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Indigenousknowledge and scientific weather forecast: Implication for climate change adaptation strategiesin Dessa'a, Tigray, North Ethiopia

Mengistu Tilahun[1, 2*]

[1]Department of Wildlife and Ecotourism management, P.O.Box 231, Mekelle University,Ethiopia

[2] Institute of Climate and Society (ISC) P.O.Box 231, Mekelle University, Ethiopia

*Corresponding author: Tel: +251925441375; Mengistu Tilahun, Mekelle University, Ethiopia

E-Mail address:**mengeedu2006@gmail.com**

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Abstract

Indigenous knowledge contributestoclimate change adaptation measures for the community. Therefore, this study wasaimed to: i) Forecast and characterize climatic variables (maximum temperature, minimum temperature and rainfall),ii)explore indigenous knowledge weather forecast,iii) identify climate change adaptation strategies using analogues method,iv)identify indigenous knowledge of climate change adaptation strategies. The climate modeling RCPs (RCP4.5 and RCP 8.5) were used with three general circulation model (GCMs). The backward analogues method was chosen to identify analogues sites. An informal and formal meeting with key informants, interviews, focus group discussionsand direct observation were used.Three hundred fifty (350)households were selected throughrandom sampling. Maximum temperature and minimum temperature of the study area will be increased by 3.87^0c and 4.27^0c respectively in future up to 2099. Higher (84mm)and lower (-67)rainfall will be expected inendterm and near term respectively.Indigenousknowledge'sof weather forecast at Dessa'a were identified.Backward analogues showed that the climate variables of Dessa'a will be similar with the current climate variables of Ethiopian rift valley at 2050. Therefore, climate change adaptation strategies currently practiced in Ethiopian rift valley can be adopted by Dessa'a as climate change adaptation strategies.

Key Words:Adaptation strategies, Climate change, Indigenous knowledge and Weather forecast

1. Introduction

Climate has always been changing, is changing, and will continue to change (Hoffman andSchrag, 2000). There are several evidences of the physical and ecological impacts of recentclimate change (Walther et al., 2002). The scientific evidence suggests that theclimate is changing;due to human activities that are exacerbating natural changes in the climate(Intergovernmental Panel on Climate Change (IPCC), 2001).Climate change will bring opportunities to some and increasedvulnerability to others, especially those who are already marginalized. The pattern ofadaptability and differentiated impact is confirmed in historical and contemporary records ofcoping with the consequences of climatic changes (McIntosh et al., 2000).

Indigenous knowledge is in complement with scientific knowledge systems.In recent years, there has been an increasing realization that indigenous knowledge is avaluable source of information for climate change adaptation. Indigenousobservations of climate change have come from regions where the co-operation betweenscientists and indigenous peoples is strongest (Robinson and Herbert, 2001; Hunn, 1993).

Abebe (2011) argues that indigenous knowledge is based on experience and habitually established over centuries of use. Indigenous knowledge for adaptation to climate change in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change(4th IPCC) state that the integration of indigenous people's knowledge and observations helps in developing collective responses to climate change (Parry et al., 2007). Incorporating indigenous knowledge into climate change adaptation leads to the development of effective adaptation strategies that are cost effective, participatory and sustainable (Robinson and Herbert, 2001).

Rural communities in the dry lands of Ethiopia have over centuries, relied on indigenous knowledge for forecasting the future climate variables and coping with numerous weather related stressors in the absence of seasonal forecasts generated by numeral or statistical models. As a result, indigenous knowledge about how local populations have adapted to previous droughts has the potential of providing important guide for addressing current and future climatic events. Hence, combining local indigenous knowledge and practices with conventional scientific forecasts contribute to the building of more robust adaptation measures that could benefit the community (Qand'elihle, 2004).

Ethiopia including the study area ischaracterized by recurrent droughts, the magnitude and intensity of which have been on an increase over the last 100 years and consequently in the destructionforest cover caused by it (Benson andClay, 1998; Brooks, 1999). Records show that the climate change has experienced droughts (Hulme et al., 2001).

However, there are no further study towards integrating indigenous knowledge andscientific forecast to recommend climate change adaptation strategies at the study area. Therefore, this study aimed to forecast and characterize future climatic variables (maximum temperature (Tmax), minimum temperature(Tmin) and rainfall),assess indigenous knowledge of weather forecast, identify possible climate change adaptation strategies in Dessa'ausing analogues method and indigenous knowledge.

2.1. Description of the Study Area

Dessa'a lies between 13^0 $20^'$ and 14^0 $10^'$ North latitudes and between 39^0 $32^'$and $39^0 55^'$ East longitude. It falls within two regions of Ethiopia. Namely,Tigray and Afar Region. In Tigray Region, it touches three woredas (districts); Saesie Tsaeda Emba, Atsbi Wonberta and Enderta. Administratively, the former two woredas (districts) are foundin the Eastern zone of the region and the later one in the Southern zone of the region (Figure 1.). In Afar Region it touches the districts Shikhet, Berahle,and Dalol (EWNHS, 1996).

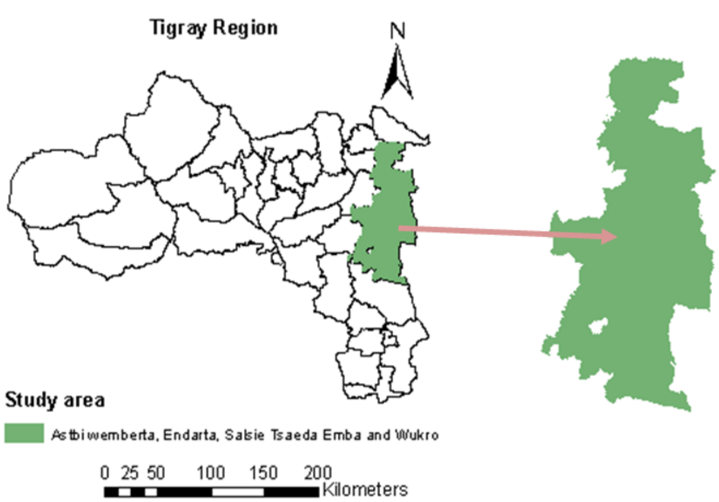

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Figure 1: Map of the study area Dessa'a (Mengistu, 2016)

2.2. Methodology

2.2.1. Climate data source and climate variables forecast approach

Climate data is the major requirement for the analysis of current and future climate change. Therefore, 30-years climate data of Dessa'a which was daily weather dataset (maximum temperature, minimum temperature and rainfall) from 1980-2009 were obtained from Ethiopian national metrology agency (ENMA). The climate data was calibrated and used as baseline for future climate projection of the study area. The agricultural modeling intercomparison and improvement project (AgMIP) climate scenario generation were used to generatefuture scenarios using climate modeling of Coupled Model Intercomparison Project Phase 5 (CMIP5).

The latitude (3.65^{o}), longitude (39.44 ^{o}) and average elevation (2000meters above sea level) of Dessa'a were used to generate future climate scenarios. The script was created 120 delta adjusted data files (3 time scales (near term, midterm and end term) x 2 RCPs (4.5 and 8.5) x 20 GCMs). The climate modeling RCPs (RCP4.5 and RCP 8.5) mainly recommended by AgMIP (agricultural modeling intercomparison and improvement project) were used.

Three time slices 2010-2039 (for near term), 2040-2069 (for midterm) and 2070-2099 (for end term) were chosen. General Circulation Model (GCM) was used for projection of the future climate variables (Robert, 2007). The general circulation models used were; CCSM4 (Community Climate System Model) of USA, which has Spatial Resolution ($\mathrm{Lon} \times \mathrm{Lat} \sim \mathrm{Levels}$)ranges $288 \times 192\mathrm{L}26$, HadGEM2-ESMet Office Hadley Centre (Hadley Centre Global Environment Model) of UK, which has spatial resolution ($\mathrm{Lon} \times \mathrm{Lat} \sim \mathrm{Levels}$) ranges $192 \times 145\mathrm{L}40$ and MIROC5 (Model for Interdisciplinary Research on Climate) which has spatial resolution (Lon × Lat ~ Levels) ranges 256 × 128L40 (T85) (Sillmann et al., 2008). These GCMs were selected based on their consistency among regions, their wide use in recent assessments, resolution, and performance in regions (Alexander Clarke Ruane, Ibid).

The set of delta adjusted .AgMIP files were created for maximum temperature (Tmax), minimum temperature (Tmin) and rainfall. Four digit codes were used to identify the location of dataset (ETDECEXA.AgMIP, ETDEEEXA.AgMIP, ETDEGEXA.AgMIP, ETDEIEXA.AgMIP, ETDEKEXA.AgMIP and ETDEMEXA.AgMIP) for CCSM4 GCM, (ETDECKXA.AgMIP, ETDEEKXA.AgMIP, ETDEGKXA.AgMIP, ETDEIKXA.AgMIP, ETDEKKXA.AgMIP and ETDEMKXA.AgMIP) for HadGEM2-ES GCM and (ETDECOXA.AgMIP, ETDEEOXA.AgMIP, ETDEGOXA.AgMIP, ETDEIOXA.AgMIP, ETDEKOXA.AgMIP and ETDEMOXA.AgMIP) for MIROC5 GCM.

The first 2 digits (ET) are an abbreviation for the country, Ethiopia; the second 2 digits (DE) refer to the specific site location, which was assigned for Dessa'a. The fifth digit is the time period and emissions scenario C = RCP4.5 (2010-2039 for near term), E = RCP8.5 (2010-2039 for near term), G = RCP4.5 (2040-2069 for midterm), I = RCP8.5 (2040-2069 for midterm), K = RCP4.5 (2070-2099 end term), M = RCP8.5 (2070-2099 for end term) they were selected for each three GCMs. The sixth digit is the GCM of CMIP5 scenario for (E = CCSM4), (K = HadGEM2-ES) and (O = MIROC5) were used. Finally, based on the output of forecasted climate variables, line graphs showing maximum temperature (Tmax), minimum temperature (Tmin) and rainfall of study area were produced.

2.2.2. AnaloguesSite Identification Methods

The Latitude (13.65^{o}) and Longitude (39.44^{o}) was used to identify the analogues sites of Dessa'a using backward analogues method on R software. Backward analogues methodhelps to identify the current and future analogues sites of Dessa'a.Therefore, site whose current climate is analogues (similar)with the future expected climate of Dessa'a was identified using backward analogues method. Environmental parameters particularly temperature and rainfall were used to identify the analogues site of study area.

2.2.3. Data collection from Local Community andSample size

The data for this study were collected from both primary and secondary sources. Combination of formal and informal methods of data collection techniques were employed to generate adequate and reliable data.

The household survey was conducted at Saesie Tsaeda Emba, Atsbi Wonberta, Enderta, Shikhet, Berahle and Dalol districts. A total of 350(three hundred fifty) households were selected through random sampling from7000(seven thousand) households inthe districts.Questionnaires were properly distributed and subsequently, interviews were conducted by the researchers. At the end of the formal survey in each village, discussions were held with key informants including wereda administrator, elder people, women and development agents.

2.2.4. Data analysis

R statistical software was used to identify analogues site of the study area.It generates climate scenarios from CMIP5 using 30-year baseline climate data. Statistical Package for Social Science (SPSS) software was used to analyze questionnaire data collected from the community.

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3. RESULT AND DISCUSSION

3.1. Characterize and Forecast Climatic Variables

Thefuture maximum temperature (Tmax), minimum temperature (Tmin) and rainfallof the study area varied according to GCMs used. The maximum temperature will be increased from 26.9^{o}C to 32.5 ^{o}C by HadGEM2-ES GCM for RCP 8.5 in end term, 30.5^{o}C by CCSM4 GCM for RCP8.5 in end term and 29.2^{o}C by MIROC5 GCM for RCP8.5 in end term (Figure 2(a)). Generally the projection of Tmax showed that, there will be an increase of Tmax by 3.87^{o}C in future up to 2099.

The minimum temperature will increased from the base line 12.9^{o}C to 19.0^{o}C by HadGEM2-ES GCM for RCP 8.5 in end term, 16.7^{o}C by CCSM4 GCM for RCP8.5 in end term and 15.8^{o}C by MIROC5 GCM for RCP8.5 in end term (Figure 2(b)). Therefore, the Tmin shows that there will be an increase of Tmin by 4.27^{o}C in future up to 2099.

The higher rainfall will be expected in end term RCP 8.5 by MIROC5 GCM which is 684.8mm, in end term RCP 8.5 by HadGEM2-ES GCM which is 601.9mm and in end term RCP 4.5 by CCSM4 which is 579.7mm at the study area (Figure 2(c)).The lower rainfall will be received in nearterm RCP 4.5 according to forecast of rainfall by HadGEM2-ES GCM.

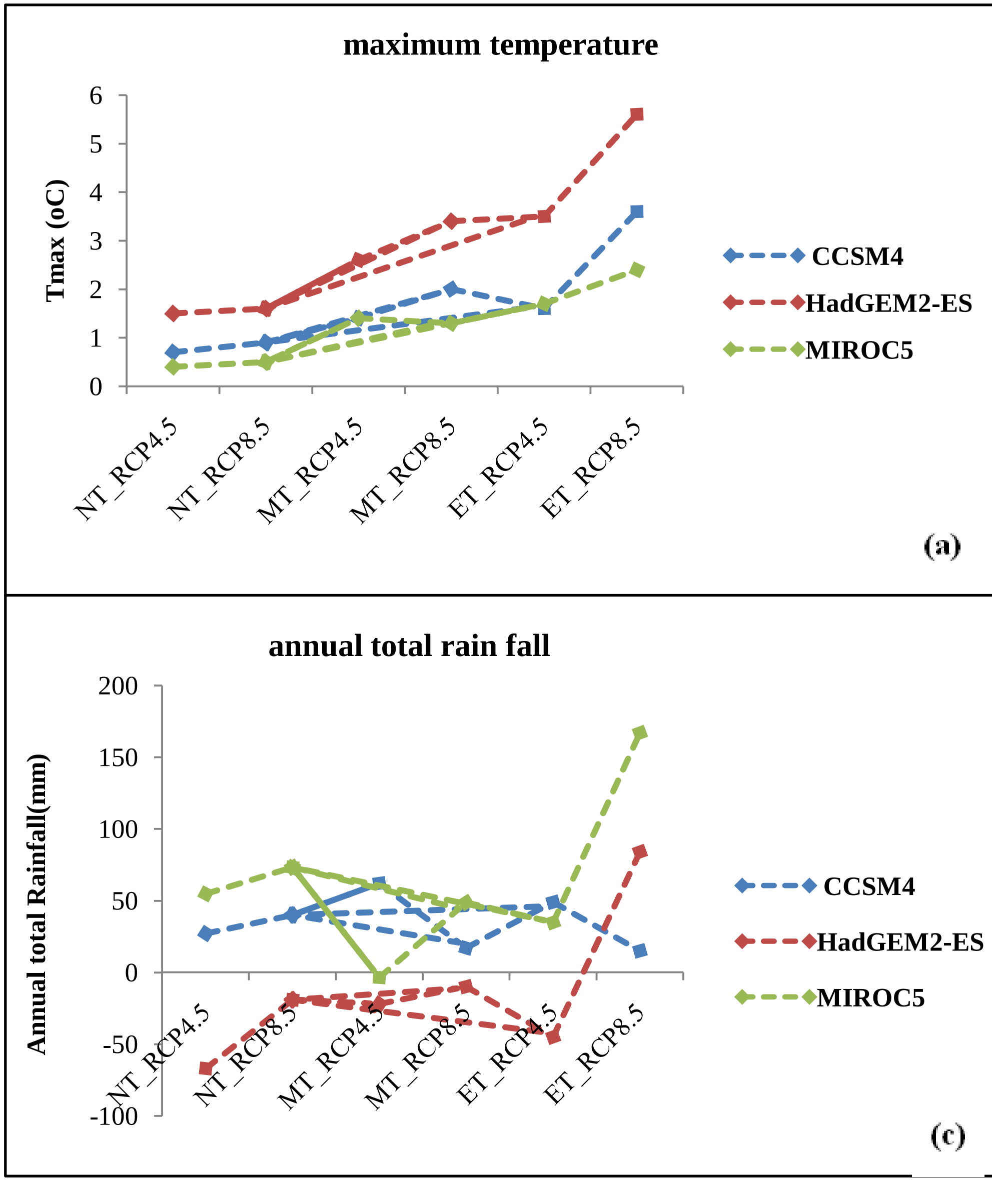

Figure2: The future maximum temperature (**a**), minimum temperature (**b**) and rainfall (**c**) of the study area

According to this study, there will be an increase of temperature at the study area which also supported by Griffiths et al. (2005). The global temperature is forecasted to rise by 1.4 - 5.8^{o}C over the period 1990 to 2100 due to increases of greenhouse gas concentrations in the atmosphere. Studies made by National meteorology agency (NMA) under climate change national adaptation program of action of Ethiopia (NAPA)(2007) have also shown, 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.

As a result, in near term (2010-2039) RCP4.5, there was a recurrent draught and El Nino events at the study area particularly in 2015/2016.In addition, associated with temperature change and rainfall pattern, dry up of water points in some parts of the tabias and flood events have seen at the study area especially in 2015/2016. Therefore, poor people, specifically agriculture dependent communities and Agro- pastoral at Dessa'a were faced draught and flood events in 2015/2016.

National meteorology agency (NMAE) has also shown that the trend of annual rainfall shows more or less constant when averaged over the whole country (NAPA, 2007). According to this study, the rainfall at the study area will be increased.

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3.2. Indigenous Knowledge weather forecast

Seven major indigenous knowledge of weather forecasts around Dessa'a were identified (Figure 3). According to most respondents (37.4), the behavior of animals like courtship, noise and movement patterns of certain animals for mating,predict the future weather conditions.Particularly, if oxen, male donkey and male goat display courtship, make noise and search females for mating during grazing or on their way back home in the evening is an indicator of rainfall upcoming season.

Dry dusty wind blows(19.7)used to predict rainfall patterns.When wind blows from the southern side bordering Raya to Dessa'a, the rain season is just approaching. If wind blows from northern part of Tigray (Shire high lands) to Dessa'a, the rain season is not as expected in rainy season.The continuous dry dusty wind blows going from terrestrial to water body, indicated less rain upcoming season and vis-versa according to respondents.

The nesting behavior of birds (11.1) and the appearance of certain birds (10.1) are helpful in predicting the upcoming of rainy season. If unusual birds begin to build nests, surface in environment and sing melodious songs such as black or blue birds, the rain season is said to be forthcoming. But, if unusual birds begin vanish from the study area; it states the decrease of rainfall upcoming season. If ordinary chicken reared in homes stop to lay egg, it used to predict the nature of rainfall patterns which is indicates not rain upcoming season.

The timing of fruiting by local trees (10.1) plays a significant role in predicting weather patterns. If the local fruit trees bear fruits from January to end of May (winter season of study area), there is sufficient rain in upcoming season. Fruit trees like *Aloe vera*, *Acacia* and *Cadia purpurea* are frequently used to predict the eminence of the rain season. When the local fruit trees ripen earlier than the usual, the implications will mean the season experience a good rainfall pattern.

The decrease of water level in streams and ponds (4.5) is the indicator of insufficient rainfall in upcoming season.

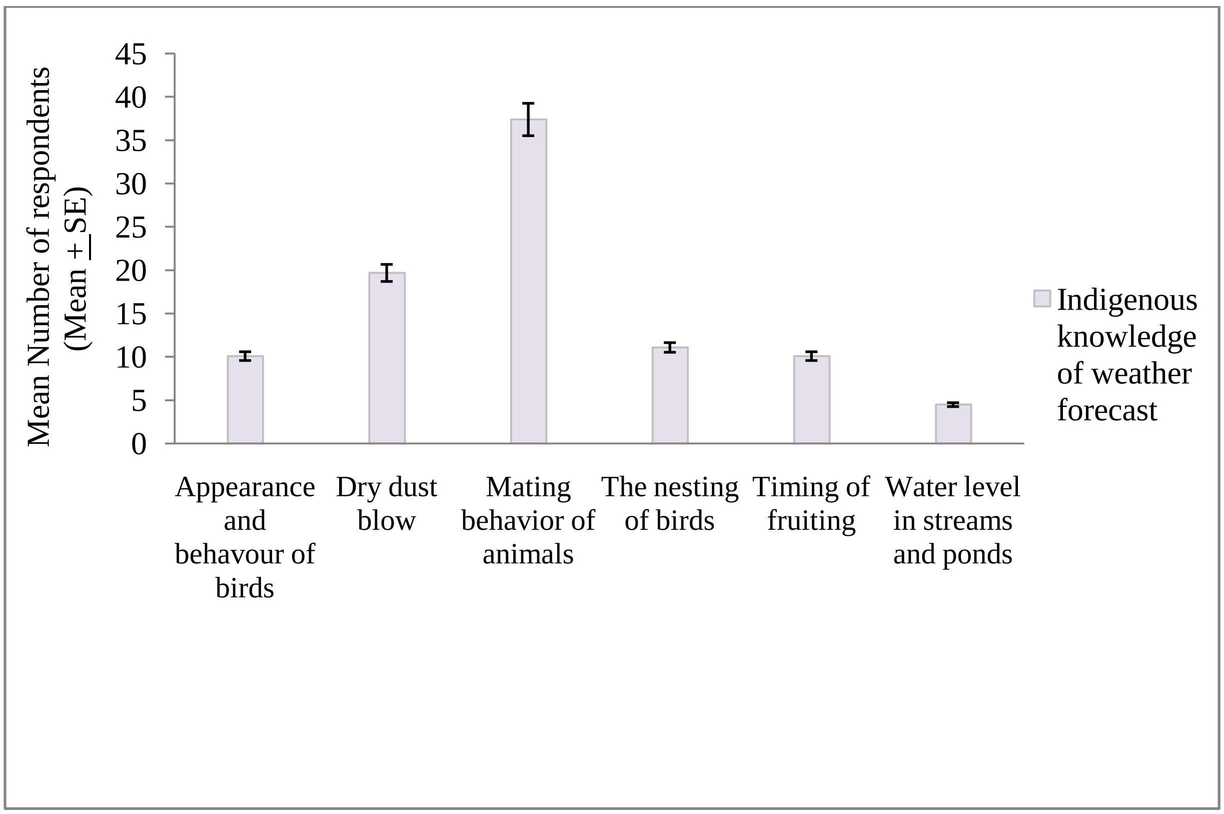

Figure 3: indigenous knowledge of weather forecasts.

According to Acharya (2011), local communities have developed a rich knowledge base of predicting climatic and weather events based on observations of animals, plants and celestial bodies. Roncoli et al. (2001) demonstrated that indigenous knowledge on rainfall forecasting can form an important part of the scientific forecasts.

Acharya (2011) proposed that the behavior of animals can reliably be used to predict the onset of the rainy season and upcoming rain since animals alter their behavior to suit upcoming natural dangers. Even though, prediction of good season based on animals behavior, using animals for prediction is supported this study.

3.3. Climate Change Adaptation Strategies using Analogues

The backward analoguesclimate change adaptation strategies showed, the rainfall of Dessa'a will be decreased by 85mm which is from 650mm to 565mm in 2050.Whereas, the temperature will be increased by 0.58^{o}C from the current average temperature which is 18.92 ^{o}C to 19.5 ^{o}C (Figure 4) .This predictions is done using current climatic data (2015), average temperature and rainfall.

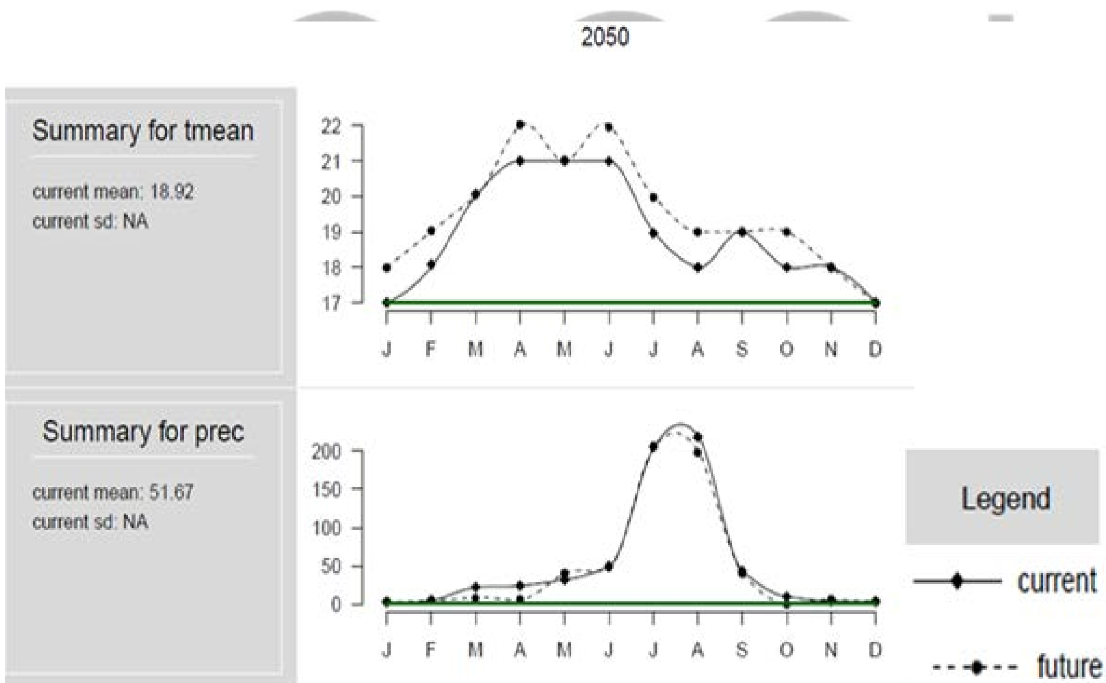

Figure 4:Current and projectedtemperature and rainfall of Dessa'a from current temperature and rainfall (2015).

These observations and projections of climate variables help to identify analogous sites of Dessa'a that ultimately provide the alternative adaptation measures in order to cope with future climate change.

Accordingly, backward analogues sites of Dessa'a found in Rift Valley areas of Ethiopia (Figure 5). Similar color of pixels represents the similarity of sites (based on temperature and rainfall), according to backward analogues site identification.The current rainfall and temperature recorded at Ethiopian rift valley will be recorded at Dessa'a after 50 years.

Therefore, the climate change adaptation strategies currently practiced in Ethiopian rift valley can be adopted to Dessa'a as climate change adaptation strategies.

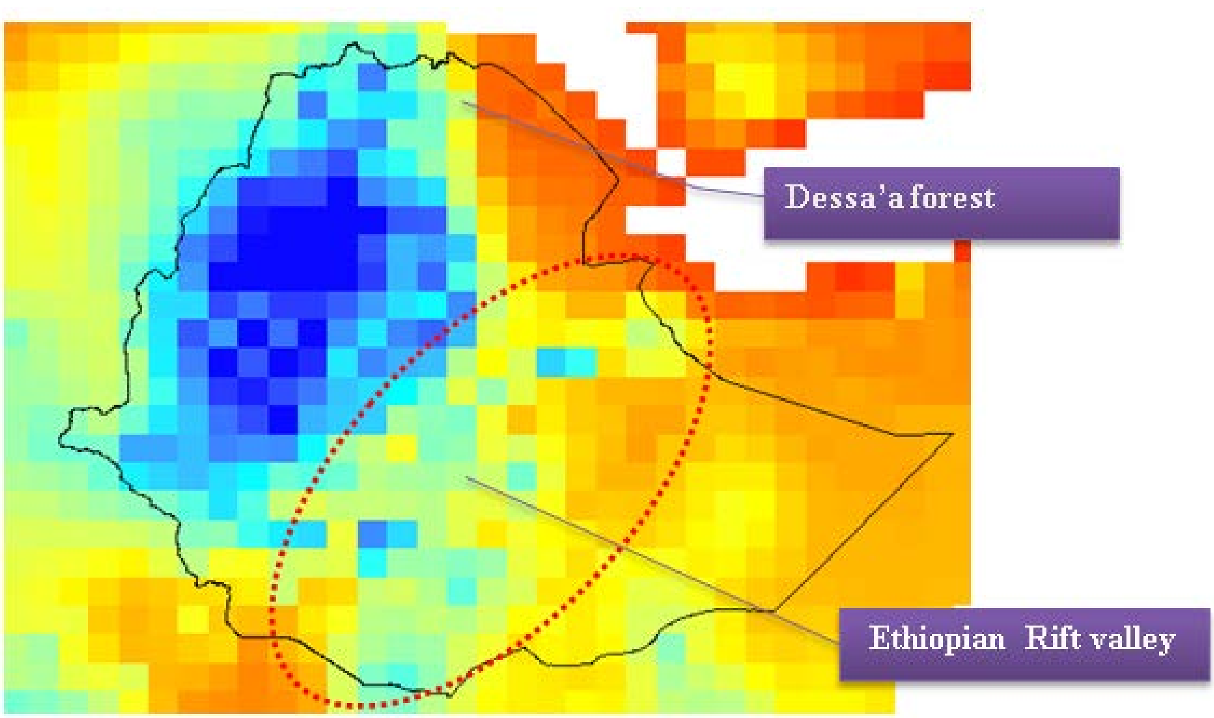

Figure 5: Analogues sites of Dessa'a

The hallegatte method of backward analogues site identification also identified Ethiopian rift valley as analogues site of Dessa'a (Figure 6). This is an indication that, climate change adaptation strategies currently practiced in Ethiopian rift valley can be adopted at Dessa'a.

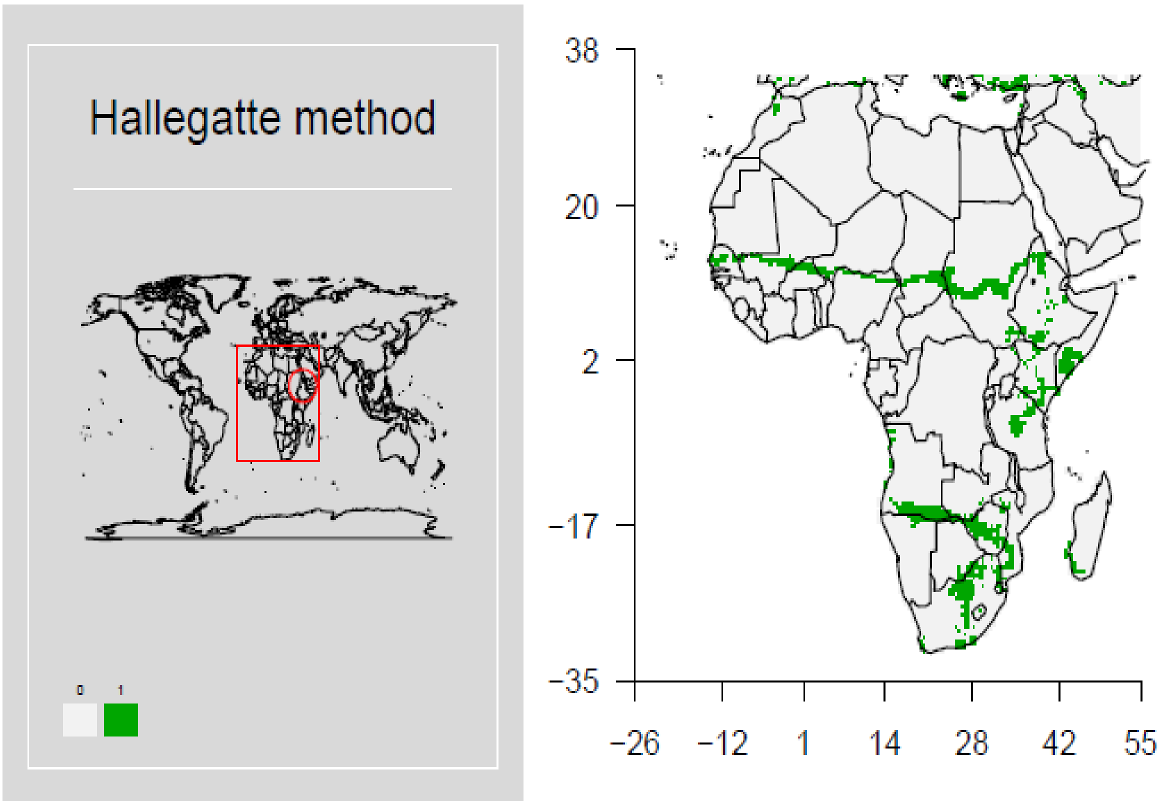

Figure 6: Analogues sites of Dessa'a using halligate (green sites are more analogue to each other).

Therefore, climate change adaptation strategies currently practiced in Ethiopian rift valley which is climate change national adaptation programme of action (NAPA) of Ethiopia (table1) can be adopted by Dessa'a as alternative climate change adaptation strategies based on analogous method of choosing alternative climate change adaptation strategies**.**

Table1: Alternative climate change adaptation strategies have been proposed for Dessa'a

No	Climate Change National Adaptation Programme of Action (NAPA) of Ethiopia Practiced at Ethiopian rift valley	Climate Change National Adaptation Programme of Action (NAPA) of Ethiopia already Practiced at Dessa'a	Climate Change National Adaptation Programme of Action (NAPA) of Ethiopia that can be adopted at Dessa'a
1	Launching environmentally sound investment that foster cleaner development mechanisms	**X**	✓
2	Environmental policy of Ethiopia: Natural resource & environment conservation	✓	**x**
3	Food security & productive safety net	**X**	✓
4	improved farming practices, drought resistant & early maturing crop varieties	✓	**x**
5	supply inputs that increase crop yield & productivity	✓	**x**
6	improved/productive animal breeds to reduce herd size & the pressure on land	**X**	✓
7	Construction of small check dams and rainwater harvesting schemes to meet water supply for domestic and irrigation use	**X**	✓
8	promote the use of alternative and or non-wood energy sources	**X**	✓
9	undertake climate monitoring programs	**X**	✓

✓ : NAPA is on practice **X**: NAPA is not on practice

3.4. Indigenous Knowledge of Climate Change Adaptation Strategies

Ten different indigenous knowledge of climate change adaptation strategies wereidentified at the study site (figure 7).92.5% of respondents stated, the constructing stone dykes is the best climate change adaptation strategy.86.5% of respondents agree with protecting river banks is climate change adaptation strategiesmainly for vegetable grower'sareas.People living at lower part of Dessa'a, seasonally depended on the river bank to grow their crops. Climate resistantvariety of Seed/crop with different susceptibility to drought is the other climate change adaptation strategy according to respondents (84%). Farmers cultivate drought tolerant crops such as wheat, sorghum and barley.Variety of livestock adapted by farmers such as goats and sheep are preferred to the rearing of camel.Because they need less pasture and tolerate drought. Restoring lands using green manure (77.5%) and controlled bush clearing (72%) during preparation of farmland for cultivation is the other way of climate change adaptation strategy according to respondents. The nomadic on the border of Dessa'a and Afar migrate with their animals during drought stressfor searching of water and pastures (70%).Fixing soil surface nutrients using tall grasses (69.5%) isthe other strategy of climate change adaptation which stabilizes the soil structure.The soils absorb higher amounts of water without causing surface run-off.It ultimatelyaid soil organic matter to improve the water absorption capacity of the soil during an extended drought. The pastoralists living on the border of Dessa'a and Afar were also usingculling of weak livestock for food during drought stress (67.5%).According to some farmers (51.5%), they bury crop residues in the field to replenish the fertility of the soil and reduce the loss of soil moisture. Burning of residue is also done to ease cultivation and is a way of controlling crop pests spreads due to climate change. Zero-tilling practices in cultivation (15%) is climate change adaptation strategy which make safe farming practices.

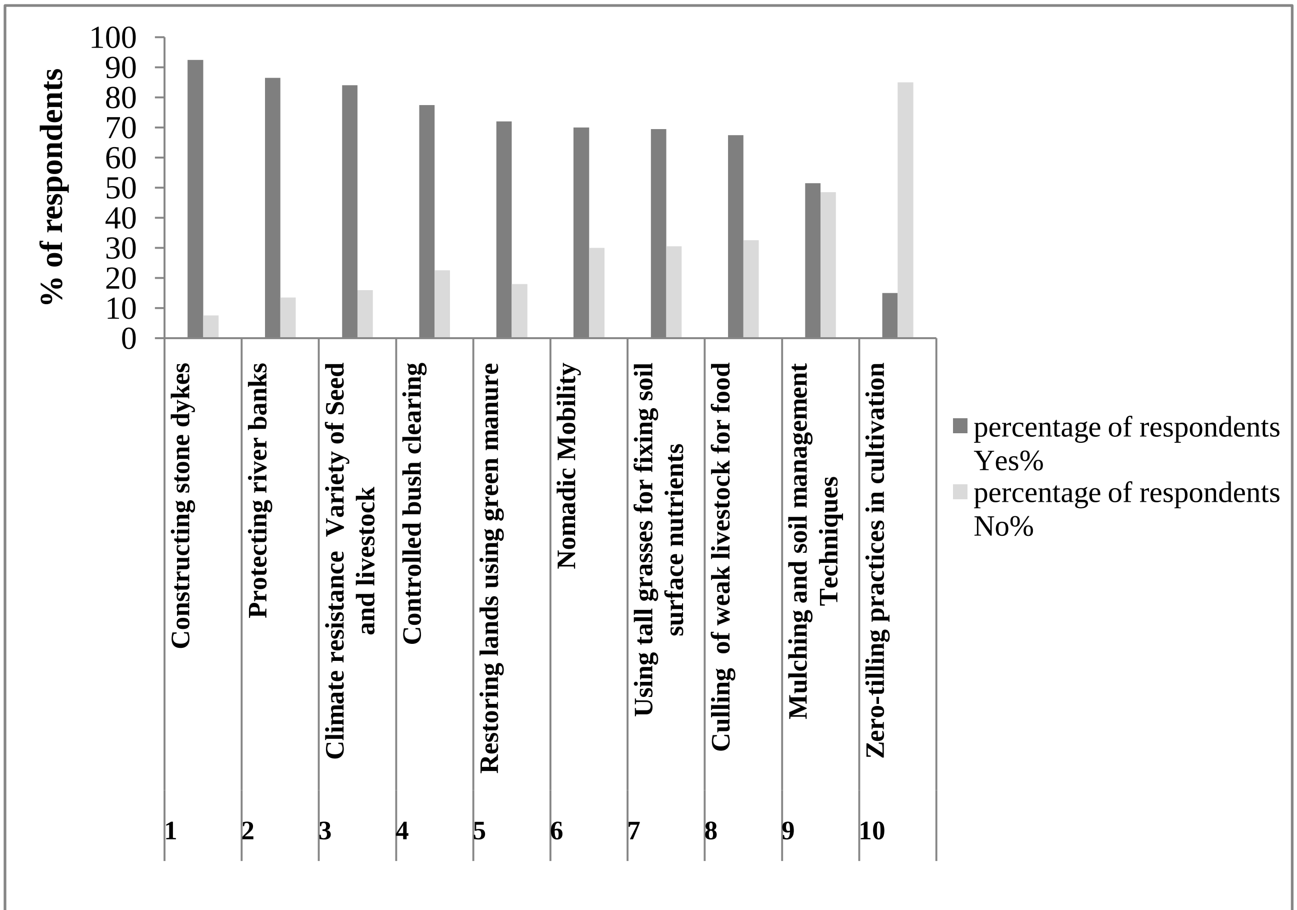

Figure 7: Indigenous knowledge climate change adaptation strategies

Indigenous people can reduce the potential damage by making tactical responses to climate changes(Kandlinkar and Risbey, 2000). Shading shelter and diversifying farming to non-farming activities were perceive as appropriate climate adaptation strategies by indigenous people according to Rashid and Charles (2008).

4. CONCLUSION

According to this study, Tmax and Tmin will increase in average by 3.87^{0}Cand4.27^{0}C respectively in future up to 2099.The higher rainfall will be expected in end term RCP 8.5 by MIROC5 GCM which is 684.8mm at the study area.

There were seven major indigenousknowledge of weather forecast at the study area.Mainly,mating of certain animals, water level in streams and ponds, insect behavior in rubbish heaps,timing of fruiting by local trees, the nesting behavior of birds, the appearance of certain birds and dry dusty wind blows. Theanalogues site of Dessa'a isfound inEthiopian rift valley. Therefore, the climate change adaptation strategies currently practiced in Ethiopian rift valley can be adopted by Dessa'a as alternatives climate change adaptation strategies.

Constructing stone dykes,protecting river banks,climate resistance variety of seed and livestock,restoring lands using green manure,nomadicmobility, using tall grasses for fixing soil surface nutrients,controlled bush clearing,mulching and soil management techniques, and zero-tilling practices in cultivationwereindigenous knowledge of climate change adaptation strategies identified at the study area.

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