare of land and an average of 0.89 for the SNNPR) the equivalent of 1.5 heads of livestock. 11.5% of the population is in non-farm related jobs, compared to the national average of 25% and a Regional average of 32%. 37% of all eligible children are enrolled in primary school, and 7% in secondary schools. 77% of the zone is exposed to <u>malaria</u>, and 61% to <u>Tsetse fly</u>. The memorandum gave this zone a drought risk rating of 348.

The Nyanngatom territory is located in the south Omo zone, consisting a community of about 20, 000 people. The Nyangatom area is a dry and hot in the very south of the country bordering Kenya. The area is situated at 360 m.a.s.l. The annual precipitation in the area is estimated to be about 400mm. The communities' livihood depends on livestock as well as agriculture.

# Data and Methodology

## Data

Daily precipitation, maximum and minimum temperature is required to calibrate and validate the SDSM model. The National Meteorological Agency of Ethiopia is responsible to collect weather data in Ethiopia. The daily precipitation, maximum and minimum temperatures, will be obtained from National Meteorological Agency. Figure 6, show the long mean daily precipitation for Jinka station, which revealed by-modal seasonality. The first rain occurs between March-April (MAM) and the second small rain occurs on November and December.

![](_page_3_Figure_8.jpeg)

# SDSM model

Global Climate models (GCMs) are the best tools to estimate future global climate changes resulting from the continuous increase of greenhouse gas concentration in the atmospheres [11]. However, due to their coarse spatial resolution, the outputs from these models may not be used directly in impact studies. Hydrological models, for instance, deal with small or sub catchment scale processes whereas GCMs simulate planetary scale and parameterize many regional and smaller-scale processes. Therefore there is a scale mismatch between GCMs and hydrological models and these needs down scaling of GCMs to catchment or sub-catchment process.

Downscaling techniques (Figure 7) emerged as a means to relate the scale mismatch between the GCMs results and the increasingly small scales required by impact community [11]. The two main approaches used for deriving local or regional scales information from the global climate scenarios generated by GCMs are dynamic downscaling which involves a nested regional climate model (RCM) and statistical downscaling techniques which employs a statistical relationship between the large scale climatic state and the local variations derived from historical data.

Statistical Downscaling Model (SDSM) is a hybrid of multiple linear regression and stochastic downscaling model developed by Rob Wilby and Christian Dawson. It is a freely available decision support tool for assessing local climate change impact using a robust statistical downscaling technique.

In SDSM downscaling, a multiple linear regression model is developed between a selected large-scale predictor variables and local scale predict ands such as temperature and precipitation (Figure 8). And the parameters of the regression equation are estimated using an ordinary Least Squares algorithm.

## Predictand=f (predictors)

# **Predictor variables**

Predictor data files for SDSM were obtained from the Canadian Institute for climate studies (CICS) website. The predictor variables for HadCM3 were provided on a grid box by grid box basis of size 2.5° latitude and 3.75° longitude (Figure 9). Jinka meteorological station has a latitude and longitude of 5°47′N 36°34′E/5.783°N 36.567°E. Table 1 shows large- scale atmospheric variables derived from the grid boxes.

The choice of predictor variable(s) is one of the most challenging stages in the development of any statistical downscaling model. This is attributed to the fact that decision largely determines the character of

![](_page_4_Figure_10.jpeg)

![](_page_4_Figure_12.jpeg)

Figure 7: Schematic illustration of the general approach to downscaling (Wilby and Dawson, 2007.

the downscaled scenario. The decision process is also complicated due to the fact that the explanatory power of individual predictor variables varies spatially and temporally. In SDSM, the selection of the most relevant predictor variables was carried out through linear correlation analysis, partial correlation analysis and scatter plots between the predictors and the predictand variables. Large-scale predictor variables representing the current climate conditions, derived from the NCEP reanalysis data sets, were used to investigate the percentage of variance explained by each predictand-predictor pairs. Table 2 shows the selected predictor variables for the stations in the downscaling experiments.

#### Trend analysis

Detection and attribution of past trends, and variability in climatic variables is essential for the understanding of potential future changes resulting from anthropogenic activities [12]. The Mann-Kendall trend test can be applied to detect the presence of trends in the streamflow, precipitation and temperature records for the South Omo basin.

#### Man-Kendall test

s

 $\sigma$ 

Man-Kendall test, a technique based on the Kendall tau statistics has been introduced to test for randomness against trend in climatological time series [12]. The test statistic (S) for the Mann-Kendall test is given as:

$$=\frac{\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\operatorname{sgn}(Y_{j}-Y_{i})}{\sigma_{s}}$$

With standard deviation

$$s = \sqrt{\frac{N(N-1)(2N+5) - \sum_{i=1}^{n} t_i(i-1)(2i+5)}{18}}$$

Where: N is the number of data,  $Y_j$  and  $Y_i$  are the data values in two consecutive periods;  $t_i$  is the number of ties, i.e equal values, of extent i and N is the number of tied groups. The function  $sgn(Y_j - Y_i)=1$  if  $Y_j - Y_i > 0$ ;  $sgn(Y_i - Y_i)=0$  if Y=0 and  $sgn(Y_i - Y_i)=-1$ 

if 
$$Y_{i} - Y_{i} < 0$$

The test statistic (S) follows the standard normal distribution and

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![](_page_5_Figure_2.jpeg)

![](_page_5_Figure_3.jpeg)

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No.	Predictors	Description	No.	Predictors	Description
1	ncepmslpaf	Mean sea level pressure	14	ncepp5zhaf	500 hPa divergence
2	ncepp_faf	Surface airflow strength	15	ncepp8_faf	850 hPa airflow strength
3	ncepp_uaf	Surface zonal velocity	16	ncepp8_uaf	850 hPa zonal velocity
4	ncepp_vaf	Surface meridional velocity	17	ncepp8_vaf	850 hPa meridional velocity
5	ncepp_zaf	Surface vorticity	18	ncepp8_zaf	850 hPa vorticity
6	ncepp_thaf	Surface wind direction	19	ncepp850af	850 hPa geopotential height
7	ncepp_zhaf	Surface divergence	20	ncepp8thaf	850 hPa wind direction
8	ncepp5_faf	500 hPa airflow	21	ncepp8zhaf	850 hPa divergence
9	ncepp5_uaf	500 hPa zonal velocity	22	ncepr500af	Relative humidity at 500 hPa
10	ncepp5_vaf	500 hPa meridional velocity	23	ncepr850af	Relative humidity at 850 hPa
11	ncepp5_zaf	500 hPa vorticity	24	nceprhumaf	Near surface ralative humidity
12	ncepp500af	500 hPa geopotential height	25	ncepshumaf	Surface relative humidity
13	ncepp5_thaf	500 hPa wind direction	26	nceptempaf	Mean temperature at 2 m

Table 1: Large-scale atmospheric variables from the NCEP reanalysis and HadGCM3 simulation output that are used as potential inputs for the multiple linear regression model.

Predictor No.	- 1	2	7	10	17	23	21	25	18	16	20	22	12	24
Variables														
Max. Temp														
Min. Temp														
Precip.														

Table 2: Large-scale climate predictors for computing surface meteorological variables at different stations with SDSM model.

therefore if the p-values is greater than significant level  $\alpha$  then there is a statistically significant trend. The p-value is the probability, under the null hypothesis, of observing values as extreme as the test statistic S. The higher the magnitude of the value of the Kendall's tau, the strong the trend is.

# Trends in Observed Meteorological Variables

Figures 10 and 11 shows time series of maximum temperature, minimum temperature and precipitation respectively, for the Jinka meteorological station. Both maximum and minimum temperature time series exhibit an increasing trend. The times series in precipitation shows no trend (Figure 12).

The Mann-Kendall non parametric trend test was applied to both times series of maximum and minimum temperature for Jinka. We obtained an increasing trend in the time series of in both maximum and minimum temperature (Table 3). No trend for precipitation.

## **SDSM Model Calibration and Validation**

Model calibration was carried out based on the selected predictor variables that were derived from the NCEP data set. Model calibration in this case was to find the coefficients of the multiple linear regression equation parameters that relate the large scale atmospheric variables derived from NCEP and local scale variables. The temporal resolution of the downscaling model for precipitation downscaling was specified as monthly. For Jinka station, from the 28 years of data, representing the current climate condition, the first 21 years of data (1974-1994) were considered during calibrating the regression model while the remaining 7 years (1995-2001) were used to validate the model.

Some of the SDSM setup parameters for event threshold, bias correction and variance inflation were adjusted during calibration to obtain a good statistical agreement between the observed and simulated climate variables. Figures 13 and 14 shows the performance of the model during validation period. The graph shows a good agreement between the observed and simulated mean daily precipitation and average wet spell lengths for all months of the year except, whereas the observed and simulated mean daily maximum and minimum temperature showed good agreement for all months of the year. Unlike temperature, precipitation is a conditional process that dependents on other intermediate process like occurrence of humidity, cloud cover, and /or wet-days. For that reason, it is identified by many researchers as one of the most problematic variable in downscaling.

# Downscaling with SDSM

After calibrating the SDSM model, using observed data and largescale predictors originating from NCEP reanalysis, the same empirical relationship with predictors, supplied by GCMs, were tuned to downscale the future climate change scenario simulated by GCMs. 20 ensembles of synthetic daily time series were generated for A2 and B2 SERS emission scenarios and HadGCM3 for the period of 139 years (2061-2099). The ensemble mean of the 20 ensemble members for the intermediate period (2021-2050) and far future period (2070-2099) were used for impact analysis.

Figures 15 and 16 shows the future projection of precipitation for the intermediate and far future for A2 and B2 future emission scenarios, respectively. The precipitation is projected to increase both in the intermediate and far future. A small increase in precipitation all over the country is also projected by Abebe [8]. It should be noted that, the down scaling of daily meteorological variables was done based on only one station and therefore the result might not be representative of the South Omo zone.

Figures 17 and 18 show the general trend in the mean daily maximum temperature at Jinka station corresponding to future climate change scenarios A2 and B2 respectively downscaled with SDSM. Form these figures, it could be seen that a general increasing trend is evident maximum temperature in most of the months of the year. The average increase in maximum temperature between the current climate and that of the intermediate period and far future is projected to be about 0.5° C and 1°C, respectively for B2 emission scenario. The maximum temperature is projected to increase in the range of 0.5°C and 1.2°C for the intermediate and far future periods for A2 emission scenario.

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![](_page_7_Figure_2.jpeg)

![](_page_7_Figure_3.jpeg)

![](_page_7_Figure_4.jpeg)

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Variables	p-values (two-tailed)	Kendall's tau	Trends
Maximum Temperature	0.077	<0.0001	Increasing
Minimum Temperature	0.094	<0.0001	Increasing
Precipitation	0.010	0.221	No trends

![](_page_8_Figure_3.jpeg)

![](_page_8_Figure_4.jpeg)

![](_page_8_Figure_5.jpeg)

![](_page_8_Figure_6.jpeg)

![](_page_8_Figure_7.jpeg)

**Figure 15:** Mean daily precipitation for control period (1961-1990), intermediate period (2021-2050) and far future (2070-2099) downscaled using HadGMC3 forcing and A2 emission scenario for Jinka station.

![](_page_8_Figure_9.jpeg)

![](_page_9_Figure_1.jpeg)

**Figure 17:** Mean daily maximum temperature for control period (1961-1990), intermediate period (2021-2050) and far future (2070-2099) downscaled using HadGMC3 forcing and A2 emission scenario for Jinka station.

![](_page_9_Figure_3.jpeg)

Figures 19 and 20 depict the trends in mean daily minimum temperature future projection for two future period and two emission scenarios. The minimum temperature is projected to increase in both intermediate and far future. For both A2 and B2 emission scenario, the minimum temperature is projected to increase in the range between 0.5°C and 1.2°C respectively, in the intermediate and far future.

# Adaptation Strategies in Nyangatom for Pastoralist Community

## Capacity building training on adaptation

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Responding to climate change will also require a long-term approach to provide the investments necessary for appropriate and sustainable development, allowing pastoralists either to adapt to their changing environment, or to transition out of pastoralism into alternative livelihoods [13]. Rangeland management as an option for climate change adaptation for the pastoralist community in Nyangatom was investigated by taking soil samples and also water harvesting potentials and other options were also investigated by Adger [14].

Generally about 12 sites were investigated for a potential rangeland management site, some are already in a very good condition for grazing, and the others are already degraded but can be soon rehabilitated and a good potential for grazing, the last one are very degraded and difficult for rehabilitation for grazing or takes long time to restore. Two potential sites were chosen from the ones which can be rehabilitated soon. One of the sites is suitable for grazing goats and the other one for both cattle and goats. Capacity building trainings were given for NGOs

![](_page_9_Figure_9.jpeg)

**Figure 19:** Mean daily minimum temperature for control period (1961-1990), intermediate period (2021-2050) and far future (2070-2099) downscaled using HadGMC3 forcing and A2 emission scenario for Jinka station.

![](_page_9_Figure_11.jpeg)

working with the pastoralist community (Figure 21). The reason for supporting these NGOs is to help people or pastoralists to rangeland enclosure works and make awareness of climate change impacts and some adaptation strategies. The NGOs identify what the advantage and disadvantage that the pasture gets from the rangeland enclosure and management.

There were treats mentioned by the participant on how and who uses the enclosed range land. One with more power can over take it prohibiting other not to graze there. In this case, the usage of the rangeland management can also be a potential cause for conflicts with in the pastoralist community. To avoid the conflict a mechanism should be devised on how and who should use the enclosed rangeland for grazing his cattle. A matrix diagram was used to identify the wellbeing of a particular house hold that could assist one to make a decision that might be prioritized for using the enclosed rangeland (Figure 22).

Adaptations to climate change vary across livelihood groups and zones. Adaptations are perceived as measures to improve livelihoods, the environment and rehabilitation of natural resources. Reforestation, water harvesting, use of irrigation, and improved productivity of crops and livestock are the common adaptation measures perceived by the different communities. The adaptation pathways identified by local communities also coincide with the adaptation pathways at the national level [6]. To boost awareness on how to manage the enclosed range land to upscale the good practices in the Nyangatom area, trainings were also given by NCDA members to selected groups from the pastoralist community with the assistance of Staffs from Horn of Africa Regional Centre/Climate change adaptation program office.

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![](_page_10_Picture_2.jpeg)

Figure 21: Capacity building training for Nyangatom Community Development Association (NCDA) and others worker from different gov't offices.

![](_page_10_Figure_4.jpeg)

The selected groups were from youth, elders, women, clan leaders and development assistance (DA) worker in the Lukulan area.

#### Treats and opportunities for climate change adaptation

For adaptation of climate change impacts on the pastoralist community in Ngangatom area, adaptation strategies were suggested by Preston [15] for water harvesting. The other options for coping with climate change are small irrigation for the rangelands that could be mixed with agricultural practices near the Omo River (Figure 23). Irrigating the enclosure with the help of motor pumps would not be a sustainable solution for adaptation as it requires a lot of money for buying the fuel. There is a need to look for other sources of energy like wind or solar, which still is not a sustainable solution as the equipment for solar and wind energy are also expensive, at which for the former energy source, the area could not be still feasible. Building a dam or a reservoir in Omo river for a small scale irrigation for their rangelands could be a sustainable solution and able to cope and live with the changing climate [16-19].

The pastoralist communities in Ethiopia occupied the vast low land areas in the East, South and South east of the country. Many rivers that are flow downstream to the lowlands for the highlands. These low land areas have a great potential for agriculture and other activities as the bear vast, virgin and fertile lands. The government of Ethiopia, in 2010 has released its Growth and Transformation plan (GTP) for the next 5 years [20,21]. One of its plans is to lease out huge amount land in the low land area to foreign and local investors. In it has also to build many sugar factory and sugar plantation, one which is being built in the Nyangatom area. As a matter of fact there are huge resettlement activities going on there on selected sites. Figure 24 shows on of the selected sites for resettlement in Nyangatom area.

Each household has allocated half hectare of land after they are displaced from their original pasture. Most of the selected resettlement place doesn't bear a fertile agriculture and pasture as they are already taken by the government for the sugar industry and plantation [23-25]. The pasture near the settlement areas are mostly covered with some invasive species that are not consumed by the sheep and cattle (Figure 25). Though most didn't want to express their feeling about the resettlement because of their security reasons, some said that they have doubt and frustration about their future livelihood as the they mostly depend on livestock.

Vulnerability to climate change effects is aggravated by social factors and the status of livelihood situation and development [6]. The development activities that are going on by the government is limiting the pastoralist activities, some pasture lands are already taken away by the government already for the sugar cane plantation and

![](_page_11_Picture_1.jpeg)

Figure 23: Omo River which is one of the largest rivers in Ethiopia which is very suitable for irrigation agriculture. Many pastoralist resides along the river and it is a means of substance them. Some pastoralists grow crops when the river recedes after the main rain season in the highlands of Ethiopia.

![](_page_11_Picture_3.jpeg)

Figure 24: Some of the selected resettlement sites near Kangaton town, Small hats are distributed here and there, some already start farming and grown corn plants on the allocated piece of land.

![](_page_11_Picture_5.jpeg)

Figure 25: Invasive plant species that happen after a major flooding of the Omo River occurred in 2006. This species almost dominate/vanish the indigenous species near the selected resettlement sites, considered as a treat for the pastoralist community for climate change adaptation.

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for building a factory for sugar production [26]. In some cases the development activities are blocking pastoralists from access to water as it is mentioned by the participants. The government has also a plan to take away hundred thousands of hectare from the pasture land that greatly threatens their existence, these action also could trigger mass migration to neighboring countries that could in turn trigger a border conflict in search of water and pasture for their cattle [27].

There are such activities like huge resettlement activities going on these areas to get huge lands for the development activities. The villagization processes are simply arbitrary and not planned a head. Thought the government claims that the resettlements going on are meant for better life to the pastoralist community to improve and modernize their way of life. There are not basic infrastructures such as schools, health posts, roads and water for the people and the livestock. These greatly hinder the pastoralist's common way of coping with climate change variability and change. The usual way that pastoralists cope with such impact of climate change is their mobility [28]. They move from one place to the other in searching of pasture land and water.

Despite the fact that they are displaced and their lands are taken away, some of the pastoralists are very hopeful on the government promises to build schools, health center and job opportunities on the sugar plantation and sugar factory that changes their life style dramatically. In addition the government has also a plan to the help pastoralists to irrigate the allocated piece of land for agriculture, rangeland or mixed. This could reduce their mobility in search of water and pasture that significantly changes their way of life, easy to get education for their kids and above all it changes their life style and means of subsistence [29]. This lift up the pastoralist community to a better living condition free from treats caused climate change and variability. To achieve this could not be easy, as it require reducing the number of life stocks to fit with the allocated piece of land, make them more productive and commercialize the animal breeding and animal byproducts. And also select better breeding animals that can be more productive and disseminate to the pastoralist community.

# **Conclusions and Recommendations**

According to IPCC [1] developing countries like Ethiopia are more vulnerable to adverse impacts of climate change and variability due to their low adaptive capacity. Agriculture accounts for nearly half of the country's GDP, more than 80 percent of its export revenues, and roughly 85 percent of employment. The agriculture sector is mainly depend on rain feed agriculture which is highly sensitive to climate change and variability. Pastoralists and agro-pastoralist account about 13% of the total population. Climate change has direct effects on livestock productivity as well as indirectly through changes on the availability of fodder and pastures. In this study the impact of climate change was assessed in the South Omo Zone, South Ethiopia, where most of the population is pastoralist or agro-pastoralist [30]. As there are scarce observed data available in the Zone, only daily meteorological data from Jinka station is used to develop statistical downscaling model.

The Statistical Downscaling Scaling Model was developed and validated using large-scale predictor variables derived from the National Centre for Environmental Prediction (NCEP) reanalysis data and observed station data that was achieved in order to establish a statistical relationship between large-scale NCEP reanalysis predictor variables and locally observed meteorological variables. The relationship obtained was then used to generate the possible future scenarios of meteorological variables such as temperature and precipitation using large-scale predictor variables obtained from the Global Climate Model, HadCM3 (Hadley Centre Coupled Model version3) outputs.

The impact assessment over the South Omo projects the precipitation to be increased in both periods. Both the minimum and maximum temperature are also projected to increase in both the intermediate and far future. The increase in temperature could lead to an increase in potential evapotranspiration that could lead to droughts in the South Omo Zone. It should also be note that the increase in changes in temperature and potential evapotranspiration doesn't have a linear relationship. One of the ways that help to adapt to climate change in the pastoralist community is capacity building. Trainings were given to the NCDA on how to manage the enclosed range land which is one of the adaptation strategies suggested by a study group. Matrix ranking was used to identify the criteria of wellbeing of a household. Matrix ranking is then used to prioritize which social group or person could use the enclosed range land and then help to management by avoiding conflict among different interest groups.

The development activities by the government have been seen differently by the pastoralist communities there. Some consider it as a treat because they are displaced from their land and forced to migrate to other location in search of pasture and water for their livestock. Others considered it as opportunity, as the government promise to build infrastructures such as schools, health Centre and help them irrigation agriculture that would dramatically change their way of life. A better climate change impact assessment on the South Omo zone should be done by incorporation of data that have a better spatial and temporal coverage obtained from remote sensing (Satellite measurements) or by using interpolation techniques from Neighboring stations. Before the resettlement of pastoralist, the basic infrastructure such as schools, health centers and pasture lands have to be planned ahead, to avoid mass migration in search of a pasture and water, that could lead to boarder conflict as it always is the case. Introduction of new technologies to the pastoralist community that would improvise animal productivity is also recommended. Select better breeding and more productive animals and also disseminate them to the pastoral community. The Livestock properties are not efficiently used to improve the country's economy. This would be done by commercializing livestock products in a way that pastoralist could benefit out of it and shift their means of subsistence from only animals by products to other alternatives.

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