



Adaptation to Climate Change in the Sahel: The Success Stories of Eritrea

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ABSTRACT

Climate change is a global environmental threat affecting every sector of the economy with agriculture been the most vulnerable particularly in Africa and expected to have a wide-ranging effect on the environment, and on socio-economic and related sectors, including water resources, agriculture and food security, human health, terrestrial ecosystems and biodiversity and coastal zones. The study employed systematic literature review. The review documents were selected based on pre-defined inclusion and exclusion criteria. The documents were obtained using search string “climate change impacts” or “climate environment” or “climate risk” or “climate change adaptation” or “adaptation risk” or “smallholder adaptation” or “adaptation impacts” or “adaptive capacity” or “adaptation Sahel” or “adaptation ability”. The findings of the study revealed that famers in the study area have substantial knowledge of climate change and employed various strategies to adapt to its impacts. These adaptation measures include; livelihood diversification, soil and water conservation, intercropping, irrigation, late sowing, mulching, crop rotation, sowing improve variety, agroforestry, stones and earth bund terraces, diversion of small streams and runoff to farms, and off-farm labour among others. However, there is need for further research in climate change adaptation in Eritrea the vast majority of literatures that report adaptation are grey literatures and perhaps may not be peer reviewed.

Keywords: Climate change, Agriculture, Adaptation, Sahel, Eritrea

INTRODUCTION

Climate change a global phenomenon, particularly manifested in the last three decades (Tang, 2019), however, in its Fifth Assessment Reports the Intergovernmental Panel on Climate Change (IPCC) reports that the global ocean temperature had rising by 0.85°C from 1880-2012 and further stated 1983-2012 were the warmest year in the past 800 years and global surface temperature increased by 0.2°C per decade in the last three decades (Hansen *et al.*, 2006; Tang, 2019). The Sahel region is currently facing the climate change nightmare. Changes in climate that affect the sustainability, biophysical and economic settings of the region (Giannini *et al.*, 2003, 2005, 2008; Reynolds *et al.*, 2007; Lu and Delworth, 2005; Mertz *et al.*, 2009; Epule *et al.*, 2013; Epule *et al.*, 2017). According to the IPCC (2007) the temperature in the Sahel had rising between 0.2-2.0°C and substantial declined in rainfall were recorded. These variation in rainfall and rising temperatures had significant impacts on crop production, water resources, biodiversity, human health and food security with estimated 60 million people food insecure in the Sahel region (Epule *et al.*, 2017).

Eritrea had experienced temperature and rainfall irregularities associated with climate change for several decades, thus garnering much attention in understanding the adaptation strategies by farmers to deal with impacts of climate change. Eritrea located in the Sahel region, geographically vulnerable to the impacts of climate change. The country is ravaged by changing climate and associated climate related hazards such as prolonged drought during EL-Nino periods resulting in declined of agricultural productivity (Ghebrezgabher *et al.*, 2018). The current adaptive capacity is weak in Eritrea and

delineated among the countries with high level food insecurity which exacerbate the impacts of malnutrition.

Realizing the impacts of climate change gave birth to adaptation research (Pielke *et al.*, 2007). Therefore, prospects for adaptation are open, realistic and therefore can be incorporated into current policy goals (Stern, 2006; Karl *et al.*, 2009; Costello *et al.*, 2009; Garnaut, 2008; Berrang-Ford *et al.*, 2011). Similarly, the “task of adaptation is not inherently unique, as humans have long lived with climate variability and developed management decisions to cope with variability and change” (Dovers, 2009; Smit and Wandel, 2006; Burton *et al.*, 2002).

Adaptation is a central factor that will influence the potential severity of climate change on farmers and food production (Lobell *et al.*, 2008), while relatively inexpensive changes, such as shifting sowing/planting dates or shifting to established crop varieties that can minimize the negative impacts, the greatest benefits are likely to come from more costly interventions including scientifically modified new varieties of crops and expansion in irrigation agriculture (Lobell *et al.*, 2008). These adaptations would require significant investment from producers, states, scientists, non-governmental organizations, regional and self-help groups, all of whom are faced by many other requirements for their resources (Smit and Skinner, 2002). A variety of possible agricultural adaptation solutions have been proposed, reflecting steps or activities that could be taken to reduce the anticipated adverse effects. They cover a broad range of aspects (technical, financial, managerial), scales (global, regional, local) and participants (government, industries, farmers) (Skinner *et al.*, 2001).

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Most of these are probable or potential or adaptation steps rather than those currently implemented (Smit and Skinner, 2002)

Being a global phenomenon and affecting every sector of the economy directly or indirectly. There is keen interest to identify and understand the adaptation measures in place in response to the changing climate in Eritrea particularly in the agricultural sector which is more vulnerable to climate change.

MATERIAL AND METHODS

The Study Area

Eritrea, a country found in the northern part of the Horn of Africa and geographically located on latitudes 12° N and 18° N and 36° E and 42° E (Araia, 2005; Ghebregabher and Yang, 2018; Ghebregabher *et al.*, 2018). It has a landmass area of, about 125,700 km² inclusive of the islands, and a coastline spanning some 1,720 kilometres. (Ministry of Land Water and Environment, 2015). The country shares boundary with Sudan in the north and west and Ethiopia in the south, Djibouti in the south-east and the Red Sea in the east (Ministry of Land, Water and Environment, 2007). The population of the country is estimated at 6.5 million people as of 2013 with 2.9% annual population growth (Nyssen, 2004; Ogbazghi and Bein, 2006; Ghebregabher *et al.*, 2018; Ghebregabher and Yang, 2018). The country has an estimated total land area of 124,300km² and 1900km of coastline (Ministry of Land, Water and Environment, 2015).

The Eritrea's climate (arid and semi-arid) is highly variable and unpredictable being influenced by the expanding desert encroachment, the prevailing impacts of Red Sea and associated impacts of land physical features (Ministry of Land, Water and Environment, 2007; Ghebregabher and Yang, 2018; Ghebregabher *et al.*, 2018). Temperature varies considerably in the country. The eastern lowland having an annual mean of 31°C and maximum of 48°C, while in the highland areas the mean temperature is 21°C with maximum of 25°C. Similarly, in the western lowland areas the annual mean is 29°C with a maximum of 36°C (Ministry of Land, Water and Environment, 2007; Ghebregabher and Yang, 2018). The country is divided into six agro-ecological zones; the moist highland 500-700mm (15-21°C), arid highland 200-500mm (15-21°C), sub-humid 700-1100mm (16-27°C), moist lowland 500-700mm (21-28°C), arid lowland 200-500mm (21-29°C) and semi-desert < 200 (24-32°C) with summer and winter seasons (Ministry of Land, Water and Environment, 2001). The south-westerly monsoon wind associated with rainfall and concentrated in the months of July and August and affects the central highlands and western lowland areas. The winter rains ideally occurred in the months of November-March and are influenced by north-easterly continental wind. These rains affect coastal areas and the eastern and southern escarpment (Ministry of Land, Water and Environment, 2001; 2007; Ghebregabher and Yang, 2018; Ghebregabher *et al.*, 2018).

Methodology

Literature on climate change and adaptation assessment for the agricultural sector was systematically reviewed. The data was collected in Nov-Dec 2020.

Systematic Literature Review

Systematic reviews have, first and foremost, been established within medical sciences as a means of summarizing research findings in a systematic, transparent and reproducible manner and have been referred to as the gold standard between reviews (Davis *et al.*, 2014; Snyder, 2019). Systematic review can be described as a research method and procedure for the identification and critical evaluation of current literature as well as for the compilation and analysis of data from a particular research (Liberati *et al.*, 2009). The aim of systematic review is to classify all crucial and relevant findings that satisfied the pre-specified eligibility criteria in order to address specific research question or hypothesis (Snyder, 2019).

Document Identification Methods

Searching of relevant studies were conducted between 7th November and 22nd December, 2020. A comprehensive search of eight databases were conducted. The databases searched were Scopus, African Journal Online (AJOL) ProQuest, Elsevier, Research gate, Google and Google scholar (Haby *et al.*, 2016). The documents were obtained using search string "climate change impacts" OR "climate environment" OR "climate risk" OR "climate change adaptation" OR "adaptation risk" OR "smallholder adaptation" OR "adaptation impacts" OR "adaptive capacity" OR "adaptation Sahel" OR "adaptation ability". Keywords were searched in title and abstract, including where otherwise indicated in the supplementary files. Results were imported into excel spreadsheet and remove duplicates (Moher *et al.*, 2009; Haby *et al.*, 2016). The search was undertaken and evaluated by the author as per the eligibility criteria. The complete text of any potentially relevant document has been retrieved for further consideration. The author precluded on the inclusion side so there was some uncertainty as to its inclusion in place to ensure that no crucially significant articles were lost (Dolenc and Rotar-pavlič, 2019).

Methods of Selecting Documents to be Included in the Analysis

The inclusion and exclusion criteria narrow down to full length research papers, relevant documents found useful, systematic and scientific and the keywords selected had to be included in the article's title or abstract, the articles had to refer to the adaptation and climate change (Dolenc and Rotar-pavlič, 2019). The review was based on peer reviewed and grey literature on climate change adaptation published between 2000 and 2020 (with 2 relevant articles published in 1995 and 1996) (Berrang-Ford *et al.*, 2011). Papers not in English, beyond the search duration and apart from articles and reviews have been removed. This query extracted 230 articles. However, after all recovered documents were checked on the basis of title and abstract to evaluate the appropriateness or validity for final assessment and inclusion for review (Berrang-Ford *et al.*, 2011; Ford *et al.*, 2011; Berrang-Ford *et al.*, 2015; Dolenc and Rotar-pavlič, 2019).

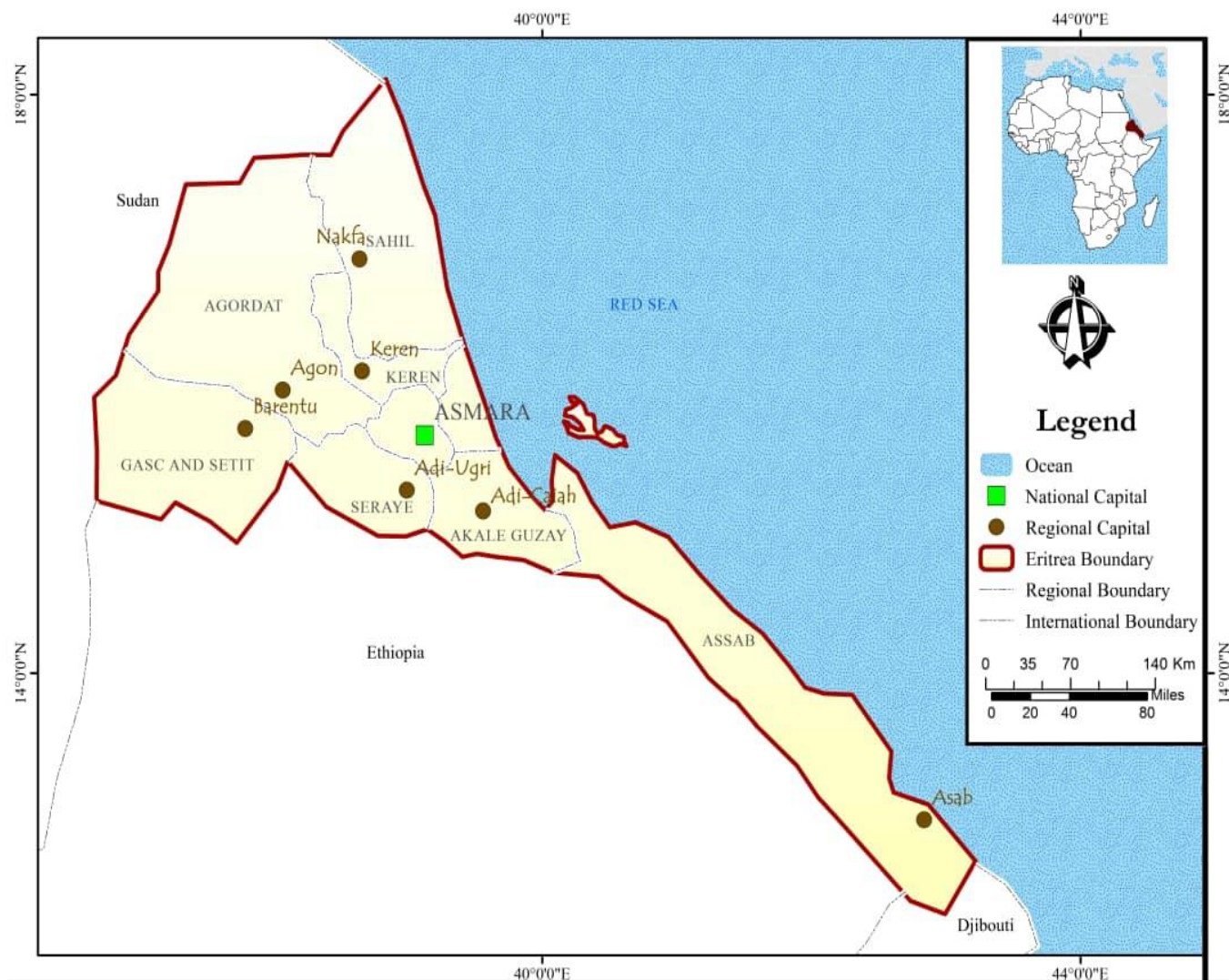


Figure 1: The Study area.

Table 2. Inclusion and exclusion criteria for documents

In clusion	Exclusion
First stage keyword search	
English written articles	Non-English articles
Article written between 2000-2020	Pre-2000 and after 2020
Index in Scopus, Elsevier, google, google scholar, AJOL, ProQuest and Research gate	Articles not found online and mentioned databases
Systematic reviews and research papers	
Second stage	
Title and abstract review	
Humans	Natural
Adaptive response	Mitigation, vulnerability only
Practical focus	Conceptual, theoretical focus
Present	Prehistoric or future
Adaptation activities or actions	Predictive model and vulnerability assessments or intention to act

Adopted from Berrang-Ford *et al.* (2011)

Methods for Assessing Study Quality

The appropriateness of each of those studies was assessed based on the quality of the articles and rhyme with string of searches (Dolenc and Rotar-pavlič, 2019)

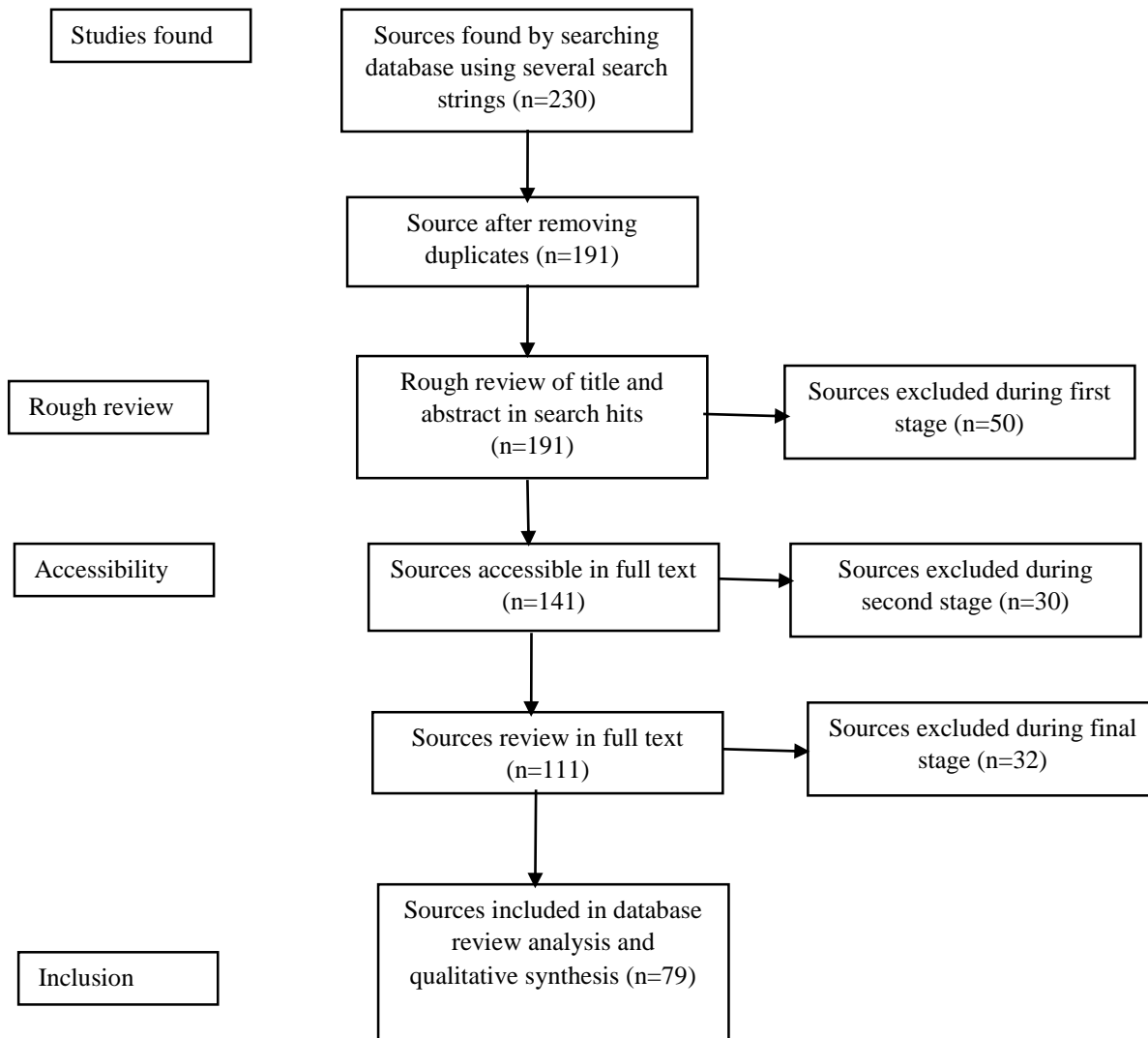


Figure 2. Documents selection criteria

RESULT AND DISCUSSION

Vulnerable groups and the need for adaptation

In Eritrea the most vulnerable groups to the impacts of climate change are people that directly or indirectly depend upon natural resources for their livelihood. Women, children and elderly are the most affected groups. However, the vulnerable groups include subsistence farmers, usually rain-fed, spate and irrigated farmers, rural dwellers that depend on forest and woodland are highly vulnerable, pastoralists, fishermen, Island residents are also vulnerable (Ministry of Land, Water and Environment, 2007). In this paper the emphasis is on agricultural vulnerability and the need for adaptation in the sector.

The major adaptation options and needs identified for crop production in the study area include “improve soil fertility and moisture retention using conservation, fertilization and alternative cropping techniques, increase water supply through irrigation, water diversion structures, ponds, wells, and the optimization of farming practices, control pests and plant diseases through regular weeding, crop rotation and planting appropriate crops, timing crop cultivation in direct response to changing pattern of rainfall and breeding drought-and-disease resistant high-yield crop to maintain and or improve crop production level” (Ministry of Land, Water and Environment, 2007).

What are the adaptation options?

Despite ever increasing challenges posed by climate change especially to the agricultural sector farmers employed several adaptation measures to ameliorate the impacts of changing climate for sustainable crop

production. However, (Epule *et al.*, 2017) classified adaptation measures in the Sahel (Eritrea included) into four (i) technically related adaptation options; climate monitoring, climate forecasting, soil conservation, high yielding varieties, drought resistant crops/animals, reforestation/afforestation, changes in planting dates, water harvesting, increase or decrease livestock, early or late planting, planting of perennials, embankment/dyke/dams, mixed farming, managing biodiversity, agroforestry, adaptation of animal traction, (ii) indigenous problem solving adaptation options; dietary changes, ownership of multiple farms, preservation and storage, income diversification, migration, re-sowing, animals in stable, pasture management, more farm inputs, fallowing, labour management, indigenous knowledge, being nomadic, alley farming, destocking, removing crops that are not doing well, buying foods/government relief, seed preservation, basin around crop, changes in tillage, (iii) socially related adaptation options help from community organizations, spiritual/prayer/religion, partnership with projects, creating committee for natural resources management, investing in education for kids, giving up kids (iv) economic related adaptation options; market gardening, savings, selling of assets, access to credit, remittances, sell of livestock for grains among others. Preference of adaptation options is usually influenced by social status of the farmers especially education, age and gender. Educated, young male households usually accept and assimilate new innovations for adaptation to climate change (Jin *et al.*, 2015).

Table 3. Assessment of off-farm agricultural adaptation measures to climate change

Adaptive strategies	References
Conservation agriculture Advantages Soil and water conservation, high crop productivity and profitability, high yield Disadvantages Knowledge and technologically intensive, low adoption rate among farmers	Ling-ling <i>et al.</i> (2011), Singh and Serraj (2011),
Agroforestry Advantages Regulate runoff and soil erosion as well as minimizing loss of water, soil organic matter and nutrients. Agroforestry enhances the activity of micro-organisms, biological activity, improve soil physical properties idle for crop production, increase yield, and improve biodiversity and economic benefit to farmers. Disadvantages It requires long-term period for optimum results, complexity in land management, require quality seeds and market accessibility.	Bein <i>et al.</i> , (1996), Dean <i>et al.</i> (1995), Kiyani <i>et al.</i> (2017), MLWE, (2007)
Stones and earth-bound terraces Advantages Contributes to the reduction of slopes and natural functions as a transporting surface for eroded materials, enhances infiltration and reduces surface runoff and velocity and minimize soil erosion. Disadvantages Associated with surface erosion as a result of surface flow redistribution, vertical changes in soil physical properties, the presence buried hollows, where ground water convergence occurs, rising up of perched groundwater table and lateral infiltration.	Hammad <i>et al.</i> (2004), Petit <i>et al.</i> (2012), Stavi <i>et al.</i> (2018), Tarolli <i>et al.</i> (2014)
Soil and water conservation Advantages Reduces soil erosion associated with water and wind as well as improving soil fertility, improves soil moisture and activities of micro-organisms in the soil, protect the soil against the impacts of rain-drop, decrease runoff velocity, improve water infiltration capacity, and	Gachene <i>et al.</i> (2019), Guo <i>et al.</i> (2020), Han <i>et al.</i> (2018), Wolka <i>et al.</i> (2018)

<p>enhances borrowing activity of earthworms which helps in improving percolation of water through soil profile.</p> <p>Disadvantages Labour intensive, loss of agricultural land/cultivable land as a result of construction of soil and water conservation structures.</p>	
<p>Intercropping and <i>Hanfets</i></p> <p>Advantages Weed-suppressing capacities, diversification of plant cover to break development cycle of pests, high yield because the mixture may allow each individual crop to exploit available resources at the niche to which it is adapted best. Intercropping enhances yield stability and serve as an insurance against climate variability and drought. “if one component fails, the other component makes use of additional space and resources and compensate for yield reduction.</p> <p>Disadvantages Space limitation capacity. Although it is much more effective, especially in smaller spaces, when two share a field, you can only grow half as many of each crop than if you had one field dedicated to each. “selection of appropriate crop species and the appropriate sowing densities, including extra work in preparing and planting the seed mixture and also extra work during crop management practices including harvest”</p>	Sati (2008), Woldeamlak <i>et al.</i> (2008), Smyth (2018), Lithourgidis <i>et al.</i> (2011)
<p>Late sowing and early maturing crops</p> <p>Advantages Late sowing helps in utilizing of maximum moisture and avoid the negative impacts of false rain which might lead to resowing again. While early maturing crops are best against the impacts of climate variability due to their genetic ability to grow mature within short period of time before the rain ceases.</p> <p>Disadvantages Late sowing usually associated with extra tillage and weed pressure, crop options, extensive soil moisture monitoring and yield loss.</p>	Sime and Aune, (2018)
<p>Irrigation</p> <p>Advantages Irrigation supplement moisture. There is need for a certain amount of moisture to adequately nourish crops. If rainfall is insufficient, there should be a shortage of water requirement compliance, it also improves the yield of crops as well as cash crop production and provides minerals and nutrition to crops.</p> <p>Disadvantages Irrigation is usually associated with water logging, salinity and alkalinity of land, ill aeration of soil, high cost of irrigation development, lack of clear policy on irrigation development.</p>	Velasco-Muñoz <i>et al.</i> (2019), Tadesse and Bissrat (2005)

Adopted from: Gruda *et al.* (2019)

Evaluation of coping strategies identified by farmers and stakeholders

The criteria used for evaluation of adaptation strategies is adopted from Ebi *et al.* (2011) based on his study on smallholder farmers adaptation to climate change. The adaptation options identified and analysed include the assessment by farmers and stakeholders the efficacy, costs and feasibility of addressing climate change impacts, the extent to which assistance would be required and the adequacy for addressing current climate variability. Farmers have been very worried about recent and expected climate change; they conclude that climate change would be more extreme than predictions. Farmers concentrate primarily on adaptation options that may have greatest immediate effect on decreasing current vulnerability, but would require additional financial and technical assistance (Ebi *et al.*, 2011). As an indigenous ecological knowledge obtained in different parts of Africa. However, Laube *et al.* (2012), state that farmers often diversify their farming and other livelihood activities as an adaptation strategy for risk reduction and disaster management

Off-farm labour/sell of labour

Off-farm labour/sell of labour is another adaptation strategy to ameliorate the impacts of climate change. The most rational and common evidence indicate that off-farm labour substantially contributes to the increasing household income in Eritrea as found in other developing

nations (Lanjouw, 2000; Escobal, 2001; Shittu, *et al.*, 2006; Haggblade, *et al.*, 2010; Shittu, 2011; Shittu, 2014). Research data shows that primary reason for off-farm labour supply among farm household in Eritrea and other developing nations has always been a desire to have a diversify sources of income to manage risk (Shittu, 2014). When farming become less lucrative and more dangerous as a result of climate change and variability and market fluctuation or failure, household are been forced to diversify to other economic activities especially in cities. In other situations, however, household are more likely to be drawn into the off-farm market particularly when returns to off-farm jobs are higher or less risky than in agriculture. Rural households are engaged in a wide range of activities as part of their survival strategies, they grow crops in their fields, serve as wage labourers in other farms, or run a small shop and other manufacturing and service activities. Off-farm labour are essential sources of income to farming households. However, “seven different activities as source of income were identified: crop production, livestock production, agricultural wage labour, non-agricultural wage labour, any kind of wage-employment (agricultural and non-agricultural wage employment), non-agricultural self-employment, both self and wage-employment (off-farm)” (Teame and Woldu, 2006).

Remittances

Remittances plays a vital role in livelihood diversification as a coping strategy to climate change. Remittances are classified as current private transfers from migrant workers resident in the host country for more than a year, irrespective of their immigration status, to recipients in their country of origin (World Bank, 2020). Sending remittances improve household income significantly, increase in per capita and per capita expenditure. There is also transfer of ideas, practices and norms between societies of origin and destination and vice versa (Anghel *et al.*, 2015). The receiving household is expected to use the remittances not only for consumption but also saving and buying household assets (Cuong and Linh, 2018). About one-third of the population in Eritrea is living abroad and one-third of the country's budget is also derived from remittances (Hirt and Saleh Mohammad, 2018).

Mixed farming

Mixed farming systems, is a promising adaptation strategy among farmers. The system shows some progress by emphasizing on the use of integrative and holistic strategies and dispassionately building on and utilizing the natural and local resources base without exhausting it, thus enhancing biodiversity, maximizing complementarities between crops and animals systems and, finally, growing

opportunities for farmers livelihood (González-García *et al.*, 2012). Mixed farming improve the quality and productivity of farmland, reduce dependency on external inputs and costs, increase the per capita profitability, improve nutrient cycling, livelihood diversification and generate economies of scope at farm level (Ryschawy *et al.*, 2012).

Agroforestry

In the meantime, agroforestry can reduce climate change by establishing and improving carbon sinks by extracting carbon from the atmosphere by photosynthesis and storing it in biomass and (Albrecht and Kandji, 2003; Reppin *et al.*, 2020). Agroforestry is also identified as one of the best adaptation measures (Dinesh *et al.*, 2017). Similarly, "Agroforestry practices, such as the integration of leguminous trees into fallow periods between two cropping seasons (improved fallow), or intercropping short- and long-term trees with crops (dispersed intercropping), can lead to higher crop yields in many parts of the tropics" (Hall *et al.* 2005; Reppin *et al.*, 2020), and increased well-being (Thorlakson and Neufeldt, 2012; Reppin *et al.*, 2020). Similarly, agroforestry enhances soil fertility and local or micro climate, reduction in soil erosion, improvement in soil Nitrogen and soil organic matter, provision of ecosystem services and reduction of dependence on natural forest (Apuri *et al.*, 2018).

Table 4: Coping Strategies and Potential Adaptation Projects Identified by farmers and stakeholders

Current coping strategies		
Autonomous	Projects/programmes	Potential adaptation activities
<ul style="list-style-type: none"> ▪ Diversion of small streams and run off to fields ▪ Stone and earth bund terraces ▪ Check dams ▪ Crop rotation ▪ Fallow systems ▪ Contour farming ▪ Mixed cropping ▪ Late planting and early maturing crops ▪ Cash for work ▪ Off farm labour ▪ Remittance from family ▪ Accumulation of food in good rain years ▪ Growing expensive products ▪ Integrating crop/livestock ▪ Constructing wells, dams, ponds ▪ Using water conservation oriented irrigation system (e.g. drip irrigation) ▪ Using early maturing vegetable plants ▪ Reduction of irrigated field size during drought ▪ Replacing perennial plants by annuals ▪ Increasing depth of water wells during drought ▪ Growing expensive products ▪ Integrating crop/livestock ▪ Sell of fire wood and charcoal ▪ Produce vegetables, fruits forage/ fodder which require less water ▪ Growing expensive products ▪ Integrating crop/livestock ▪ Safety net for food ▪ Seed selection 	<ul style="list-style-type: none"> ▪ Research in drought resistance crops ▪ Multiplication and distribution of drought resistant crops ▪ Food safety nets for needy households during disaster such as drought ▪ Promoting diversion of streams and run off to fields ▪ Preparing integrated production models ▪ Water use management and regulation ▪ Developing water conserving irrigation techniques ▪ Enhance spate irrigation ▪ Applied research on crop resistant vegetables ▪ Promoting self-reliance programmes for women headed families 	<ul style="list-style-type: none"> ▪ Stone and earth bund terraces on farmlands to conserve soil and moisture ▪ Breeding of drought and disease resistant high yielding crops to promote crop production ▪ Implementation of diversion structures to supplement water to rain-fed agriculture ▪ Application of fertilizer (both organic and inorganic) to improve soil nutrients and increase water holding capacity of soil ▪ Conservation tillage through application of crop residue to reduce evaporation and accordingly retain moisture. ▪ Planting moisture efficient crops such as pearl millet and water melon on river beds ▪ Crop rotation (rotating legume and non-leguminous crops) to improve soil nutrients, soil moisture and decrease soil born pests and disease. ▪ Selection of healthy and vigorous seeds to increase resistance to drought, pests and diseases and to increase productivity ▪ Improve farm management technology such as row planting depth etc. to increase production. ▪ Use late planting and early maturing crops to secure crop production at times of low and variability of rains ▪ Contour farming to retain soil and moisture on cultivated fields. ▪ Weeding to reduce competition of weeds against plants for soil nutrients and moisture ▪ Mulching using crop residue to retain soil moisture from evaporation ▪ Increase irrigation through construction of dams, ponds, and water wells for increased crop production ▪ Mixed cropping such as barley and wheat, sorghum and finger millet, sorghum and sesame etc. to secure production if one type of crop fails. ▪ Soaking of seeds into water prior to planting to hasten and secure germination. ▪ Biological soil conservation (strip cropping, planting grasses and leguminous plants on edges of plots) to strengthen physical soil conservation structures so as to retain moisture and soils in the cultivated fields. ▪ Introduction/ expansion of irrigated agriculture especially spate irrigated for crop and livestock production.
<ul style="list-style-type: none"> ▪ Crop rotation ▪ Crop diversion ▪ Developing wells, ponds & dams ▪ Water supply from spring & river beds ▪ Mulching ▪ Drill planting (<i>chulika</i>) ▪ Deep seeding 		

Source: Ministry of Land, Water and Environment (2007).

Table 5: Evaluation of adaptation option for Eritrea. Adopted from Ebi *et al.*(2011)

Adaptation options	Comment	Assistance required	assistance	Time	Effectiveness in minimizing the impacts of climate change	cost	feasibility	Adequacy for current situation
<i>Mulching</i> Incorporation of crop residue, hay, straw, and fresh-cut forage or cover crops	Little or no-training is required for this operation	This could be implemented and achieved at household and or community level	Very low	Short-term	Very low	Very low	High	Very high
<i>Channel</i> Diversion of small streams and runoff to the fields	Little or no-training is required for this operation	Technical assistance required	Low	Short-term	Medium	Medium	High	High
<i>Crop rotation</i> crop to be rotated depends on the onset of rain, soil type, crop type and availability of land. Example barley and wheat, sorghum and teff; maize and pearl millet and sesame	Training maybe required	Technical assistance required	High	Short-term	High	High	High	Very high
<i>Integrating crop and livestock.</i> Increases the diversity, along with environmental sustainability, of both sectors and at the same time it provides opportunities for increasing overall production and economics of farming	Training maybe required.	This could be implemented at household or community level with aid of technical assistance.	High	Long-term	Very high	Very high	High	Very high
<i>Soil and water conservation.</i> Involving stone terraces, earth bunds, water diversion and drainage, plough	Training maybe needed	Technical assistance is required and could be achieved or implemented at household or community level.	High	Short-term	High	Medium	Very high	High
<i>Planting improve variety crop.</i> Planting crops that mature within a short period of time.	Sensitization to farmers for the adoption of improve variety seeds	This could be implemented with technical and financial assistance	High	Long-term	Medium	Low	Medium	Medium
<i>Fallowing.</i> Temporary closure of farm to restore nutrients and soil fertility	Training maybe needed	Technical assistance is required and could be achieved or implemented at household or community level	Very low	Long-term	Medium	Low	High	High

CONCLUSION

Climate change had severely ravaged agriculture and the environment. Rising temperatures and evapotranspiration, erratic and inconsistent rainfall, soil degradation and loss of crop productivity are some of the observed impacts climate change. The study observed the range of adaptation strategies to climate change by farmers in Eritrea. The results show that a lot have been done in terms of adaptation to ameliorate the impacts of climate change. The autonomous adaptation by farmers shows a promising result as well coordinated programmes by government and NGOs that involves research and knowledge transfer. The study highlights the importance of some of the identified adaptation options in dealing with impacts of climate change and variability. However, there is need for further research in climate change adaptation in Eritrea the vast majority of literature that report adaptation are grey literatures and perhaps may not be peer reviewed.

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