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LOW-CARBON and CLIMATE RESILIENT INDUSTRIAL DEVELOPMENT IN AFRICA



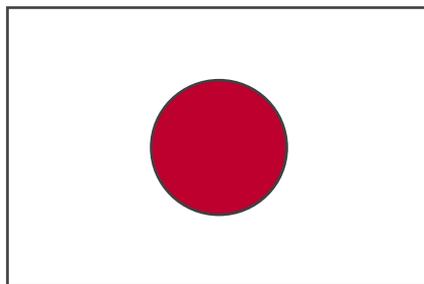
SYNTHESIS REPORT

METHODOLOGY

VALUE CHAIN MATRIX

LOW-CARBON and CLIMATE RESILIENT INDUSTRIAL DEVELOPMENT

EGYPT • KENYA • SENEGAL • SOUTH AFRICA



From the People of Japan

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PART ONE

SYNTHESIS REPORT

LOW-CARBON and
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PROJECT
COMPONENTS:

*National level policy
assessments*

and

*Vulnerability and
low-carbon industry
assessments
in sub-industries*



1. INTRODUCTION

In order to create awareness and demonstrate the opportunities, as well as benefits, of low-carbon growth and climate resilient development in the productive industries in African countries, UNIDO applies Green Industry policy instruments, practices and techniques. This is one of UNIDO's regional projects on low-carbon and climate resilient (LCCR) industrial development in four African countries: Egypt, Kenya, Senegal and South Africa.

UNIDO is an agency of the United Nations that specialises in promoting industrial development for poverty reduction, inclusive globalisation and environmental sustainability. The first phase of the LCCR project consists of two components: national level policy assessments, and vulnerability and low-carbon industry assessments in selected sub-industries. Results of these assessments will be the basis for producing synthesis reports of industry value chains.

Government action assesses the vulnerability and sensitivity of each industry to the impacts of climate change on the national industry, key resources, and locations with regard to the current climate and future climate change. This component maps previous and ongoing actions taken by the government in each country. Green Industry will assist the effective implementation and operationalisation of the existing national policies and strategies for industry.

Each country team assessed vulnerability and Green House Gasses (GHG) emissions in two selected sub-industries. Quick preliminary vulnerability assessments were conducted at selected production facilities/enterprises to explore the need and opportunities for the application of Environmentally Sound Technologies (ESTs) and Green Industry techniques and practices. Methods for EST and Green Industry technological transfer will be planned and disseminated to promote low-carbon growth and climate resilient industrial development. This report synthesises policies and vulnerability assessments produced by National Cleaner Production Centers in the four African countries, as well as the value chain of industries in Egypt and Kenya.

The goal of the assessment is to establish the industry vulnerability to climate change in the four case countries. The project focuses on industry structure, resource requirements and locations in the context of the projected impact of climate change. The objectives of the project assessment were:

- To determine the technological, managerial and operational capacities of industries to achieve low-carbon and climate resilient industrial development.
- To examine the challenges and opportunities inherent in the national frameworks for low-carbon and climate resilient industrial development.

“ Methods for EST and Green Industry technological transfer promote low-carbon growth and climate resilient industrial development. ”

“
Assessment’s goals:
To determine capacities of industry;
To examine the challenges and opportunities;
To propose areas of improvement.
 ”

- To propose potential areas of improvement for low-carbon and climate resilient industrial development.

To achieve the objectives of this assessment, a combination of information types and sources was used and multiple methods followed. The information required for the assessment was obtained primarily through a series of consultative stakeholder workshops with various key representatives of government agencies in the focal industries and reviews of existing policies, strategies and action plans relating to low-carbon and climate resilience. Face-to-face interviews were conducted for the target participants who could not attend the workshops. The agencies chosen for the consultation process were informed of the relevance of their mandate to the initiative.

This report also uses climate information data to analyse current and future challenges in important industries in each country. Climate information section employs two sets of climate data on rainfall and temperature. The data were obtained from climate information portals (CIP). The period of data from CIP is 1979–2000. The projected future climate changes for the location across ten different statistically downscaled CMIP5 GCMs for RCP 4.5 because RCP 4.5 assumes that global annual GHG emissions (measured in CO₂-equivalents) peak around 2040, with emissions declining substantially thereafter. The observational data from the target governments and the Food Agriculture Organization (FAO) is used to compare the data of CIP. Anomalies are calculated relative to the historical period 1980–2000. The solid bars in the climate data represent the range between the middle 80% of projected changes and so excludes the upper and lower 10% as these are often considered to be outliers.

“
Information sources and methods used:
Workshops;
Interviews;
Climate information data from CIP;
Observation data from the governments;
and FAO.
 ”

The aims of the climate information section are to give general knowledge and recommendations on climate information, including the projected trends of rainfall as well as the current condition of temperature to support a target sector. For example, in the Egypt case, this section assesses how current trends and long-term projected changes in temperatures and rainfall in Giza affect the potential for wheat cultivation, and how any impacts can be addressed.

Selected (sub)-industries in the four case countries are as follows:

Number	Country	Industry	Sub-industry
1	Egypt	Agriculture	Fruit Juice and Wheat
2	Kenya	Agriculture	Tea
3	Senegal	Fisheries and food	Frozen Fish and cereal milling industry
4	South Africa	Agriculture	Potato, Maize and processed vegetable





2. EGYPT

2.1. Geographical Location, Demographics and Economic Activities

Egypt is located in the north east of Africa from latitude 22°N to 32°N. The total area is 1,001,450 km² with a coastal line of 3,500 km on the Mediterranean area and Red Sea. Egypt is divided into Upper and Lower Egypt by the Nile River, which is the main source of water for drinking and agricultural purposes. The population of Egypt is approximately 82.5 million whereas 97% of the inhabitants live in three major regions: Cairo, Alexandria, and other places along the river banks. The density of the Egyptian population is about 1,500 people per square kilometre (United Nations, World Population Prospect, 2012). Egypt has a dry and hot desert climate. In the winter season, the climate is mild with some rain in Lower Egypt and less rain with warm sunny days accompanying cool nights in Upper Egypt. During the summer season, the climate is hot and dry all over Egypt with the average temperature ranging from 17°C to 20°C (Lelieveld, et. al. 2012).

Agriculture, media, manufacturing, natural gas and tourism are the main economic activities in Egypt. Due to a rapidly growing population and limited arable land, as well as Egypt's dependency on the Nile River, there is economic stress, which makes Egypt rely on the tourism industry as well as remittances from Egyptians who work abroad as main sources of income. Manufacturing (chemicals, food products, textiles, cement and building materials, paper products, derivatives of hydrocarbons, iron, steel, and car industries) is counted as one of the largest economic industries in Egypt, comprising roughly 25% of the gross domestic product GDP. Among these, the food industry remains the most important industry and the oldest economic activity in terms of GDP in Egypt (GAFI, 2014). Most of Egypt's food industry is privately owned. There were 5,296 companies operating in the agribusiness industry with a total capital of EGP 14 billion in the year 2014. Though the GDP growth rate reached 2.2% in 2011–2012, the unemployment rate has risen from 9.4% to 13%. Egypt's economy has staggered since former President Hosni Mubarak's downfall, as continued political instability has spooked investors and hindered economic recovery (Egypt Independent, 2013).

Climate change in Egypt is projected to increase temperatures and potentially reduce precipitation (UNDP, 2010). Flash floods, earthquakes, desert locusts and storms are the types of natural disasters that commonly occur in Egypt. The Nile river delta is also at risk due to rise in sea level. The flow rate within the Nile is quite sensitive to abstractions for industry and agriculture, which is due to the economic activities. There are economic industries and



Capital:
Cairo

Surface:
1,001,450 km²

Population:
82.5 million

Density:
1,500 people
per km²

Average temp.:
17°C to 20°C



activities that are expected to be affected by climate change and related hazards – such as agriculture, water, energy, health and transportation – and generally in the coastal zones. The road specifications and level are not designed for protecting the land from sea level rise caused by global warming.

The coastal area in the Mediterranean shoreline is the most vulnerable to the rise of the sea level. The wetland of the Nile delta produces 60% of the fish caught in Egypt (Oczkowski, et.al. 2008). Meanwhile, the Mediterranean coast has been developed for tourism activities and industrial towns. The rise of the sea level may lead to erosion, particularly in the endangered zones (ENCPC, 2014). When the shorelines recede towards agricultural land, the salinity of the groundwater will increase. The coral reef in the coastal area of the Red Sea region will bleach quickly, leading to environmental pressure. There will be a negative impact on the social and economic aspects of the coastal zones in Egypt due to the climate change. However, with certain measures and rehabilitation processes, the environmental pressure and vulnerability of the area can be reduced.

2.2. Industrial Analysis and Climatic Disaster for Different Industries

As the largest consumer of oil and natural gas in Africa, Egypt was responsible for 20% of the total oil consumption and about 40% of the total dry natural gas consumption in Africa in the year 2013 (KPMG, 2013). The government gives subsidies to this industry, which cost them USD26 billion in 2012. This contributes to the rise in energy demand and a higher budget deficit. In the water sector, agriculture, drinking and industrial sources are the highest consumers. Approximately 80% of the drinking water supplies come from the Nile canals and 20% from the groundwater. Water sector is the most vulnerable to climate change in Egypt's water industry (Gemal, et. al. 2011). Industry is a growing sector in the Egyptian national economy (Ministry of Water Resources and Irrigation, 2013), the average water footprint of industrial products per unit of industrial value added is 133 m³/1000 US \$ from 1996-2005. In addition, in the agriculture industry, water footprint per ton of crop or derived crop product at national level is 539,223 m³/ton from 1996-2005. This number left water saving related to trade in agricultural and industrial products which are 11,796.3.1 Mm³/yr and 355.3 Mm³/yr respectively (Mekonnen, Hoekstra, 2010). Lack of water resources increases the crop failure occurrence due to the drought. Another threat is the spread of plant fungal diseases and drought.

The temperature rise will increase water evaporation and agricultural water consumption. Crops such as wheat, maize, cotton, rice, tomato and sugar cane will all suffer decreases in yield and productivity if the temperature rises by 2°C – 3.5°C and will require increased water consumption by 4.1% – 6.2%. For instance, the wheat productivity could fall by 9% if the temperature rises by 2°C (IDSC, 2011). The temperature rise will also affect animal production (milk and meat production) and their health. There will be an increase in diseases that are common to human and animals such as avian flu, foot and mouth disease. Animal and human fascioliasis is becoming an endemic clinical and epidemiological health problem in Egypt (Soliman, 2008). Sudden climate change in some geographical areas will lead to multiple injuries and migration, which will result in an unhealthy population density. The migration then affects the social and economic impact (McMichael, et.al. 2012). Those are ef-

“ The temperature rise will increase water evaporation and agricultural water consumption. It will also affect animal production. ”

fects of changes in precipitation, temperature and water demand in upstream Egypt, Beyene (et.al. 2010) found that the Nile River is expected to experience increase in streamflow early in the study period (2010–2039), due to generally increased precipitation. Nile river is very exposed to upstream changes.

Another crop plays a major role in Egypt's agriculture is fruit growing (Zaki, 1992). The fruit-planted area has expanded over the last three decades to reach about 200 000 feddans (84 000ha). A wide variety of tropical and sub-tropical fruits are produced, including: grapes, bananas, mangoes, guavas, apples, peaches, nectarines, strawberries, apricots, pears, pomegranates and mangoes, but 30-50% of total fruit production is citrus fruits, primarily oranges that represent 65-85% of that figure (El Shereif, 2016). Production is mainly concentrated along, and dependent upon, the River Nile and delta (Figure 1). Egypt has competitive advantage in the processing of fruit juices, arising from the availability of fruits during off-seasons and also through a direct cost/quality advantage (Ecorys, 2005). In addition, most of the required fruits (industry inputs) are planted in Egypt and consequently there is no need to import such inputs. The sector has grown from 713,000 USD to 13.5 million USD in six years from 2007 to 2012 (Selim, 2009). Although highly dependent on irrigation, Egypt has better water access than many of its neighbors (Abdallah et al., 2015), rendering it a strong regional agricultural supplier (See Egypt's country report).

2.3. Policies for Vulnerability to Climate Change

Egypt first identified its vulnerabilities to climate change and desired response strategies in 1999 through its Initial National Communication. This was continued through its Second National Communication in 2010. The content of the Initial National Communication was determined, in part, by a series of background studies completed between 1995 and 1999 (Sowers, et. al. 2011). These studies included a vulnerability assessment of the country's freshwater resources, a review of the prior framework of the government's action plan on climate change, the assessment of the policy options addressing climate change (mitigation and adaptation) in the agriculture industry, adaptation to sea level rise, and an adaptation technology assessment.

The lead government bodies responsible for climate change are the Ministry of State for Environmental Affairs and the Egyptian Environmental Affairs Agency (EEAA). An Inter-Ministerial National Climate Change Committee composed of governmental and non-governmental stakeholders and chaired by EEAA was created in 1997 (Agrawala, et.al. 2004). More recently, in 2009, a pre-ministerial decree to establish a national Centre for Climate Change was issued.

Policy actions are also ongoing in that, while not specifically integrating climate change adaptation, address some of Egypt's key climate vulnerabilities. For example, a National Committee for Integrated Coastal Zone Management has been established, and regulations introduced that require inclusion of Integrated Coastal Zone Management (ICZM) in development plans. Also, a National Integrated Coastal Zone Management Strategy is being developed. Elements of this strategy are expected to include 1) Upgrading adaptive capacity through establishment of institutional systems for monitoring, building databases, modelling and upgrading awareness; 2) Adopting a proactive no-regrets policy in planning and enforcing regulations for follow up; 3) Carrying out research on renewable energy, salt tolerant plants, desalination; and 4) Considering geo-engineering activities for protection against sea level rise (Abul-Azm, et. al. 2003).

“ In 2009, a pre-ministerial decree to establish a national Centre for Climate Change was issued. ”

Furthermore, through implementation of the 2005 National Water Resources Plan, Egypt could reduce its vulnerability to future water shortages. Measures in this plan include: improvement of irrigation systems, redesigning canal cross sections to reduce evaporation loss, improving drainage, and resolving conflicts between users more quickly (Hamouda, et. al. 2009). Requirements for water in Egypt, which is predominately drawn from the Nile River, are continuously increasing due to population increase and improving standards of living, as well as the governmental policy to encourage industrialization and agriculture.

Given the size and diversity of Egypt, and its recognised vulnerability to climate change impacts, particularly water scarcity and sea level rise, a high number of adaptation projects – relative to other countries in North Africa – have been found to be underway in the country. However, this level of activity is moderate, at best, if compared to the degree of adaptation action in countries in eastern, western, and southern Africa (Sowers, et. al. 2011). The number of projects being undertaken exclusively in Egypt is approximately equal to the participation in regional projects.

Egypt has also identified some cross-industrial actions that would contribute to its adaptation efforts including public awareness campaigns, development of climate models, increasing the capacity of researchers, encouraging exchange of data and information, and enhancing precipitation measurement networks in upstream countries of the Nile basin as well as the installation of modern early warning systems (Klein, et. al. 2007).

The Egyptian government has identified its vulnerabilities to climate change and has expressed the desire to respond with some strategies and actions since the 1990s (Brooks, et. al. 2009). A climate change action plan has been developed to address mitigation and adaptation actions that focus merely on the agriculture industry and coastal area. However, the policy does not specifically integrate the action plan with key climate vulnerability. Cooperation between the government and other local and internationally funded projects is present in some areas, though the level of activity is still moderate. Therefore, it is important to prepare some action plans through monitoring to improve the implementation procedure, planning, and resource allocation among the stakeholders. It is also important to propose actions that prioritise industries like water, agriculture, coastal zones and health, and include the vulnerability of each industry and the proposed actions in each step. The government and related agencies, as well as other authorities, should independently identify and describe the roles and responsibilities of each industry (ENCPC, 2014).

“
Through implementation of the 2005 National Water Resources Plan, Egypt could reduce its vulnerability to future water shortages.
”

2.4. Value Chain

Agriculture consumes the largest amount of the available water in Egypt, with its share exceeding 85% of the total demand for water (Ministry of Water Resources and Irrigation, 2014). The Egyptian economy has relied heavily on the agricultural sector for food, feed, fibre and other products. It provides livelihood for about 55% of its population, employs 30% of the labour force, contributes approximately 17% of the GDP and 20% of all foreign trade earnings (El-Nahrawy, 2012). In view of the expected increase in demand from other industries, such as municipal and industrial water supply, the development of Egypt's economy strongly depends on its ability to conserve and manage its water resources.

Egyptian agricultural land can be classified into “Old-land” and “New-land”. Old-land comprises the lands of the Nile Valley and the Nile Delta, which have been irrigated and intensively cultivated since ancient times, and represent about 80% of the cultivated area. New-land consists of lands that have been reclaimed (or are in the process of being reclaimed) relatively recently (International Fund for Agricultural Development, 2005); it represents about 20% of the cultivated area. The cultivated land base of Egypt is about 3.5 million hectares, with a total annual cropping area of about 6.2 million hectares, representing 176% of the total cultivated land area (Ministry of Agriculture and Land Reclamation, 2005).

From 1341 m³ per capita of total water footprint of national consumption in Egypt, 1213.1 m³ are used in the agriculture products. Meanwhile, industrial products consume 53.3 m³ per capita of the water footprint. It is shown by major consumption category and by internal and external component (m³/yr/cap). The Ministry of Agriculture and Land Reclamation and the Ministry of Water Resources and Irrigation have set an integrated plan for land reclamation through several mega projects targeting about 3.7 million acres (1.4 million hectares) to be reclaimed by 2017 (UNDP, 2010). This strategy considers two types of mechanisms to procure the required water resources for reclaiming the targeted areas. The first mechanism entails the efficiency increase of the current agricultural water use, minimising irrigation water losses and the second entails increasing non-conventional water resources share in agriculture.

In case of fruit juice industrial value chain, many processes except collection, transportation, preparation, packing and post-process storage, were perceived to be vulnerable to climate hazards such as temperature rise, drought, heavy rain and flood (See Egypt’s country report). Due to poor packaging, lack of cold chain facilities, rough transport, and multiple handling, the Egyptian perishable products sector like the fruit is constrained by a transportation and storage system that is very damaging to product quality. It is estimated that up to 40% of total production of highly perishable products are damaged or lost in transit and handling (Ecorys, 2005; Selim, 2009), although this probably varies with the perishability of the product. Agricultural raw material losses could be as much as 60% (Selim, 2009). With high rates of spoilage, these transport and handling issues mean that supply to the food processing industry is often unreliable and inconsistent in terms of both quality and quantity, and therefore result in reduced productivity (Koscielski, Lotfi, & Butterfield, 2012). Furthermore, usually due to inadequate temperature control, the final products of food processing are at higher risk of suffering quality defects or being destroyed; especially those that require freezing or chilling (James & James, 2010).

2.5. Climate Change Challenge for Wheat Industry

As explained above, agriculture is one of the main economic activities in Egypt. Food processing industries, together with manufacturing industries (chemicals, textiles, cement and building materials, paper products, derivatives of hydrocarbons, iron, steel and car), are counted as one of the largest economy sectors in Egypt with 37.55% of the GDP (Index Mundi, 2014). Most of the food industry is privately owned and relies on ag-

“
Development
of Egypt’s
economy
strongly
depends on
its ability to
conserve and
manage its
water resources.
”

riculture. The formal sector of the industry generates an output of 31 billion EGP (8% of total GDP) representing almost 25% of the industrial manufacturing output (Selim, 2009).

Agriculture is one of the sectors that is responsible for the most water consumption. The crop yield will drop rapidly due to the climate change. The temperature rise will increase water evaporation and water consumption in the crops. Crops such as wheat, maize, cotton, rice, tomato and sugar cane have the lowest yield and productivity if the temperature rises by 2 - 3.5°C and will lead to increased water consumption by 4.1% - 6.2%. For instance, the wheat productivity will fall by 9% if the temperature rises by 2°C (IDSC, 2011).

Wheat is the major winter cereal grain crop and the third major crop in terms of area planted, at around 600,000 feddans¹ (El-Sheriff, n.d). Food industry depends on wheat industries, which rely on wheat production. Wheat production potential in Egypt is assessed only under irrigated conditions from winter and summer rainfall, both for areas already irrigated and for those which may come under supplemental irrigation in future. Small areas of land that could grow wheat with irrigation from local groundwater sources such as springs are left out of consideration because of their limited extent and preferred alternative uses. The Middle Egypt and the Nile Delta are suitable areas for wheat. The mean daily temperature during the wheat growing period at Giza (Middle Egypt) is 15.7°C, and 16.4°C at Mansoura (Nile Delta) (FAO, n.d-a). Giza has a harder challenge for growing wheat since the city has water demand which is growing faster than Mansoura

¹ 1 feddan = 1.038 acre

(Ouda, et al. 2016). Giza is the third largest city in Egypt and is located in the west bank of the Nile. The analysis below uses data from Cairo station because it is the station nearest to Giza, which is located 20 km southwest from central Cairo.

2.5.1. Historical Climate Data

The timing of the onset and the cessation of the winter season, during which there is some rain, is important for crop management including wheat cultivation. Figure 1 clearly shows that for the 1979–2000 period, the rainfall in the Giza region was characterised by seasonal pattern over the years. The climate monthly average shows that November to March have more than 3 mm of rainfall. In April to October, the rainfall is below 1 mm/month. Therefore, Giza has clear differences between winter and summer seasons.

The driest month has historically been July with the monthly average of around 0 mm from 1979 to 2000. The wettest month has been December with the average total monthly rainfall of 5.5 mm, which is still a very dry condition. The minimum average temperature was 9°C in January, while the maximum average temperature was 34°C from June to August.

The total monthly rainfall data for the period of 1979–2000, as shown in Figure 2, indicates that the highest total monthly rainfall occurred in March 1989, namely 26 mm. This condition had implication to irrigation water for wheat cultivation. The decrease of rainfall since 1990 had been affecting water shortage along irrigation system.

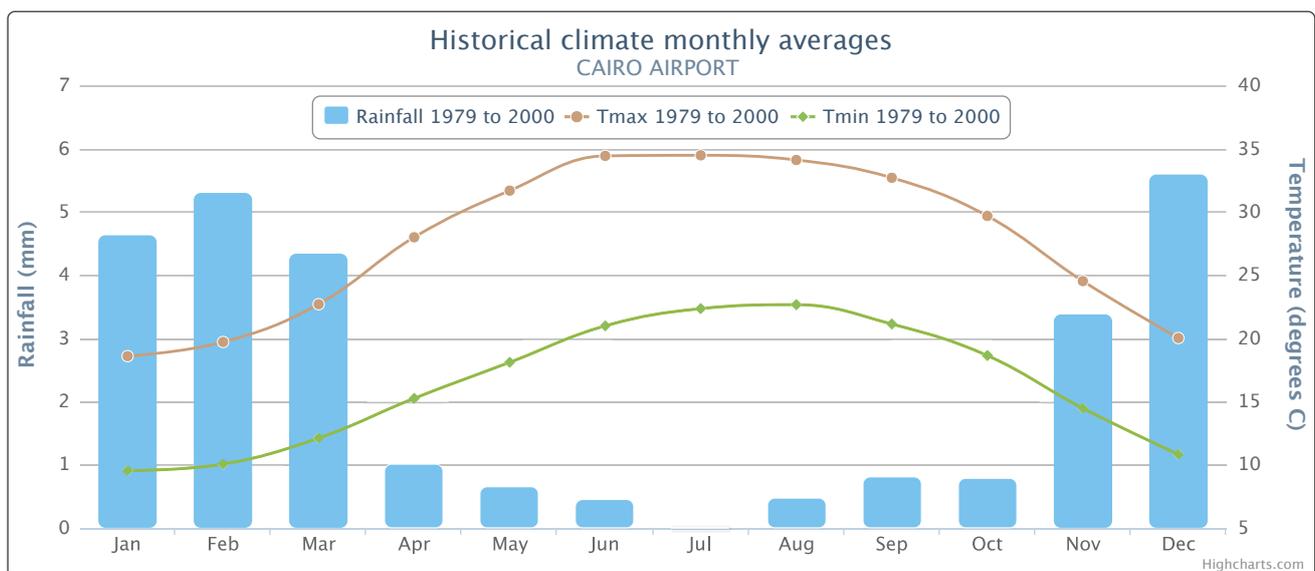


Figure 1. Historical Climate Monthly Average in Giza from 1979 to 2000. The temperature changes significantly throughout the year. There is clear mild winter and hot summer in Cairo Airport Station, Giza.

2.5.2. Future Climate Projections

From the statistical downscaled data CMIP5 GCMs (General Circulation Models) for RCP (Representative Concentration Pathway) 4.5 scenario projection for Giza shown in Figure 3, the total rainfall is likely to change in 2040–2060. The 2040–2060 projections indicate that the total monthly rainfall is likely to increase only in January, February, April and November. Most other models suggest that the total monthly rainfall will decrease in all months except April. Meanwhile, in December it is likely to decrease significantly compared to the observed rainfall. March is mildly wet, but it will get drier. This projection will

have impact on future condition of irrigation water in Egypt. Decrease of rainfall will reduce support for water resources management.

In addition to the rainfall projection, the average maximum temperature scenario projection (Figure 4) indicate hotter conditions, especially from May to October. Generally, the result of projection shows similar patterns as the rainfall projection. The average maximum temperature is likely to increase over the years. All models suggest increase in average maximum temperature up to 35°C, especially in May and October. June to August are projected to be the hottest months.

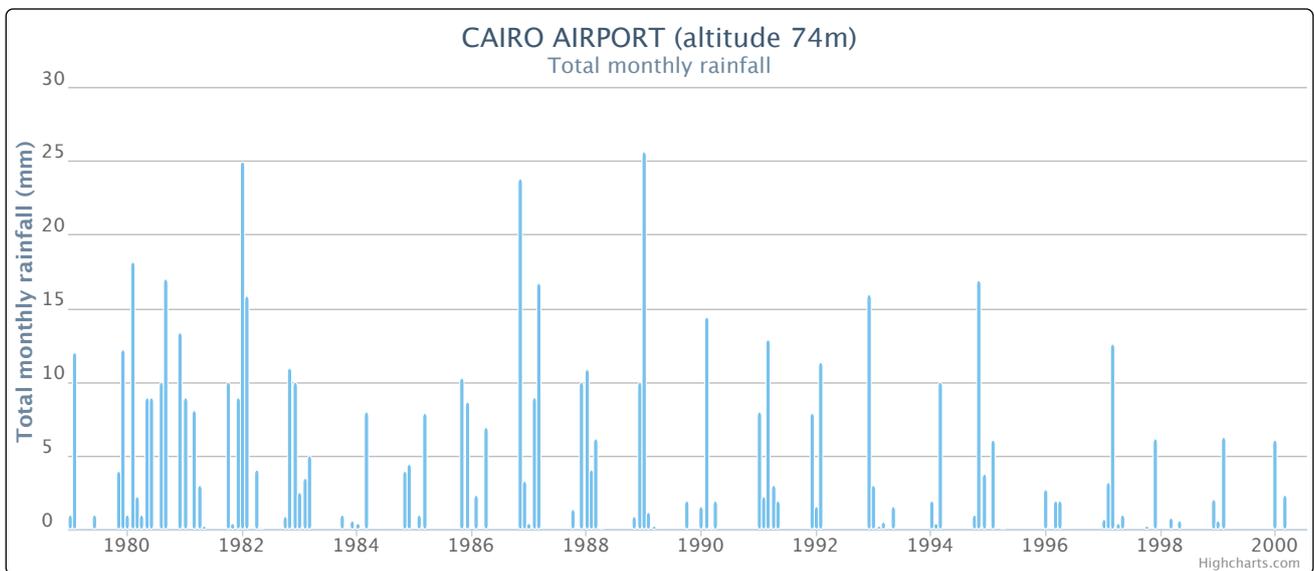


Figure 2. Total Monthly Rainfall in Giza

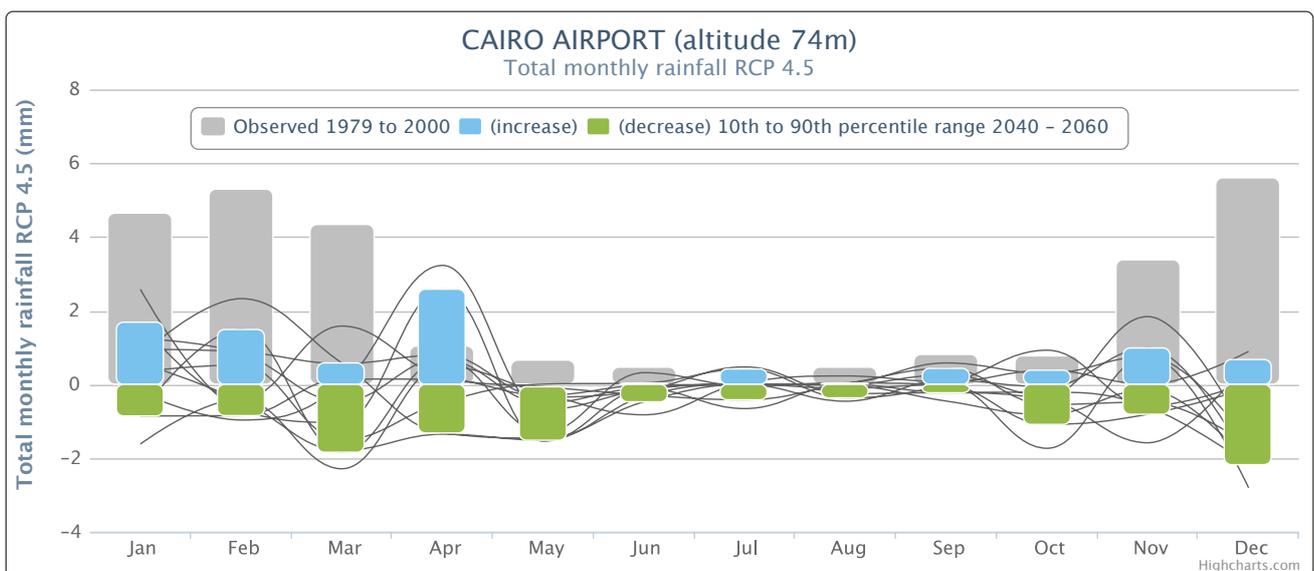


Figure 3. Total Monthly Rainfall Projection for Period of 2040–2060 Based on RCP 4.5 in Giza. The lines show the results for each of 7 climate models.

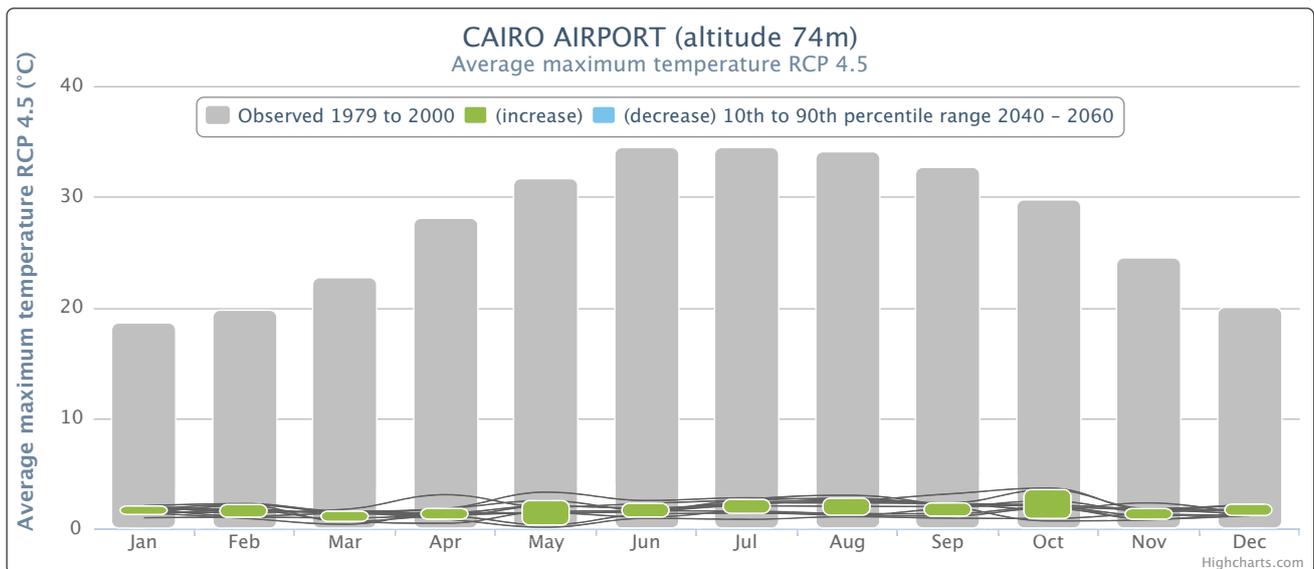


Figure 4. Average Maximum Temperature for Period of 2040–2060 based on RCP 4.5 in Giza. The lines show the results for each of 7 climate models.

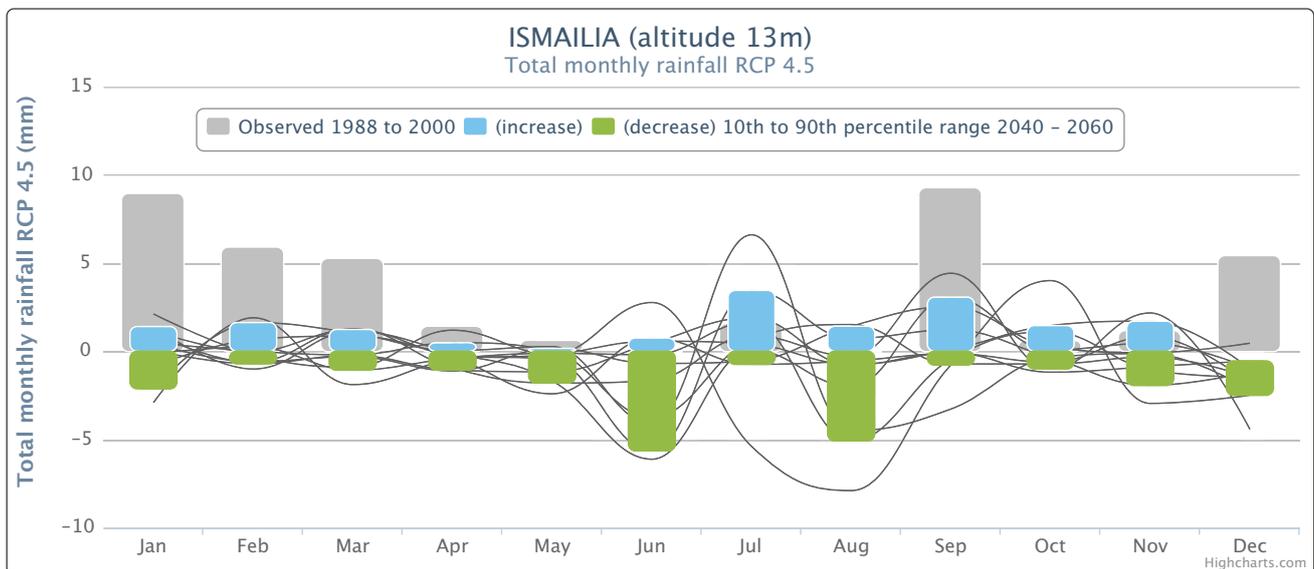


Figure 5. Total Monthly Rainfall Projection for Period of 2040–2060 based on RCIP 4.5 in Ismailia

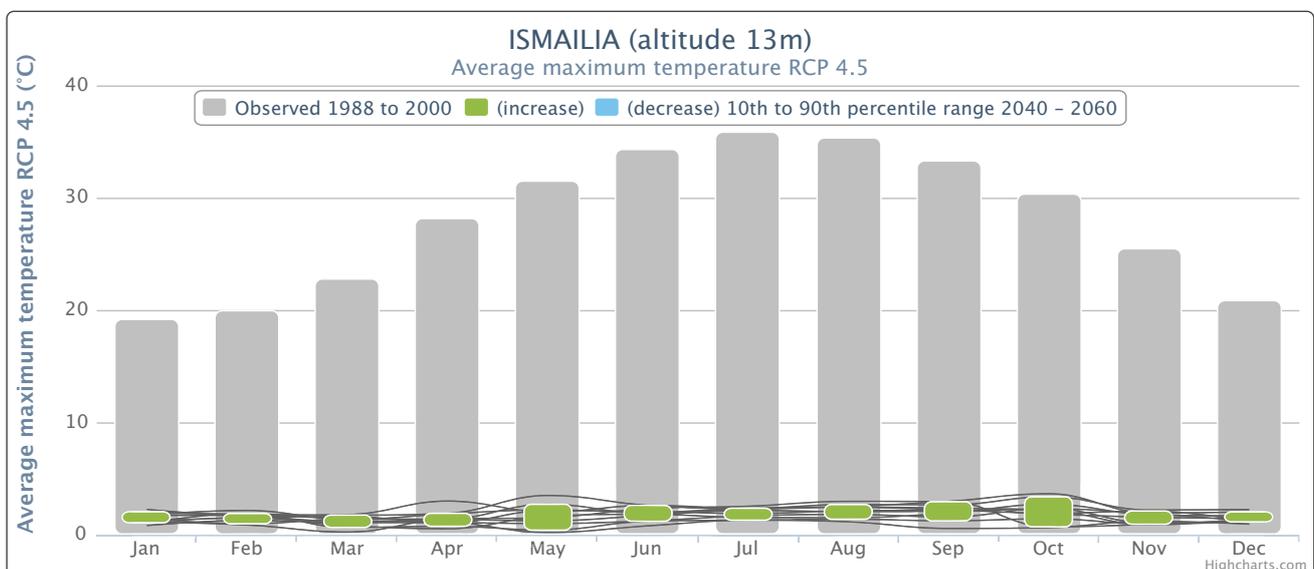


Figure 6. Average Maximum Temperature Projection for Period of 2040–2060 Based on B1 (2046–2065) in Ismailia

2.5.3. The Climate Comparison With Other Station

When we look through the data from the Ismalia station, the future climate projections based on RCP 4.5 Scenario suggest patterns almost similar to our earlier interpretations for the Cairo station. For example, in terms of rainfall (Figure 5), the amount of rainfall will decrease in most of the months. The average maximum temperature (Figure 6) is also increasing across the year in both stations. However, in contrast to Cairo station, the amount of rainfall in Ismalia station is projected to increase in July and September. Likewise, there are more months projected to be drier in Ismalia.

2.5.4. Conclusion and Recommendation for Wheat Industry

The growth requirements for wheat released by the FAO shows that wheat grows best in the region with an annual rainfall of 450–650 mm or 1000–1500 m³ per cropping period per feddan (Ibrahim FN, Ibrahim, et al. 2003). It means that currently there is less rainfall than would be needed for optimal wheat production.

There are 3 levels of land suitability, namely S1 (minimum number), S2 (maximum number) and N (not suitable). Based on Table 1, a land will be very suitable for wheat cultivation if it has an annual rainfall about 664 mm.

There are 3 levels of land suitability, namely S1 (minimum number), S2 (maximum number) and N (not suitable). Based on Table 1, a land will be very suitable for wheat cultivation if it has an annual rainfall about 664 mm. So, historical data for the Giza region (Figure 1) and the annual rainfall based on weADAPT–CIP indicate that Giza could be categorised as N area for wheat cultivation if the area doesn't have good irrigation because the annual rainfall in this area is about 100 mm. Wheat which is grown at the moment is because there is old irrigation system in place. In addition, based on the trend projection (Figures 3 and 4) for the period of 2045–2065, it is likely that monthly rainfall will decrease in this region (except in May and November). This could have a negative impact for wheat farmers in Giza as the suitability will decrease as a result of a decline in precipitation.

When we look at temperature, the other growth requirement for wheat, it could also be an obstacle for wheat cultivation. The current average temperature over the Giza region ranges from 15 °C to 25°C (Figure 1), which is ideal for wheat growth. Based on Growth Degree Day tool, the temperature limiting criteria for potential growing season is 2°C–30°C (Neamatollahia, et al. 2012). However, in the future, the average maximum temperature is projected to increase to over 30°C. This condition will be difficult for wheat cultivation.

Climate change is one of the main issues for wheat cultivation. Our analysis suggests that efforts by the district government to improve water drainage structures and irrigation canals might help increase the suitability level for wheat cultivation. A further detailed technical study on the assessment and ranking of adaptation options would complement this work and would be important in making decisions regarding the vulnerable zone. Further research in creating new wheat varieties that can be planted in a region with less annual rainfall is also important in supporting the farmers in Giza.

Egypt receives less than 80 mm of rainfall a year, and only 6 percent of the country is arable and agricultural land, with the rest being desert. This leads to excessive watering and the use of wasteful irrigation techniques such as flood irrigation [an outdated method of irrigation where gallons of water are pumped over the crops]. Nowadays, Egypt's irrigation network

“The average maximum temperature is projected to increase to over 30°C. This condition will be difficult for wheat cultivation.”

“Key industrial issues include improving storage facilities, cold transportation efficiency and value added post-harvest production for small-quantity industry.”

draws almost entirely from the Aswan High Dam, which regulates more than 18,000 miles of canals and sub-canals that push out into the country’s farmlands adjacent to the river. This system is highly inefficient, losing as much as 3 billion cubic meters of Nile water per year through evaporation and could be detrimental by not only intensifying water and water stress but also creating crop failure (Gohar, Ward, 2010). A further decrease in water supply would lead to a decline in arable land available for agriculture, and with agriculture being the biggest employer of youth in Egypt, water scarcity could lead to yield losses of wheat.

At the moment there is very little rainfall in Giza, and wheat can only grow through irrigation from the Nile. So rainfall change will affect less on wheat, because wheat has to be irrigated. The fact that rainfall decreases 1-2mm/month during the rainy season makes very little difference, because the water has to come from the Nile or groundwater. In order to see the effects of changing water availability, it needs to be checked from water flow in the Nile. For rainfed production, Giza may have virtually no land suitable in the future, because it needs 450mm/year at the bottom end of the water requirements. Estimates of such potentials for other countries should be given, considering agroecological suitability for growing rainfed wheat only or, more realistically, a mix of several crops (Marquina, A. 2002). Good wheat production would make the wheat industry resilient, which would in turn help the food industry to provide food security. There are some key industrial issues such as improving storage facilities, cold transportation efficiency and value added post-harvest production for small-quantity industry. Wasted wheat due to poor infrastructure in the storage network is a big problem in Egypt (McFeron, 2015). The projected climate can make this condition worse if there is no effort from stakeholders to repair the storage facilities. Poor transportation can also increase wasted wheat. For the small wheat industry which cannot afford reliable transportation and facility for its distribution, it is better to consider value added post-harvest production such as biodegradable plastics, paint stripping, raw materials for cosmetics and ethanol.

Table 1. Land Suitability Level for Wheat (FAO, n.d-b)

Requirement	Land suitability level		
	S1 (minimum)	S2 (maximum)	N (not suitable)
Temperature (°C)	2	30	<2 and >30
Water requirement/ annual rainfall (mm)	556 (Applied irrigation under current climate)	664 (under climate change)	<450 and >664
Elevation (m)	0	3000	>3000
pH	6	8	<6 and >8

Wheat cultivation growth requirements for the Giza region suggest that it currently has insufficient rainfall for optimum wheat production. The decrease in rainfall has implications for Wheat, without looking at the effects

of changing water availability at likely water flow in the Nile is really hard to support, because Wheat isn't rainfed. Efforts to improve water drainage structures and irrigation channels may help to combat projected decreases in rainfall for wheat and other crops such as maize, rice, tomato and sugar cane, new crop varieties that can accommodate increases in temperature, to address the spread of fungal diseases and drought, will be needed. Other adaptation measures are needed in Egypt to address sea-level rise, storms and an increasing competition for water, through improved coordination, the preparation of action plans, the establishment of monitoring processes to improve implementation procedures, planning and resource allocation amongst stakeholders.

2.6. Climate Change Challenge for Fruit Juice Industry

Egypt's fruit juice market could be worth USD730 million by 2020, according to a new report by Market Publishers (Galán Saúco, 2002). The product categories in this industry include: Orange juice, Grapefruit juice, Other citrus juice, Apple juice, Pineapple juice, Grape juice, Tomato juice, Other single fruit juice and Mixtures of juices (GRDS, 2013). One of pure-brand juices is Juhayna which is a favourite in the highly-competitive Egyptian juice market. Juhayna is Egypt's Leading Dairy, Yogurt and Juice Producer which was established in 1983. It has 45,000 Retail Outlets and 7 Manufacturing Facilities. The resources come from its 5,500 Feddans of Reclaimed and Cultivated Land and distributed by more than 1,000 Vans and Trucks.

Juhayna is Egypt's top premium juice producer, a market leader in the Egyptian juice sector with a 23% share of the total juices market. It has production of high quality juices from fruit pulps and concentrates. It is manufactured at El Dawleya factory. Juhayna produces concentrates from fruits ranging from oranges to grapes to mangoes (Juhayna, 2013). The analysis and recommendation are based on climate data from Cairo Station above because the El Dawleya factory and its orange farm are located around Cairo.

Favourable annual precipitation for orange varies from 125–500mm, though oranges are frequently grown in areas receiving 1000–1500mm of rain. It means that currently there is less rainfall than would be needed for optimal orange production, especially if the area doesn't have good irrigation. During the growing period, the temperature should range from 12.8°C–37.8°C. In the winter dormancy, the ideal temperature range is 1.67°C–10°C. Mature, dormant trees have survived 10 hours at temperatures below -3.89°C, but the fruits are damaged by freezing temperatures between -1.11°C to 3.33°C. Young trees may be killed outright by even brief frosts. Hardiness, however, varies with the cultivar and rootstock, Seedling orange trees of bearing age are capable of enduring more cold than budded cultivars. Prolonged cold is more injurious than short periods of freezing temperatures (Morton, 1987). Historical data for the Cairo region (Figure 1) indicates that Cairo could be categorised as suitable area for orange farming because the average temperature range in this area is 0°C–33°C.

Based on the trend projection (Figures 3 and 4) for the period of 2045–2065, it is likely that monthly rainfall will decrease in this region (except in May and November). This could have a negative effect for orange farmers in Cairo as the suitability will decrease as a result of a decline in precipitation.

“Cairo could be categorised as suitable area for orange farming because the average temperature range in this area is 0°C–33°C.”

Climate and climate change is also one of the main issues for orange farming. Our analysis suggests that efforts by the district government to improve water drainage structures and irrigation canals might help increase the suitability level for fruit cultivation. A further detailed technical study on the assessment and ranking of adaptation options would complement this work and would be important in making decisions regarding the vulnerable zone. Further research in creating the new fruit varieties that can possibly be planted in a region that has less annual rainfall is also important to help farmers in Cairo.

The increasing periods of heavy rain predicted (Radhouane, 2013) will have a notable effect on the fruit juice industry. Heavy rain has a significant effect on storage, especially on open storage areas at some facilities. This will lead to damage of some raw materials, like vegetables, fruits and chemicals, used in the production process. The possibility of heavy rain occurrence is increased in the delta region and coastal areas which are agriculture and industrial areas. Heavy rain on-farm, at flowering particularly, can wipe out or severely damage entire crops (El Yaacoubi et al., 2014; Sthapit et al., 2012). Furthermore, heavy rain may delay transportation and distribution processes (See Egypt's country report).

2.6.1. Conclusion and Recommendation for Fruit Juice Industry

Recent scientific researches have been conducted related to climate change adaptation relevant to the fruit growing sector in Egypt (McCarl et al., 2013; Paciello, 2015; Sthapit et al., 2012) 2015; Sthapit et al., 2012. At-farm level, changing management practices is among the most important adaptation measures for the industry to navigate the impacts of climate change. Internationally, systems are being developed that can better predict flowering times for certain fruit trees, calculating pollination confidence and coincidental conditions for damaging weather events like frost or heavy rain (Primary Industries Climate Challenges Centre, 2016). Introducing ways to protect against insects, shade, and cool fruit at certain times is proving effective (Darbyshire, 2016; Refaie, Esmail, & Madany, 2012; Sthapit et al., 2012). The agriculture sector in Egypt is dominated by small farms which use traditional practices that do not comply with internationally recognized standards; farmers, for example, tend to overuse and misuse agricultural chemicals and use outdated technologies and tools for land preparation, irrigation, and harvesting (Koscielski et al., 2012). Improving extension and updating to climate smart farming techniques would improve farm resilience. Simple climate smart interventions such as mulching and preserving ground cover can improve soils and mitigate the extent of dust storms (Sthapit et al., 2012; Swain, 2016). Using different combinations of different levels of improved surface irrigation system efficiencies and applying deficit irrigation are considered as means of increasing the capacity of surface irrigation systems in old land in order to overcome the negative impacts of climate change (Smith et al., 2013; Sterman, 2009). Changing cultivars is often cited as one of the most effective adaptations to climate change (Attaher, Medany, & Abou-Hadid, 2009) as new varieties and cultivars can be chosen that cope better with reduced water availability and the increased average temperatures, have increased resiliency to pests and disease, and have increased yields (McCarl et al., 2013; Smith et al., 2013).

Good orange production would make the fruit juice industry resilient, which would help the food industry in defending food security. There are some key industrial issues such as improving storage facilities, cold

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transportation efficiency and value added post-harvest production for small-quantity industry. The major challenges for Egyptian oranges are transportation costs, distance between competitors and the destination markets, and seasonality of production. In Egypt, there is a large increase in the internal transport costs, in addition to customs clearance at the port and shipping commissions. These increases represent significant challenges for the Egyptian exporter. The increase in the production equipment costs will also affect the crop prices in the coming years. The projected climate can intensify this condition if there is no effort from stakeholders to solve the problems. Poor transportation can obstruct export of oranges to Saudi Arabia (250,000 tons), Russia (238,000 tons), United Arab Emirates (80,000 tons), Ukraine (75,000 tons), Iraq (70,000 tons), England (68,000 tons) and Netherlands (57,000 tons) (AGQ, 2015).

For the small orange farming or industry which cannot afford consistently good transportation for its distribution, it is better to consider value added post-harvest production. Whole oranges, orange pulp and peel withdrawn from the market which may otherwise be wasted, could be suitable for feeding animals (Justin, et.al. 2013). For a large company, one of its long-term strategy built on three complementary pillars is investment in infrastructure and organic growth market reach. These strategies can be considered as recommended adaptation measures for fruit juice industry in Egypt. Researchers need to demonstrate the benefits of adaptation options, industry needs to promote change amongst growers, and governments must ensure policy encourages change.

“ For a large company, one of its long-term strategy is investment in infrastructure and organic growth market reach. ”





3. KENYA

3.1. Geographical Location, Demographics and Economic Activities

Kenya is located across the equator in East Africa from latitude 6°S to 6°N. The land area is approximately 582,646 km². On the west side of Kenya, the climate is tropical but characterised by diverse topography that comprises the coastal plains of the Eastern Plateau, Great Rift Valley, highlands and the Lake basin (MARCHANT, 2005). In 2009, Kenya's population was estimated at 39.8 million with growth rate of 2.6%. About 31 million of the population lives in rural area while the urban population is about 8 million, with a growth rate of about 4%. That growth, grazing pattern of strong population together with deforestation and climate change causes much environmental damage (USDs 2010).

Vulnerability of low-carbon and climate resilient industrial development is a major environmental challenge in Kenya. Livelihood and economic activities in Kenya are highly vulnerable to climate change in space and time. Most of the area in Kenya is dry, with less than 500 mm of rainfall per year, which limits the potential of agro based economic activities (See Kenya's Country Report). Land degradation is a major issue in Kenya, partly determined by grazing and deforestation; while biomass use is at 78% of the energy consumed in the country (MENR, 2010).

3.2. Industrial Analysis and Climatic Disaster for Different Industries

One of main industries in Kenya is tea industry. It is started from tea plantations which are situated in the highland areas of the Great Rift Valley, Mt. Kenya, the Aberdares, and the Nyambene Hills in the Central Kenya and the Mau escarpment, Kericho Highlands, Nandi and Kisii Highlands and the Cherangani Hills; with altitudes between 1500m and 2700m above the sea level. In 2007 it was estimated that 149 000ha was planted (Amde, Chan, Mihretu, & Tamiru, 2009). Factories are located near the place of production. However, the tea industry has been confronted by high production costs, poor infrastructure, low levels of value addition and product diversification, inadequate research, development and extension, and declining global tea prices (Amde et al., 2009). These current obstacles are more exposed to the change of climate variability.



Capital:
Nairobi

Surface:
582,646 km²

Population:
39.8 million

Biomass energy:
78%



“

One of main industries in Kenya is tea industry.

”

The frost that occurred during 2011 mostly affected tea production across the country and resulted in diminished turnover of processed tea (GoK, 2011). In a technological capacity, Kenya's energy system is highly dependent on climate sensitive hydropower. Droughts decrease river flow, whilst floods lead to siltation – both affecting energy output. Another aspect that exposes industries greatly to climate change vulnerability comes from the structural ownership. The assessment divulged that a majority of industries are characterised by weak business ownership structures, primarily functioning as family entities or sole proprietorships. Another aspect of vulnerability is the decreased supply of agricultural commodities, which triggers the shut-down of industrial processes and, consequently, resulting in staff layoff (Gallai, et.al. 2009).

The vulnerability to climate change in Kenya threatens industrial shut-down, and changing temperatures and precipitation, leading to decreases in availability and increased prices of critical raw materials in the supply chain. Despite these challenges, opportunities for enhancing the operational capacity of industries for low-carbon and climate resilient development in terms of reducing energy and water scarcity is presented in the adoption of Resource Efficient and Cleaner Production (RECP) programmes that have been initiated in some parts of the country such as LVEMP in the lake Victoria basin (KNCP, 2014).

Aspects of the operational capacities of industries were also examined as part of the larger orientation of the country to low-carbon and climate change resilient development. Several operational capacity dynamics of the industries were considered. To begin with, the technical skills at the managerial level of the industries were found to be very low (Lall, 2004). This has had the effect of jeopardising the opportunities by highlighting issues relating to climate change in the routine activities as well as diminishing the sense of commitment of top management of the industries to pursue actions and strategies that are responsive to the search for low-carbon and climate change resilient industrial development.

3.3. Policies for Vulnerability to Climate Change

Kenya is endowed with a very rich set of policy, legislative, and institutional frameworks critical to advancing the course of low-carbon and climate change resilient industrial development. These instruments are embedded in various industrial operational structures of governance in the country. The Constitution of Kenya (2010) creates the space for development of responsive policies, legislations and strategies on climate change adaptation and mitigation by providing for the right to a clean and healthy environment. Part two of the constitution on environment and natural resources grants the state specific powers to institute measures to promote sustainable use of natural resources, enhance public participation in environmental governance, establish environmental impact assessment, and audit an equitable distribution of natural resources. The constitution further provides for distribution of functions between national and county governments, thereby paving the field for multilevel actions and programmes on environmental sustainability (Murugu, 2014). To this end, the extent to which the policies and legislation of the country adequately respond to climate change issues is largely dependent on the degree to which the parliament promulgates legislations.

The Kenya Vision 2030 is the blueprint that espouses economic, social and political pillars. Environmental issues are encapsulated in the social pillar. The vision proposes strategies to improve the environment. They include: promot-

ing environmental conservation; improving pollution and waste management through the design and application of economic incentives; commissioning of public-private partnerships (PPPs) for improved efficiency in water and sanitation delivery; enhancing disaster preparedness in all disaster prone areas; and improving the capacity for adaption to climate change (Vision, 2007). It emphasises application of efficient energy use in consumption and production processes, including enhancing energy with exploitation of more renewable energy sources. Reform of public sectors is also stated as fundamental to national development. In addition, the vision recognises the centrality of science, technology and innovations (STIs) across the pillars but does not peg specific STIs on strategic goals for promotion of environmental sustainability.

To this extent, the vision provides important direction for addressing issues of climate change in both adaptation and mitigation. Mitigation is, however, implicitly taken care of in the context of energy efficiency, renewable energy, environmental conservation, and pollution and waste management.

In addition to the Constitution and the Kenya Vision 2030, there are other policy and legislative frameworks that directly or indirectly address climate change. One of the frameworks is the Environmental Management and Coordination Act (MENR, 1999), which is the principal instrument of the government for the management of the environment. With respect to implementation of EMCA, the National Environment Management Authority (NEMA) is mandated to exercise general supervision and coordination of matters relating to the environment. It plays a role in mainstreaming the environment into policies, plans and programmes, and to prepare the annual state-of-environment report (Adams, 2003).

NEMA found its scope was too wide and often in conflict with the mandate of other ministries and agencies. Faced with the choice of enhancing the capacity of NEMA to deal with climate change issues, Kenya opted for it. This is provided for in the National Climate Change Bill which establishes the National Climate Change Council (Kasperson, Berberian, 2011). It will be a corporate body whose function will be to advise national and county governments on legislation and other measures for climate change mitigation and adaptation, coordinate and prepare reports, and undertake negotiations on climate change matters.

In case of tea industry, there is a lack of earnestness and commitment in regards to making the appropriate investments in low carbon and climate change resilient industrial development. Information related to climate change has been relegated to the periphery of the management decisions and policy actions. Adaptation and mitigation measures might be better communicated in terms of tailored cost-benefit outlooks and strategies for the value chains of individual operations. Disseminating and championing success stories of climate-innovators in the sector and practical ‘climate-smart’ (See Kenya’s contry report).

3.4. Value Chain

One of the major contributors to national income and the private sector main employer in Kenya is the tea industry. Different from the other world leading tea-producing countries, Kenya only consumes around 5% of its production. As the rest is exported, Kenyan tea production represent around 20 percent of the world’s tea exports (Hicks, 2009). A wide range of actors are involved

“ Kenya is endowed with a very rich set of policy, legislative, and institutional frameworks critical to advancing the low-carbon and climate change resilient industrial development. ”

“ The chain could be characterised as a vertically integrated value chain, in which direct links between manufacturers and producers are common. ”

in the Kenyan tea leaf to the cup value chain. The chain comprises those stakeholders involved in the production of green leaf tea and converting it into a bulk packaged product available for blending and sale to consumers.

The chain could be characterised as a vertically integrated value chain, in which direct links between manufacturers and producers are common. The main tea packers have influence through all the value chain, from the farm input supply to the tea-bag retail. This characteristic is different from other similar commodities such as cocoa and coffee, in which multinational companies only operate in specific parts of the production chain (Van der Wal, 2008).

The value addition of tea starts at the factory, where processing and grading are done. After grading, most of the tea is sold mainly through the Mombasa Tea Auction, some through direct contracted sales, and a little at factory gate (CPDA, 2008). Traditionally, tea out of Kenyan factories is known for its high quality, so it usually attracts good prices. The second stage of the value addition is the blending and packaging stage. Although the Government of Kenya (GOK), the Tea Board of Kenya (TBK) and other stakeholders had made efforts so that this stage is carried in the country, it mainly occurs in the consumer countries and is controlled by the big multinational tea companies (Kagira, et.al. 2012).

As shown in Figure 7, Kenya’s tea value chain is completely divided for the smallholders, grouped under the KTDA, and the plantations. Both meet at the Mombasa Tea Auction, which sells around 80 percent of Kenyan Tea. The rest is traded through direct sales, or at factory gate, either for export or local consumption (FAO, 2013).

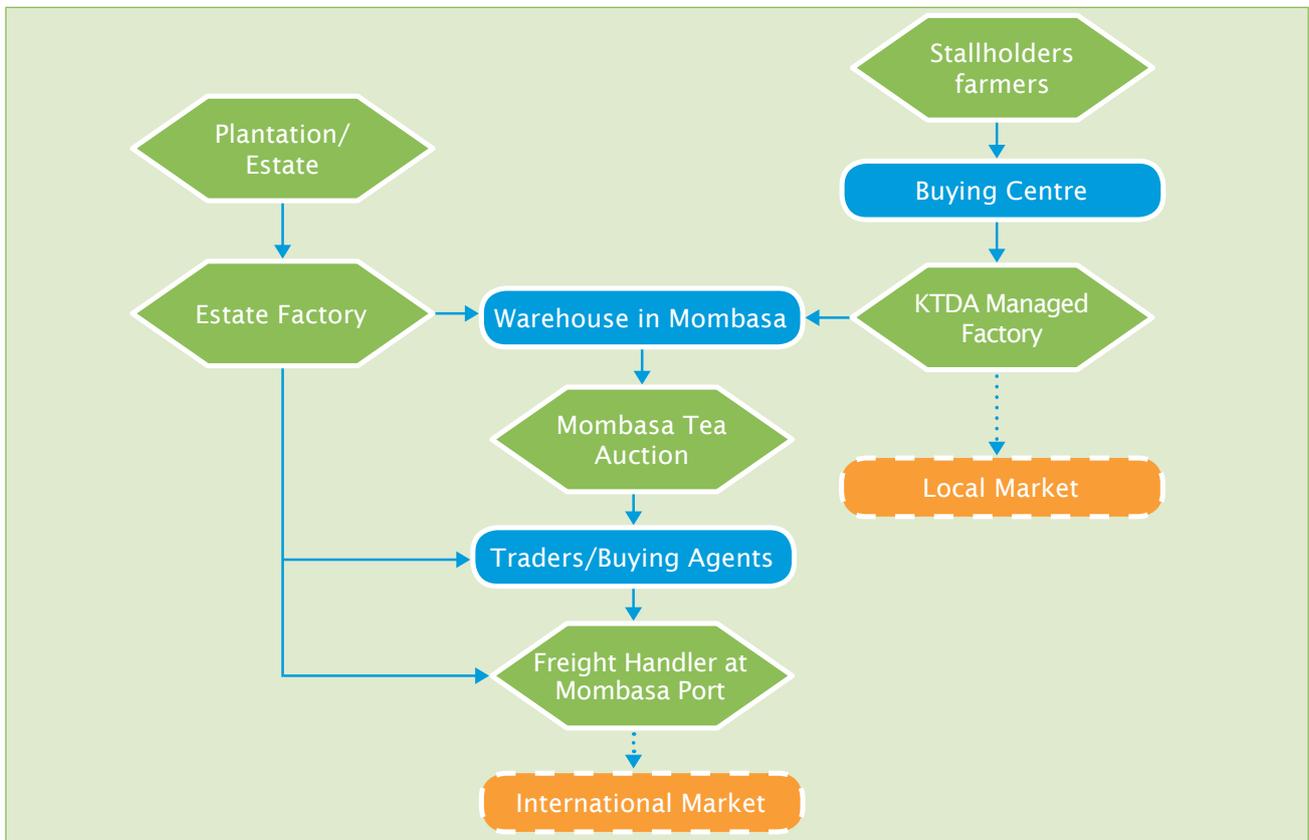


Figure 7. Kenya Tea Industry Simplified Value Chain.

A vulnerability matrix was compiled to capture the extent tea stakeholders perceive various climate hazards to impact tea industry production processes. Stakeholders perceived a threat of significant impact on the following exposure units: plucking (4), plant husbandry (3), drying (2) and fermentation/ withering/ land preparation/ planting (1); although the probability and prevalence of the hazards occurring should also be considered to determine their adaptation priority. Exposure units from the stage of land preparation through to the stage of drying were all thought to be at risk of medium impact from at least one of the climate hazards (See Kenya’s country report).

3.5. Climate Change Challenge for Tea Industry

Kenya is the largest tea growing country in Africa and the fourth-largest producer of tea in the world after India, China and Sri Lanka, and is the only country in Africa to produce a substantial amount of tea for the world market. Most of the tea in Kenya, around 90%, is grown on farming operations of one acre or less (Orindi, Ochieng, 2005). Tea is central to Kenya’s economy and contributes to 4% of the GDP with tea export, representing 26% of the total export earnings (Ratetea, 2015).

Tea is grown in the areas at high altitude – more than 1500 m above sea level – with adequate rainfall and low temperatures. The annual rainfall needed is 1200 mm up to 1400 mm and well distributed throughout the year, while the temperature required is 16–29°C (Omondi, 2015). In Kenya, tea farming can be divided into the highlands on the east and west of the Rift Valley, including Kericho and Nandi in the western highlands and Nyambene and Nyeri in the eastern highlands (SoftKenya, n.d).

One of the main problems facing the tea industries in Kenya is climate change, including drought, rising temperature, hail and frost. The increasing impact of climate change is generating unpredictable harvest, leaving many small scale tea farmers and the industries struggling to plan for the future. This section shows how the climate information will support tea industries to determine the suitability of a tea plantation in the future to increase tea production, especially for the Kericho region as one of the major tea plantations in the western Rift Valley.

3.5.1. Historical Climate Data

The long-term monthly climatology of total rainfall and monthly average maximum and minimum temperatures are showed in Figure 8. The driest month in the period of 1979–2000 has historically been in December, with average monthly rainfall around 80 mm, and the wettest was in May, with an average of 250 mm. During the period, the average monthly rainfall was about 150 mm, indicating that the Kericho region has enough precipitation for tea plantation.

Historically, the highest average maximum temperature was in February and the lowest was in July. The minimum temperature recorded was 10.53°C in September and the maximum was 25.60°C in February. The wide gap between average maximum and minimum temperature is significant.

“ One of the main problems facing the tea industries in Kenya is climate change, including drought, rising temperature, hail and frost. ”

These monthly climatology values calculated from the historical monthly record data, as shown in Figure 9 below, indicated different climate variables for the location. This is useful for identifying particular climate events such as floods and droughts as well as observing long term variability or trends. The data indicated that the highest total monthly rainfall during the period occurred in May 1987 with 450 mm and the lowest was in February 1997.

There is also rise in temperature. The impact of increasing temperature potentially can increase tea yields. However, a positive correlation exists between air temperatures and tea yields only when soil moisture is adequate (Cheserek, 2013). Furthermore, incidences of extreme temperature, either cold or hot, suppress

tea yields: daytime maximum temperature in excess of 30°C leads to a reduction in the rate and desired habit of growth for processing, and whilst heat can improve tea quality, heat extremes potentially damage leaves (Carr & Stephens, 1992; Cheserek et al., 2015). Warmer temperatures, combined with increased humidity, will potentially proliferate new pests and diseases (Chang & Brattlof, 2015; Cheserek et al., 2015; Ethical Tea Partnership, 2011; Schepp, 2009) whilst destabilizing existing habitat and ecosystems unable to adapt (Cracknell, 2015). New pests and disease will incur additional costs and will require new techniques to be appropriately managed (See Kenya’s country report).

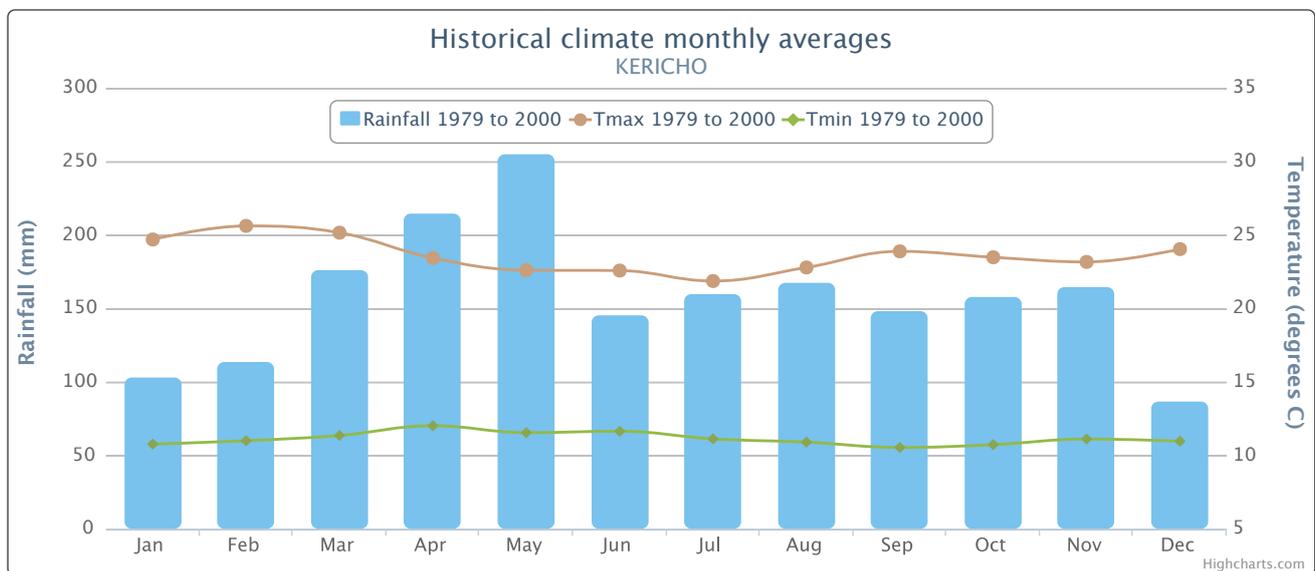


Figure 8. Historical Climate Monthly Average in Kericho, 1979–2000

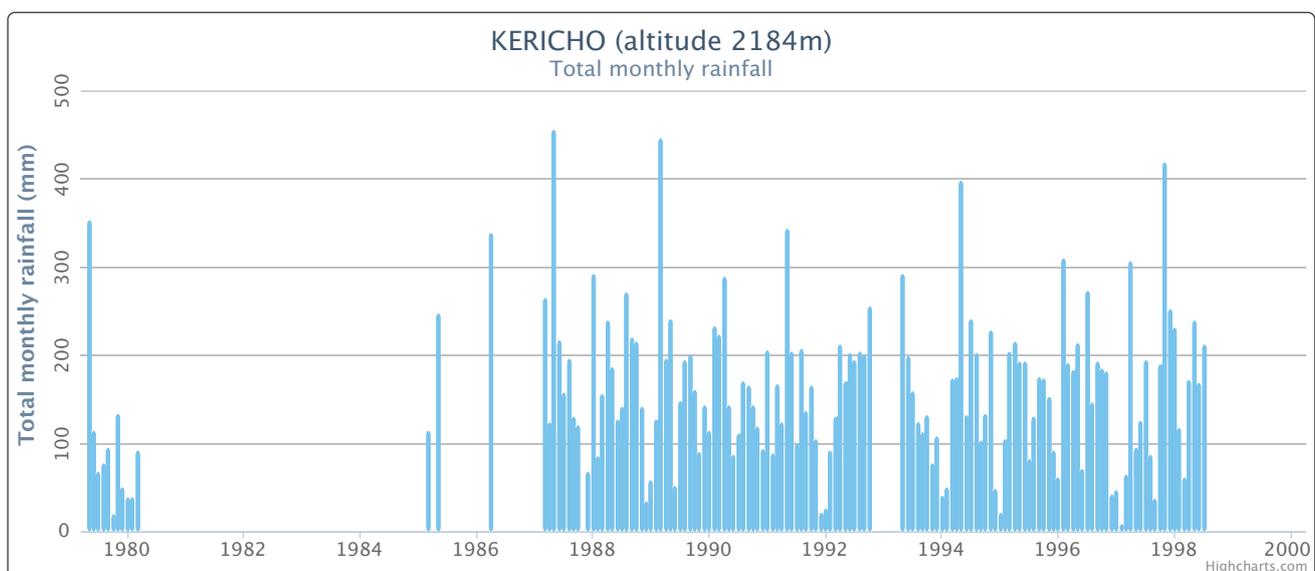


Figure 9. Total monthly rainfall in Kericho, 1979–2000

3.5.2. Future Climate Projections

The projected future changes for the location across 10 different statistically downscaled CMIP5 GCMs for RCP 4.5 because RCP 4.5 assumes that global annual GHG emissions (measured in CO₂-equivalents) peak around 2040, with emissions declining substantially thereafter. According to midterm projected changes for the period of 2040-2060 shown in Figure 10, in general, the total monthly rainfall is predicted to increase from September to April. In the rest of the year, decrease in total monthly rainfall is possible and can take place throughout mid year from May to August.

The highest increase of total monthly rainfall in the period is expected to occur in November with an in-

crease of approximately more than 30 mm. Overall, the high decrease in total monthly rainfall is predicted to occur in May and June, almost -50 mm. This such decrease will affect the total rainfall in the region. The Kericho region is predicted to receive inadequate total monthly rainfall.

For the long-term projection, as shown in Figure 11, total monthly rainfall decrease is less than those for the midterm projection. The decrease of total monthly rainfall is predicted to occur in only a few months, namely, April, May and June; however, the change is more drastic. The total monthly rainfall in May does not increase; however, the total monthly rainfall in the Kericho region is still more than 100 mm. There's a likely increase from July to February and March is uncertain.

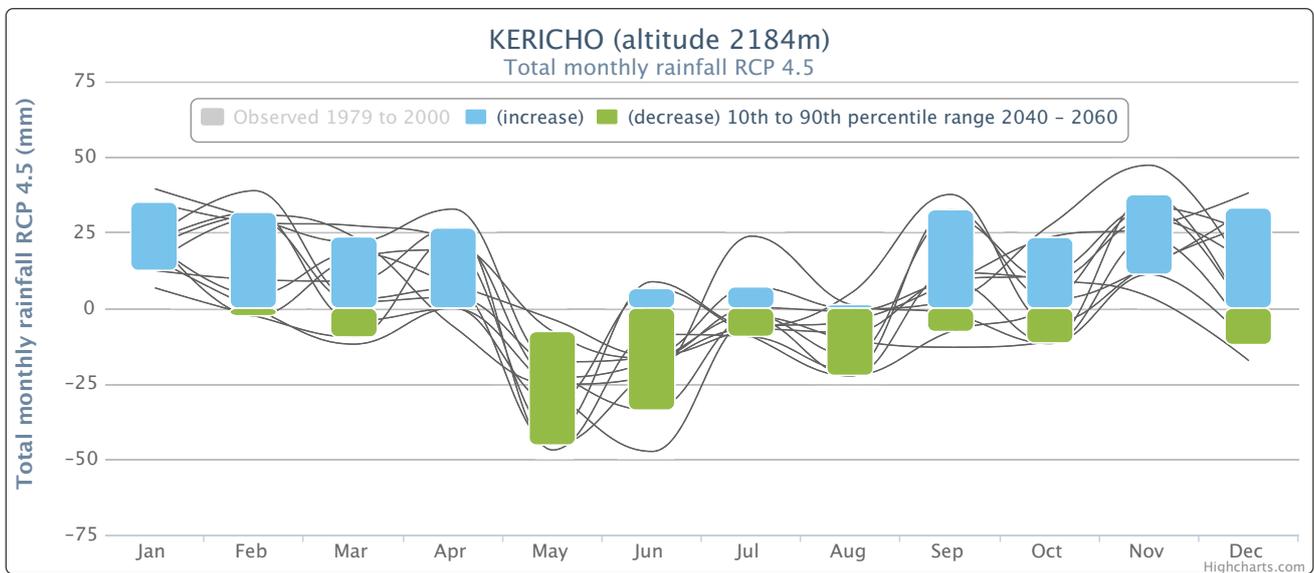


Figure 10. Projected Changes in Total Monthly Rainfall RCP 4.5 in Kericho Station, 2040–2060 (CIP, 2001)

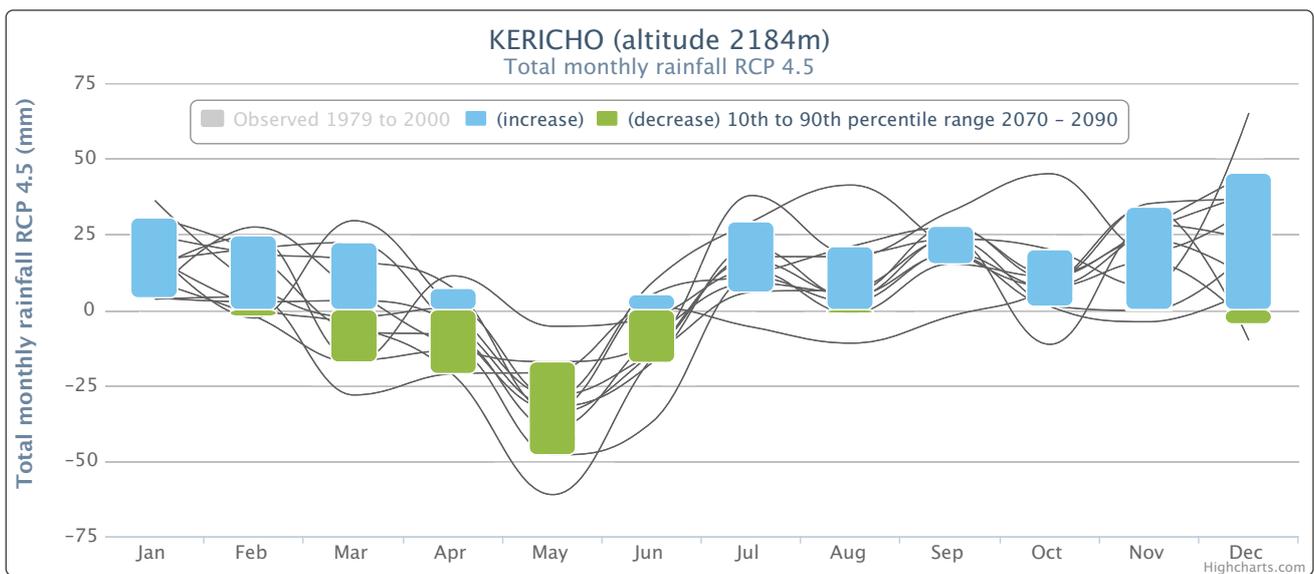


Figure 11. Projected Changes in Total Monthly Rainfall RCP 4.5 in Kericho Station, 2070–2090 (CIP, 2001)

The average maximum temperature in the period of 2040–2060 (Figure 12) indicates a rise in average maximum temperature throughout the year by a range of 0.4°C to 2°C. The highest increase is predicted to occur in June and September, whereas the lowest possible to occur in April. Meanwhile, the average minimum temperature is predicted to increase by a range of 0.6°C to 2.2°C, as shown in Figure 13. This projection indicates that differences between maximum and minimum temperatures in the period of 2040–2060 become smaller compared to the observed period (1979–2000). The maximum temperature is projected to reach 26.6°C, while the minimum temperature is forecasted to reach 9.3°C.

In the projection for long term period (2070–2090), as shown in Figure 14 and Figure 15 below, both average maximum and minimum temperatures are expected to experience a slight increase compared to the midterm projection. This condition will affect suitability area for tea growing in Kericho. It is expected to reduce suitable area for tea plantation.

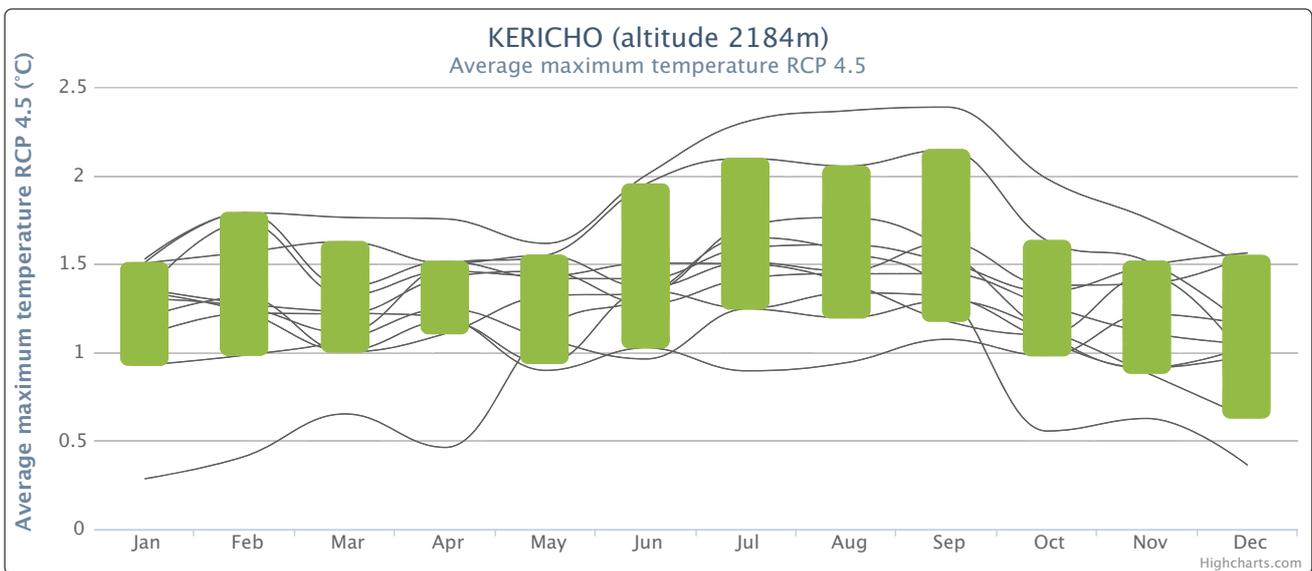


Figure 12. Projected Changes in Average Maximum Temperature RCP 4.5 in Kericho Station, 2040–2060 (CIP, 2001)

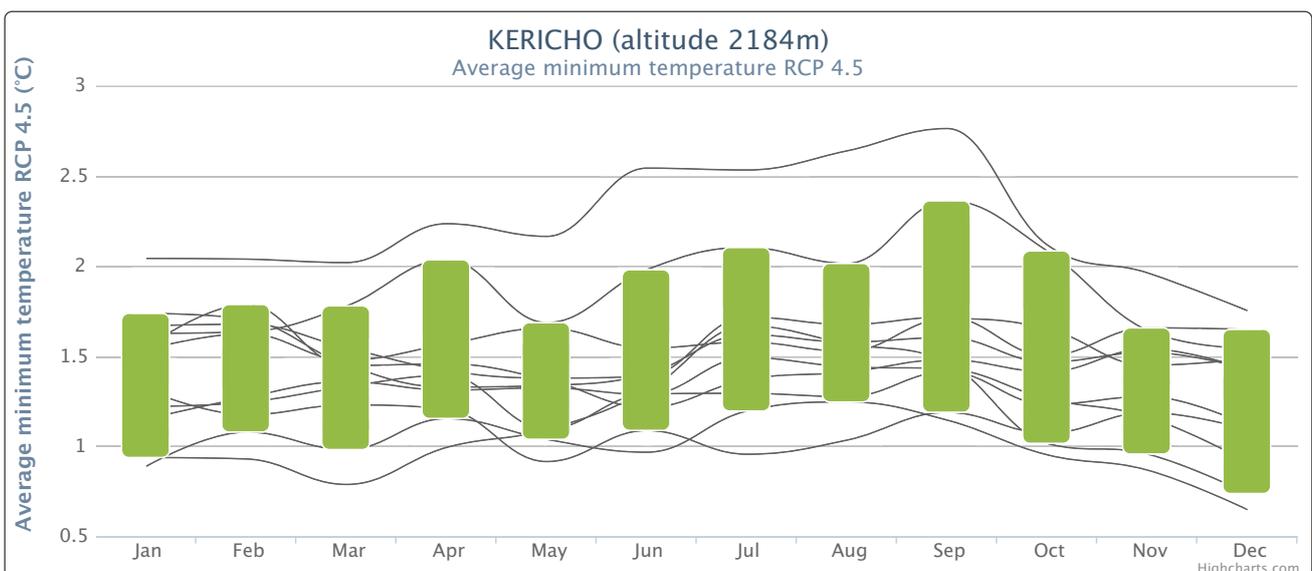


Figure 13. Projected Changes in Average Minimum Temperature RCP 4.5 in Kericho Station, 2040–2060 (CIP, 2001)

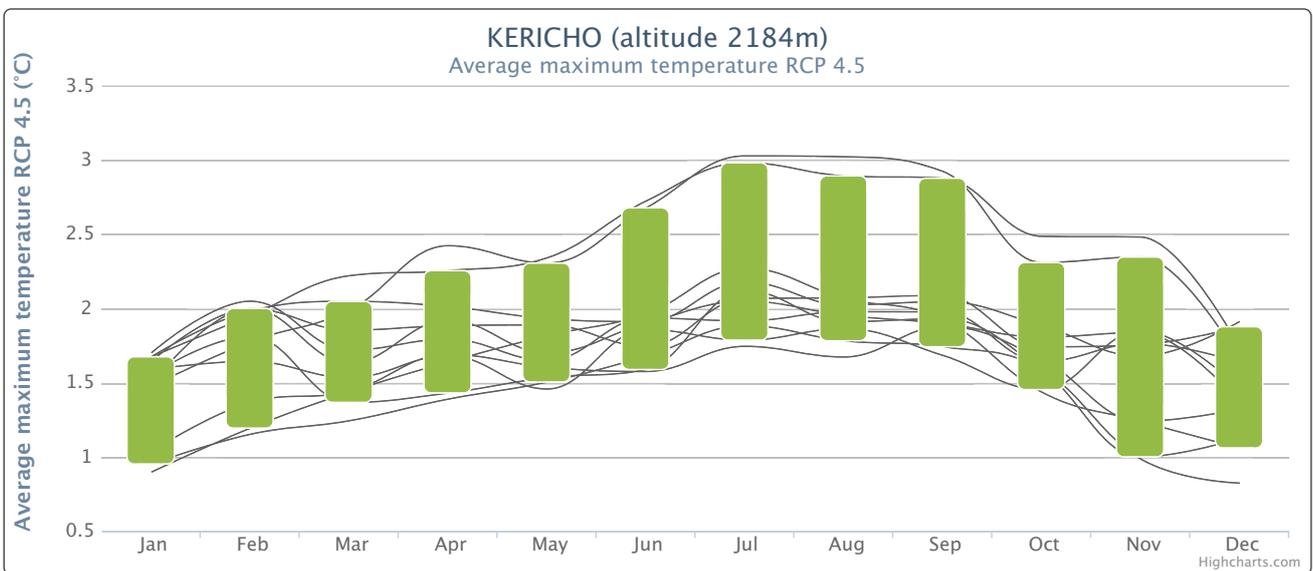


Figure 14. Projected Changes in Average Maximum Temperature RCP 4.5 in Kericho Station, 2070–2090 (CIP, 2001)

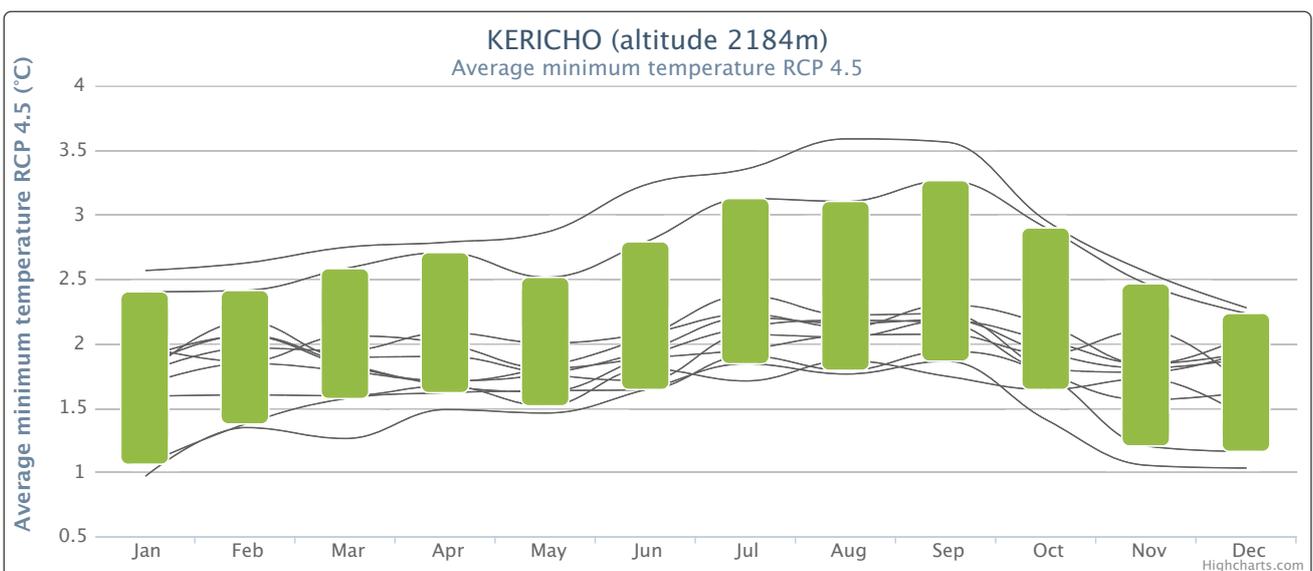


Figure 15. Projected Changes in Average Minimum Temperature RCP 4.5 in Kericho Station, 2070–2090 (CIP, 2001)

3.5.3. The Climate Comparison With Other Station

The total monthly rainfall in the Nakuru region is expected to increase in the midterm (2040–2060) period, according to scenario RCIP 4.5, as shown in Figure 16. The historical climate monthly average and the projection for the midterm period shows that the Nakuru region is still drier than the Kericho region in spite of the predicted increase in the future.

The projected temperature of Nakuru station show that the average maximum in the region will be less than in the Kericho region. The highest average maximum

temperature in the period of 2040–2060 will occur in July and August with an increase by 2.25°C, while the lowest will be in December with an increase of nearly 0.5°C. Meanwhile, the projected highest and lowest average monthly maximum temperature in the Kericho region is increasing by 3°C and 1°C respectively. Moreover, the hot period occurred from June to September. Lower projected temperature in Nakuru may help tea industry to extend or remove the tea plantation to Nakuru once Kericho will be not suitable for tea growing due to temperature rise.

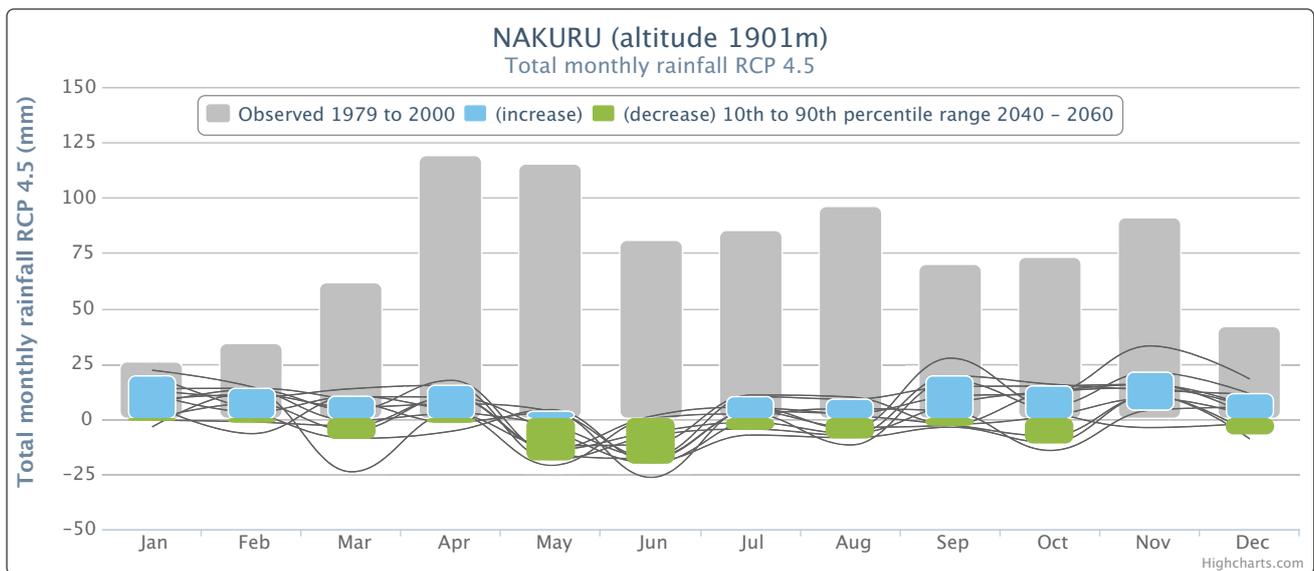


Figure 16. Projected Changes in Total Monthly Rainfall Scenario RCP 4.5 in Nakuru, 2040–2060

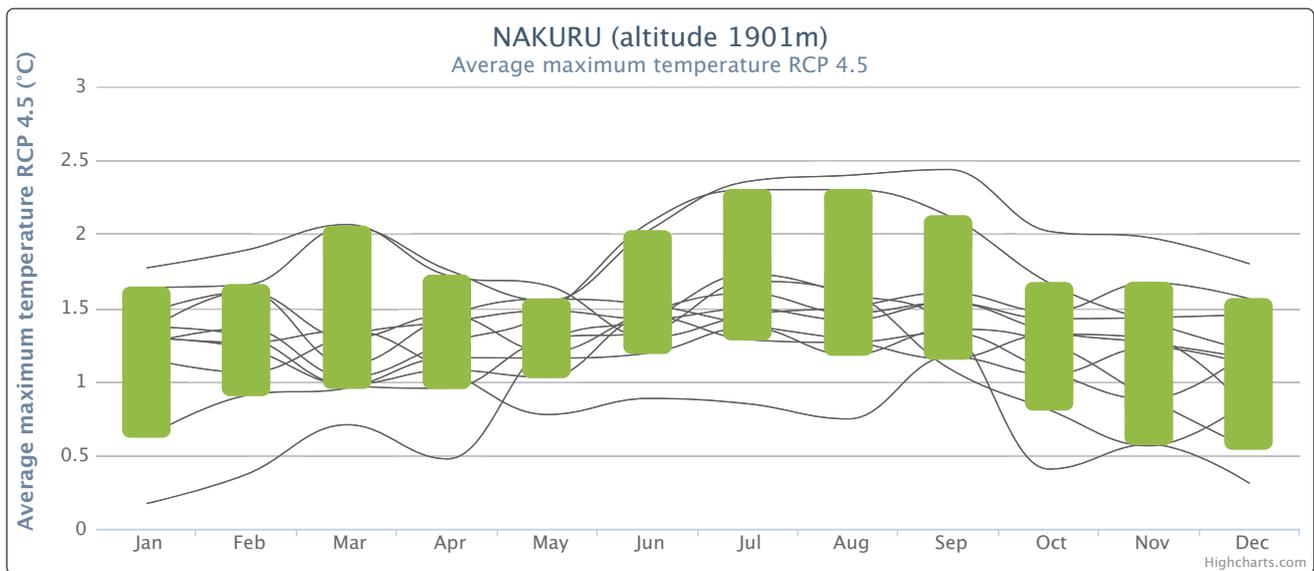


Figure 17. Projected average maximum temperature in Nakuru, 2040–2060

3.5.4. Conclusion and Recommendation for Tea Industry

Kenya possesses a rich set of policy, legislative and institutional frameworks that are embedded in various industrial operational structures of its governance for implementing low-carbon and climate resilient industrial development. Opportunities exist to enhance the implementation of existing legislation.

FAO (2012) found that 'A Geographic Information System (GIS) approach was carried out to predict the impact of progressive climate change on tea suitability in Kenya from 2000 to the year 2075. The implications are that the distribution of suitability's within the current tea-growing areas in Kenya would decrease not because of rainfall amounts but its distribution and rise in mean air temperatures beyond the threshold of 23.5°C. Preliminary results suggest that that suitability of tea growing areas is expected to increase of 8% by 2025, but drop by 22.5% by the year 2075. However, suitability research is continuing. The key issue for tea in Kenya is rising temperatures, which will push the areas suitable for cultivation to higher altitudes and in some areas mean it can't be grown. This condition will change tea suitability across different regions in Kenya.

Increasing temperatures will affect tea industry in Kenya. Major impacts on food production will come from changes in temperature, moisture levels, ultra-violet (UV) radiation, CO₂ levels, and pests and diseases. There will be change in the current locations of tea-growing areas in Kenya, and some of the areas are expected to become less suitable for tea-growing if there is a temperature rise of 2 degrees Celsius. In Kericho, an upward trend of $\approx 0.2^{\circ}\text{C}/\text{decade}$ was observed in all three temperature variables ($P < 0.01$). Mean temperature variations in Kericho were associated with large-scale climate variations including tropical SST ($r = 0.50$; $p < 0.01$). Local rainfall was found to have inverse effects on minimum and maximum temperature. Three versions of a spatially interpolated temperature data set showed markedly different trends when compared with each other and with the Kericho station observations. It presents evidence of a warming trend in observed maximum, minimum and mean temperatures at Kericho during the period 1979 to 2009 using gold standard meteorological observations. Although local factors may be contributing to these trends, the findings are consistent with variability and trends that have occurred in correlated global climate processes. This condition will reduce suitability of Kericho as tea region (Omumbo, et. al. 2011).

During tea processing, extreme temperatures could interfere with withering where air temperature should not exceed 35°C; higher temperatures reduce enzymatic action in the leaf (Senthil Kumar, Murugesan, Kottur, & Gyamfi, 2013). Excessive heat during fermentation can have an adverse effect on the balance of tea quality and flavour: theaflavins (responsible for tea 'brightness') can be catalyzed prematurely by heat, and deteriorate to suboptimal levels before the end of processing. Because of this, air temperature for fermentation should be maintained between 25°C and 27°C with 95% humidity (Senthil Kumar et al., 2013). Climate extremes could also affect tea if packaging has performance shortcomings. Numerous studies mention tea quality being deteriorated in storage by temperature and humidity (Obanda & Owuor, 1995; Preedy, 2012; Senthil Kumar et al., 2013).

Climate and geography are key factors in determining both where tea can be grown and how the tea grows. In the Kericho region, climate change models projections for rainfall suggests that it will be suitable for tea plantation until the year 2090. However adaptation measures such as a new tea species that are resistant to low temperature, hail and frost, will still be needed as the minimum temperature is too low and will affect the growth and the quality of tea. The Nakuru area is less suitable for planting tea because the average monthly rainfall is less than 100 mm and not spread evenly throughout the year. To adapt to these conditions, the tea researcher or the government might have adaptation measures such as a new tea species that are resistant to low temperature, hail and frost. As tea industries depend on the tea plantations, the farmers may have to support the adaptation actions. Renewable energy technologies may help to improve the storage and the transportation system efficiency and sustainability; allowing the tea production industry to allocate its budget for assisting the production stage adaptation to climate change. The industries need to connect energy-agriculture nexus to produce sustainable energy for supporting tea value chain. It is also important to consider increasing value added post-harvest production for small plantations.

Resource efficient and cleaner technologies are fast emerging and need to be incorporated in tea key processing areas but their uptake in the tea industries is generally low due to primarily low awareness levels and inhibiting costs, especially for small-holder farmers. Their uptake can result in low carbon and reduced climate change and vulnerability. Although some adoption is occurring, there is need for capacity building on climate change issues and funding of the technologies by industries geared towards low carbon and climate resilient industrial development.



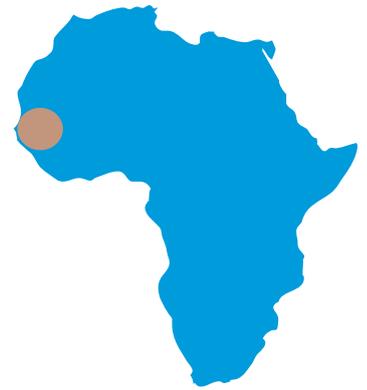
4. SENEGAL

4.1. Geographical Location, Demographics and Economic Activities

Senegal is located in the far west of Africa. The total area of Senegal is approximately 196,722 km². It is a flat country and the highest point of the country is Fouta Djallon foothill. The population of Senegal is approximately 13.9 million with most of the population living in urban areas in the west and the centre of the country (Gerdes, 2007). The annual demographic growth rate is about 2.7%. The power supply is provided by thermal power plants, while the energy system in Senegal relies on traditional biomass like wood and charcoal, and is dependent on oil imports (ISW, 2010).

The poverty rate in Senegal is 46.7% of the population, the unemployment rate is about 25.7% of the total population and the informal industry employs 48.8% of the labour force and it contributes to 41.6 % of the Senegalese GDP and with contribution by the non-agricultural industry at 57.7% (ANSD, 2013). The agriculture sector contributes a small GDP of 13.7%; livestock 3.7% and fisheries 1.3%, while employing almost 60 % of the workforce. The Senegalese economic activities are diverse, but the country is vulnerable to external factors such as international economy and fluctuation of the world's prices (Diao, et.al. 2007). The country's activities are also dependent on natural resources, which amplifies their vulnerability to climate change.

Senegal has two types of distinct seasons: the dry season from November to April and the rainy season from May to October. Of the total area of Senegal, 700 km is coastline area. The annual average rainfall is 687 mm (FAO aquastat, 2005). The northern part of Senegal has less rainfall (300 mm) than the southern part (1500 mm). In spite of the low rainfall, Senegal is well endowed with water resources which represent, potentially, 7 billion m³ per annum and renewable groundwater 3.5 km³/year. Arable soil represents 19% of the total surface in Senegal, with 66 % of it used for cultivation. Only 2 % of this area is under irrigated cultivation. The vegetation consists of steppes, savanna and forest. Forest areas occupy 45.1% of the national territory (8 673 000 hectares), of which 18.4% are primary forests (Planchon, 2014).



Capital:
Dakar

Surface:
196,722 km²

Population:
13.9 million

Demographic growth:
2.7%

Annual rainfall:
687mm



4.2. Industrial Analysis and Climatic Disaster for Different Industries

“ In Senegal, projections show a temperature increase of up to 3°C, with most of the warming area in the coastal zones. ”

Climate change in Senegal will affect productive industries and the biophysical environment. Projections show a temperature increase of up to 3°C, with most of the warming area in the coastal zones (See Climate change challenge for Fishery Industry). Rainfall is expected to decrease, and climate change will further increase the number of urban dwellers facing water shortages. In some cities, water availability will decrease owing to climate change, whereas other cities will see increases, with more cities having less water than having increased flows. Climate change does not greatly change the aggregate number of urban residents facing seasonal shortage, although the effect for particular cities may be large (McDonald, et. al. 2011). It is likely to increase water shortages in Senegal. It also alters water quality and salinity, as well as increase tension between agriculture industries, industrial industries and domestic industries. The assessment of damage caused by floods indicates that the government will lose US\$ 104 million and the rehabilitation will amount to US\$ 204.4 million, so the overall impact will cost US\$ 308.4. The impact is amplified by deficiency of regional planning and the lack of respect for town planning (Diagne, Ndiaye, 2012).

In the agricultural sector, it is expected that cereal production will decrease by 30% per capita by the year 2025. The cereal milling industry in Senegal mainly serves the domestic market (Matsumoto-Izadifar, 2008), providing important staples and critically contributing to the country's food security (See Senegal's country report). Even so, cereal-based exports are estimated at 9% of food-related exports, approximately 105 million USD (Center for International Development at Harvard University, 2016; World Bank, 2016). This will result in significant change in the food industries and will affect food production quality as well as quantity of milk and meat production (Parry, et.al. 2004). There are larger yield losses on rainfed groundnuts and rice under the Max Planck (ECHAM) model and the MIROC (Univ of Tokyo) projections in parts of the country. Key challenges are low agricultural production, limited capacity of the economy to create sustainable jobs, and inadequate resource allocation to social services, all contribute towards industry (Msangi, 2014).

In the coastal areas, human activities put pressure on coastal development and the fragile environment. Coastal erosion is the biggest threat in Senegal. It affects the fishery industry. Fish is a major source of protein for the Senegalese population. Fishing plays a dominant role in the Government's policy towards generating employment. It currently generates about 100,000 direct jobs (fishermen) for nationals, of which more than 90 per cent are in small-scale fishing. The fishing industry also contributes to Government revenue through different agreements (UNEP, 2001).

The Senegalese authorities are aware of the climate change and realise that it must be integrated into the policy of socio-economy development of the country. The government has initiated a decisive turn towards emergence through the emerging Senegal plan. Other funded projects also initiated and proposed some actions for mainstreaming the climate change in the industrial policy, particularly in the food processing industry, including through environmental assessments and climate risk management tools (Kok, et. al 2008).

One of the Senegal projects, the Bureau de Mise a Niveau has a mission to promote enterprises through the implementation of upgrading programmes that enable competitiveness and the mitigation of environmental impact in Senegal. It also promotes the Green Industry in agro food processing industries. The project methodology uses a consultancy and participatory approach based on SWOT (strength, weakness, opportunity, and threat) analysis on how climate change interacts with socioeconomic issues, especially agro food industry and vulnerability existence in Senegal (Duvail, Hamerlynck, 2003). The SWOT analysis is used as a strategic guideline among stakeholders in industrial industries to find the relevance of the climate change and dynamic interaction with the strategic exploitation of the environment in Senegal. It will enable the stakeholders to define the scenario for temporal horizon of the climate projection for the periods 2031-2050 and 2081-2100.

4.3. Policies for Vulnerability to Climate Change

The industrial policy of Senegal follows a horizontal approach based on the improvement of the private business environment and it is characterised by the private industry promotion through SMEs (small medium enterprises). The SMEs are regarded as essential sources of employment, a driving force for economic development, richness creation and fighters against poverty. Due to the private industry involvement, upgrading policy is needed in the industrial restructuring policy in Senegal (Eifert, et. al. 2005). The upgrading policy aims to accompany enterprises in an improvement process based on competitiveness key factors while planning ahead up to 2020 and rebalancing factory constructions. It will fill the gap of regional disparities characterised by a strong concentration of companies, especially in the Dakar region (Kanbur & Venables, 2007).

Industrial vulnerability to climate change in Senegal is expressed differently depending on whether it concerns territory or specific industrial industries. Various documents of environmental strategy do not mention specific industrial vulnerability. The industrial vulnerability in relation to climate change is expressed in sensitive areas, such as coastal areas (Mbow, et. al. 2008). It is shown by industry's dependence on agricultural raw materials and fishery, industry access to resources for adaptation actions and quality of industrial equipment or obsolescence.

The policy of climatic risk is analysed at three levels: vision in medium and long term, strategic industry orientations and implementation from a strategic viewpoint of vision in the long term, and operational viewpoint. The operation goes through industry policies and programmes set up by mitigation adaptation requirements. The strategic framework analysis will be done by international climate commitments of Senegal, the National Strategy of Economic and Social Development, and the Emerging Senegal Plan (PSE). The PSE constitutes the framework of new development strategy defined by the Senegalese authorities over the period 2014–2035. It is based on an integration approach of all public development policies including SNDES (Stratégie Nationale de Développement Economique et Social). It is articulated around three major axes: structural transformation of economy and growth; human capital and social protection; and sustainable development, governance, institutions, peace and security (Bass & Dalal-Clayton, 2012). The climate change issue is also addressed at city/province level.

“
The Emerging Senegal Plan (PSE) constitutes the framework of new development strategy defined by the Senegalese for 2014–2035.
”

Based on the policies and regulations mentioned above, Senegal participated in the programme entitled “Towards territories emitting fewer greenhouses gases and more resilient to climate change”. The programme helps to develop the original cooperation between Senegalese regions and French regions in the fight against climate change (Scheffran, et. al. 2012). Due to its geographical location on the Atlantic Ocean seafont and a flagrant imbalance of industrial facilities and human settlements, Senegal has identified risks and disasters as constraints to its economic and social development. Risks can be related either to natural hazards, particularly flooding, or to technological hazards from industry (Pelling & Wisner, 2012).

The Senegalese government also promotes actions for taking into account the food industry vulnerability in adapting to climate change. It aims to integrate adaptation to climate change into industry policies, carry out an environmental assessment of the Emerging Senegal Plan and integrate climate risk assessment in the different components of the PSE, encourage the development of management tools for climate risk across firms, assess industry needs for information, and perform vulnerability studies (Challinor, et. al 2007). The study on the vulnerability of industry to climate change has shown political and institutional initiatives to adapt to climate change. However, several of the initiatives and sustainable policies still need to be improved.

“
The fisheries industry plays a prime role in the Senegalese economy and society.
”

4.4. Value Chain

The fisheries industry plays a prime role in the Senegalese economy and society, particularly in frozen fish and the area of export and the satisfaction of food needs and employment (Ndiaye, n.d). Sole fish is one of the most important commercial species that are caught all year round in Senegal waters by artisanal fishermen. The value chain approach helps to enhance the competitiveness of sectors, identify and understand both the major opportunities for upgrading and the driving constraints to market growth, and to generate recommendations for priority actions that can result in increased benefits for sole fishery sector participants (Sahay, et. al. 2006). One of the elements of the value chain is industrial processing plants.

With no deep water port for the industrial fleet to land, industrial seafood processing plants rely exclusively on the purchase of fish from the artisanal fishery for processing and export. Presently, there are five major processing plants (International Pelican Seafood Ltd., Kendaka Fishing Company, National Partnership Enterprise, Atlantic Seafood Company, and Rosamond Trade), three of which are presently exporting to the European Union (EU). Two plants (National Partnership Enterprise and Kendaka Fishing Company) are temporarily closed due to lack of raw material (fish) and high operating costs. Later in the same year, only one firm remained open which is Atlantic Seafood Company (Niang, 2005). It is hoped that the new deep water port in Banjul under construction will tackle the problem of lack of raw material supply and need to operate below capacity. Lack of fish for processing is an annual problem, but is most severe during times of religious holidays (Ziegler, et. al. 2011). The Senegalese dominate the coastal fishery, so the amount of fish from the artisanal fishery available for processing drops significantly when most of the Senegalese fishermen return to Senegal for Ramadan and Tobaski (religious holidays) causing closures of most processing plants.

According to the Department of Fisheries, the processing plants provide permanent and part-time employment for 1,500 to 2,000 people; mainly women. The data shows employment at three operating processing plants at the time of the SFVCA survey (Atlantic Sea Food Company, National Partnership Enterprise, and International Pelican Sea Food Ltd.). Together, the three plants are operating at about 14% of full capacity, and this is not cost effective (Elhabib, et. al. 2014). According to plant managers, the reason is lack of raw material, which in this case, is sole fish.

Analysis from the SFVCA survey indicates that 226 Mt of sole fish were processed and exported in 2008 by the following exporters: Atlantic Sea Food Company (94%), Momodou Sow (2.5%), Musa Kaire/Barra Fishing Company (2.2%), Mawdo Ngum (1.3%), and International Pelican Sea Food Ltd (0.10%). Atlantic Sea Food Company ships primarily frozen sole fish to Netherlands, Spain and South Africa. Located in Banjul, the Atlantic Seafood Processing Plant is the most active industrial seafood processing company. This firm presently ships approximately 70 containers of frozen fish per year, mainly sole and cuttlefish. Maximum capacity of the plant is about 6 tons/day for cuttlefish and 3-4 tons/day of sole fillets (Fatajo, et. al, 2010).

In cereal milling industry, its stakeholders perceived a threat of significant impacts from climate hazards on the following exposure units: harvesting, storage, cooking, and drying, although the probability and prevalence of the hazards occurring should also be considered to determine their adaptation priority. All exposure units were thought to be at risk of medium impact from at least one of the climate hazards considered. Warming is associated with the increase of temperature, less rainfall and less humidity (See Senegal's country report). Heavy rains affected harvesting, transportation and storage of the industry. From 1970s to 1990s, crops have been ruined, communities and their infrastructure damaged, and supply chains disrupted by heavy rains (Teng & Ni, 2016; World Food Programme, 2013).

“ In cereal milling industry, its stakeholders perceived a threat of significant impacts from climate hazards on the following exposure units: harvesting, storage, cooking, and drying. ”

4.5. Climate Change Challenge for Fishery Industry

Senegal has a coastline of 718 km and a well-stocked river system, including the Saloum river, the Gambia river and the Senegal river, which cover an area of 340,000 km². The industry accounts for 11% GDP and 17% jobs (West Africa Trade, 2008). It employs about 84 600 people, mainly full time fishermen, operating in marine or inland waters. Another estimated 47 800 people work in auxiliary activities, including in particular artisanal fish processing and marketing. This covers a total of 129 500 jobs in the Senegalese fisheries sector according to the BNP case study. 92 percent of this total work in small-scale activities. Two-thirds of the employment are in marine fisheries. Other sources cite close to 600 000 employees in fisheries related activities, including occasional and indirect employment (FAO, 2008). Senegal has the highest consumption of fish in Africa with 37 kg/capita/year (Peterson, et al., 2006). Fisheries is essential for Senegalese population food security and economic growth because it is also the first provider of export earnings. People living in rural inland fishing industries are among the most vulnerable in Senegal. Many scholars have studied vulnerability of coastal fishery in Senegal, however it is difficult to find study about inland fishery. This is becoming a relative importance of the inland fishery against the coastal fishery.

Inland fisheries production has been decreasing steadily as Senegal suffers from severe water constraints, despite an extensive water network that includes the Senegal, Gambia and Casamance rivers. Some areas of the country receive less than 300 mm of water per year and rainfall has decreased by an average of 10 to 20 mm per year since the 1980s (CILSS in Peterson, et al., 2006). In the worst case, this would mean a reduction in rainfall by 720 mm had happened, which was substantial and quite a severe condition. The 1980s were a period of very low rainfall, but there has been a recovery since then. Statistically significant precipitation decreases of around 10 to 15mm per decade have, however, been observed in the southern regions of Senegal in the wet season (JAS) between 1960 and 2006. Some unusually high rainfalls have occurred in the dry season (JFM) in very recent years (2000–2006), but this has not been part of a consistent trend (UNDP, n.d).

Senegal river is one of the three main rivers where inland fisheries are found. The analysis below uses climate data from Saint-Louis Station because this city is located near the mouth of the Senegal river. The analysis is also trying to look at what happens to flow in the Senegal River and precipitation change over the country as a whole. Most of the change in flow come from changes upstream in central Senegal, and also in Mali. There are several modeled studies of the effects of climate change on the Senegal River. The Senegal River has its main source in the FoutaDjalon Mountains in Guinea and provides water to the semiarid parts of Mali, Senegal and Mauritania. There has been a long-lasting drought in the Senegal River Basin for more than 30 years. As drought persists, the state of aridity increases in the sahelian zone of Senegal ba-

sin. The decrease in rainfall has led to a corresponding decrease in river flow, e.g. a 20% decrease in rainfall resulting in a 30–40% decrease in available water resources (Oyebande, Odonuga, 2010).

The change of rainfall patterns has effects on fisheries. Oyebande and Odonuga (2010) found that the reduction of continental wetlands combined with the decline in the rate of river flow would lead to the modification of the ecological niches and the life cycles of aquatic species, fish in particular. The loss of the coastal wetlands and the mangroves, among other things, will affect the local economy, which depend on fishing.

4.5.1. Historical Climate Data

The long-term monthly climatology of total rainfall and monthly average minimum and maximum temperatures of St. Louis climate station in the period of 1979–2000 are shown in Figure 18. These monthly climatology values are calculated from the historical monthly record data shown in Figure 19.

The average monthly rainfall in the Saint-Louis area was very low except in the wet season between July and October. The wettest month has historically been September with an average rainfall of 89 mm, while the driest month has been April. The highest total monthly rainfall in the period of 1979–2000 in Saint Louis has occurred in September 1987 with around 247 mm. However, in general, Saint-Louis region has low total monthly average rainfall and it tends to experience drought. The average temperature in the Saint-Louis region ranged from 17°C to 34°C. The difference in maximum temperature is small throughout the year compared to the minimal temperature.

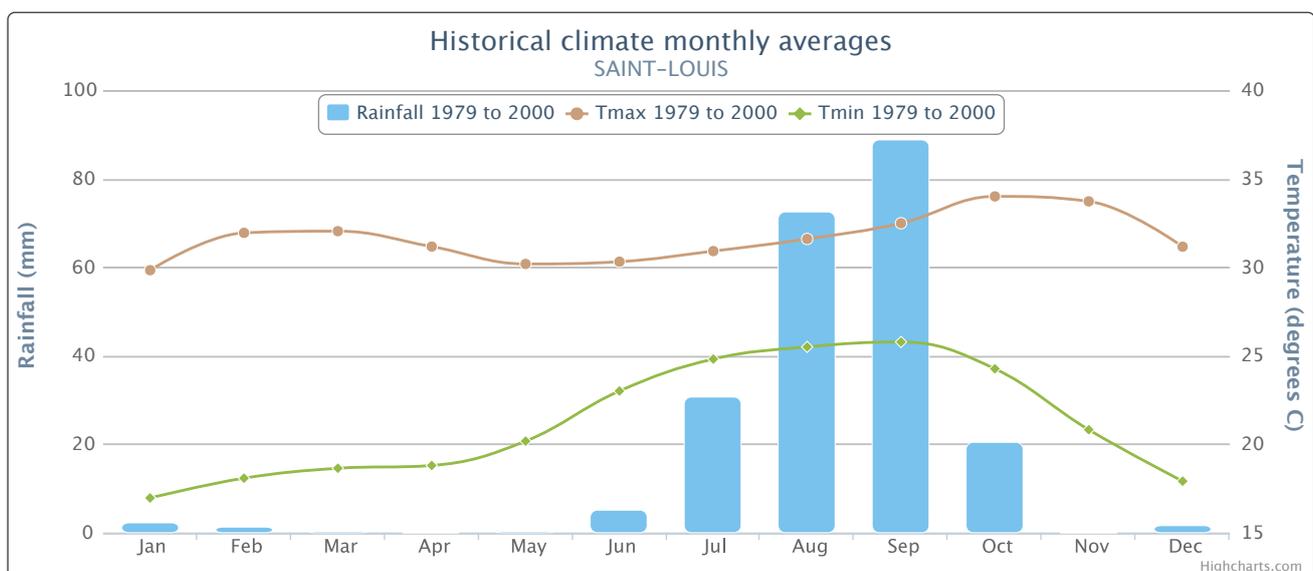


Figure 18. Historical Climate Monthly Average in Saint-Louis, 1979–2000 (CIP, 2001)

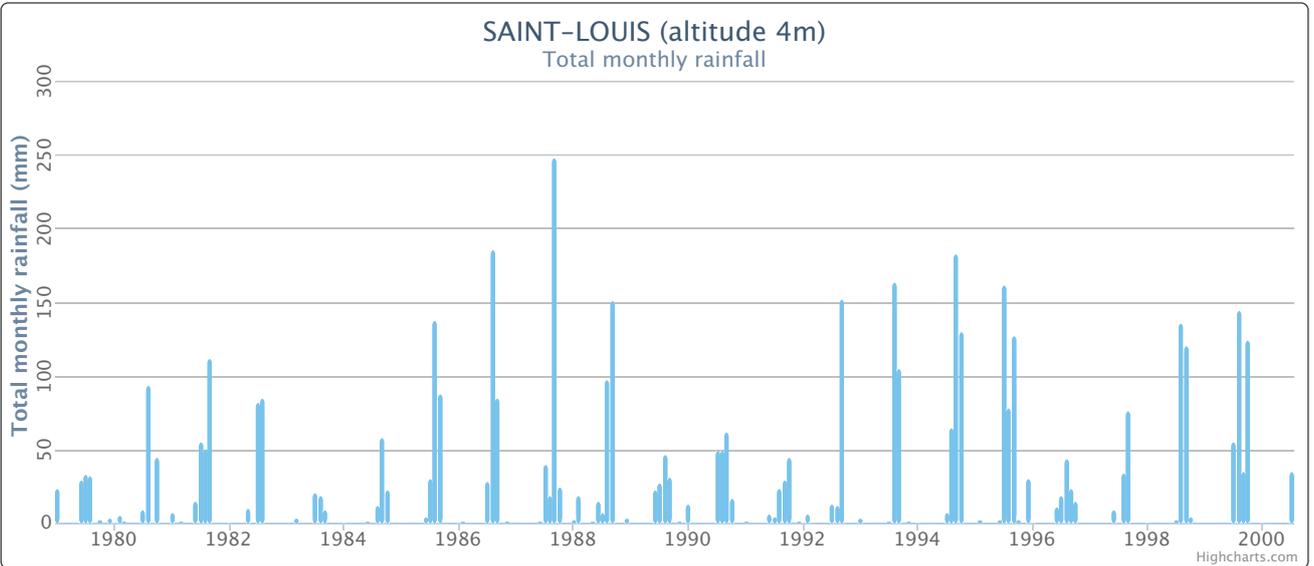


Figure 19. Total Monthly Rainfall in the Period of 1979–2000 in Saint-Louis (CIP, 2001)

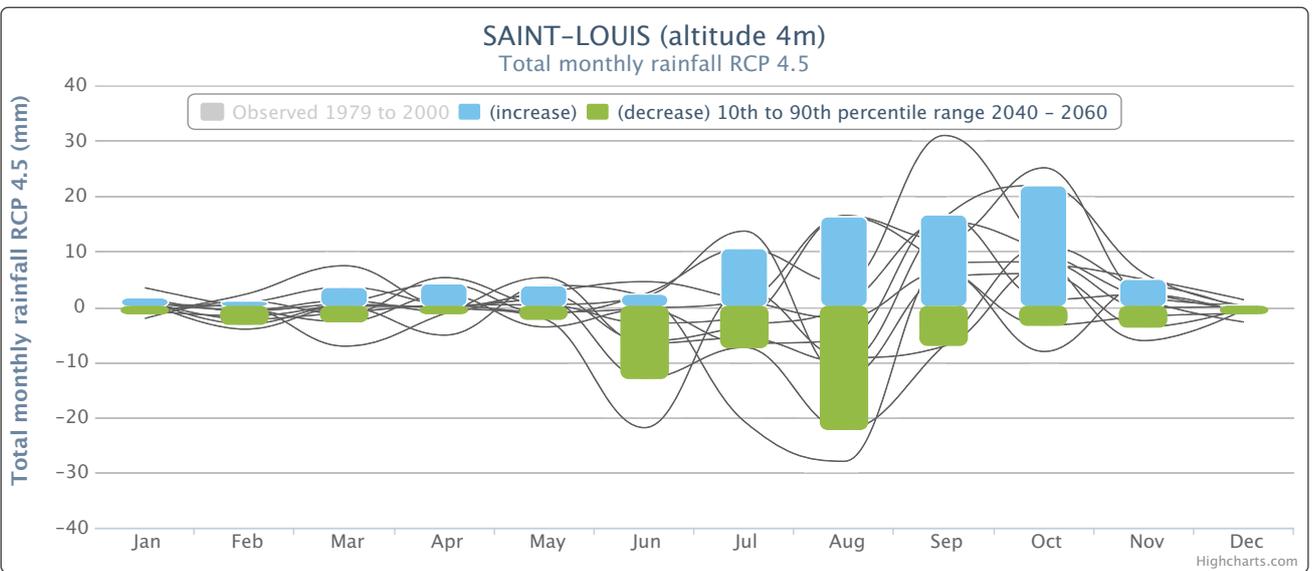


Figure 20. Projected Changes in Total Monthly Rainfall RCP 4.5 in Saint-Louis, 2040–2060 (CIP, 2001)

4.5.2. Future Climate Projection

Projected climate changes for Saint-Louis are modelled across 10 different statistically downscaled CMIP5 CMs for RCP 4.5. In the midterm period in Figure 20, the projection indicates an increase in total monthly rainfall throughout the year. While increases are likely in September and October, there's a strong possibility of a decrease in August. The patterns between 2040-2060, and 2080-2100 are similar. However, during the long-term period, a few models indicate a possible decrease in total monthly rainfall. The high-

est decrease is predicted in August. In general, the total monthly rainfall may still increase, but it will depend on the month within the period of 2040-2060. For the long-term projection (2070-2090), the total monthly rainfall is increasing in late rainy season (Figure 21). Generally, the variability in precipitation will increase during the rainy season.

The average maximum temperature in the midterm period becomes higher. The change is more significant during the drier months (Figure 22).

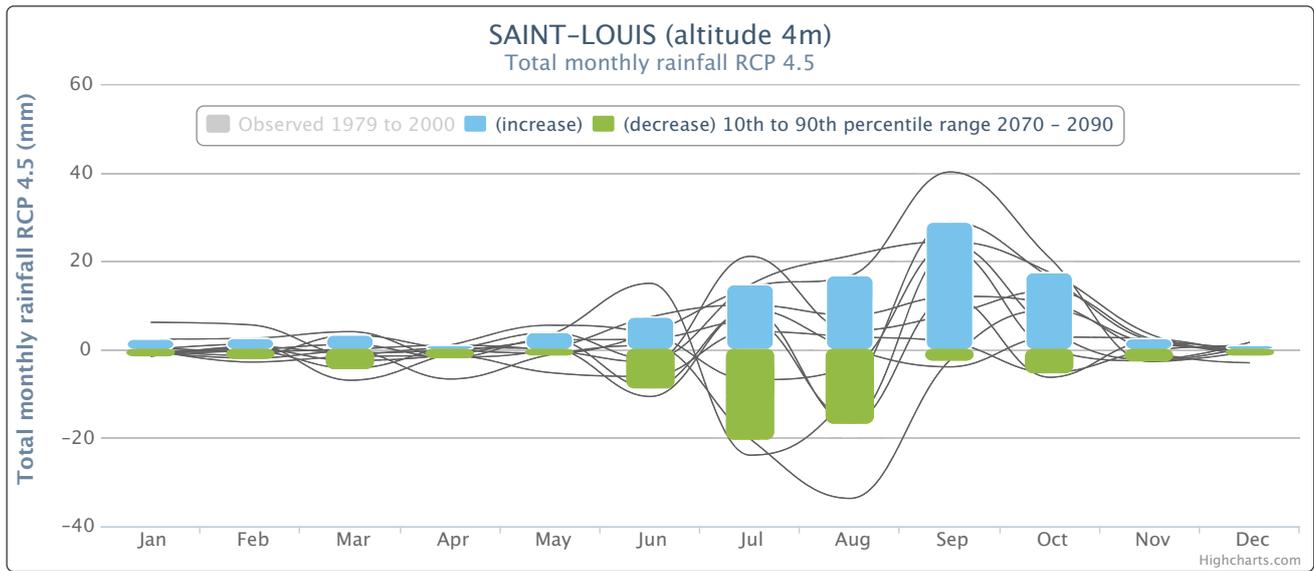


Figure 21. Projected Changes in Total Monthly Rainfall RCP 4.5 in Saint-Louis, 2070-2090 (CIP, 2001)

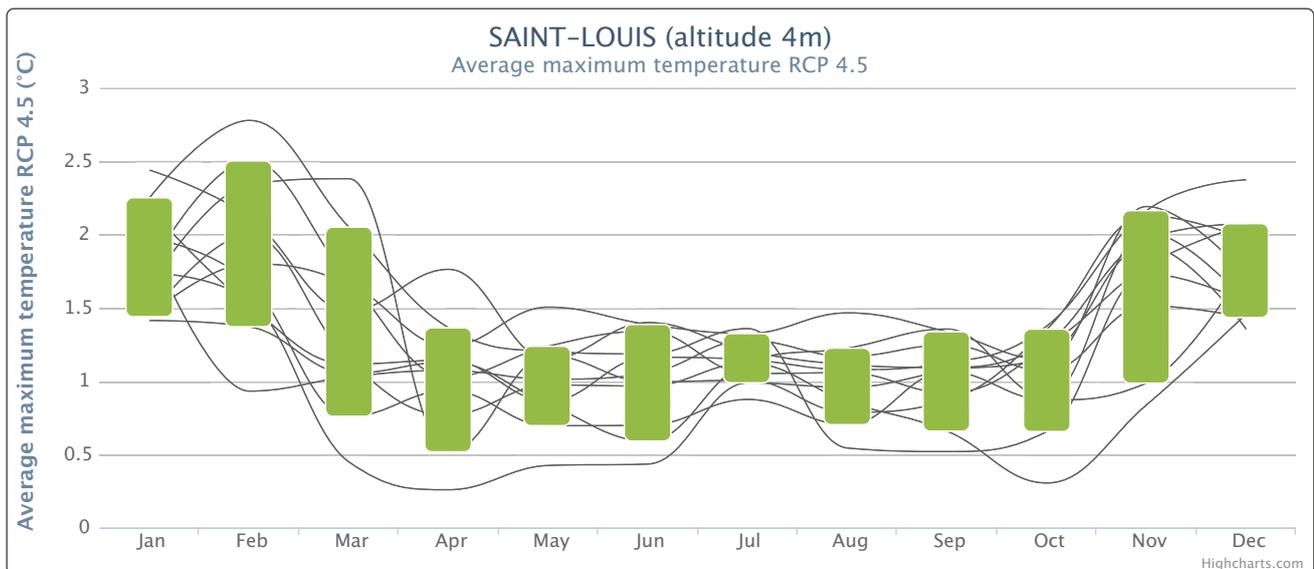


Figure 22. Projected changes in average maximum temperature RCP 4.5 in Saint-Louis, 2040-2060 (CIP, 2001)

4.5.3. The Climate Comparison With Other Stations

Rosso station is the nearest station from Saint-Louis station. The decrease in total monthly rainfall in Rosso station is expected to be more than in the Saint-Louis station for mid-term period projection (Figure 23). Rosso region is predicted to be drier than the Saint-Louis region. The projected average maximum temperature in Rosso station has almost similar pattern to that of the Saint-Louis station. However, the projected temperature increase in Saint-Louis is higher than in Rosso (up to 2.5°C).

“ Rosso region is predicted to be drier than the Saint-Louis region. ”

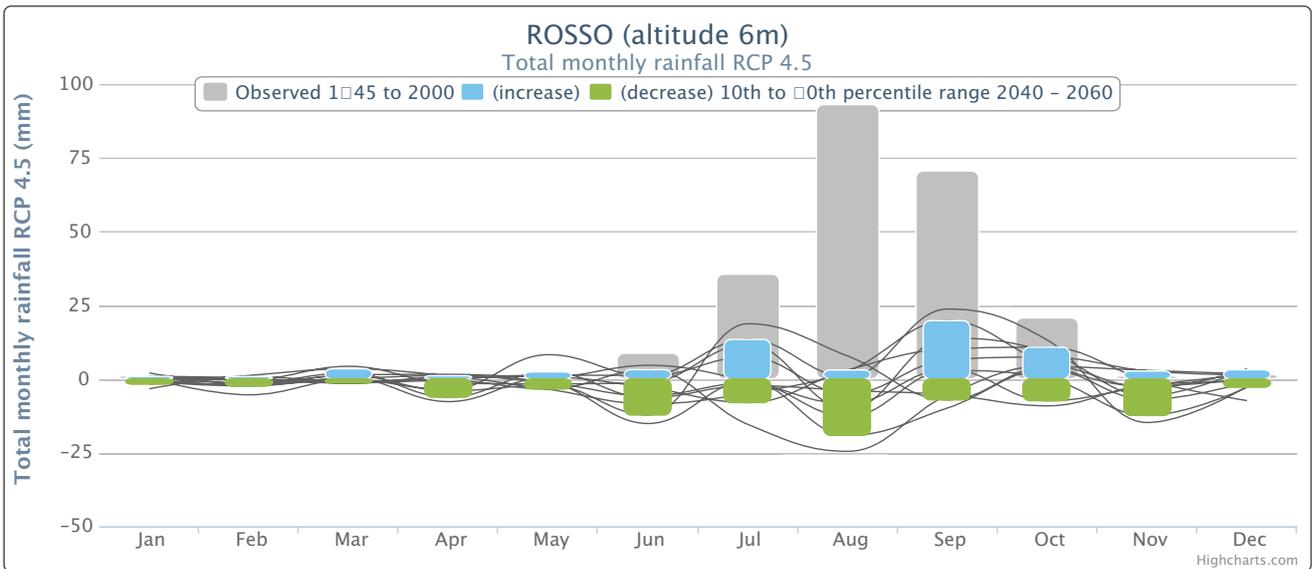


Figure 23. Projected Changes in Total Monthly Rainfall Scenario RCP 4.5 in Rosso Station, 2040–2060 (CIP, 2001)

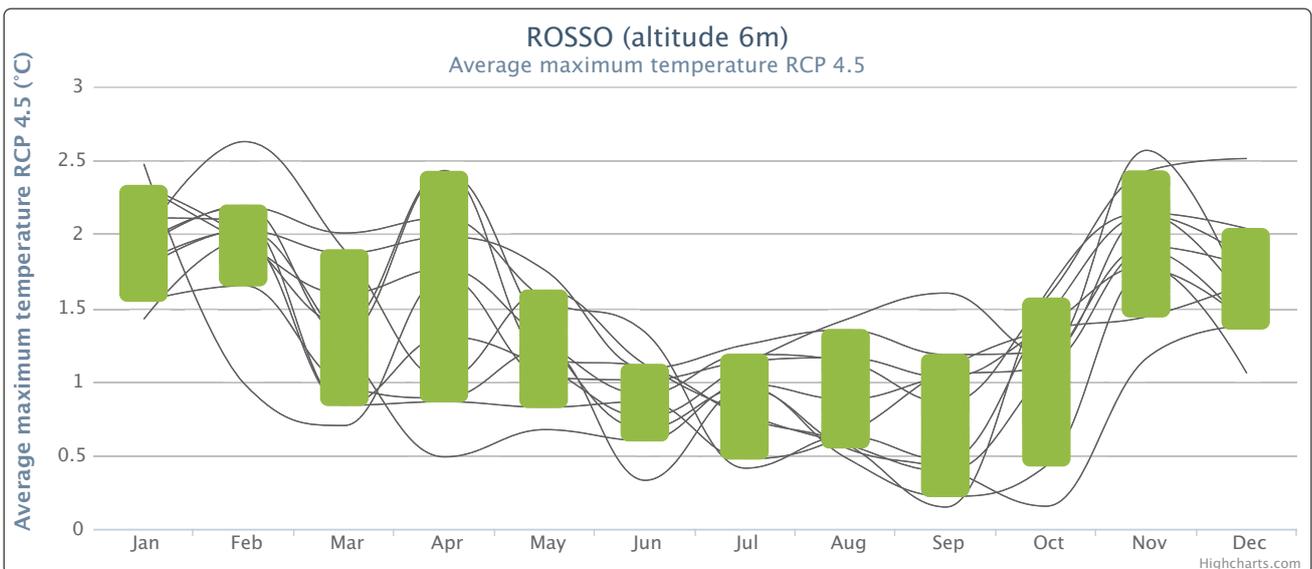


Figure 24. Projected Changes in Average Maximum Temperature Scenario RCP 4.5 in Rosso Station, 2040–2060

4.5.4. Conclusion and Recommendation for Fisheries Industry

The Senegalese government has the technical capacity to integrate climate change in their development policies and plans through several of their political and institutional initiatives. Opportunities exist to improve regional planning, the implementation of town plans and the use of renewable energy.

Fish and fishery products play a fundamental role in food industry to support food security for the Senegalese population. However, for long-term period the projection predicted that the part of the Senegal river represented by the Saint-Louis station will experience decrease in total monthly rainfall. It could potentially reduce the fish production in the area. Inland fish are vulnerable to climate change because they have limited habitat availability and they have a more direct link with terrestrial systems, human land use patterns and human water use. There is relationship between change in temperature and precipitation, and fish production. Rising water temperatures is radically altering aquatic ecosystems. Climate change is modifying fish distribution and the productivity of freshwater species. This has impacts on the sustainability of fisheries and aquaculture, on the livelihoods of the communities that depend on fisheries and fishery industry. The effect of changing rainfall patterns and water use impact on inland (freshwater) fisheries and aquaculture (Cheung, 2008).

In the situation over Senegal in general, there are several potential examples of climate impact pathways on inland fisheries (Modified from Allison et al, 2005 and FAO SFLP, 2007)

To overcome the problem, the government of Senegal and related stakeholders have to work more on promoting the integrated programme of irrigation and aquaculture. The integrated programme will help the fisheries industries to increase the exports as well as small-scale fishing to cover the domestic market. The fishing industry supports jobs for the Senegal population, counting in those who work in processing, supply, marketing and distribution. The stakeholders need to pay serious attention to this issue to make this industry sustainable for people's livelihoods.

The fishing industry has to strengthen its communities through provision of services such as insurance and weather warnings to reduce the climate risks. For example, when rainfall decreases, it reduces opportunities for fishing and aquaculture as part of rural livelihood systems. It reduces diversity of rural livelihoods and putting greater risks in fishing or greater reliance on non-fishing income. Climate insurance should help this condition. Another strategy is supporting participatory natural resource management and sustainable fishing operations, as well as assistance in post-harvest processing and preservation to maximise added value, employment and minimising waste from both fisheries and aquaculture industries.

“

Opportunities exist to improve regional planning.

”



5. SOUTH AFRICA

5.1. Geographical Location, Demographics and Economic Activities

South Africa is located between latitudes 22°S and 35.5°S and longitudes 16°E and 33°E. It has a coastline of 2,798 km and the surface area is 1,219,602 km². The land is divided into the interior plateau and the area between the plateau and the coast. The climate is temperate, ranging from dry regions in the north-to-west to warm and humid climate in the eastern area (Fox et al., 2000). Average annual rainfall in South Africa is about 450 mm. The precipitation is quite variable, with uneven distribution and seasonal rainfall. The southern and eastern parts have the lowest temperatures.

The economy activities in South Africa are mining, agriculture, fisheries, vehicle manufacture, food processing, textiles, telecommunications, energy, financial and business services, real estate, transportation, tourism and trading. The highest contribution to the national economy, with a share of 33.8% of gross value added (GVA) is by the Gauteng Province. This province has the largest share (23.9%) of the South African population estimated to be about 54 million in the year 2014, of which 27.6 million were female. Meanwhile, the smallest population (2.2%) is located in the Northern Cape (Stats SA, 2014a).

5.2. Industrial Analysis and Climatic Disaster for Different Industries

About 81% of the total land area (100.7 million hectares) in South Africa consists of agricultural land with 84 million hectares covered by natural pastures and the rest of the area (16.7 million hectares) cultivated for crop production. The agricultural industry is divided into three activities: animal production, field crops and horticultural products. Agriculture industry contribution to the GDP has decreased over past decades, but it still plays an important role in the country's economic activities. The agro processing industry is becoming more important in South Africa (Benhin, 2006). The forestry, timber, pulp and paper industries also play a major role in employment and contribute to the economy, especially for the rural community. Over 80% of the entire planted area of commercial plantation is certified by the Forest Stewardship Council and certified ISO 14001 as being sustainable managed (DAFF 2014). In its fishing industry, South Africa has a well-established business worth an estimated six billion rand per annum and contributes to about 1% of South Africa's GDP (DEA, 2013). The fishery industry faces challenges to ensure sus-



Capital:
Cape Town
Surface:
1,219,602 km²
Population:
54 million
Annual rainfall:
450 mm



“ About 81% of the total land area (100.7 million hectares) in South Africa consists of agricultural land. ”

tainability of fish resources usage. Overexploitation and illegal harvesting are some of the problems in the fishery industry. There is no assessment of the supply chain of the fish industry and therefore there is a need for measurements management and implementation of rebuilding strategies (WWF, 2011). This industry is quite vulnerable to climate change. Fishery productivity and diversity in South Africa can change due to the change in sea surface temperature, water flow, distribution, the size of the resources, and condition and connectivity of species resources.

Another industry is mining; it contributes to 8% of the GDP and provides direct and indirect jobs to the community (FCO 2015). However, socioeconomic benefits of the mining industry have been under threat due to the recent spates of strikes and labour unrest. It also causes environmental impacts such as water pollution, significant greenhouse gas emission, and large amounts of water and energy consumption (Hamann, 2004). The extreme weather has a direct impact on mining production, which has implications for the metal value chain.

Mining industry products are related to infrastructure for the transportation and tourism industries. The transportation industry contributes 9% of the GDP and about 750 000 people are employed in this industry (Stats SA, 2014b). Transportation industry produces greenhouse gases. This is mainly due to the fossil fuel dependence. Climate change can be a threat for this industry, especially in supply chain services. Therefore, integrating the climate change information into transportation industry planning can help to minimise risks to infrastructure and the supply chain from extreme weather events.

The tourism industry in South Africa is dependent on natural assets and its environment which are expected to be impacted by climate change. The impact could have effects on socioeconomic components of the regions and undermine the tourism industry's capacity to contribute to the country's economy. The industry is considered to be highly sensitive to climate. A key factor of the industry vulnerability is nature-based tourism. A number of studies have highlighted that climate change is very likely to pose a significant threat to the biodiversity in South Africa (Driver et al., 2012).

All the industries above are dependent on energy industry such as electricity. The electricity production and supply industry are the largest GHG emitters in South Africa (DEA 2014). The increasing emissions from the industry were attributed to increase in consumption of coal resources. There are many old coal fired power plants in South Africa. These power plants operate less efficiently to generate electricity and use high temperature. High temperature may cause air heater pack in the power plant and emit more particulate matter. Electricity production is also dependent on water resources which makes it more vulnerable to climate change. The water is stored in dams and reservoirs and supplied via inter-basin transfer schemes, pumping stations, and pipelines. The electricity industry uses about 3% of the national water supply (DWA, 2013).

For their energy need, the agro-food processing industry is largely dependent on electricity. The largest consumer of this energy is the sugar milling and refining component of the food industry. The agro-food processing industry is vulnerable to competitive land uses. The companies and firms may choose to locate themselves further away from urban areas, closer to agricultural suppliers, or remain within urban agglomerations closer to customer markets (Donovan 2009; Lambert and McNamara 2009). The agro-food processing industry is dependent on water supplies. The municipal supply of water will decrease in the future due to lower rainfall coupled with an increase in the future consumption of water, resulting in a deficit in the municipal water supply.

5.3. Policies for Vulnerability to Climate Change

South Africa is approaching the limits of increasing productivity from a declining resource. As such, the government has prioritised the expansion of the plantation area in South Africa in regions where it is economically, environmentally and socially appropriate to do so (DAFF 2013b). Increasing the area under forestry is considered a priority in the Industrial Policy Action Plan of the Department of Trade and Industry (DTI). However, the areas that are both available and suitable for commercial forestry in South Africa are limited and much of this limitation is driven by a competition for water, which is a scarce resource in the semi-arid country (Dyer 2007). This limited availability of suitable forest land has contributed to the decline in the rate of new afforestation in South Africa, in addition to factors related to water legislation and stricter procedures around granting the necessary water licenses (DAFF 2014b).

Forestry is one of the key industries of climate change and it needs to be considered an important national policy concern. The different tree species and hybrids planted in commercial forests in South Africa have different climatic constraints and it determines the climatically optimum growth areas where these species can be matched for optimal growth and volume production. Changes in temperature and rainfall regimes are likely to impact the extent and location of land climatically suitable for specific genotypes (Warburton and Schulze 2008; DEA 2013).

Meanwhile, the food division is quite dominant in the economy share and contributes approximately 31% of the GDP (DAFF 2013a). It is recognised by the industrial policy plan action (IPAP) for creating and initiating a new job. The risk and uncertainty of agriculture activities in South Africa is influenced by climate change issues such as environmental degradation and water scarcity (Rogerson, 2014). As South Africa is regarded as a water scarce country with high variability in the climate conditions and limited fertile land, the challenge for the agriculture industry is to remain productive and to contribute to food security.

“South Africa is approaching the limits of increasing productivity from a declining resource. Increasing the area under forestry is considered a priority...”

5.4. Value Chain

South Africa is known for diverse and wide variation in the fruit and vegetable industry. The process of producing commodities such as fruits and vegetables right up to consumption proceeds along a value chain (Musvoto, 2015). The fruit and vegetable industry in South Africa is comprised of a number of sub-industries, and these include vegetable, potato, citrus, subtropical fruit and deciduous fruit like apples, pear, apricots, peaches, nectarines, plums and table grapes. The fruit processing industry in South Africa is growing rapidly with some of the products sold in the local market and some exported. The value chain of this industry includes processing, distribution and sale. A key element of food value chains is the cold supply chain. The cold supply chain is defined as the procurement, warehousing, transportation, and retailing of the food product under controlled temperature conditions. In the livestock industry, the value chain pays more attention to the final stage of production prior to slaughter; cattle and sheep are sent through a feedlot for finishing. DAFF (2013) estimates that about 80% of broiler producers are small and micro enterprises.

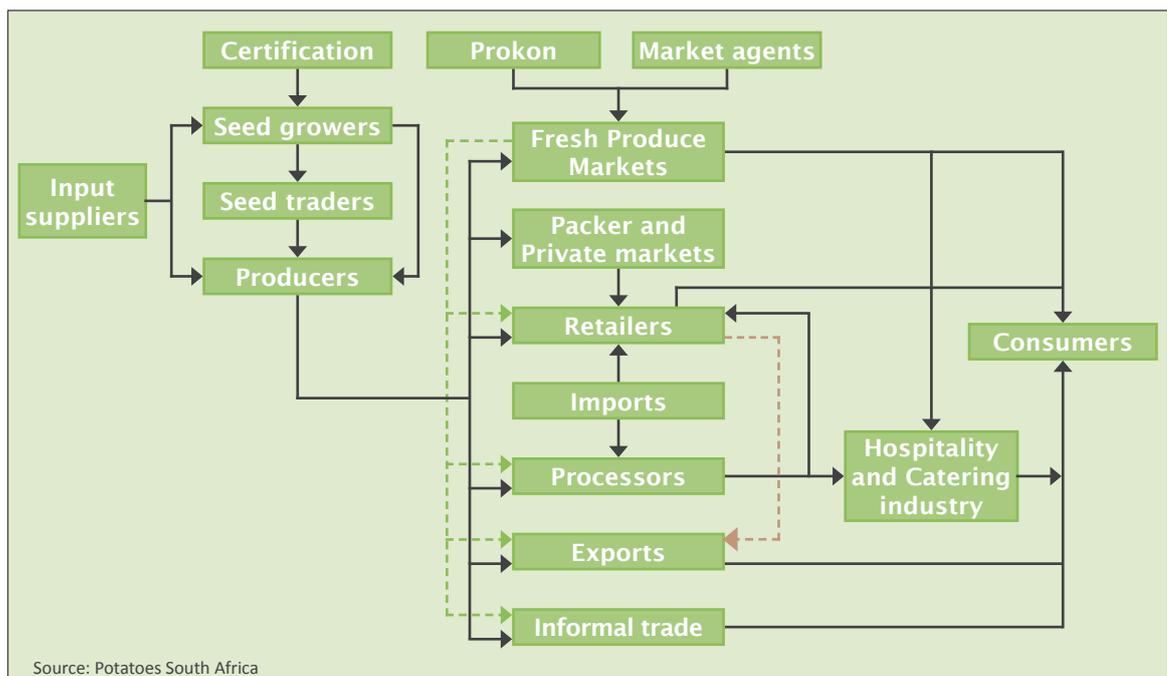
The value chain of the broiler industry includes a primary industry that focuses on production, like rearing the birds, which requires inputs from chicken breeders in the form of chicks, feed from feed companies for maize

“ South Africa is known for diverse and wide variation in the fruit and vegetable industry. ”

production, and veterinary supplies from pharmaceutical companies. In the secondary industry, there are abattoirs, wholesalers, importers, exporters, and retailers (Vermeulen, et.al. 2008). Electricity is also a significant input due to the need to maintain a cold chain which chills and freezes the products. A large amount of waste is generated in chicken abattoirs and some of the waste can be processed into by-products. The waste that is not processed into by-products is disposed of in various ways – by burial, rendering, land application, municipal landfill, collection by farmers for animal feeding, burning and composting – depending on the waste type (Molapo, 2009).

The following discussion will focus on the main segments of the potato value chain (see Figure 25) which are the informal sector and the formal sector. In informal sector, according to Potatoes South Africa, during 2011 informal traders were responsible for the distribution of 53% of all fresh potatoes sold on the fresh produce markets and for 30% of all potatoes sold, including informal trade from fresh produce markets, urban and rural sales. Currently an unknown number of informal traders purchase 10kg pockets from fresh produce markets, or directly from producers, repackage them into 1kg or 2kg plastic bags and sell these (or just sell the potatoes loose) in a number of settings in both rural and urban areas (Shackleton, et.al. 2010). This form of trading in urban areas has reportedly emerged as a direct result of changes in urban eating habits and urbanization.

The formal sector consists primarily of the large retailers in South Africa, such as Fruit and Veg City; Pick ‘n Pay, Shoprite-Checkers, Spar and Woolworths, and small retailers such as greengrocers and independent stores. It consumes an estimated 38% of all fresh potatoes produced, excluding any processed potatoes products that also go through normal trading channels. The formal trade in potatoes generally concentrates on the sale of high quality fresh potatoes, either loose or in smaller packaging. Some of the formal traders undertake their own packaging, brand advertising and sometimes even semi-processing of fresh potatoes through direct purchases from producers, dedicated wholesalers and fresh produce markets (DAFF, 2012a).



Source: Potatoes South Africa

Figure 25. Potato supply chain in SA

5.5. Climate Challenges for Vegetables Industry

The global financial crisis left exporters in developing countries faced with shrinking or marginal export growth in many of their developed country markets so they would be looking towards large emerging markets like South Africa that offer significant potential for exploitation. South Africa imported US\$ 29 million worth of vegetables from the African region in 2012 (Nahman & de Lange, 2013). The market has room for new exporters in nearby countries of counter-season fresh produce like citrus, avocados, grapes, bananas and watermelons. It also has openings for dried beans, dehydrated vegetables and nuts, private-label canned vegetables and spice mixes, as well as chillies, turmeric, peppers and cumin (Theyse, 2014).

Vegetables is another staple foods in traditional SA diet. Consumers with high standards of living are part of a growing middle class with growing demand for variety and “out of season” product. Increasingly urban consumers with more income and less time create demand for quality and convenience products (Isaacson, 2005). Growth in tourism also fueled a demand for more variety and growth of food service industry. As well as increasing health awareness, this has create opportunities for nutritional/ health and diet products. Strong infrastructure, increasingly prominent middle class and fairly stable economy makes South Africa an important emerging market and export gateway to sub-Sahara region (Goldstein, 2002).

Potato is one of most popular vegetable crops in SA. The drought and hot conditions have had a negative impact on yields in almost all the potato production regions in South Africa with farmers selling 3 million less bags of 10kg potatoes on the markets. Retailers and industry experts in South Africa say that the high price trend for potatoes is set to end soon. Last month, South Africa recorded its highest price increases for potatoes with a 10kg bag going up to R76.76 in Cape Town according to the latest information by Potatoes SA. But the organisation said the average prices could come down as more potatoes would be coming from the eastern Free State (Fresh Plaza, 2016). This analysis aims to provide information to readers on the use of climate information for supporting the potato industry – particularly over the eastern Free State region, using data from Bloemfontein station.

The climate trends in South Africa show an increase of rainfall intensity during the summer and spring seasons in the central interior and the south eastern part. South Africa is projected to become warmer with slight increase in temperature, which exceeds 35°C, whereas low temperature is less frequent (DEA, 2013). There are also some identifiable areas where significant changes in certain characteristics of precipitation have occurred over the period 1910 to 2004 (Kruger, 2006). These conditions are vulnerable for the water/temperature requirements for Potatoes which will be explained in the next section.

5.5.1. Historical Climate Data

The historical seasonality plot below shows the long term monthly climatology of total rainfall and monthly average minimum and maximum temperatures. This provides a useful overview of the annual seasonality for a location as it indicates warm and cool periods as well as wet and dry periods. Different climate regimes will have very different seasonality. These monthly climatology values are calculated from the historical monthly record data given in Figure 26.

“
Potato is one of most popular vegetable crops in South Africa.
”

During 1979–2000, the Free State had six months dry season, i.e. April to September, and also six months rainy season, i.e. October to March (Figure 26). The wettest month has historically been February, with a monthly average of almost 100 mm from 1941 to 2001. On the other hand, the driest months have been June and July with almost no rain. The annual precipitation for Bloemfontain is approximately 541 mm. Historically, the minimum average temperature recorded was below 0°C in June and July, while the maximum average temperature was 31°C in January.

The historical climate records plot in Figure 27 shows the historical record of different climate variables for the location. This is useful for identifying particular climate events such as floods and droughts as well as observing long term variability or trends.

As shown in Figure 27, the data from 1940 to 2000 indicate that, historically, total monthly rainfall peaks have predominantly occurred during the rainy season (February and January), but there was remarkable rainfall variation over the years. The records show months with particularly high rainfall, with totals of more than 400 mm, e.g. 1988, whilst the drought period at Free State has occurred in 1980 to 1982.

5.5.2. Future Climate Projections

The plot below (Figure 28) shows the range of projected future changes for this location across 10 different statistically downscaled CMIP5 GCMs for scenario RCP 4.5. This total monthly rainfall is the scenario for future period 2040 to 2060. The result of Scenario model RCP 4.5

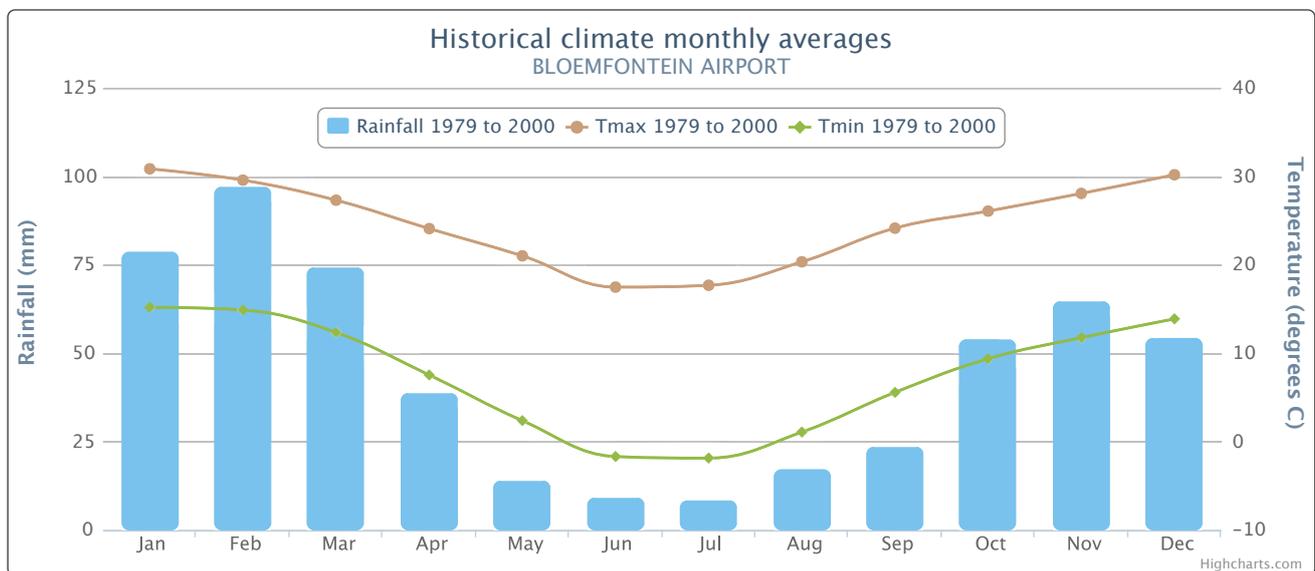


Figure 26. Historical Climate Monthly Averages in Free State

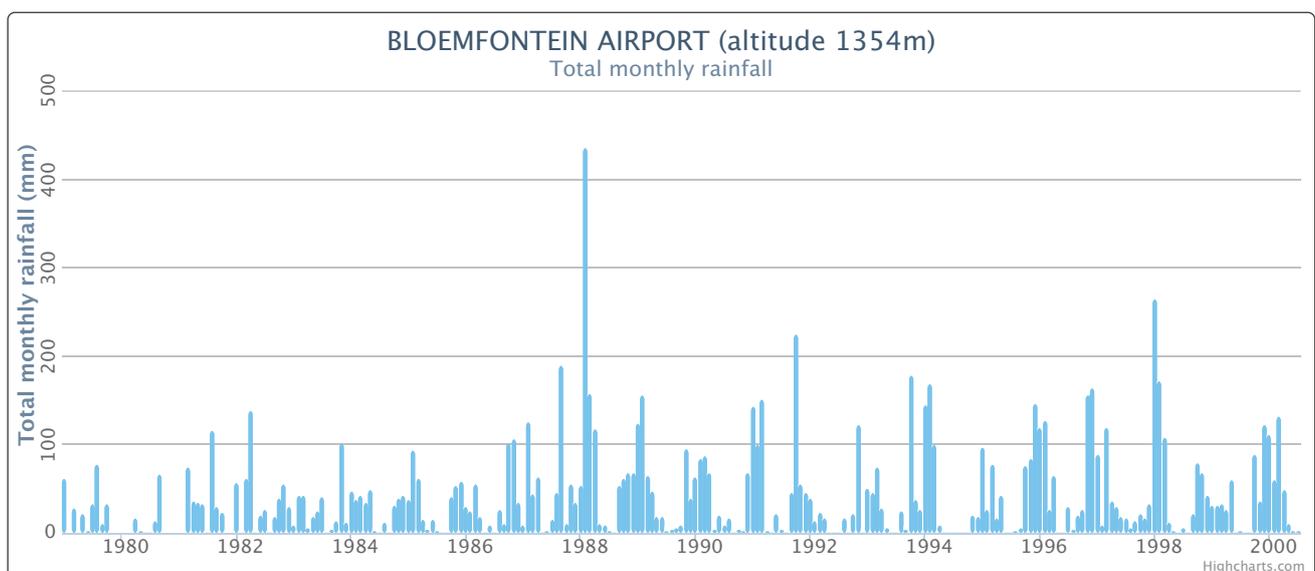


Figure 27. Total Monthly Rainfall in Free State

has the pattern where the dry season (April–September) monthly precipitation shows little change compared to the historical level. In contrast, there is uncertainty over changes in the rainy season (October–March), with some months where increases are expected, some where decreases are expected, and some where the models disagree about likely changes.

In general, the rainfall and the temperature scenario has a related pattern, the decrease of rainfall with uncertainty and increase of temperature. As the goal is to know how the climate risks may evolve in the longer term, we looked first at the mid-term projections to ensure that these choices are sustainable in the longer term. We also looked at the projection of average maximum temperature for the same period, as shown in Figure 29. Looking at both the projec-

tions, it can be seen that the projections support each other's patterns. In 2040–2060, December to March is the wet season and it is varied, with a decrease in December and March, but an increase in January and mixed signals for February. It affects the dry seasons may become worst in Free State. For the projected temperature, there is slight variation in changes projected for both the seasons. In downscaled CMIP5 GCMs for scenario RCP 8.5 (Figure 30 and Figure 31), there is a slightly greater magnitude of change, the increase of the temperature are higher than RCP 4.5 in all months. There is also decrease of rainfall but with a mixed picture, overall in November, January and February. The possible change to annual rainfall total is about 20-30 mm. This change will impact on suitability for potatoes.

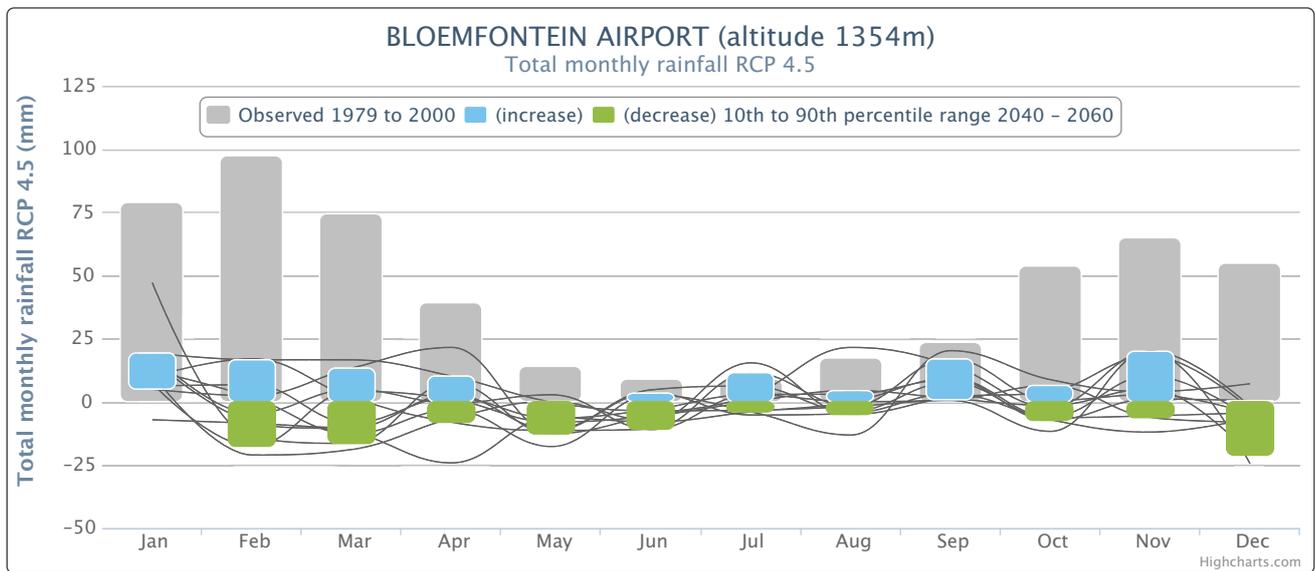


Figure 28. Projected Changes in Total Monthly Rainfall Scenario RCP 4.5, Free State, 2040–2060.

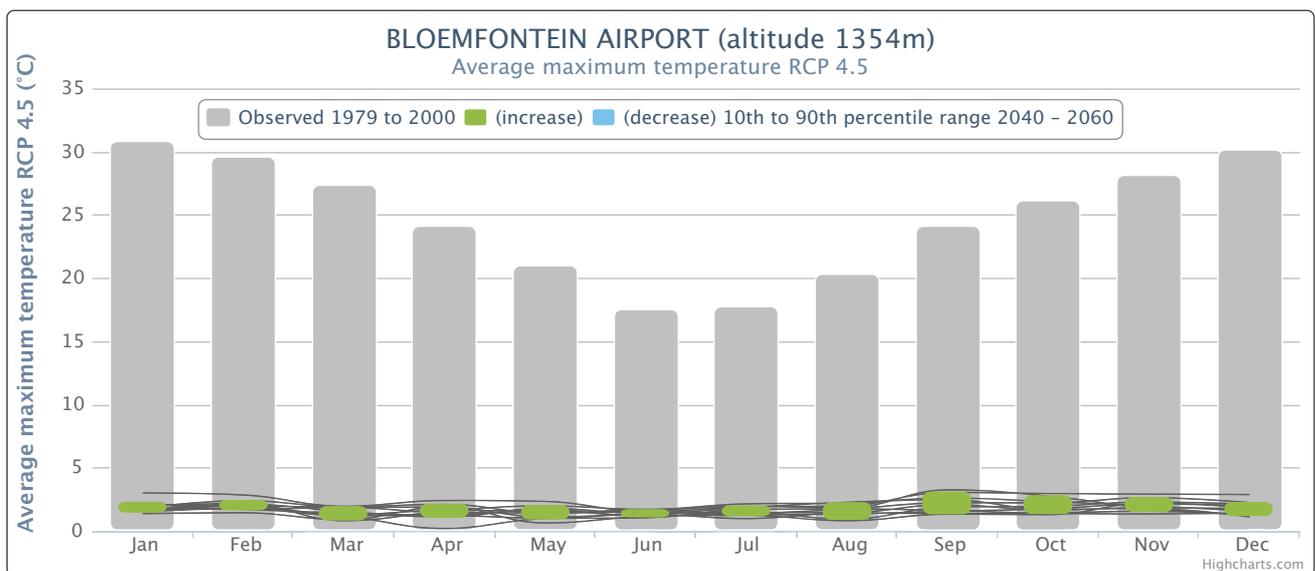


Figure 29. Projected Changes in Average Maximum Temperature Scenario RCP 4.5, Free State, 2040–2060.

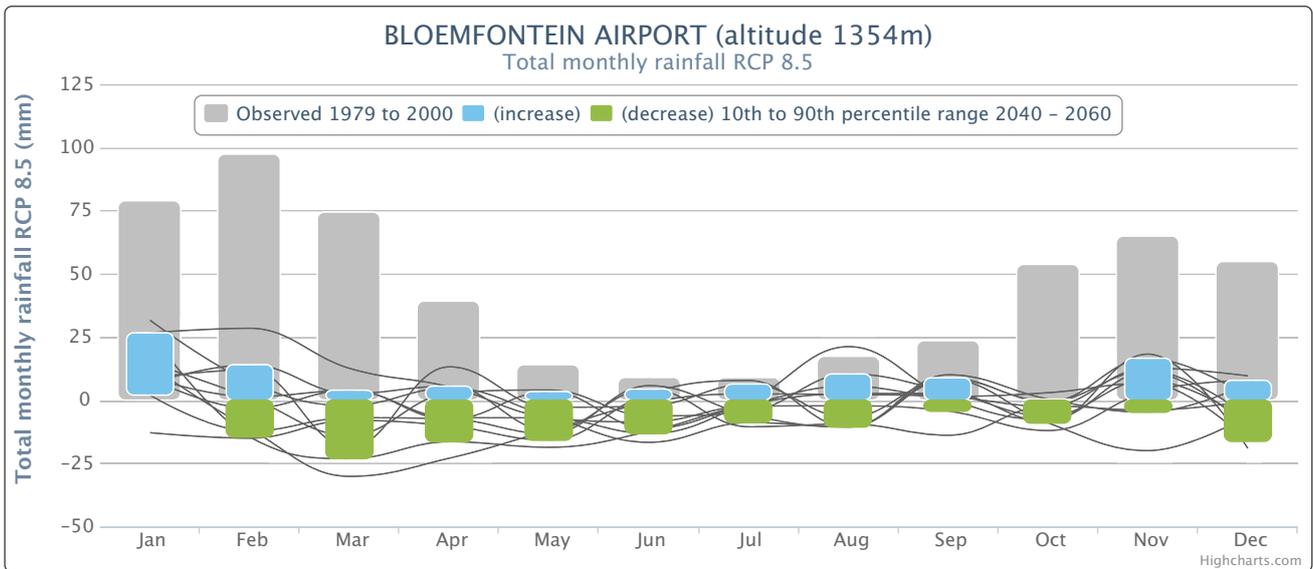


Figure 30. Projected Changes in Total Monthly Rainfall Scenario RCP 8.5, Free State, 2040–2060.

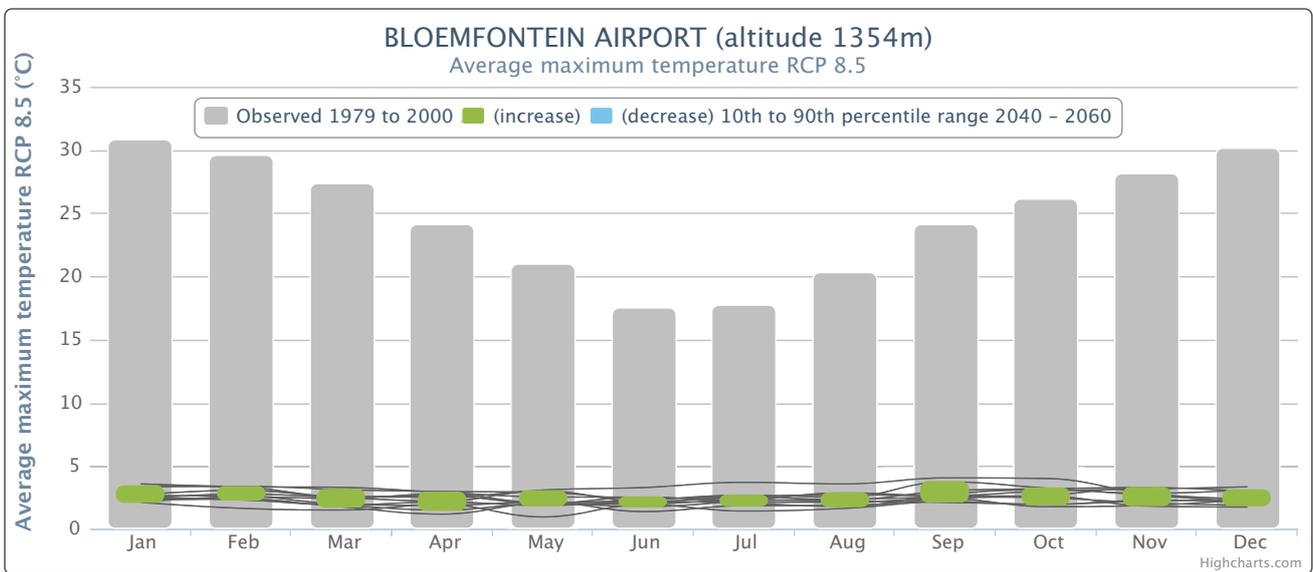


Figure 31. Projected Changes in Average Maximum Temperature Scenario RCP 8.5, Free State, 2040–2060.

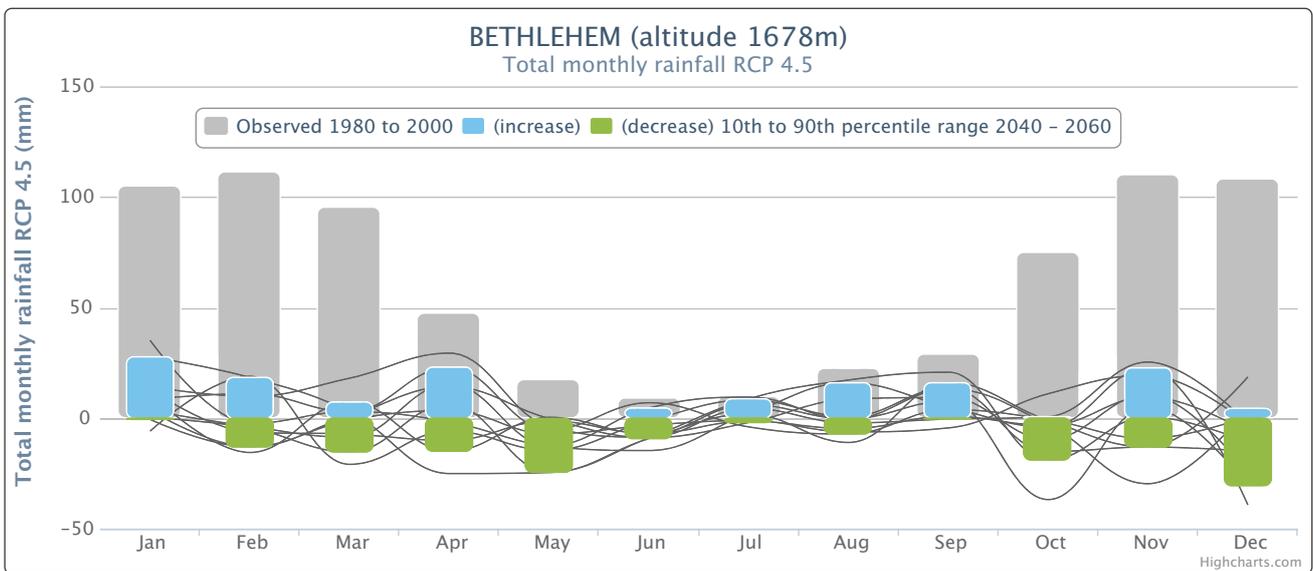


Figure 32. Projected Change in Monthly Rainfall Data Using CMIP5 RCP 4.5 for Bethlehem

5.5.3. The Climate Comparison With Other Stations

Looking through the data of the Bethlehem station (Figure 32), its future climate projections suggest almost similar patterns to our earlier interpretations for the Bloemfontein Free State, except in October. During that month, the rainfall in Bethlehem is decreasing, but at Free State there is little change. However, when we compare in August, the future climate projection is quite different. There will be increased rainfall in Bethlehem while it will remain the same in Bloemfontein. This local climate difference indicates there is influence from other factors like distance and topology of both stations. The distance between the two stations is 248 km. The Bethlehem lies at an altitude of 1,700 metres (5,600 ft) and this contributes to its cool climate with frosty winters and mild summers. Meanwhile, Bloemfontein is situated on dry grassland at 29°06'S 26°13'E, at an altitude of 1,395 m (4,577 ft) above sea level (Huntley & Walker, 2012).

5.5.4. Conclusion and Recommendation for the Vegetables Industry

South Africa has the technical, managerial and operation capacity needed to attain low-carbon and climate resilient industrial growth. Opportunities include the expansion of the use of advanced water resource management, whilst challenges relate largely to lower projected rainfall and in meeting increasing demands of water.

The productivity of potato in Free State (25 ton/ha) was still below the average for SA (39 ton/ha) (Westhuizen, Zyl, 2013). It may be a consequent of climate suitability as shown in Table 2 and historical climate monthly average (Figure 1). Free State temperature is only suitable for the cultivation of potato from October to March from a climate perspective. It might be due to the rainfall being less than optimal. In general, water deficits in the middle to late part of the growing period tend to reduce yield more than those in the early part. Where supply is limited, water is directed towards maximizing yield per hectare rather than being applied over a larger area. The minimum water required is equivalent to rainfall of 500 mm/120 day and Free State has less rainfall from December to March. Since the potato has a shallow root system, yield response to frequent irrigation is considered, and very high yields are obtained with mechanized sprinkler systems that replenish evapotranspiration losses every one or two days. Under irrigation in temperate and subtropical climates, a crop of about 120 days can produce yields of 25 to 35 tonnes/ha (11 to 15.6 tons per acre), falling to 15 to 25 tonnes/ha (6.6 to 15.6 tons per acre) in tropical areas (Haverkort, et. al. 2013). The decrease of rainfall can make the crop yields falling lower.

“South Africa has the technical, managerial and operation capacity needed to attain low-carbon and climate resilient industrial growth.”

Table 3. Climate Suitability for Potato (FAO, 2008)

Characteristics	Climate Suitability for potato	Optimum yields
Average temperature (°C)	10–30	18-20
Rainfall (120 to 150 day crop)		500–700 mm

Since the newly harvested tubers are living tissue – and therefore subject to deterioration - proper storage is essential, both to prevent post-harvest losses of potatoes destined for fresh consumption or processing, and to guarantee an adequate supply of seed tubers for the next cropping season (Pinhero, et. al. 2009).

“ Good production of potato will lead to increasing the vegetable industry – potatoes industry contributed approximately 61% to the total gross value of vegetable production. ”

For ware and processing potatoes, storage aims at preventing “greening” (the build up of chlorophyll beneath the peel, which is associated with solanine, a potentially toxic alkaloid) and losses in weight and quality. The tubers should be kept at a temperature of 6 to 8°C degrees, in a dark, well-ventilated environment with high relative humidity (85 to 90 percent). Seed tubers are stored, instead, under diffused light in order to maintain their germination capacity and encourage development of vigorous sprouts (Nourian, et. al. 2003). In regions, with only one cropping season and where storage of tubers from one season to the next is difficult without the use of costly refrigeration, off-season planting may offer a solution.

Rise in temperature may have implications for potato storage. With rainfall changes as shown in Figure 29, and projected changes in the total monthly rainfall for 2040–2060 which predict that the total rainfall will decrease, it will have impact on declining production of potato. The stakeholders need to give attention to building its industry and community resilience. To increase the production of potato in Free State, it is recommended that the government build an efficient irrigation system to ensure the availability of water for the crops and also create new varieties that are more resistant to drought to combat potential impacts of periodic drought and water shortages due to other competing water demands. Those include production of other crops, energy production, tourism, mining and meeting policy objectives to increase forested lands and expand plantation areas. There is also a reasonable chance that Free State will get hotter, it certainly will increase temperatures, therefore it is important to consider adaptation plans for potato cultivation, as well as other industries that are water dependent.

Good production of potato will lead to increasing the vegetable industry. Potatoes are the most important vegetable crop in South Africa and the world’s recognized staple food consumed by many people. In 2011, potatoes industry contributed approximately 61% to the total gross value of vegetable production, 13% of horticultural products and 3% of total agricultural products. Processing of potatoes has grown at a rapid rate over the past ten years. According to Potatoes South Africa, the processing industry represented 17% of the total potato crop during 2011 (DAFF, 2012a). The rapid increase in potato processing can be attributed to consumer need for convenient ready to eat foods. The domestic processing sector uses potatoes primarily for, French fries, crisps and frozen products. In order to cover all the potato demand and contribution, the industry needs to consider the storage technology and the transportation to maintain the high quality of potato.

5.6. Climate Challenges for Maize Industry

South Africa’s (SA) worst water shortages for 23 years have caused a decline in farming output that will lower its GDP and cause food-price increases. The drought devastating parts of SA caused the country’s farmers to lose up to US\$ 634 million in 2015 (Yende, 2015). The food industries are in a vulnerable condition.

The worst affected are KwaZulu-Natal, The Free State, Limpopo, North West and The Northern Cape, where farmers growing white maize, yellow maize, soya beans and sunflowers have incurred major losses. Meanwhile, the small population can possibly make The Northern Cape more vulnerable to drought (Gbetibouo & Ringler, 2009).

The Northern Cape has fertile agricultural land. In the Orange River Valley, especially at Upington, Kakamas and Keimoes, grapes and other fruits are cultivated intensively. Wheat, fruit, peanuts, maize and cotton are produced at the Vaalharts Irrigation Scheme near Warrenton (Maisela, 2007). Maize farming in South Africa has been practiced for thousands of years in South Africa. White maize is the staple food of the majority of South African population. The agricultural sector in South Africa contributes about 10% of the formal employment. South Africa has both commercial and subsistence farming (Davies & Thurlow, 2010).

As it is well known that climate plays an important role in the production of maize, it is important to conduct more assessments on climatic factors, including the current conditions and the projected trends. The assessments use climate information from Kimberley station, the nearest station in Warrenton where maize is produced in the North Cape. The impact of climate change on maize may add significantly to the development challenges of ensuring food security and reducing poverty. This study aims to provide information to readers on the use of climate information for supporting the maize industry – particularly over the Northern Cape region.

5.6.1. Historical Climate Data

The historical seasonality plot below shows the long term monthly climatology of total rainfall and monthly average minimum and maximum temperatures. This provides a useful overview of the annual seasonality for a location as it indicates warm and cool periods as well

as wet and dry periods. Different climate regimes will have very different seasonality. These monthly climatology values are calculated from the historical monthly record data given in Figure 33.

During 1941–2001, it seems like the Northern Cape had a longer dry season, i.e. April to December, and a shorter rainy season, i.e. January to March (Figure 33). But actually the graph below shows a rainy season from October-April. In January-March the rains overall are longer. The wettest month was March, with a monthly average of almost 70 mm from 1941 to 2001. On the other hand, the driest months were June and July with almost no rain. Historically, the minimum average temperature recorded was below 5°C in June and July, while the maximum average temperature was 32°C in January.

The historical climate records plot in Figure 34 shows the historical record of different climate variables for the location. This is useful for identifying particular climate events such as floods and droughts as well as observing long term variability or trends.

As shown in Figure 34, the data from 1940 to 2000 indicate that, historically, total monthly rainfall peaks have predominantly occurred during the rainy season (February and March), but there was remarkable rainfall variation over the years. The records show months with particularly high rainfall, with totals of more than 60 mm, e.g. February 1946 and March 1988, whilst the drought period at Northern Cape has occurred in 1964 to 1965.

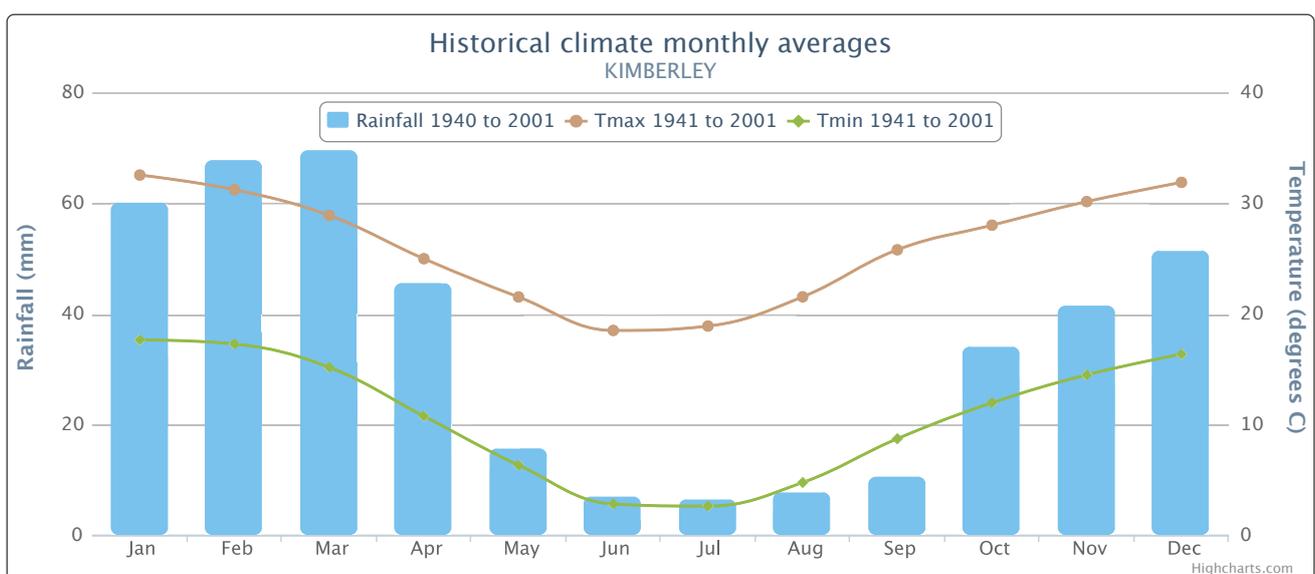


Figure 33. Historical Climate Monthly Averages in Kimberley, Northern Cape (CIP, 2001)

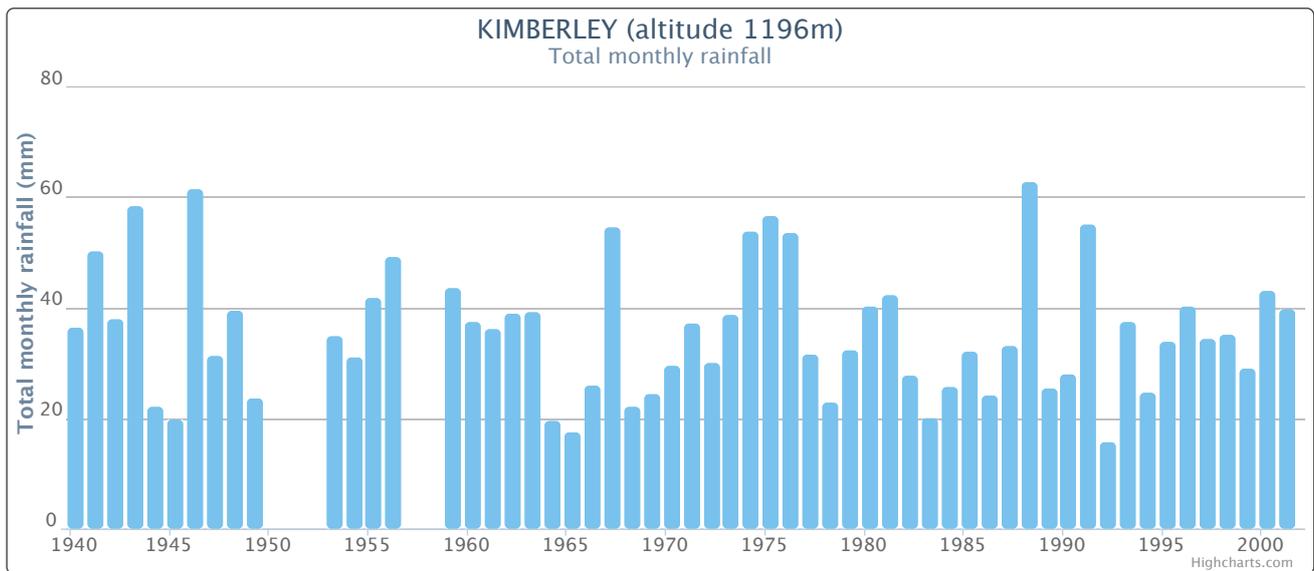


Figure 34. Total Monthly Rainfall in Kimberley, Northern Cape

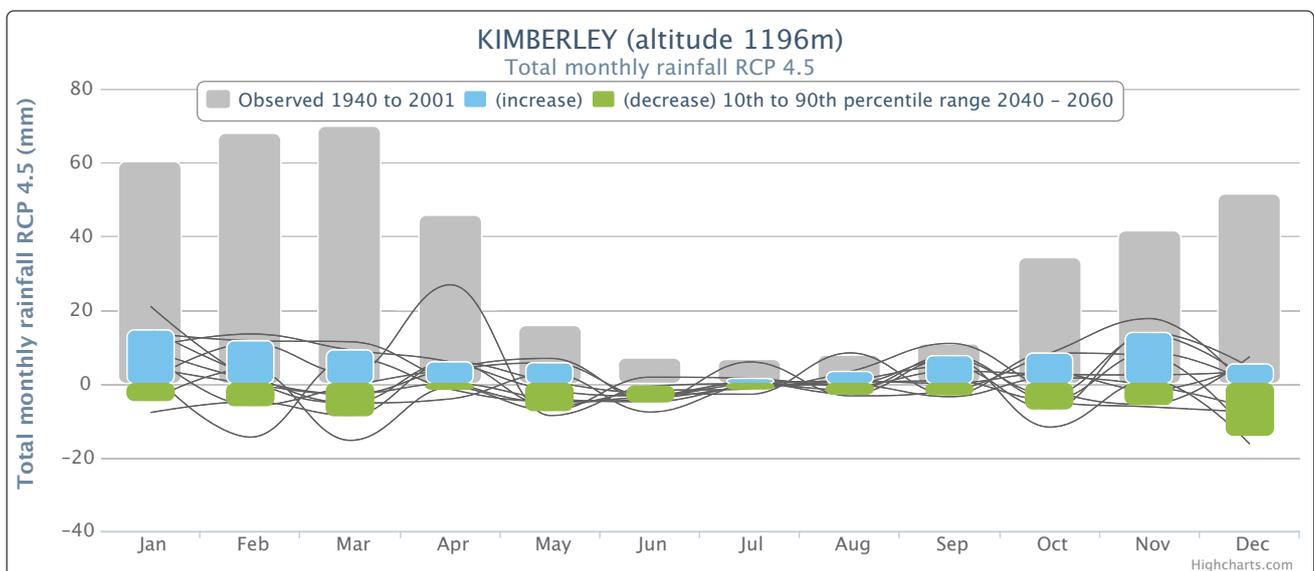


Figure 35. Projected Changes in Total Monthly Rainfall Scenario RCP 4.5, Northern Cape, 2040–2060.

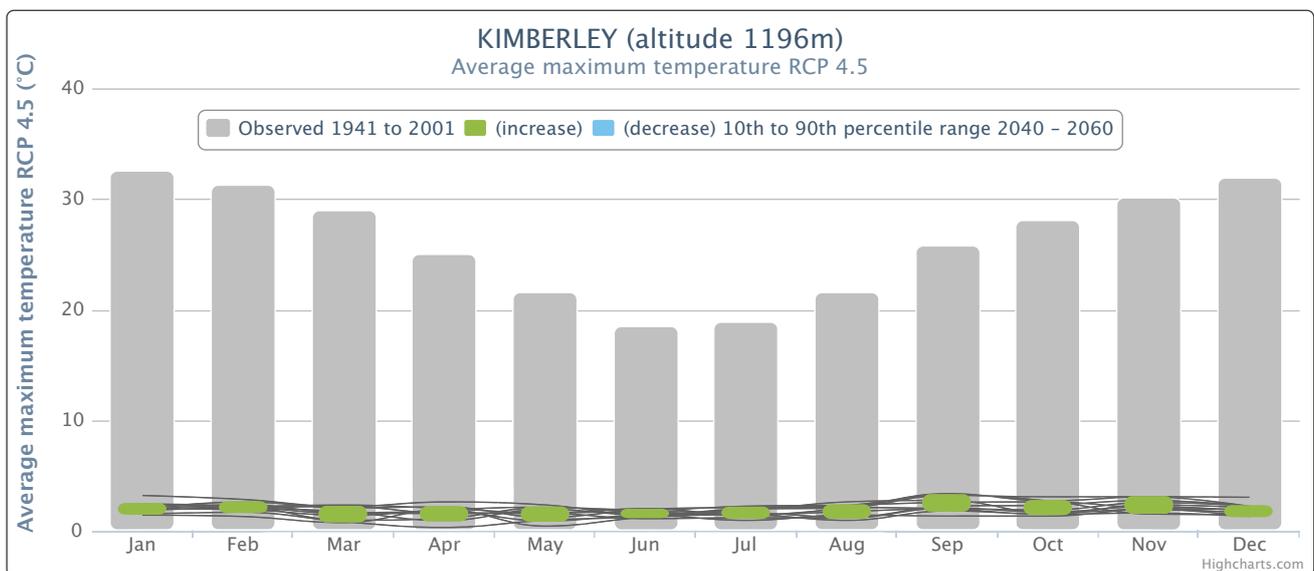


Figure 36. Projected Changes in Average Maximum Temperature Scenario RCP 4.5, Northern Cape, 2040–2060.

5.6.2. Future Climate Projections

The plot below (Figure 35 and Figure 36) shows the range of projected future changes for this location across 10 different statistically downscaled CMIP5 GCMs for scenario RCP 4.5. This total monthly rainfall is the scenario for future period 2040 to 2060. The result of Scenario model RCP 4.5 has the pattern where the dry season (April–December) monthly precipitation shows little change compared to the historical level. In contrast, the rainy season (January–March) monthly precipitation is expected to change in either direction with different magnitudes. The change in rainfall during the rainy season varies, with some months expected to increase in rainfall (Nov, Jan–Feb, Apr), some where change is uncertain (Oct, Mar), while rainfall in Dec is expected to decrease.

In general, the rainfall and the temperature scenario has an inverse pattern, increase of rainfall and increase of temperature. As the goal is to know how the climate risks may evolve in the longer term, we looked first at medium to mid-term projection to ensure that these choices are sustainable in the longer term. We also looked at the projection of average maximum temperature for the same period, as shown in Figure 27. Looking at both the projections, it can be seen that the projections support each other's patterns. In 2040–2060, the total monthly rainfall is expected to decrease in December, so that the wet seasons will become the dryer in Northern Cape. For the projected temperature, there is slight variation in changes projected for both the seasons but increases in temperature are clear. Meanwhile, the range of projected future changes downscaled CMIP5 GCMs for scenario RCP 8.5 (Figure 37 and Figure 38) shows stronger pattern than RCP 4.5 in similar trend.

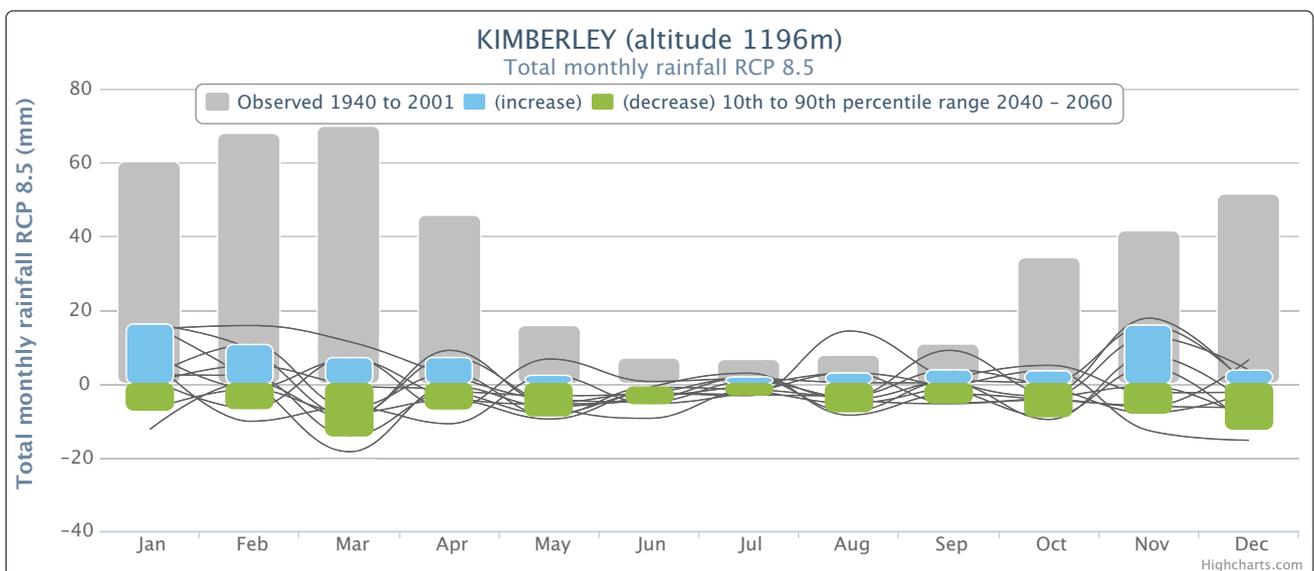


Figure 37. Projected Changes in Total Monthly Rainfall Scenario RCP 8.5, Northern Cape, 2040–2060.

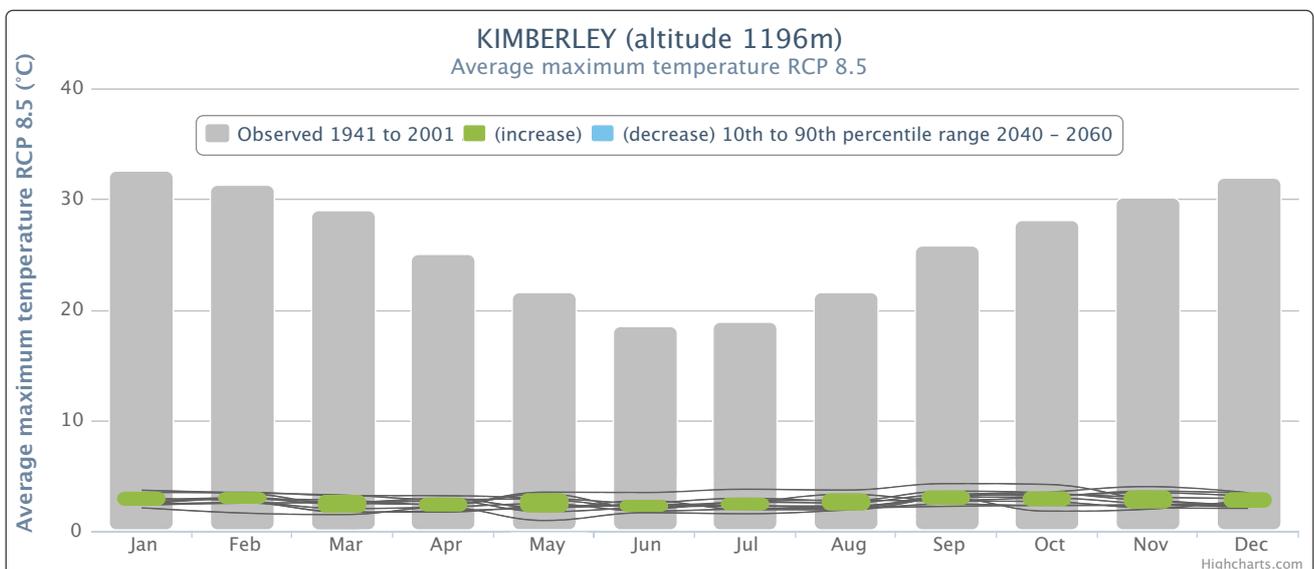


Figure 38. Projected Changes in Average Maximum Temperature Scenario RCP 8.5, Northern Cape, 2040–2060.

5.6.3. The Climate Comparison With Other Stations

Looking through the data of the Ottosdal station, its future climate projections suggest patterns similar to our earlier interpretations for the Kimberley station, except in February. During February, the rainfall in Ottosdal is increasing, but at Kimberley it is decreasing. However, when we compare with the Douglas station, the future climate projection is quite different. This difference may be influenced by the type of the area, such as rural or urban, and its topography. Kimberley is an urban area and Douglas is a rural area. It concludes that this difference affects suitability area for Maize.

5.6.4. Conclusion and Recommendation for the Maize Industry

South Africa has the technical, managerial and operation capacity needed to attain low-carbon and climate resilient industrial growth. Opportunities include the expansion of the use of renewable energy, particularly solar, whilst challenges relate largely to lower projected rainfall and in meeting increasing demands of water.

According to climate suitability as shown in Table 3 and historical climate monthly average (Figure 33) Northern Cape temperature is suitable for the cultivation of maize from a climate perspective, but the production of maize in Northern Cape was still below the average for SA (Department: Agriculture, Forestry and Fisheries, 2013). It might be due to the rainfall still being less than optimal. The water requirement for maize plants is critical at the development stage, the mid-season stage and the late season stage (approximately 1 month after planting). The minimum water required in the critical period is equivalent to rainfall of 85 mm/month and Northern Cape has a rainfall of less than 85 mm/month from January to March (Panda, et.al. 2004). Maize is very suitable for planting in the regions that have rainfall of 500–800 mm/year. However, in SA (including The Northern Cape), an estimated 80–90% of the area planted with maize is dryland which applies water use efficiency (Gouse, et. al. 2005).

Table 4. Climate Suitability for Maize

Characteristics	Climate Suitability for maize
Average temperature (°C)	15–20
Rainfall (mm/year)	500–800

Source: FAO

Rainfall changes as shown in Figure 26-27, projected changes in the total monthly rainfall under downscaled CMIP5 GCMs for scenario RCP 4.5 for 2040–2060, will only have a small impact on the production of maize. Nevertheless, there is still a need to provide attention to building industry and community resilience. To increase the production of maize in Northern Cape, it is recommended that the government build an efficient irrigation system to ensure the availability of water for the crops and also create new varieties that are more resistant to drought to combat potential impacts of periodic drought and water shortages due to other competing water demands such as production of other crops, energy production, tourism, mining and meeting policy objectives to increase forested lands and expand plantation areas. There is some uncertainty over rainfall changes, so it is possible that Northern Cape will get drier, so it is important to consider adaptation plans for maize farming, as well as other industries that are water dependent. One of adaptation options is using a crop model to evaluate the impact of various sowing decisions on the water satisfaction index (WSI) and thus the yield of maize crop. The crop model is run for 176 stations over southern Africa, subject to climate scenarios downscaled from 6 GCMs. The sensitivity of these simulations is analysed by Crespo (et. al. 2011) so as to distinguish the contributions of sowing decisions to yield variation. By compared the WSI change between a 20 year control period (1979–1999) and a 20 year future period (2046–2065) over southern Africa, these results highlight areas that will likely be negatively affected by climate change over the study region. Then, calculation of the contribution of sowing decisions to yield variation, contributed to distinguish the efficiency of adaptation decisions under both present and future climate. In most countries rainfall in the sowing dekad is shown to contribute more significantly to the yield variation and appears as a long term efficient decision to adapt. These results and additional perspectives then can be discussed in order to propose local adaptation directions.

Good production of maize will lead to its industry expansion. The maize industry is an important contributor to foreign trade through the export of maize and maize products. The industry exports mostly to BLNS (Botswana, Lesotho, Namibia and Swaziland) countries, Zimbabwe, Kenya, Mozambique, Zambia, Mauritius and, in some years, to Japan. White maize meal is the staple food of a large section of the African population and this accounts for 94% of white maize meal consumption. Food processing is recognized as a potential source of job creation as well. The international maize market, especially the US market, has a dominant influence on the local exports, particularly in terms of food aid (DAFF, 2012). In order to cover all the maize demand and job creation targets, the industry also needs to consider the storage technology and the transportation to maintain the quality of maize.

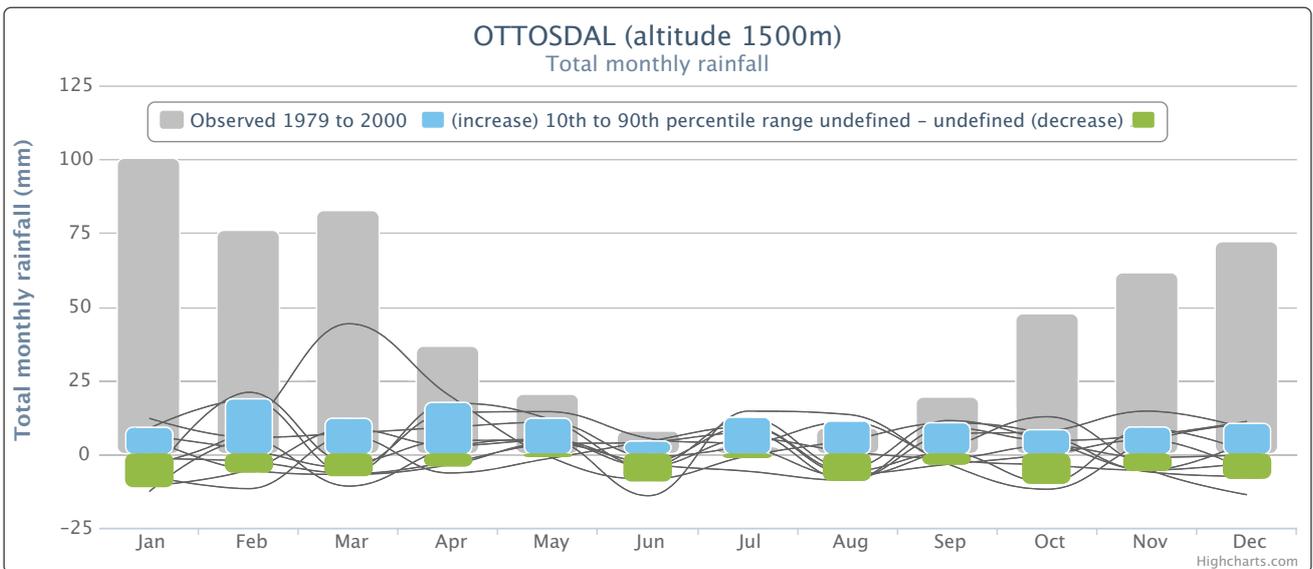
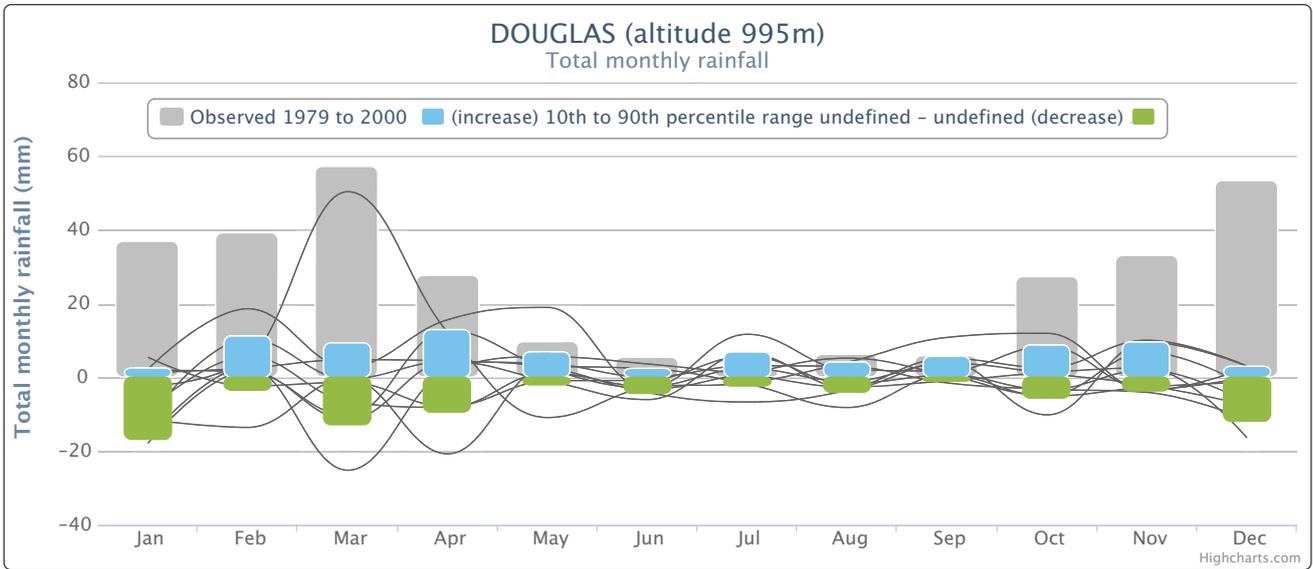
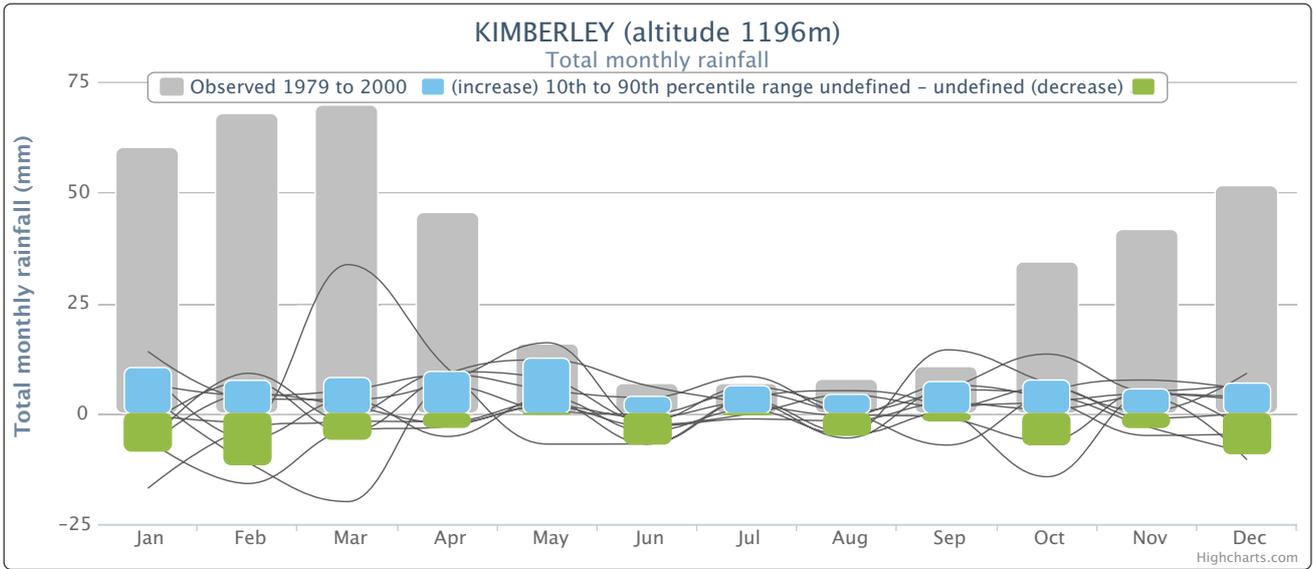


Figure 39. Projected Change in Monthly Rainfall Data Using SRES A2 for Kimberley (top), SRES A2 for Douglas (middle) SRES A2 for Ottosdal (bottom) (CIP, 2001)



6. OVERALL CONCLUSION

Wheat cultivation growth requirements for the Giza region of Egypt suggest that it currently has insufficient rainfall for optimum rainfed wheat production. Same problem applies for the orange farming. Although efforts to improve water drainage structures and irrigation channels may help to combat projected decreases in rainfall for wheat, oranges and other fruits and crops such as maize, rice, tomato and sugar cane, new varieties that can accommodate increases in temperature to address the spread of fungal diseases and drought will also be needed. In addition to improvements storage facilities and transportation efficiency in wheat and fruit juice industry, smaller producers should consider value added post-harvest production such as biodegradable plastics, paint stripping, raw materials for cosmetics and ethanol. Other adaptation measures are needed in Egypt to address sea-level rise, storms and an increasing competition for water, through improved coordination, the preparation of action plans, the establishment of monitoring processes to improve implementation procedures, planning and resource allocation amongst stakeholders.

Kenya possesses a rich set of policy, legislative and institutional frameworks that are embedded in various industrial operational structures of its governance to implement low-carbon and climate resilient industrial development. Opportunities exist to enhance the implementation of existing legislation. In the Kericho region, climate change models projections for rainfall and temperature suggest that it will be suitable for tea plantation until the year 2090. However adaptation measures such as a new tea species that are resistant to low temperature, hail and frost, will still be needed as the minimum temperature is too low and will affect the growth and the quality of tea. The Nakuru area is less suitable for planting tea because the average monthly rainfall is less than 100 mm and unevenly spread throughout the year, as well as higher predicted temperature in the future. As tea industries depend on the tea plantations, the farmers may have to support the adaptation actions. Renewable energy technologies may help to make the storage and the transportation system more efficient and sustainable; allowing the tea production industry to allocate its budget to help the production stage adaptation with climate change.

The Senegalese government has the technical capacity to integrate climate change in their development policies and plans through several of their political and institutional initiatives. Opportunities exist to improve regional planning, the implementation of town plans, and the use of renewable energy. Mid-term climate change projections for the Senegal river indicate a decrease in total monthly rainfall that could further reduce the river flow and affecting fish production in the area. As fisheries through frozen fish contribute to

“ South Africa, Kenya, Egypt, and Senegal – In all of these countries, projected decreases in rainfall and increasing water demands pose a challenge. ”

export earnings, food security and employment, opportunities exist to promote integrated irrigation and aquaculture programmes to increase exports and small-scale fishing to meet the local market demands. In addition, it will be important to ensure that the sustainability of this industry is improved through supporting participatory natural resource management, improving operations, post-harvesting processing and preservation, and waste minimization, as well as establishing climate insurance. Fishermen communities can also be strengthened through the provision of insurance and weather warnings to reduce climate risks.

South Africa has the technical, managerial and operation capacity needed to attain low-carbon and climate resilient industrial growth. Opportunities include the expansion of the use of renewable energy, particularly solar, whilst challenges relate largely to lower projected rainfall and in meeting increasing demands of water. Medium to mid-term climate change projections for the Northern Cape, South Africa, indicates a general decrease in rainfall and increase in temperature that has a low impact on maize and potato production. Nevertheless, increasing the production of maize and potato will require the building of an efficient irrigation system to ensure the availability of water, and the development of new drought resistant varieties to combat potential impacts of periodic drought and water shortages due to other competing water demands such as production of other crops and vegetables, energy production, tourism, mining and meeting policy objectives to increase forested lands and expand plantation areas.

The white maize is a staple food for a large proportion of the African population and the potatoes are the most important vegetable crop in South Africa and the world's recognised staple food consumed by many people. As food processing is recognised as a potential source of job creation, consideration should be given to improving storage technology and transportation infrastructure and planning, so that both market demands and job creation targets can be satisfied and fulfilled.

As there is also a certainly chance that the Northern Cape and Free State will become drier, it will be important to consider adaptation plans for maize farming and potato cultivation to support the vegetable industry, as well as other industries that are water dependent.

Analysis of the current and potential climate conditions to four selected sub-industries reveals a spectrum of situations ranging from lower impact in South Africa and Kenya, to those that exacerbate current non-optimal conditions in Egypt and Senegal. In all of these countries, projected decreases in rainfall and increasing water demands pose a challenge, suggesting that technological, managerial and operational capacities of all industries and other stakeholders must be strengthened to understand current water requirements and consumption and to enhance the efficient use of water in order to increase or maintain current production levels and to meet other basic and industrial needs. In addition, crop varieties that are resistant to low temperatures in Kenya, and those that are drought resistant in South Africa and Egypt, may need to be developed, in addition to the development of adaptation plans for some industries.

Further industrial development in all of the countries related to food processing will require improvement of post-harvest processing, storage technology, and transportation infrastructure and planning. Opportunities exist to ensure that low-carbon technologies are used in these improvements and to ensure that they are resilient to natural hazards.

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PART TWO

METHODOLOGIC FRAMEWORK

FOR VULNERABILITY MATRIX, POLICY
AND ACTION, AND CLIMATE VARIABLE
LINKAGE ASSESSMENTS

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Three sets of assessments
are to be conducted in one
or sequential workshops
with policy makers and key
stakeholders

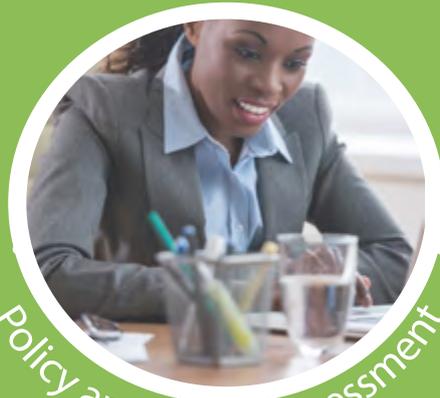
Workshop sessions



Vulnerability matrix assessment



Policy and action assessment



Climate variable linkage assessment



1. INTRODUCTION

The methodological framework of vulnerability matrix, policy and action, and climate variable linkage assessments were designed after assessing the experiences of international experts and the research of renowned organisations including CARE International, Stockholm Environment Institute, weADAPT.org, and University of Cape Town (For example, see CARE International, 2009 and Stockholm Environment Institute, 2007).

This framework uses agricultural industries to explain the process as agriculture is considered the most vulnerable sector in Africa (Hope Sr, 2009, Lema & Majule, 2009, Roudier, 2011). However, the framework can be applicable to any industries that are potentially affected by climate related disasters. These industries include agriculture and tourism as well as any industries requiring transportation and logistics since drought, flood, heat waves, and heavy rain affect them as well (Venner & Zamurs, 2012; Meyer, 2013).

The intended targets of this framework are technical staff working in government agencies and non-governmental organizations (NGOs), researchers and consultants involved in planning and policy making, particularly at sub-national levels. Basic knowledge on climate change and weather related disasters are required to understand the purpose of this framework. Moderate, although not necessarily as an expert, information on interactions between environmental, social, industry and weather related disasters need to be prepared before workshops with key stakeholders. This methodology should be read not only by researchers and consultants, but also by a facilitator developing the matrix with stakeholders.

This section first explains the framework of overall stakeholder exercises and how this relates to the report writing. Secondly, this section explains vulnerability matrix, policy and activity assessment, and climate linkage.

“

This methodological framework was designed after assessing the research of renowned organisations including CARE International, Stockholm Environment Institute, weADAPT.org, and University of Cape Town.

”

2. FRAMEWORK OF REPORT AND ASSESSMENT PROCESSES

Overall, the methodological framework has three sets of assessments, namely a vulnerability matrix assessment, a policy and action assessment, and a climate linkage assessment as shown in Figure 1. These sets of assessments are expected to be conducted in one or sequential workshops with policy-makers and key stakeholders. A vulnerability matrix will be developed first to identify processes that are sensitive to climatic disasters in a targeted supply chain. Disasters affecting these key processes will be also identified. In the policy and action assessment, the national project team ask what the policies in place are and previous actions taken for the key processes and disasters, and determine the potential actions and policies to be conducted in the future. Lastly, the team identify the different types of climate and other required information to make the policies and operational actions and procedures through pre-assessed knowledge and the Climate Information Portal (CIP) that is developed by The University of Cape Town’s Climate Systems and Analysis Group (CSAG, 2016).

“ The methodological framework has three sets of assessments, shown in Figure 1. ”

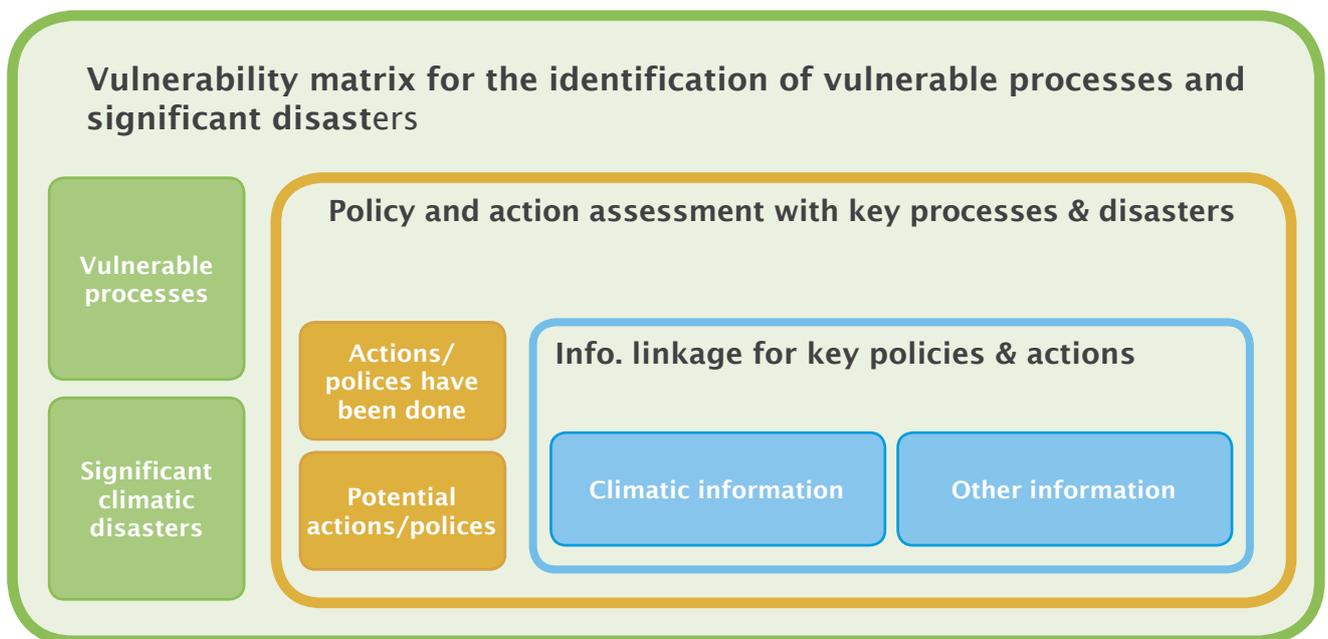


Figure 1. Framework of a stakeholder exercise. A vulnerability matrix identifies the most vulnerable process and disasters. A policy and action assessment discuss the policies and actions that had been conducted and should be carried out. Information linkage component identifies information required for the suggested policies and actions, including climate and non-climate information.

It is important to emphasise that the assessment used here is mainly based on the perception of stakeholders about the current and past climatic disasters. This means that this assessment is based on two assumptions: 1) Current climatic disasters will affect the target industry in the future at least as much as today, and 2) The perception of stakeholders is reasonably accurate. There are many uncertainties in the climate change prediction and the uncertainties will not disappear (Murphy, et. al., 2004; Knutti & Sedlacek, 2013). Elements subject to climatic hazards and trends are called ‘exposure units’ (Füssel & Klein, 2006; Jones, 2001).

Two types of vulnerability concepts associated with climate change adaptation have been widely accepted. The vulnerabilities of climate change have been defined differently, but it is categorised between outcome and contextual vulnerabilities (Takama, Takeshi, et al. 2016; Adger, 2006; O’Brien et al., 2007; IPCC, 2007). Outcome vulnerability defines vulnerability as the overall effect of climate change, once climate impacts, and adaptive capacity have been considered (Figure 2). Contextual vulnerability assumes that vulnerability is determined by the potential characteristics of issues, context, purpose, and system. Moreover, the context including social advancement, environmental issues, and economic developments is a part of UNIDO’s Green Industry initiative and related to the resilience to climate change (UNIDO, 2011). The green industrial initiative will reduce social and biophysical stresses. As a result of this, green industry will increase the resilience and reduce the vulnerability to climate change (Figure 3).

Scientists think that if the characteristics of an exposure unit, including socioeconomic status, geographical location, and political stability mean that it cannot cope with current climatic disasters, the unit is already vulnerable, i.e. contextual vulnerability (O’Brien et. al. 2007; Räsänen 2016) (Figure 2). In other words, contextual vulnerability assumes that vulnerability is determined by the potential characteristics of issues, context, purpose, and system. In the vulnerability matrix exercise, the assessment with stakeholders are based on the contextual vulnerability.

Since the vulnerability matrix and policy and action assessments focus on the contexts of the exposure unit, climatic information should not be the only factors considered during the workshop. It is recommended to identify current climatic conditions and disasters for the target industries briefly before the stakeholder workshop to check the credibility of stakeholders’ perception during the workshop. Subsequently, the perception can be checked after the stakeholder assessment by expert interviews with meteorological office and disaster management office as well as desktop studies. After the policy and action assessment, the results of vulnerability assessments and key adaptation policies and actions are linked with relevant climate information and the linkage brings this overall methodology into the framework of “outcome vulnerability” (Figure 2). If the climate information is gathered from relevant meteorological stations in Climate Information Portal (CIP), where the quality of information is good, it is always advantageous to follow up with expert verification.

“ Assessment used here is mainly based on the perception of stakeholders... ”

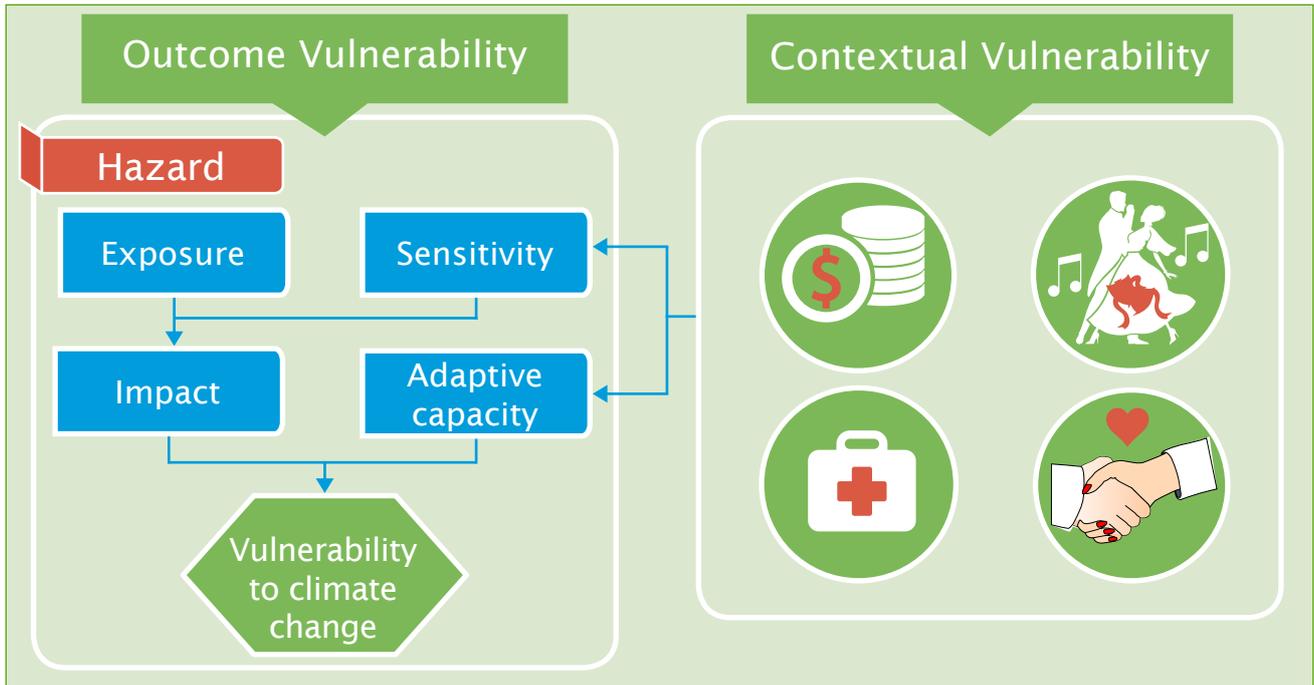


Figure 2. Vulnerability concepts and importance of finding issues, context, purpose, system, etc. Outcome vulnerability defines vulnerability as the compound result of impact assessments and adaptive capacity. Contextual vulnerability assumes that vulnerability is determined by the potential characteristics of issues, context, purpose, and system (Source: Takama, Takeshi, et al. 2016).

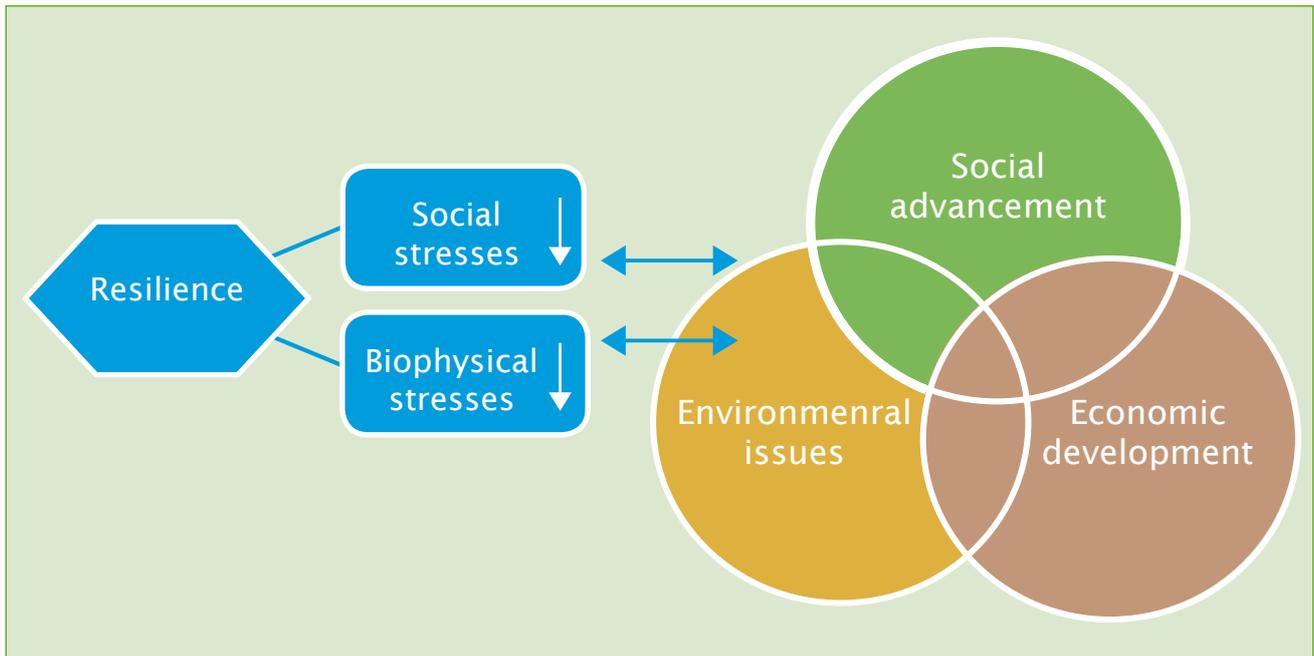


Figure 3. UNIDO’s green industrial initiative will reduce social and biophysical stress and therefore increase the resilience to climate change.



The assessment framework could be used for writing a report (Figure 4). The report writing process has an equivalent framework as the assessment framework, i.e. assessment purposes, workshop guideline, a vulnerability matrix, policy and action assessment, information linkage assessment, the clarification of assumptions and conditions, and feedback to policy makers and stakeholders. Identify assessment purposes, for example, understanding “why this assessment is needed”, “for whom this project is working”, and “when and where is the assessment area” is the first and can be the most important and crucial step in the assessment framework. Hence, this need to be clarified before the workshop and will be a source of introduction in the project report. The policy and action assessment has the most interesting discussion in the report

as this section recommends adaptation strategies for vulnerable processes. Similarly, interesting, the climate information linkage assessment and subsequent interviews with key stakeholders will advise on how the policies and actions can be achieved with the specified sets of information such as annual precipitation in a target region and market assessments.

In other words, it is important to recognise the reasons behind every step and how these steps contribute to the project report. The vulnerability matrix is an important output of the stakeholder exercise, but this is not the only output from the stakeholder exercises. The information gathered during the matrix construction is equally useful, if not more useful, in capturing contextualised information in the report.

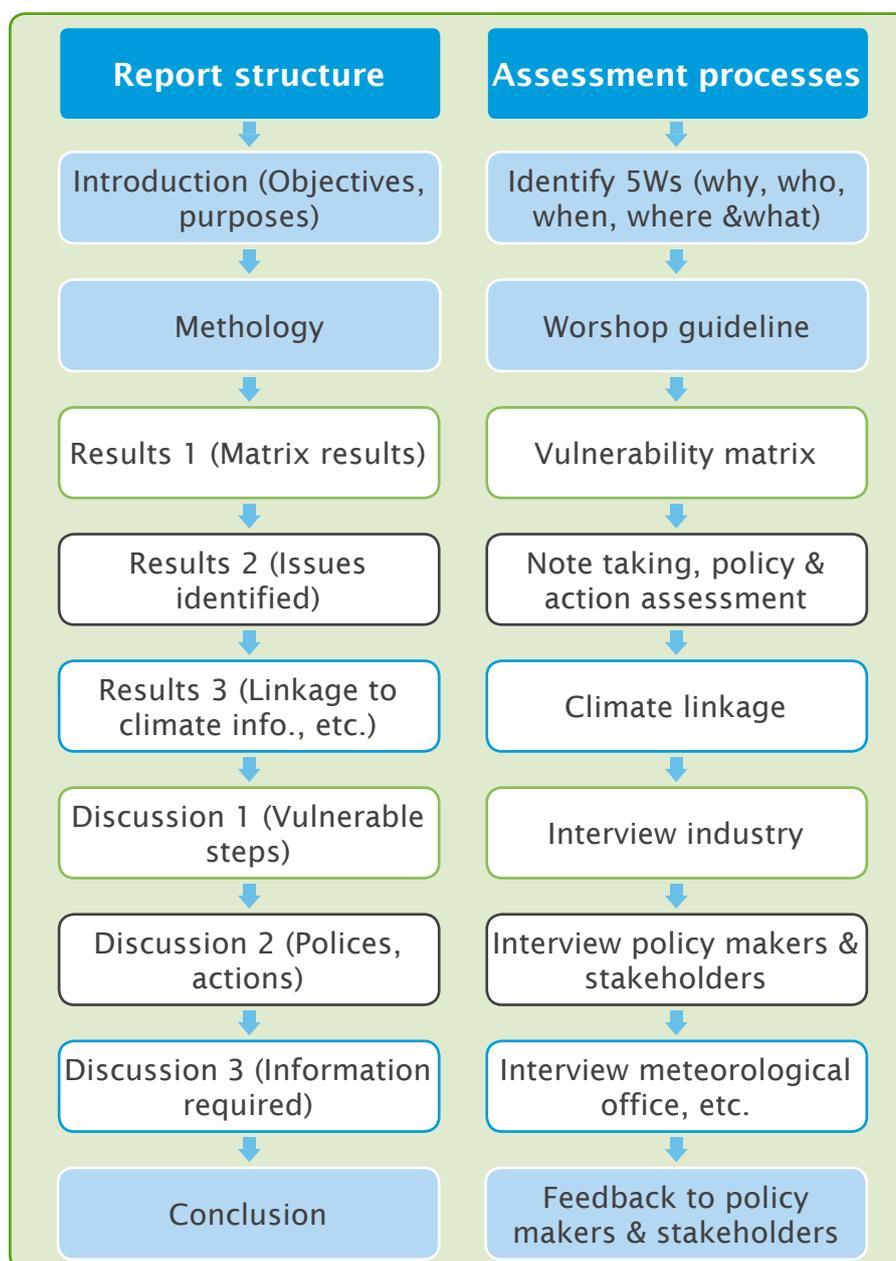
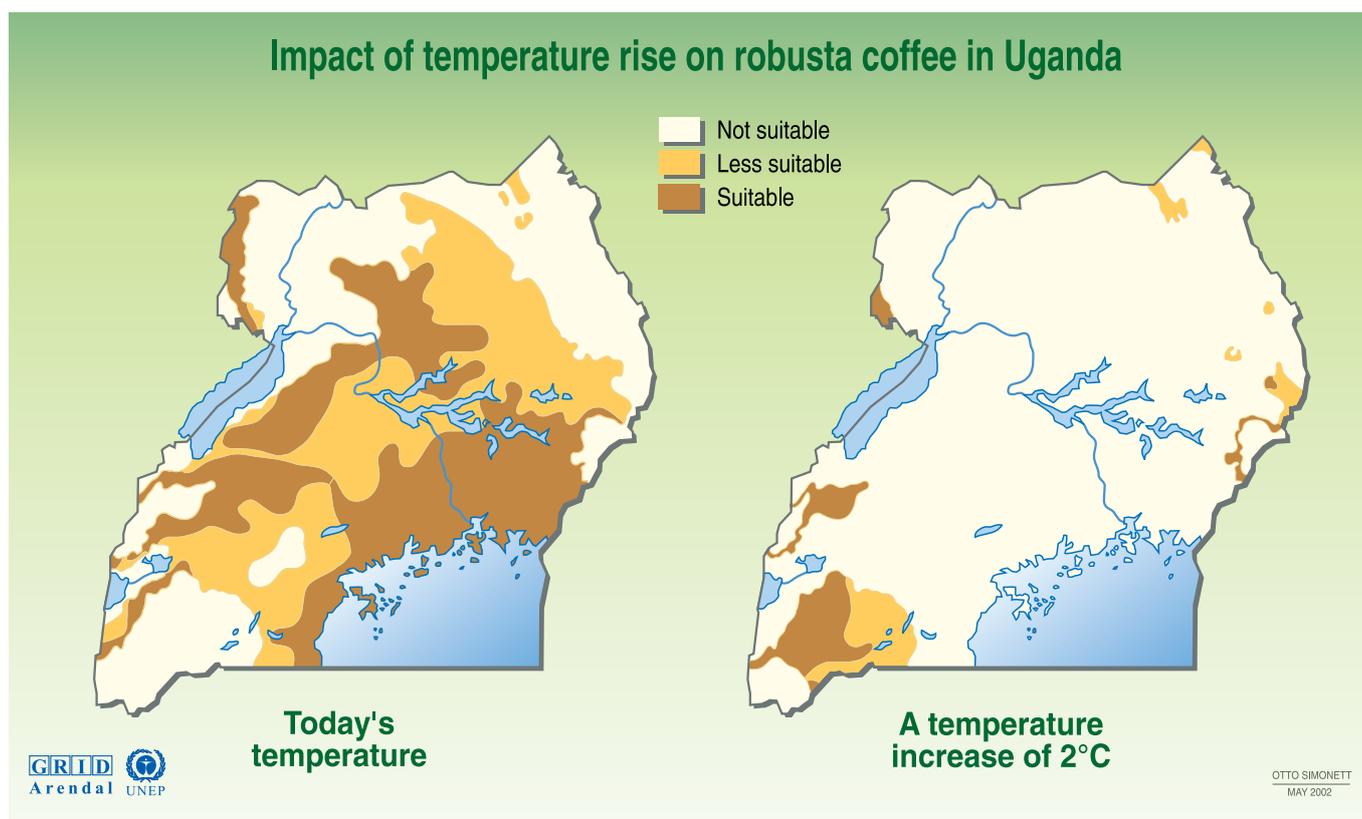


Figure 4. Reporting process is linked to the process of the three assessments.

2.1. Identifying Purpose of the Assessments

Understanding the purpose of the assessments is the most critical activity in this framework. The outcome of the assessment changes as the purpose of the assessment changes. For example, production in a coffee region in Africa was expected to decrease as a consequent of increasing drought severity (Figure 5) (SIMONETT, O. and UNEP/GRID-ARENDAL, 2005). In this case, a vulnerability assessment and adaptation planning for local farmers and a local coffee production company could make the recommendations for an irrigation system and agroforestry to preserve water. However, if the assessment was for an international coffee company, a recommendation may include shutting down the existing coffee production in Africa and buying coffee from Vietnam or Indonesia instead. In the latter case, moving their supply chain from Africa to Indonesia may be a good international strategy, but local African producers will be worse off from losing their international clients (DAVIS, et. al, 2012;

TUCKER, et. al. 2010). The outcomes will be significantly different depending on assessment purposes, so it is necessary to discuss the reason(s), objectives and intended targets behind the project.



Source: Otto Simonett, Potential impacts of global warming, GRID-Geneva, case studies on climatic change. Geneva, 1989.

Figure 5. Impact of Temperature Rise on Robusta Coffee in Uganda. In Uganda, the total area suitable for growing Robusta coffee would be dramatically reduced with a temperature increase of 2°Celsius. Only higher altitude areas would remain suitable, while the rest would become too hot to grow coffee. This study show the vulnerability of developing countries, whose economies often rely heavily on one or two agricultural products (Source Simonett, UNEP/GRID-Arendal, 2005).

Box article 1: Facilitation steps for identifying purposes of assessments

The first step of the workshop is identifying the purposes of the sequential assessments. For this, it is absolutely essential to include key stakeholders as participants, who should be part of the decision making team on how and when to conduct future adaptation policies and actions. It should also include experts who are part of the industry and possibly meteorological agency officers to provide credible information.

In this discussion, everyone has to be well-informed of the aim(s) of subsequent assessments and that the participants are asked to provide realistic purposes. For example, at the end of the workshop, an outcome for understanding bottlenecks for a particular sector in a specific location within foreseeable time period will be useful, even in the absence of an ideal solution, which works regardless of time and location. For this purpose, it will be helpful for participants to consider the 5Ws (why, who, when, where & what) before proceeding with the rest of the workshop. For example:

- Key users of an assessment, i.e. (1) which local organisation is willing to cooperate in developing climate change adaptation policies and activities? (2) Where the organisation is located and when the assessment will be conducted?
- Exposure unit, i.e. what is the vulnerable object, group and industry the project is assessing for?
- Purpose of the assessment, i.e. which policy and activity proposals the project may contribute to?
- Assumption of the assessment, i.e. which information is important as variables and what is good enough as assumptions?

The discussion focuses on the area of the assessment. It is important to identify planned adaptation policies and activities to make the assessment useful, and support science based policies and activities (MOSER, S.C. and BOYKOFF, M.T., 2013). After identifying the purpose, the workshop focuses only on issues, location and time relevant to the target industries, policies and activities.

2.2. Climate Change Vulnerability Matrix and Policy and Action Recommendation

The vulnerability matrix is developed by key stakeholders in a workshop. The matrix focuses on assessing production processes or supply chain in a targeted industry and their exposure to climatic disasters including frost, floods, cyclones, etc. A fairly rapid participatory exercise with stakeholders evaluating existing knowledge on climate vulnerability provides a first-order vulnerability assessment. This is useful in the identification of existing and planned strategies, policies and activities for the vulnerabilities as well as understanding the assumptions and issues raised during this exercise. Therefore, contextualised information obtained by note takers is as important as the semi-quantitative result of the vulnerability matrix.

Participants are asked to list all production processes down the left vertical axis of the matrix under the head-

ing 'exposure units'. Henceforth, the rows of the table are organised according to a hierarchy of production processes that are essential in productive activities. The potential climatic threats will be listed in the columns of the matrix, as shown in Table I. This matrix exercise will assess the key impacts of climatic disasters to the pre- and post-harvesting processes of the target exposure unit such as a variety of crop, livestock and small farmers involved. A severe heavy rain affects the drying process of millet processing and as a result it will affect a millet production company. In other words, this matrix assessment tries to identify a bottleneck in the flow of production processes.

As a rapid, scoping exercise, the matrix is filled by ranking each cell according to a four-point scale:

- 3 = significant impact on the exposure unit
- 2 = medium impact on the exposure unit
- 1 = low impact on the exposure unit
- 0 = no impact on the exposure unit

The rating of sensitivities depends on the outcome of exposures and hazards, and is used to identify the relative significance amongst exposure units and hazards. “3” is interpreted as “the impact on the exposure unit was not coped with historically or is unable to cope without an external support”. The number of “3s” is summed by rows and columns to show the overall vulnerability of the exposure unit. The group finalises the 3 or 4 most vulnerable exposure units based on the summed number by rows as well as contextual information identified during the exercise. The note taker summarises the key points of discussion that lead to the scores assigned, and any disagreements on the scores. The most severe climate disasters are also chosen in a similar way by summed number in each column. Please see Box 2 for more detail on this process.

After the matrices are completed, the assessment moves into the second stage which is identifying policies and actions to cope with the vulnerabilities. Before discussing potential policies and actions, it is necessary to study what policies and activities are currently in use and implemented in the past (Tschakert & Dietrich, 2010). From this lessons-learnt approach, the assessment distinguishes the different (if any) policies and activities that stakeholders would like to adopt and highlights the organizations responsible and involved in these policies and activities. Please see Box 3 for more detail on this process.

Table 1. Example of a vulnerability matrix for a millet processing production

	Climatic risks						Exposure indices	Potential policies/activities
	Flood	Drought	Insect invasion	Heavy rain	Delay rain season	... other		
Frequency	+	+	+		+			
Agricultural process								
Harvesting	3	3	3	2	1		3	
Transportation	2	0	0	1	0		0	
Storage	3	0	3	3	0		3	
Cleaning	2	0	0	0	0		0	
Dehulling	2	0	0	0	0		0	
... others							0	
							0	
Millet processing process								
Milling	0	0	0	0	0		2	
Granulation	0	0	0	0	0		2	
Grading	0	0	0	0	0		0	
Cooking	2	0	0	0	0		0	
Drying	2	0	3	3	0		0	
Packaging	2	0	3	3	0		0	
Transportation	2	0	0	1	0		0	
Distribution/sales	2	0	0	0			0	
... others							0	
# of 3s	2	1	4	3	0			

Box article 2: Facilitation steps for climate change vulnerability matrix

The exercise to construct a vulnerability matrix will be the main activity. The matrix illustrates technical issues using the indicators of vulnerability to a range of climatic risks. The analysis should focus on a particular region and industry. In this case, the project focused on production processes in a targeted business and industry against climatic disasters.

After preparing a matrix in advance (Table 1), the facilitator asks the group to focus on major processes and supply chain in their targeted industry as exposure units and list them. The group then work backward to list all production processes. If the list is too long, the group is asked to identify the exposure units that they consider to be most important in terms of the focused industry and climate change disasters.

List these prioritised exposure units down the left side of the matrix on a vertical axis. Thus, the rows of the table are organised according in a hierarchy of production processes that are essential in productive activities. For example, a general relationship between climate and the pre-harvesting processes will affect a variety of crop and livestock production activities as well as small farmers in agricultural industry. A severe heavy rain affects the drying process of millet processing and thus, it will affect a millet production company.

The next step is to list the present climatic threats (and possibly opportunities too) and trends that are significant for the list of production processes. These climatic risks are the columns of the matrix. Some judgments are required to distinguish the boundary of weather events and distinct threats. For instance, flood is often a significant threat in rural livelihoods, pre-harvesting agricultural business and a transportation system (Few, 2003; Barrow, 2014; Schweikert, et. al. 2014). Ordinary flood events may be internalised into a part of normal business, but heavy rain may not be (Dufty, 2010). Therefore, In this case, it is a good idea to list flood and heavy rain separately as shown in Table 1.

Please iterate the process and refine the rows and columns of the matrix. One of the purposes is to show how the thresholds of vulnerabilities differ between exposure units. The definition of flood risk can be quite different for different production processes and supply chain.

To assess the sensitivity of each exposure unit to each climatic risk, the group need to fill in the matrix by ranking each cell. A rapid, scoping exercise uses a four-point scale as shown below:

3 = significant impact on the exposure unit

2 = medium impact on the exposure unit

1 = low impact on the exposure unit

0 = no impact on the exposure unit

The assessment has to ensure that everyone in the group understands the scoring system. The rating of sensitivities depends on the outcome of exposure and hazard. This exercise will be used to identify the relative significance amongst the exposure units and hazards. Therefore, it will not be good if everything is “3” as the analysis cannot identify which exposure units and disasters are more important for further discussion. It may be appropriate to interpret “3” as “the impact on the exposure unit was not coped with historically or is unable to cope without an external support”.

Subsequently, the number of high scores such as those with a “3” has to be counted as this will provide a robust scoring system and hence recommend these processes as the ones incapable of coping with climatic disasters based on the definition in the previous step. With some caution, it may be interesting to sum the rows and columns into aggregated indicators.

The group makes a consensus and finalises the 3 most vulnerable exposure units. The note taker summarises the key points of the discussion that lead to the consensus scores, and any disagreements on the scores. The most vulnerable exposure unit selected by stakeholders is not necessarily the one with the most 3s in the scoring system. For example, pre-harvesting processes are expected to be more vulnerable in an agriculture related industry. However, if the purpose of the assessment is to find adaptation strategy for post-production, it is inevitable to place more weight on post-harvesting processes. The most severe climate disasters will also be chosen in a similar way.

Box article 3: Facilitation steps for assessing adaptation policies and actions

Following the identification of vulnerable exposure units is the discussion of existing policies and actions as well as proposals for the future. The main purpose of this discussion is to identify policies, activities and responsible organization(s) that could possibly work together to cope with vulnerabilities identified in the previous exercise.

Focusing on the three or four most vulnerable value chain processes in the face of inefficient or insufficient policies and actions, both previous and current, the group need to discuss the reasons behind the inefficiencies or insufficiencies of these policies and actions. The note taker transcribes the key points of the discussion, which can be categorised under different issues such as technology availability, economic viability, social acceptance, institutional support, financial availability and behavioural aspects. Similar discussion can be adopted for the most devastating climate disasters.

Based on the lesson(s) learnt from unsuccessful policies, actions and current circumstances, the group needs to identify realistic policies and actions which have not been implemented and may solve the vulnerable situation of certain value chain processes. For example, a conventional cold storage might not have been working well to cope with heat waves because of frequent electrical black out. In this case, evaporative cooling using charcoal that does not require electricity may work as potential adaptation action for heat waves (Tripathi, et. al, 2015; Noble, 2003). Write down key policies and activities mentioned in the discussion on the relevant row and column of the matrix and then report the results of the discussion back to other groups. If time allowed, discuss the possibility of collaboration to formulate more detailed policies and activities together with stakeholders. If not, please plan to design them further after the workshop.

2.3. Link Climate Variables to Planning Adaptation Policies

In this assessment, the policies and actions for the most vulnerable value chain processes are linked to climate variables. The objectives of linking climate variables are to identify (1) the climate information needed for target hazards, policies and actions; and (2) existing climate information and (3) information that can be gathered, even through informal climate observation systems. Under the contextual vulnerability theory, an analyst may define the vulnerability without climate information; however, if they can access climate information, more specific policies and actions can be designed. For example, if a road transportation can be a bottleneck for a fruit industry and the government plans to improve the road network, they would like to know where specifically they need to improve the connection. The precipitation information tells the location of heaviest rainfall and amount of rainfalls expected. In this exercise, communication means of climate information, which will be useful for the target policies and activities, will be identified as information linkages. Moreover, an online approach to get preliminary climate information is also discussed.

The vulnerability matrix as well as policy and action assessments focuses more on the issues at hand, but still considers potential climate disasters. Without linking climate variables, this assessment still works as a contextual vulnerability assessment on value chain. The link with climate information strengthens the vulnerability assessment, predicting outcome vulnerabilities more accurately and provides more opportunities for appropriate responses to potential climatic disasters (Figure 2).

Moreover, adaptation actions may not be practical enough if there is a mismatch in information on the geographical, institutional and temporal scales and needs for decision-making (Klein and Juhola 2014). Solving such problem require climate services that aim to produce, curate and tailor materials to meet stakeholder demands. The European Roadmap for Climate Services describes climate services as “transforming climate-related data – together with other relevant information – into customised products such as projections, forecasts, information, trends, economic analyses, assessments (including technology assessments), counselling on best practices, development and evaluation of solutions, and any other service in relation to climate that may be of use for the society at large”

(Street, 2015: 2). The Global Framework on Climate Services (GFCS) emphasizes the importance of providing “actionable information”, which is the key to “bridging the gap between users’ needs and climate services capabilities” (WMO, 2014). We need to facilitate shared understanding and learning to shape required climate information for influencing targeted climate actions (Jones et al., 2015). This exercise finds climate variables which are transformed into climate information and services.

For example, if road transportation delivering fresh fruits to a juice factory is affected by flood events, a few actions can be considered depending on the types of floods. If floods on the road happen for many days, but not severely, trucks with high vehicle height and appropriate tires will be an adaptation option as the trucks can go through the flood areas. If floods happen less often but more significantly, better storage management with cold storage capability and better flood forecast work as adaptation actions. When a severe flood is forecasted, more fresh fruits will be delivered to the cold storage of the juice factory before the flood.

To understand the areas needing flood support and adaptation options, the frequency and intensity of flood events, and their underlying drivers such as consecutive wet days and precipitation intensity, have to be collated, interpreted and understood. For the option with the cold storage, the station data of consecutive wet days can be sufficient, but more precise climate information is needed for the option of trucks with high vehicle height. The grid data of maximum daily precipitation along the logistic area will confirm a delivery route by the trucks.

Required climate variable eventually needs to be checked at a meteorological agency, though some information is available online. This assessment used Climate Information Portal (CIP)¹ developed by Climate System Analysis Group, University of Cape Town. CIP is a web interface that integrates observational and projected climate data and guidance documentation that facilitates the best use of the climate data. The CIP has been designed to be easy and intuitive to use to provide easy and simple access to various climate variables. The CIP allows any users access to climate change information such as precipitation and minimal and maximal temperatures of most developing countries in Asia and Africa without specific training. The website weADAPT.org² provides a simple step-by-step guidance on how to use CIP. The assessment is designed for use by technical staff working in government agencies and non-governmental organisations, as well as researchers and consultants involved in planning and policy making processes, particularly at sub-national levels. Using the assessment requires a basic to moderate level of knowledge on climate dynamics, the interactions between environmental, social and economic systems, as well as statistics.

If station data for the project site is not available on CIP, it is necessary to contact the national meteorological service and/or the local government office responsible for strategic information / Geographic Information System (GIS) / scientific services and enquire if they have data for your project location. Moreover, the climate data from the meteorological service have to consist of meta-data and be quality-controlled. Otherwise, extra processes are needed before the data can be used in the project.

“ This assessment used Climate Information Portal (CIP) of the University of Cape Town and weADAPT. ”

¹ <http://cip.csag.uct.ac.za/webclient2/app/>

² <https://www.weadapt.org/knowledge-base/using-climate-information/guide-to-using-climate-information>

Box article 4: Facilitation steps for linking climate variables to planning adaptation policies

This exercise is not necessarily to provide accurate information for numerical questions as those should be backed up by further research. For the hazards of concern and relevant policies identified, this exercise aims to identify critical variables such as precipitation for drought, unit of measurement such as millimetres for precipitation or Celsius for temperature, important period such as daily or monthly, and the level of detail such as gridded or station data. Other important information needed may include the onset of the rainy season. The informations are needed to assess how change will impact on the relevant hazard.

The types of climate information that might be needed for integrating climate change information into decision making are daily maximum temperature (Tmax), daily minimal temperature (Tmin), daily/weekly/monthly total, maximum and minimal precipitations as well as consecutive dry and wet days.

Examples of the type of climate variables that might be needed to assess the potential degree of climate hazard(s) could be as follows:

- Drought: evapotranspiration, dry spells (number of days \times mm)
- Winds: wind speed. maximum daily wind speed
- Heat wave: number of days Tmax $>$ x°C
- Flash floods: hourly or daily precipitation $>$ x mm; annual max daily precipitation; decadal cycles
- Water logging: soil water deficit, precipitation
- Landslide: soil moisture; accumulative daily rainfall
- Riverine: flood number of rainy days consecutively
- Cold spells: number of days T $<$ x°C
- Air quality/pollution: diurnal temp cycle, cloud top pressure
- Soil desiccation: evapotranspiration
- Fire: onset of rainy season; 5 consecutive dry months with Tmax $>$ x°C



Box article 5: Facilitation steps for using Climate Information Portal to support adaptation planning and policy-making

This exercise follows guidelines on using the climate information on CIP which were originally developed on weADAPT.org³. CIP can produce quickly and easily accessible climate data for many locations across Africa and some across Asia. This exercise is the process of social and institutional learning in a specific context on climate-related risk which was investigated in the last exercise and not a meteorological exercise on the projecting climate. The climate information needed is dependent on the stakeholder group, situation, and location. In a fresh juice industry, farmers may need a pinpoint daily precipitation data to grow fruits. In contrast, a distribution company may want to have monthly grid data on precipitation to decide an optimal delivery route. Climate information on adaptation options, risk and opportunities will never be perfect or complete as there will always be some sources of uncertainty in climate change. However, this does not mean that you cannot make robust and legitimate decision. Instead, an analyst needs to consider multiple viewpoints and knowledge, bringing together a team of responsible leaders and make decisions with the stakeholders.

This evaluation will identify the key climate sensitivities in your study area or project site, based on the livelihoods/economic activities practiced and the infrastructure and services relied upon. The assessment will find the historical periods, time of year, frequency of climate impacts experienced and other elements that occurred during the unfavourable climate conditions, consequently making the impacts worse.

Step 1 – Clarify data demand and supply for the vulnerability, policy and actions

Based on the vulnerability matrix exercise, this step reaffirms the initial question that the climate data from CIP in this exercise was carried out for. For any location, there may be a wide range of climate data available, only some of which are relevant to the focus of the target exposure units discussed above. Temperature projections may not be useful for the distribution process unless cold transportation is considered. A clear planning or policy question as

³ <https://www.weadapt.org/knowledge-base/using-climate-information/guide-to-using-climate-information>

well as the result of the vulnerability matrix can be considered to decide which data are important, and to what level of detail is required. Only relevant climate data and graphs will be included in the final report for explaining the key policies and actions to adopt for the vulnerability condition.

Step 2 - View climate stations on CIP and current climate conditions

From the CIP website⁴, turn on “African merged stations CMIP5”. Go to the target location of interest on the map and look for surrounding stations where climate data is available. Click on the station closest to the vulnerability assessment area that has the most similar climate conditions. In some cases, the closest station in terms of distance is not the most similar. Consider the influence of elevation, mountains, water bodies, forests, etc. when selecting station of choice. A graph of historical climate by monthly averages are presented at that location. From the data, an analyst can find, for example, the rainy season periods such as months with the most rainfall on average and the average temperature range throughout the year.

It may be beneficial to download graphic images for documentation to show a good overview of the average climate of the selected location over the last few decades. If the station is not close to the project site, it is important to add some text drawing attention to the fact that there might be local variability in the climate. The extent of such variability is location-specific, depending on the topography, land cover, proximity to the ocean, etc.

Step 3 - View future climate projections

This step looks at future climate projections. Clicking through to the future climate scenarios with downscaled projections for selected station. The projections were based on numerous global climate models that have been statistically downscaled to the station location. The projections show the variables where the central value and the spread were generated by 10 different climate models across two different emissions scenarios, namely RCP 8.5 and RCP 4.5.

⁴ <http://cip.csag.uct.ac.za/webclient2/app/>

RCP stands for Representative Concentration Pathways, a new set of scenarios, based on different radiative forcing levels that are linked to different concentrations of greenhouse gases (Collins, et. al., 2013). Climate projections based on two of the four RCPs are presented in CIP. RCP 8.5 is the high-end scenario in which most countries have continued with carbon intensive industries and lifestyles while RCP 4.5 is the lower-middle scenario in which emissions have been cut considerably but more could still be done.

Looking at the projections is a useful process to consider the difference in climate between recent past and near future, as grey observed series show the historical records and coloured projected anomalies show changes relative to the observed climate (For example, Figure 6). The difference also indicates the direction, range and magnitude of change at critical times of a year.

Step 4 - Look at data for other nearby stations

It will also be useful to look at other stations near the target site if other stations show significantly different historical and projected patterns. If so, the causes of significant differences, for example, height of the sta-

tion, should be considered. Proper adaptation policies and actions should be conscious of the differences and their causes.

Step 5 – Linking climate information and policy and actions

The previous steps identify how the climate has been in a target location and how it might change in the future under various scenarios. This step looks at what this might mean for the policies and actions identified in the vulnerability matrix exercise. This analyse how the work, infrastructure and services that the industry provides can be affected by the changes in climate. Then, the step will again consider what the industry could do and will plan and make new adaptation policies and actions in preparation for the new patterns.

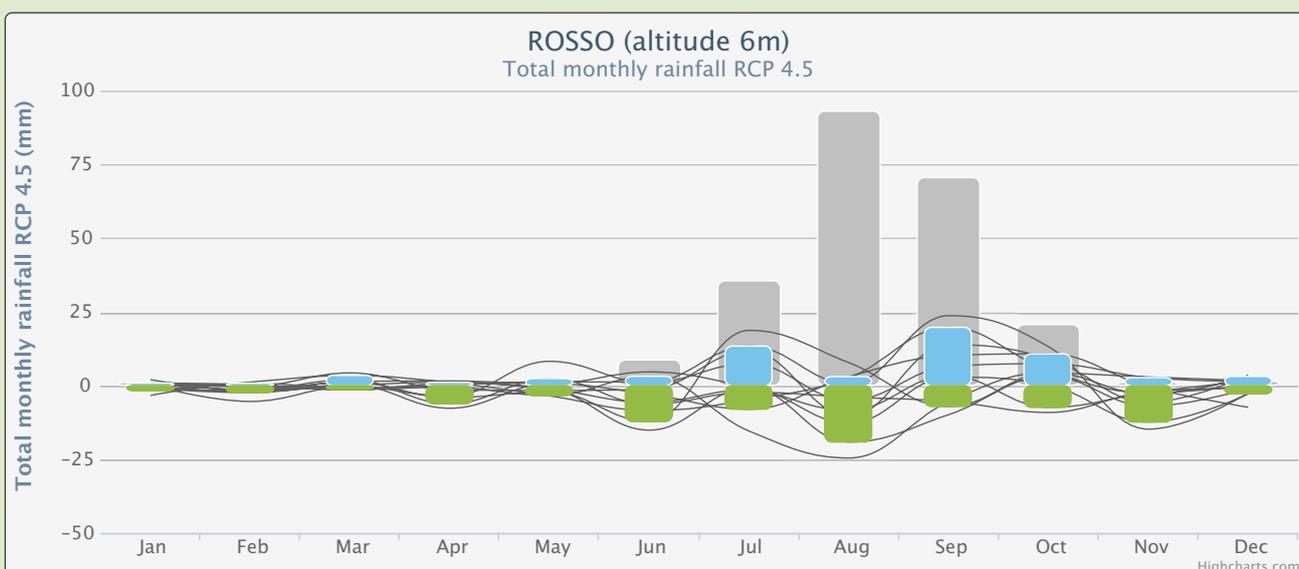


Figure 6. Projected Changes in Total Monthly Rainfall Scenario RCP 4.5 in Rosso Station in Senegal, 2046–2065 (CIP, 2001)



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PART THREE

VALUE CHAIN MATRIX

**ASSESSING THE VULNERABILITY OF
INDUSTRIAL VALUE CHAIN**

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1. INTRODUCTION

Egypt and Kenya are two of the vulnerable countries in Africa which have been selected as a part of regional projects on low-carbon and climate resilient (LCCR) industrial development in African countries.

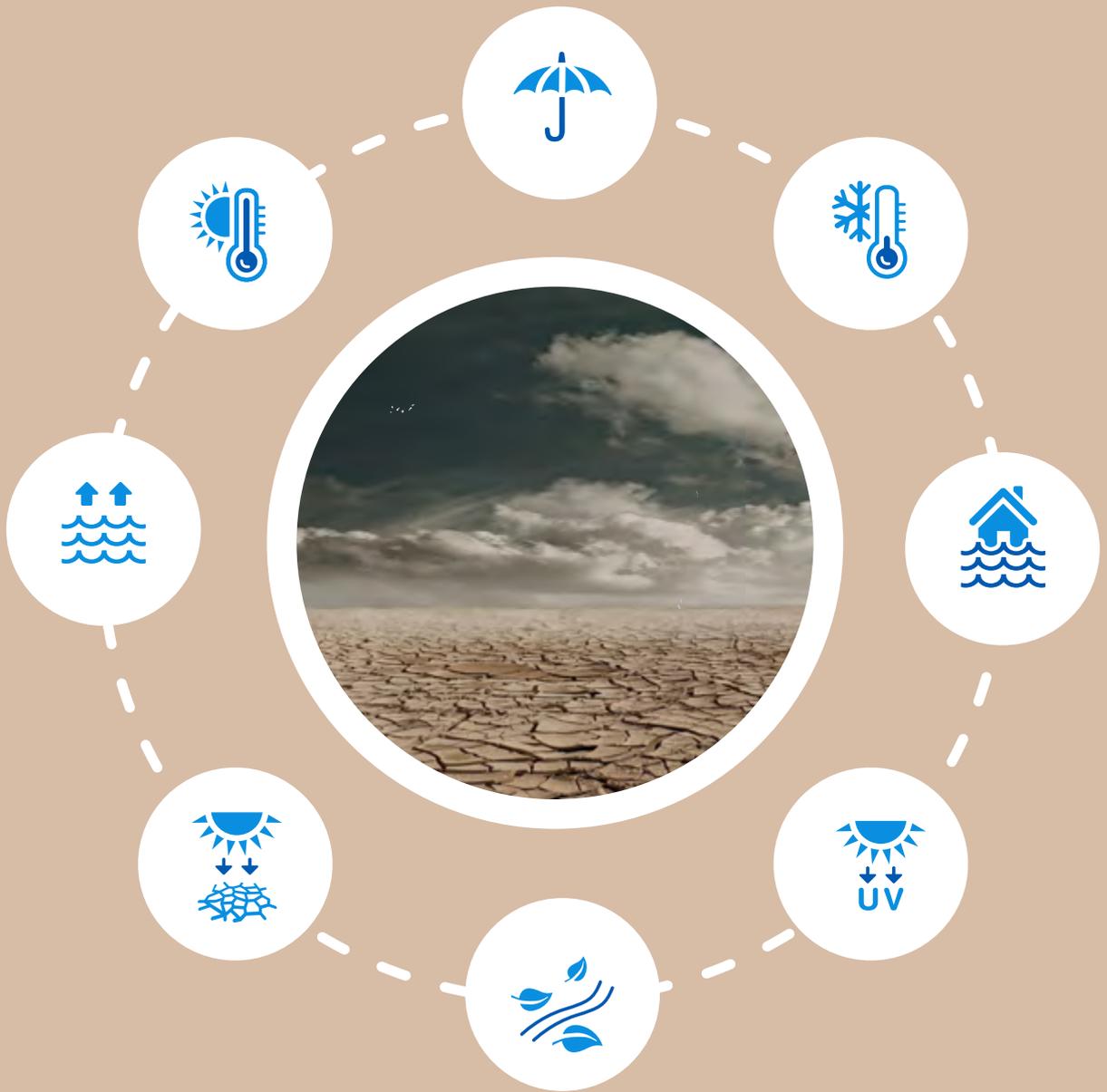
Egypt has a wide range of active agro-food industries, where both public and private sectors are involved, with the private and investment sectors playing a progressively important role. The current agro-food industries range between very developed industries, such as the cane sugar and meat industries; and newly introduced and developing ones such as flavours, aromatic and food additives industries (Raynolds, 2004). At this point, a quick review of some of the presently active agro-food industries in Egypt, their role and size, their prospects and some of the obstacles facing them, might be appropriate.

In Kenya, agriculture is one of major industries alongside forestry and fishing, mining and minerals, industrial manufacturing, energy, tourism and financial services. Within the agriculture industry, sugar is the second largest contributor to Kenya's agricultural production growth after tea (Riisgaard, 2009).

This report studies the vulnerability of selected major industries in Egypt and Kenya based on the vulnerability matrix. The matrix was developed to identify processes that are sensitive to climatic disasters in a targeted value added chain. The processes were developed with the vulnerability matrix. It is measured on a scale of 0-3 depending on their impact (0 = no impact on the exposure unit, 1 = low impact on the exposure unit, 2 = medium impact on the exposure unit, 3 = significant impact on the exposure unit) (See Methodological Framework). The result of the matrix can be utilised to prepare mitigation and adaptation strategies for the selected industries.

“ Egypt and Kenya – a part of regional projects on low-carbon and climate resilient (LCCR). ”





2. CLIMATIC DISASTER

The vulnerability matrix considers several weather-related disasters. Weather-related disasters appear to be increasing in frequencies with more severe outcomes throughout Africa and the world, affecting many industries. Weather predictions have become much more accurate but even with all the technology available, the extent of drought-related damage involves many variables, one of which relates to the awareness and actions of the people affected by the drought (Taylor, et. al., 2012).

2.1. Heavy Rain



Heavy rain has a significant effect on storage, especially in open storage areas in some facilities. This will lead to damage of some raw materials, such as the chemicals used in the industrial production processes. A substantial increase in hazards related to heavy rain is projected over Africa in the future (Hellmuth, 2007).

2.2. Flood



Flooding in key agricultural production areas can lead to widespread damage to crops, fencing and loss of livestock. Crop losses through rain damage, waterlogged soils, and delays in harvesting are further intensified by transport problems due to flooded roads and damaged infrastructure. The knock-on effects of reduced agricultural production can often impact well outside the production area as food prices increase due to shortages in supply (Piao, et. al. 2010).

Floods will mainly affect the transportation process especially final product transportation as the final products are mostly cold products which need to be delivered in time to avoid spoilage (Venner & Zamurs, 2012; Meyer, 2013). Transport access is essential for industrial partners to deliver the products. Never is that basic access more appreciated, and more desired, than when it's taken away from us, in a major flood. Movement is essential to both producers and consumers to restoring value chain to normal. The transportation systems must keep people and goods moving in proper condition and getting product value chain working again soon after a disaster such as flood.

Floods are incredibly destructive, causing millions of damages to main roads network. In addition, not only one transport type is lost to the floodwaters, as ferries are shepherded to safety in bay, trucks are moved to higher ground, and

“ The vulnerability matrix considers several weather-related disasters. ”

the rail system similarly secured. The ferries can lose most of their pontoons and kept out of action for a modest period. The floods can hit city/area systems hard. The electrical rail system can stop functioning due to loss of electricity as part of the area power outage. There are potential landslides across the rails, fallen trees along the road and smashed signals (Suarez, et. al. 2005).

2.3. Frost Bite



Frost bite affects the storage of raw materials especially in open storage areas. It also affects the blanching process as it will require more energy to reach the required temperature of blanching (Yi & Huanwen, 2009).

2.4. Strong Wind



The transportation of raw materials and final products are the most affected processes in fruit and vegetables processing as some roads and ports are closed when faced with strong wind (Jussila, et. al, 2014). Storage of raw materials is also affected as some of the raw materials might be damaged by the dust and sand blown in by the wind.

2.5. Rise in Sea Level



Any rise in the sea level might affect the areas nearby if there are any industrial facilities close to the sea. Coastal areas all over the world are expected to suffer from impacts of sea level rise as well as other impacts, in addition to already existing problems of coastal erosion, subsidence, pollution, land use pressures and deterioration of ecosystems (El-Raey, et. al. 1999). One such case is the Mediterranean Sea, where major industries facing this sea are affected by rise in sea level. The sea level rise in Mediterranean was observed with the climate variables and compared with detected trends. The economic and social consequences of sea level rise have direct impacts on major industries together with indirect impacts on the economic system (Dubois, et.al 2013).

2.6. Drought



Drought is a prolonged period of no rainfall. If drought occurs, there will be shortage in water and this will have one of most significant effects on the entire agro-food industry as water is involved in many industrial processes. These processes included washing of the raw materials, cooling and blanching of products (Seneviratne, 2007).

2.7. Rise in Temperature



Global warming or rise in temperature appears to have been occurring for the last 30-50 years. This warming may only be a short-term fluctuation but could be a longer-term trend. It is still inconclusive based on the available

“Coastal areas all over the world are expected to suffer from impacts of sea level rise.”

evidence whether man is causing the warming. No “natural” causes for global warming have been confirmed yet. One possible new theory proposed is that galactic cosmic radiation (GCR) modulated by solar activity affects low-level cloud cover and is causing the warming (Vardiman, 2007). Rise in temperature is the most im-

portant disaster as it will have a significant effect on the industry at different levels. First, it will affect the fruits and vegetables that will become rotten or spoiled (McMichael, 2007). Secondly, it will affect the electric cables causing disruption to electricity supply and all the industrial processes will be stopped.





3. EGYPT

One of the major enterprises in Egypt is the fruit and vegetable processing industry, occupying a significant place in food supply (Waldhauer, 2015). The output of these types of industries in Egypt was estimated to exceed 20 billion Egyptian Pound (EGP), greater than any other industrial sectors and comprising almost 40% of the industrial activities in the country and achieving 10-18% annual increase in output (both quantity and value) (Omran, Pointon, 2004). Meanwhile, over recent decades the meat processing industry has also made tremendous adjustments to meet the increasing demand for inexpensive and safe supply of meat and poultry (Taha, 2003).

3.1. Vegetables and Fruits Processing

The vulnerability matrix for vegetables and fruits processing was developed with representatives from EEAA (Egyptian Environmental Affairs Agency), UNIDO, Food Technology Centre, EMA (Egyptian Meteorological Authority) and national experts from ENCPC (Egyptian National Cleaner Production Center). The matrix focused on production processes in a targeted business and industry, namely Fruit and Vegetables Processing against climatic disasters including frost, floods, cyclones, etc.

3.1.1. Value Chain and Vulnerability Matrix

The fruit and vegetables value chain is presented in Figure 1. This value chain includes several segments: inputs, production, packing and storage, processing and distribution and marketing. The important inputs for production in this industry are seeds, fertilizers, agrochemicals (herbicides, fungicides and pesticides), farm equipment and irrigation equipment.

Logistics and transportation fulfils key supporting functions, while government regulatory bodies are required to approve the sanitary and phytosanitary conditions of outbound products. Due to the fragile and perishable nature of the product, a high degree of coordination between the different participants along the chain is required. This ensures that the perishable product reaches its destination in good condition (Gereffi & Fernandez-Stark, 2011). Cold storage units are used throughout the chain to keep the produce fresh, and both air and sea freighting supported by the cold chain are key elements to ensure timely delivery.

“ One of the major enterprises in Egypt is the fruit and vegetable processing industry – achieving 10-18% annual increase in output. ”

Gereffi & Fernandez-Stark (2011) found that the main stages of the value chain are as follows:

Inputs: Elements needed for production, such as seeds, fertilizers, agrochemicals (herbicides, fungicides and pesticides), farm equipment and irrigation equipment.

Production for Export: Includes the production of fruit and vegetables and all processes related to the growth and harvesting of the produce, such as planting, weeding, spraying and picking.

Packing and Cold Storage: Grading, washing, trimming, chopping, mixing, packing and labeling are all

processes that may occur in this packing stage of the value chain. Once the produce is ready for transport, it is blast chilled and placed in cold storage units ready for export.

Processed Fruit and Vegetables include dried, frozen, preserved, juices and pulps. Many of these processes add value to the raw product by increasing the shelf life of the fruit and vegetables.

Distribution and Marketing: The product is distributed to different channels; including supermarkets, small scale retailers, wholesalers and food services.

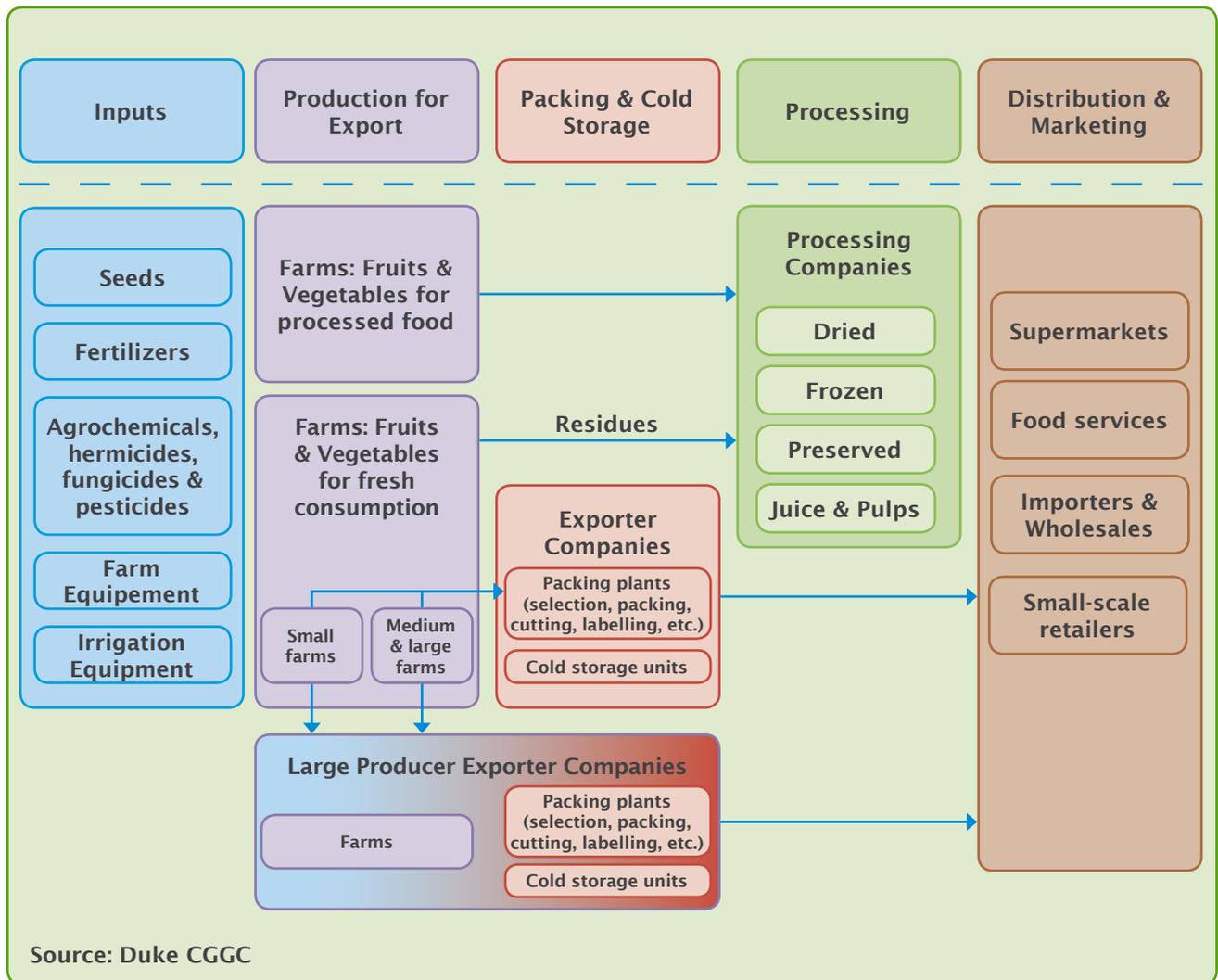


Figure 1. The Fruit and Vegetables Value Chain



The matrices (Table 1 and Table 2) started from the collection process and not from the agriculture process. There are many types of fruits and vegetables that are used as raw materials for collection process and many parameters vary according to the type of the product (Seasons of agriculture, location of agriculture, agriculture in greenhouses or open-field, etc). The matrices cover different areas in Egypt.

Table 1. Climate change vulnerability matrix for Frozen Fruit and Vegetables

	Heavy Rain	Flood	Frost Bite	Strong wind	Rise in Sea Level	Drought	Rise in Temperature	Number of 3s
Frequency	–	–	–	–	+	+	+	
Collection	1	0	0	0	0	0	0	0
Transportation	1	2	0	2	0	0	2	0
Storage	3	0	1	2	0	0	3	2
Washing	0	0	0	0	0	3	0	1
Cutting	0	0	0	0	0	0	1	0
Blanching	0	0	1	0	0	3	2	1
Water Cooling	0	0	0	0	0	3	2	1
Freezing	0	0	0	0	0	0	3	1
Sorting	0	0	0	0	0	0	1	0
Packaging	0	0	0	0	0	0	1	0
Cold Storage	0	0	0	0	0	0	3	1
Transportation	1	3	0	2	0	0	3	2
Number of 3s	1	1	0	0	0	3	4	

“ The matrix focuses on Fruit and Vegetables Processing against climatic disasters, including frost, floods, cyclones. ”



Table 2. Climate change vulnerability matrix for Fruit Juice

	Heavy Rain	Flood	Frost Bite	Strong wind	Rise in Sea Level	Drought	Rise in Temperature	Number of 3s
Frequency	—	—	—	—	+	+	+	
Collection	1	0	0	0	0	0	0	0
Transportation	1	2	0	2	0	0	2	0
Storage	3	0	1	2	0	0	3	2
Washing	0	0	0	0	0	3	0	1
Preparation	0	0	0	0	0	0	1	0
Cooking	0	0	1	0	0	3	2	1
Dilution and sugar addition	0	0	0	0	0	3	2	1
Pasteurisation	0	0	0	0	0	3	3	2
Packing	0	0	0	0	0	0	1	0
Sterilisation	0	0	0	0	0	3	3	2
Storage	0	0	0	0	0	0	0	0
Transportation	1	3	0	2	0	0	3	2
Number of 3s	1	1	0	0	0	5	4	

“ Storage of frozen fruit and vegetables is highly affected by heavy rain and rise in temperature. ”

After a brainstorming session with different stakeholders to identify the potential climate change disasters that might affect fruit and vegetables processing sector, we agreed on discussing these following factors.

Storage of frozen fruit and vegetables is highly affected by heavy rain and rise in temperature. Future climate projection shows that the average maximum temperature is likely to increase over the years. Average maximum temperature will increase up to or more than 35°C, especially in May and October. June to August are projected to be the hottest months (See Synthesis Report). Rise in temperature has minor effects on other production processes such as the fruit and vegetables blanching, cooling and transportation. Rise in temperature also affects the storage of fruits and vegetables (Wilson, et. al. 1999). It is proven by the matrix that, in addition to storage, it also affects

the freezing process and transportation of the products significantly as the energy required to reach the freezing temperature will be substantially larger. Transportation is disrupted by flood as well. Meanwhile, drought has been occurring in Egypt and causing shortage in water; and it has one of the most significant effects on this industry as water is required in many industrial processes (Arafat & Ezz, 2015). These processes are washing of the raw materials, cooling and blanching of fruits and vegetables. Even so, transportation and storage are still more affected along the value chain.

In fruit juice industry, transportation and storage are also the most affected processes, alongside pasteurisation and sterilisation processes. These four processes are highly affected by rise in temperature. Temperature affects water availability and water is a key raw material crucial for production of juice. Water is used in the pasteurisation and sterilisation processes for the juice (Mohamed, et.al, 2010). Drought affects the most number of processes including washing, cooking, dilution and sugar addition, pasteurisation and sterilisation. Historical climate data shows that for the 1979–2000 period, the rainfall pattern in the agriculture region was characterised by drought (See Synthesis Report) suggesting that drought is a manageable climate condition in Egypt to a certain extent. On contrary, unexpected heavy rain is more likely to impact on storage and flood poses a threat for transportation process.

Egypt is subjected during some periods of the year to heavy rain, greatly affecting the roads and increased periods of heavy rain have remarkable effects on the storage in the industry. Flooding during January 2010 is highlighted here as an example of a recent extreme precipitation event affecting Egypt. In January 2010, heavy rain exceeding 80 mm/day, led to the worst flash-floods in Egypt since 1994. The floods affected the Sinai Peninsula, the Red Sea coast and the Aswan Governorate in southern Egypt, and led to 15 deaths and hundreds of homes destroyed (Attaher and Medany, 2011). This kind of flooding lead to transportation disruption and the damage of some raw materials, for example some vegetables, fruits and chemicals used in the production process (Workshop, per. com). Possibility of heavy rain occurrence increases in the delta region and coastal areas, which are our target areas.

In the past, Egypt was subjected to floods, especially in Upper Egypt, that caused damages and so might be subjected to floods again with the changes in the climate. Frihy (2001) in Ocean and Coastal Management Journal indicated that the dam was successful in controlling floodwaters and ensuring continuous water supplies, but water consumption became excessive and would have to be controlled. Some valuable land was lost below the dam because the flow of Nile silt was stopped, and increased salinity remains a problem. Furthermore, the drought in the Ethiopian highlands — the source of the Nile River’s water — caused the water level of Lake Nasser, the Aswan High Dam’s reservoir, to drop to the lowest recorded level in 1987. In 1996, however, the level of water behind the High Dam and in Lake Nasser reached the highest level since the completion of the dam (White, 1988; Wolters, et. al, 2016). Controlling the floodwater is important for reducing threat to transportation process in the industry.

Another climate variable is frost bite. It can occur in the early winter mornings, and affects the fruits and vegetables as raw materials (Paul, n.d). It also affects blanching process of the frozen fruit and vegetables industry. In fruit juice industry, it impacts on cooking process. Frost bite affects the value chain in small scale. In medium scale, there is strong wind which occurs

“ In fruit juice industry, transportation and storage, alongside pasteurisation and sterilisation processes are highly affected by rise in temperature. ”

in Egypt's spring season with limited effects but increased intensity and frequency may affect agriculture and related industries (Yizhaq, et. al. 2007). The transportation of raw materials and final products are the affected processes in fruit and vegetables processing due to road closures as a consequent of strong wind (Youssef, et. al., 2011). The storage in the industry as well as the fruit juice industry are also affected by the strong wind.

Along Egypt's northern and eastern borders are Mediterranean Sea and Red Sea, hence, any rise in the sea level affect the areas with industrial facilities near the sea. Many of these facilities facing the seas are part of the major industries in the country. The spatially-average projected sea-level rise by 2040-2050 will be 9.8 and 25.5 cm in the Mediteranian Sea in MIN50 and MAX50 scenarios, respectively (GALASSI & SPADA, 2014). However, based on the matrix above, the sea level rise doesn't affect the frozen fruit, vegetables and fruit juice industries.

In conclusion, for Frozen Vegetables and Fruits, a rise in temperature is the most significant disaster as it affects four production processes so the industry must make an adaptation plan for this kind of disasters. Droughts and water shortage affects three industrial key processes, namely washing, blanching and water cooling. As the second most significant disaster based on the matrix exercise, the industry must know how to adapt to it. In general, the most industrial processes affected by the climate related disasters are storage and transportation as they are exposed twice.

For Fruit Juice, drought is the most significant disaster as it affects five production processes, namely washing, sterilisation, cooking, dilution and sugar addition and pasteurisation; so, the industry must make an adaptation plan for this kind of disasters. A rise in temperature affects four key industrial processes as the second most significant disaster and the industry must prepare to adapt to it. The industrial processes most affected by the climate related disasters are storage, pasteurisation, sterilisation and transportation as they are exposed twice.

“ Industrial energy efficiency has constantly improved in recent years. ”

3.1.2. Mitigation Potential

The result from value chain analysis advocates that the industry needs mitigation and adaptation strategies to increase resilience of the vulnerable processes. There are several mitigation measures to attain higher energy efficiency and hence Green House Gasses GHG mitigation. Below is the list of energy efficiency measures for fruit and vegetable processing industry presented in the US energy guideline (Shah, 2012).

Cross Cutting Energy Efficiency Measures

The world faces a looming and potentially calamitous weather, with demand for cold technology like air conditioning and refrigeration growing so fast that it threatens to undermine pledges and targets for global warming (Stern, 2007). The result of vulnerability assessment (VA) above indicated that drought will have significant impact leading to increased consequential use of cold technology. Therefore, energy saving technology will be important as a mitigation measure. Nearly more than half of the global delivered energy and almost 40% of worldwide CO₂ emissions are attributable to industrial activities (DE DONATIS, 2012). Industrial energy efficiency has constantly improved in recent years, despite the existence of a wide range of barriers, and several cross-cutting energy efficiency measures (EEM) being exploited is as follows.

a) **Steam Systems**

Many manufacturing facilities can recapture energy by installing more efficient steam equipment and processes, and applying energy management practices (Fritzson, Berntsson, 2006). Use the tools listed below to optimize performance and save energy.

Boilers	Steam Distribution Systems	Process Integration
Boiler process control	Improved distribution system insulation	Process integration
Flue gas heat recovery	Steam trap monitoring	Pinch analysis
Reduction of flue gas quantities	Insulation maintenance	
Condensate return	Leak repair	
Reduction of excess air	Steam trap improvement	
Blow down steam recovery	Flash steam recovery	
Properly sized boiler systems	Steam trap maintenance	
Boiler replacement		
Improved boiler insulation		
Direct contact water heating		
Boiler maintenance		

b) **Motor Systems and Pumps**

The motor system is the part of the central nervous system that is involved with movement. It moves fluids (liquids or gases), or sometimes slurries, by the mechanical action of a pump device (Nezhadian, Orchard, 2003). Use the tools listed below to optimize performance and save energy.

Pumps	Motor Systems
Pump system maintenance	Motor management plan
Multiple pumps for variable loads	Strategic motor selection
Pump system monitoring	Maintenance
Impeller trimming	Properly sized motors
Pump demand reduction	Adjustable-speed drives
Avoiding throttling valves	Power factor correction
Controls	Minimizing voltage imbalances
Replacement of belt drives	
High-efficiency pumps	
Proper pipe sizing	
Properly sized pumps	
Adjustable-speed drives	

c) **Refrigeration Systems**

Refrigeration is a process of moving heat from one location to another under controlled conditions. Heat transfer is traditionally driven by mechanical force but can also be driven by heat, magnetism, electricity, laser or other energy sources (Yoon, et. al. 2003). The tools listed below can be used to optimize performance and save energy.

Refrigeration	Cooling Load Reduction	Reducing building heat loads	Compressors	Condensers and Evaporators
System Management	Piping insulation	Removal of excess surface water	Compressor control systems and scheduling	Keeping condensers clean
Good housekeeping	Properly sized motors	Free cooling	Adjustable-speed drives	Adjustable-speed drives on condenser fans
Refrigeration system controls	Minimizing heat sources in cold storage areas		Floating head pressure control	Automatic purging of condensers
Monitoring system performance	Hydrocooling		Compressor heat recovery	Cycling of evaporator fans in cold storage
Checking for refrigerant contamination	Reducing heat infiltration in cold storage areas		Indirect lubricant cooling	Reducing condenser fan use
Ensuring proper refrigerant charge	Geothermal cooling		Dedicating a compressor to defrosting	Adjustable-speed drives on evaporator fans
Efficient piping design			Raising system suction pressure	Reducing condensing pressure
				Demand defrost
				Use of axial condenser fans
				Water defrosting

d) **Compressed Air Systems**

Compressed Air Systems offers a huge selection of the efficient air compressors for mitigation measure (Smith, Klosek, 2001). The tools listed below carry many models of reliable and durable recommendations.

- System improvements
- Improved load management
- Maintenance
- Pressure drop minimization
- Monitoring
- Inlet air temperature reduction
- Leak reduction
- Controls
- Turning off unnecessary compressed air
- Properly sized pipe diameters
- Modification of system in lieu of increased pressure
- Heat recovery
- Replacement of compressed air by other sources
- Natural gas engine-driven compressors

e) **Self-Generation**

Self-generation is the production of electricity for own use with a captive power plant installed, usually on one’s own premises. It can be owned by the consumer, or by a third-party under a power-supply contract (Verbong, Geels, 2007). Some of the tools are as follows.

- Backpressure turbines
- Tri-generation
- Combined heat and power
- Photovoltaic panels

Process-Specific Energy Efficiency Measures

The integration of know-how in energy performance such as energy efficiency, energy use and consumption in organizations needs a knowledge management system and a procedure for the consideration of energy aspects. The new approach is to link a systematic methodology for the identification of energy saving potential to the proposal of measures for their improvement. This approach requires a detailed analysis of the technical and structural facts in production processes. The outcomes of this analysis combined with a database of common measures are generating company-specific measures. The measures are going to be evaluated by defined criteria. The results will be provided for the different roles in an organization. Examples are user-specific checklists or processes for individual tasks. With this approach, it is possible for organizations to recognize and to document their knowledge about energy efficiency and to build up a base for a continuous improvement process (Dorr, et.al. 2013).

Blanching	Evaporation	Pasteurisation and Sterilisation	Peeling	Emerging energy efficient technologies
Upgrading of steam blanchers	Maintenance	Sterilizer insulation	Heat recovery from discharge steam	Heat pump drying
Heat recovery from blancher water or condensate	Mechanical vapor recompression	Helical heat exchangers	Dry caustic peeling	Carbon dioxide as a refrigerant
Heat and hold techniques	Multiple effect evaporators	Compact immersion tube heat exchangers	Multi-stage abrasive peeling	Ohmic heating
Steam recirculation	Concentration using membrane filtration	Induction heating of liquids		Geothermal heat pumps for HVAC
	Thermal vapor recompression			Condition-based motor monitoring
	Freeze concentration			Pulsed electric field pasteurisation
				Advanced rotary burners
				Pulsed fluid-bed drying
				Magnetically-coupled adjustable-speed drives

“ Over recent decades the meat processing industry has made tremendous adjustments to meet the increasing demand for inexpensive and safe supply of meat and poultry. ”

3.2. Meat Industry

Over recent decades the meat processing industry has made tremendous adjustments to meet the increasing demand for inexpensive and safe supply of meat and poultry (Ayele et al. 2003). We developed the matrix along value chain in a targeted business and industry in Meat Processing against climatic disasters including frost, floods, cyclones, etc. The matrix (Table 3) covers different areas in Egypt.

3.2.1. Value Chain and Vulnerability Matrix

The meat market is relatively old but highly variable depending on production condition of the country, change in consumer preferences and greater demand for high quality products with adequate guarantee of food safety (Ayele et al. 2003). The livestock market is structured so that the marketable livestock from the major producing areas reaches the final consumer or end-user after passing through complex channels along the supply chains involving various actors including producers, middlemen, livestock trading cooperatives, traders, live animal and meat wholesalers (Getachew, et. al. 2008). Using the initial results from the rapid market survey linking live animal and meat wholesalers with secondary and primary markets, the generalized supply chains and marketing channels for live animal and meat wholesalers for beef is depicted in Figure 2.

Inputs refers to the main products and services that cattle farmers need to raise cattle, including feeding regime of farm, veterinary services or care, and seed stock (breeding).

Production includes three distinct stages of cattle farming, representing three different types of farmers: those with cow-calf operations (who keep calves through to weaning), stockers and backgrounding (who rear cattle with pasture, supplements range, and forage), and feedlot operators (who restrict cattle movement and feed them a high-energy diet of grains to achieve desired slaughter weights). Cattle are moved from farm to farm according to these production stages, often crossing state lines (Lowe, Gereffi, 2009).

Processing and distribution: the meat is primarily processed into ground meat for fast food or supermarket retail. Once cattle reach slaughter weight of 1,100-1,300 pounds, they are slaughtered by packing operations, some of which also process meat products such as sausage or meat balls (Lowe, Gereffi, 2009). Many of these operations also perform further processing into more elaborate meat products including those that appear in prepared frozen meals. Distribution is achieved through wholesalers or direct sales to retailers, although the wholesale role is increasingly being performed by the large packers and processors themselves. Distribution is also performed by food service suppliers (Lowe, Gereffi, 2009).

Marketing refers to supermarkets, restaurants and food service operators. Food service operators outside the restaurant category provide dining and vending services for corporate clients such as offices, universities and healthcare institutions.

The matrix (Table 3) started from the feeding regimes of farms as there are many types of meat used as raw materials for this sector and many parameters that vary per the type of the product (seasons, location, indoor or open-field, etc). The matrix covers different areas in Egypt.



Figure 2. Meat value chain

Table 3. Vulnerability matrix for meat industry in Egypt

	Heavy Rain	Flood	Drought	Frost Bite	Strong wind	Rise in Sea Level	Shortage of Water	Rise in Temperature	Number of 3s
Frequency	-	-	-	-	-	+	+	+	
Feeding regime	2	2	2	3	3	0	3	3	4
Veterinary Care	1	2	1	2	3	0	3	3	3
Transportation to slaughterhouse	1	1	0	1	2	0	0	2	0
Slaughter	0	1	0	0	0	0	3	0	1
Removing of bones and skin	0	1	0	0	0	0	1	0	0
Cutting	0	0	0	0	0	0	0	3	1
Cooling / Freezing	0	0	0	0	0	0	0	3	1
Transportation to factory	1	1	0	0	2	0	0	3	1
Cold Storage	0	0	0	0	0	0	0	3	1
Removing of bones	0	0	0	0	0	0	0	3	1
Chopping	0	0	0	0	0	0	0	3	1
Adding Spices and mixing	0	0	0	0	0	0	2	3	1
Compressing	0	0	0	0	0	0	0	3	1
Packing	0	0	0	0	0	0	0	3	1
Freezing	0	0	0	0	0	0	0	3	1
Transportation	1	1	0	0	2	0	0	3	1
Number of 3s	0	0	0	1	2	0	3	13	

The result of matrix above shows that farm feeding regime is the most vulnerable process. It is highly affected by many climate situations. The process is significantly influenced by frost bite, strong wind, shortage of water and rise in temperature. Similarly, veterinary care is also highly affected by the same situations, but to a lesser extent for frost bite which affects the veterinary care moderately. All transportation processes, to slaughterhouse, factory and shops are also sufficiently affected by strong wind and rise in temperature. Heavy rain, flood and frost bite have minor impact on the transportation processes.

Egypt is subject during some periods of the year to heavy rain and this affects many processes in the meat industry, and increased periods of heavy rain will have remarkable effect on the industry (Youssef, 2011). Heavy rain will directly affect the process of feeding the cattle within farms as it affects the crops, roads and transportation.

Historically, Egypt was subjected to floods, especially in Upper Egypt, that caused damages and might be subjected to floods again with the changes in the climate (Youssef, 2011). It's not frequent but it sure has a significant effect on all the processes which take place outside the factory i.e. feeding the cattle, veterinary care and transportation.

Another threat is frost bite that occasionally occurs in the early winter morning and has a remarkable effect on the animals' health at the farms. Due to climate change, the temperature in Cairo reached -1°C in January 1998. Egypt is starting to have increasingly severe winters and frost bite may occur more frequently, in addition to already significant effects on roads and transportation. (Hameed, 2003).

Strong wind also has impact on several processes, as demonstrated in Egypt's spring season with limited effect but any increased intensity and frequency (Ahmed, 2011) in future might affect the transportation and animals' lives inside the farm. Along Egypt northern and eastern borders are Mediterranean Sea and Red Sea so any rise in the sea level might affect the vicinity and any industrial facilities near to the sea (Emery, Aubrey, 2012). Due to the climate change the sea level is expected to increase, this will affect the agricultural sector in Lower Egypt which will, in turn, affect the meat processing industry badly resulting in Egypt having to rely more on imported processed meat.

Meanwhile, drought occurrences in Egypt result in water shortage and this will have one of most significant impact on this industry as water is involved in many industrial processes (El-Sadek, 2010). Egypt already lies under the poverty line with insufficient fresh water sources so feeding of the animals will naturally be affected. In addition, shortage of water will affect the following processes: Slaughter and Mixing.

Among the disasters, rise in temperature is the most important disaster as it will have a significant effect on the industry at different levels. It affects all the processes, except slaughtering and removing of bones and skin. Firstly, rise in temperature will affect the cattle's health. Secondly, it will affect the energy consumption especially in summer when the industry experiences many black outs due to power shortage and this will increase the production cost accordingly. Climate change is causing warmer weather in Egypt during summer, hence, adaptation measures should be applied to prevent black outs by reducing the energy consumption during summer:



4. KENYA

The sugar industry in Kenya dates to 1922, with the establishment of the first sugar factories. The industry directly and indirectly supports 5 million Kenyans representing about 16% of the entire Kenyan population. Sugar cane growing is also a major source of income to over 150,000 shareholders. In Kenya, sugarcane is grown on flat regions in the Western, Nyanza and Coast Provinces. About 85% of the total cane supply is from small-scale growers whilst the remaining is from the nucleus estates of the sugar factories (Mulwa, et. al. 2009).

Meanwhile, the tea industry plays an important role in the Kenyan agricultural sector and the economy at large, with tea production contributing to about 11% of the total agricultural sector's contribution to Gross Domestic Product (GDP) (Kenya Economic Report, 2013). The annual tea exports amounted to about Kshs 79 billion in 2012 and contributed to 26% of the total foreign trade earnings. In addition, the tea industry supports directly and indirectly approximately 5 million people making it one of the leading sources of livelihood in Kenya. However, the tea industry has been faced with various challenges including: high cost of production, poor infrastructure, low level of value addition and product diversification, inadequate research, development and extension services and declining global tea prices (Gesimba, et. al. 2005).

4.1. Sugar

The Kenya sugar sub-sector supports 20% of Kenya's population and accounts for 15% of agricultural GDP. There are seven major sugar factories in Kenya with a total installed capacity of 22,150 tonnes of cane per day (TCD), which at full capacity for 300 days a year would produce approximately 550,000 tonnes of sugar. This is short of local demand now estimated at over 600,000 tonnes (Odek, et. al. 2003). The consumption of sugar in Kenya is mainly for direct human consumption and industrial use.

4.1.1. Value chain and vulnerability matrix

Kenya's sugar value chain consists of three main components— production, processing and distribution. Sugarcane production in Kenya is dominated by smallholder farmers (outgrowers), with only a few factory-owned farms (nucleus estates). The processing component of the value chain consists of 11 public, private and mixed-owned factories distributed throughout the country's sugarcane production areas (Jabuya, 2015). Sugar distribution after processing is highly integrated between wholesalers, retailers and importers.

“
The tea and sugarcane industries support directly and indirectly approximately 5 million people each.
”

As illustrated in Figure 3, outgrowers generally sell their product to sugar mills that process the sugarcane into raw sugar, which is then sold to the local food industry and households through wholesalers and retailers (KSB, 2010). The by-products of the processed sugarcane are re-used for planting or sold for energy and animal feed production.

Since domestic sugar production is insufficient to meet Kenya’s growing national demand, significant volumes of raw sugar are also imported, mainly through the Mombasa Port (Monroy, et. al. 2012). These imports are transported to major wholesale markets, where they compete with locally produced sugar in the domestic market.

Production: Outgrowers supply more than 92 percent of the sugarcane processed by Kenyan sugar factories (KSI, 2009), while the remainder is supplied by factory-owned nucleus estates. Sugarcane outgrowers in Kenya consist mainly of smallholder farmers (more than 250,000), who have low technical capacity, limited capital and produce sugarcane under rain-fed conditions.

Ratoon cropping, a farming method which leaves the lower part of the plant uncut during harvesting so that it can re-grow the following season, has proven to be cost efficient for many sugarcane producers. This system allows farmers to harvest their crop several times before replanting, though the yield of the ratoon crop decreases after each cycle. Sugarcane farmers using this farming method can obtain higher margins than those using traditional methods because they do not have pay for land preparation and seed every growing season (KSB, 2010). In Kenya, Mumia and Nzoia are the only two sugar companies that produce ratoon crops.

Harvesting and transportation represent the largest costs for sugarcane outgrowers, accounting for 45 percent of total production costs (KSB, 2010). These two activities are often considered jointly since sugarcane must be transported to processing facilities within hours of harvesting to avoid spoiling. Sugarcane harvesting is extremely labour intensive, requiring an average of 71 Man-days (KSB, 2010). Additionally, sugarcane is a bulky crop making it more expensive to transport (KSI, 2009). These costs are absorbed by farmers, as they are deducted from the producer price paid at farm gate (KSB, 2010).

Even though farmers assume the cost of harvesting and transportation, they have no real control over the transportation companies and continuously report delays of up to 12 months in the mature cane harvest due to uncoordinated and unpredictable schedules and inefficiencies in mill operations (KSI, 2009). Land fragmentation was identified as another problem affecting many outgrowers. Land owned by individual outgrowers continue to be subdivided into even smaller parcels, decreasing the efficiency of almost all farming activities (KSI, 2009).

Kenya’s sugarcane producers are organized into several different companies and cooperatives. To better represent the interests of these individual producer organizations, an umbrella organization, known as the Kenya Sugar Cane Growers Association (KESGA), was established in 1982. It is through the KESGA that farmers can lobby the government for support and negotiate sector relations (GOK, 2007).

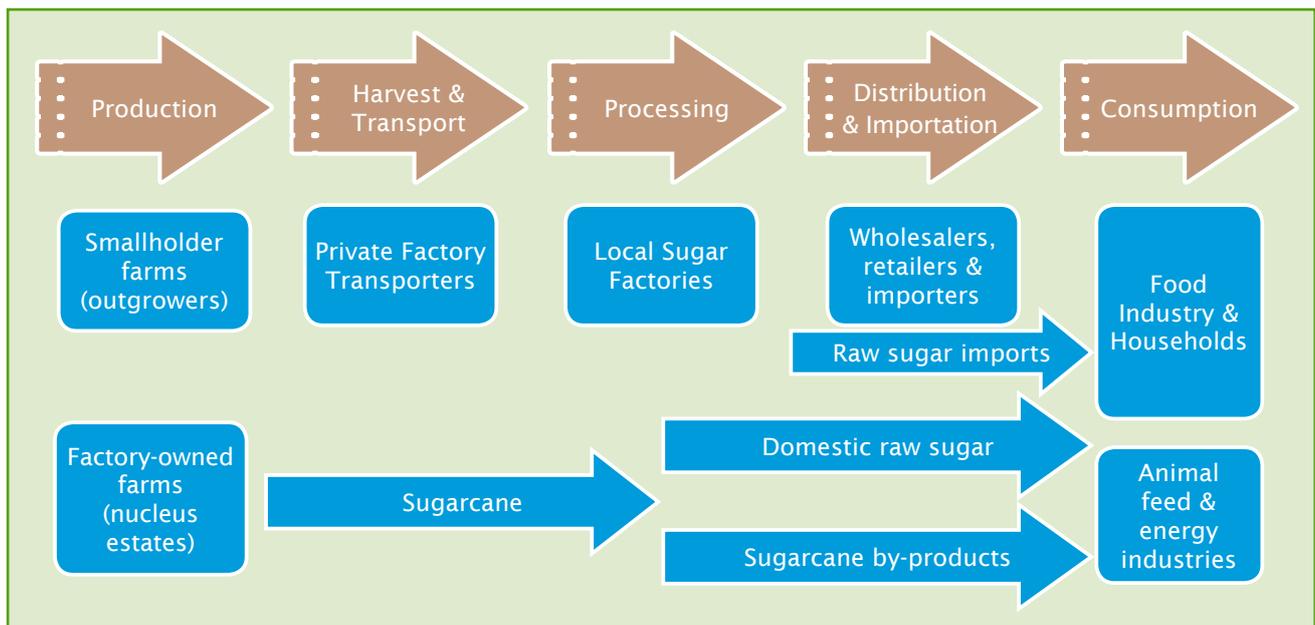


Figure 3. Kenya’s sugar value chain

Processing: Kenya’s sugar factories have the combined installed capacity to process more than 24,000 tonnes of cane per day. If this capacity were fully exploited, the industry could meet the national demand for sugar; however, factories continue to operate at a capacity utilization of only 55 to 60 percent because of significant technical and management limitations (KSI, 2009; KSB, 2010)

Monroy et. al (2012) found that every sugar factory in Kenya has its traditional supply zones, where it works together with outgrowers to obtain sugarcane inputs. Some also supplement outgrowers’ inputs with sugarcane from their own plantations. The factories coordinate with private transportation companies or provide their own transportation for sugarcane collection, scheduling it according to their quantity requirements. However, due to continuous breakdowns stemming from maintenance problems, factory demand for sugarcane is often inconsistent and unpredictable, adversely affecting local outgrowers.

Although most factory revenue is generated through sugar sales, there has been some interest in moving toward industry diversification through the exploitation of sugarcane by-products, such as bagasses and molasses, for ethanol production and energy co-generation. However, high investment costs, uncompetitive price mechanisms, limited technology and a weak legal and regulatory framework are some of the main reasons as to why little has been achieved in this direction (KSI, 2009).

Distribution: Before liberalization of the sugar industry in 1992, marketing and distribution was controlled by the government through the Kenyan National Trading Corporation, which regulated producer and consumer prices and imports (KSB, 2010). Now, after liberalization, processed sugar reaches the end consumer through an integrated network of private wholesalers, retailers, importers and distributors. The ex-factory price paid by wholesalers incorporates the cost of the sugarcane (raw material inputs), milling, processing, packaging, factory operations, the factory’s margin, and government levies, which include a 16 percent Value Added Tax (VAT) and a four percent Sugar Development Levy (SDL) imposed by the Kenya Sugar Board (KSB) (KSB, 2010).

According to the KSB’s 2010 sugar value chain analysis, the main factor hindering sugar marketing is the high cost of transportation due to large distances travelled and poor road conditions, a distribution system controlled by few players, and inadequate packaging and branding.

The stakeholders along the value chain were asked to list/consider non-climate data needed to assess the vulnerability of the exposure units and support the relevant policy making processes. There were discussions among stakeholders on which processes to include and which ones to group together. However, here, it is important that all steps are mapped without grouping or exclusion.

Table 4. Vulnerability matrix for sugar industry in Kenya

Processes units\ Disasters	Drought	Hail storm	Water stress	Flood	Heavy rain	Shift in rainy season	Wet spell	Dry spell	No. of 3s
Frequency	++		+	++	+	+	+	++	
Land preparation	0	1	0	3	2	1	2	0	1
Planting	3	1	0	3	2	2	0	1	2
Husbandry	3	3	3	3	1	2	2	2	4
Harvesting	0	0	0	3	2	1	1	0	1
Road Transport	0	1	0	3	3	0	0	0	2
Cutting and Crushing	0	0	0	0	0	0	0	0	0
Milling	0	0	3	0	2	0	2	0	1
Clarification of Juice	0	0	3	0	2	0	1	0	1
Evaporation	0	0	2	0	0	0	0	0	0
Crystallization	0	0	0	0	0	0	0	0	0
Packing	0	0	0	0	0	0	0	0	0
Distribution	0	0	0	3	2	0	1	0	1
No. of 3s	2	1	3	6	1	0	0	0	

“The intensity and amount of rain received have exceeded the soil capacity to filter water and minimize surface runoff even in fields with the most adequate conservation practices.”

Heavy rain affects land preparation even though it only lasts for a few hours. Prolonged heavy rainfall has been observed in various parts of the country. The country has already experienced severe flooding in several areas, including the agriculture area (Davies, 2016). Heavy rains come down hard and fast causing substantial soil erosion when soils are most vulnerable because of degraded crop residue cover, soil preparation by tillage and lack of crop canopy. The soil profiles are filled with water, at or near saturation. Therefore, the intensity and amount of rain received have exceeded the soil capacity to filter water and minimize surface runoff even in fields with the most adequate conservation practices (Al Kaisi, 2008).

Gitau et.al (2008) indicated that the 1-day wet and dry spells were the most dominant, with the frequency decreasing as the length of the spell was increased. Longer wet/dry spells were dominant in the wet/dry parts of the country. Wet spell affects the road transportation along the value chain. Research has identified that crash risk in wet weather increases as the duration since the rainfall increases termed the wet spell effect. The effect is especially relevant due to significantly extended durations between rainfall events across most of the country. Further research is required to ascertain how much of this effect is due to driver behaviour (i.e. have the drivers ‘forgotten’ how to drive in wet weather) or is it primarily due to the increased oil/grime on the road surface (Rowland, 2007).

Heavy rain and wet spells would delay the sugarcane distribution but it should not be tolerated. Delay in transport of raw material to the plant affects transport of products for distribution. The delay in raw material also affects the energy supply such as bagasse shortage. Some processes along the value chain have high water consumption and the source of the water comes mostly from rainfall. These processes are affected during or after disaster such as drought. The impact would last for around two years. In January 2014, the Government of Kenya declared an impending drought with an estimated 1.6 million people affected (Relief, 2014). This situation is exaggerated by water stress which is influenced by water scarcity and shortage in Kenya.

Similar processes in different part of the chain are affected differently. For instance, transportation of cane and product are affected differently by each weather disaster. It is dependent on the road conditions/different connections and transport vehicles used, and the extent of delay tolerance. Therefore, it is necessary to look at current methods in practice to mitigate these adverse weather conditions.

Each process in the whole chain is important and relevant with institutions playing important roles. Several key institutions play a role in Kenya’s sugar value chain. These include (1) the Government of Kenya (GOK), which in addition to being responsible for the sector’s overall development, is currently the sugar industry’s largest shareholder (KSI, 2009); (2) the Kenya Sugar Board (KSB), which is a public body responsible for industry regulation, promotion, coordination and equity insurance; and (3) the Kenya Sugar Research Foundation (KESREF), which is responsible for the development and transfer of appropriate technology in the sugar sector. It is important to note that after more than 25 years of industry protection and government investment, Kenya’s sugar industry is still characterized by high production costs. In 2009, sugar production costs in Kenya were the highest in the region. These costs not only limit the industry’s capacity to meet the national demand for sugar but they also hinder its ability to compete with more efficient producers in the international market.

The different policies in place can mitigate the adverse weather conditions. The policy assessment can be done at the factory and national level. The following policies and actions have been put in place

Table 5. Policies and actions for sugar industry in Kenya

Disaster	Action(s)/Policy (ies)
Drought	Disaster management Secretariat
Hailstorm	
Water stress	Water Quality Management Regulations
Floods	Disaster management Secretariat
Heavy Rain	
Shift of Rain Season	
Wet spell	
Dry Spell	

It is necessary to obtain information of certain weather parameters that are important in determining the specific mitigation measures that can be applied. This is to determine whether the existing weather conditions can complement the identified adaptation measures.

Solar energy is linked to adverse weather conditions and it can be checked with sugar research. Solar energy utilization is dependent on weather conditions, and the following weather parameters need to be obtained along with the various formulas used to ascertain the viability of solar energy in a certain location (Nafey, et. al. 2000). The weather parameters are insolation intensity (Watt/hour/m³), sunshine hours (Daily sunshine), rainfall (mm), temperatures (°C) and humidity. The condition of socioeconomic and demography such as infrastructure, road network, wage/salary, etc, need to be considered as well in determining the mitigation and adaptation strategies.

The expert pointed out that the definition of disasters varies depending on the assessment's intended targets. Defining a disaster should be done with climate experts/meteorological authority/disaster prevention authority in close consultation with the sector organizations (O'Brien, et. al. 2006). Some of the discussion issues raised includes the difference between drought and dry spell. Dry spell is an extended period without rain and drought is its longer-term impact.

Another issue is the possibility of heavy rain causing flood. Heavy rain can be for a short time but very intensive, thus may not result in flood. Continuous rain or wet spell, however, can potentially cause flood. There are also queries regarding the number of days in the absence or presence of rain for definitions of dry or wet spells, and definitions about and shift of rainy seasons as these affect each process within the value chain.

“ Kenya’s sugar industry is still characterized by high production costs. ”

4.2. Tea Sector

The tea growing regions in Kenya are endowed with the ideal climate for tea, attributed to tropical, volcanic red soils and well distributed rainfall ranging between 1200mm to 1400mm per annum that alternates with long sunny days (Gesimba, et.al. 2005). Production continues all year around with two main peak seasons of high crop between March and June, and October and December which coincide with the rainy seasons. Kenyan tea is grown free of agrochemicals because the ideal environment in which the tea is grown acts as a natural deterrent to pests' infestation and crop diseases. This natural condition guarantees the consumer the safest and most refreshing health drink.

4.2.1. Value Chain and Vulnerability Matrix

Value chain includes tea production processes. The main raw material in the tea production is the green tea leaves. The green leaves from the farm undergo the following processes of tea production (Gesimba, et. al. 2005), and hence the value chain are as follows;

Farm level: This is where land preparation, planting, crop husbandry and plucking takes place.

Weighbridge: The weighbridge clerk weighs and records the gross weight of transported green leaf on arrival from the estates. After offloading the green leaf in the reception bay, the tare weight of transport medium is taken off to determine the net weight of green leaf purchased.

Withering: This takes between 14-20 hours to allow biochemical reaction to take place. It is done to ensure that the green tea leaves attain moisture content of approximately 71% (Gupta, et. al. 2012).

CTC (Crush, Tear and Curl): The withered leaf is macerated through a rotor vane and subjected to four stages of CTC in 3 lines A, B, and C. Metals of the rotor are controlled by use of magnets through a pre-programmed protocol. The product of CTC is referred to as dhool (Kerio, et. al. 2012).

Fermenting: This is done to allow the oxidation of chemicals, transforming the dhool into black tea with quality parameters set at low temperatures of 22°C-30°C by use of continuous fermenting units (CFUs) for duration of 110-150 minutes. The target moisture content here is 67-69% (Karori, et. al. 2007).

Drying: This is to rapidly reduce the moisture content to 2.8-3.2% within 15-20 minutes, achieved through use of fluidized bed dryers and this is critical control point 1. Inlet temperatures for hot and main chambers are used as critical limiters (Temple, et. al. 2000).

Dispatching: Dispatching of packed teas is done by using contracted lorry transporters. All containers are inspected to conform to C-TPAT (Customs-Trade Partnership Against Terrorism) policy prior to loading.

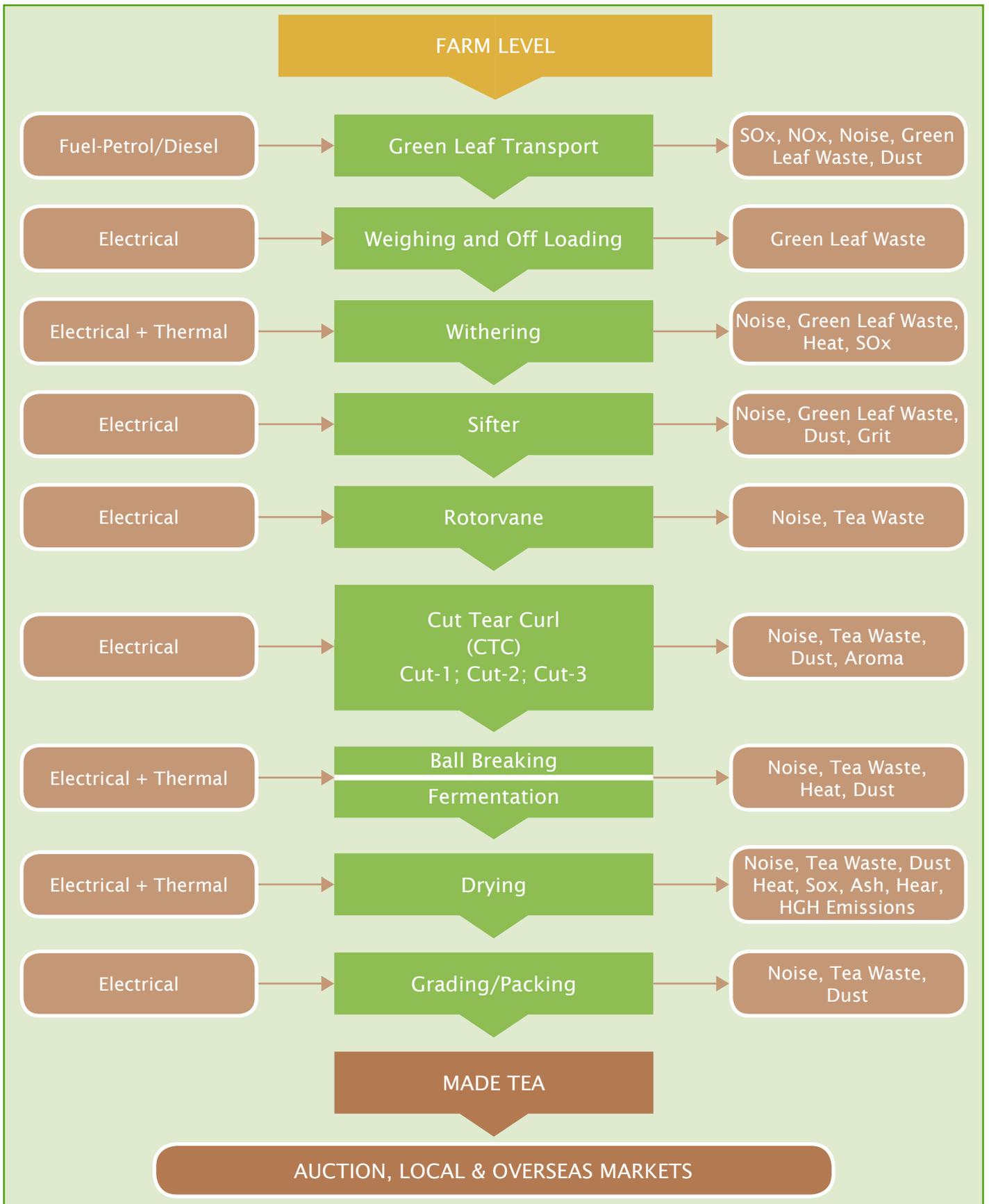


Figure 4. Tea value chain

The identified processes that are sensitive to climatic disasters in a targeted chain above were developed with the vulnerability matrix below.

Table 6. Vulnerability matrix for tea sector in Kenya

	Hail storm	Frost	Inadequate rainfall	Cold condition	No. of 3s
Frequency	+	-		-	
Land preparation	2	1	3	0	1
Planting	2	2	3	1	1
Plant husbandry	3	2	3	3	3
Plucking	3	3	3	3	4
Transportation	1	1	0	1	0
Withering	1	2	2	3	1
Cut, Tear, & Curl	0	0	1	2	0
Fermentation	2	2	2	3	1
Drying	3	2	0	3	2
Sorting	0	0	0	0	0
Packaging	0	0	0	0	0
Distribution	1	0	0	0	0
No. of 3s	3	1	4	5	

There are several climate change disasters in the tea sector. First of these is cold condition. It occurs when the temperatures are low in the absence of rain, snow and frost (Meteorological Department of Kenya). This inhibits application of fertilizers, plant husbandry and plucking process, ultimately leading to low yields. While this discourages the farmers from planting more seedlings, the more devastating effects of cold conditions are fermentation and drying as well as Cut, Tear and Curl (per. com). The gap between average maximum temperature and minimum temperature is significant. The average minimum temperature recorded was 10.53°C in September, while the forecast minimum temperature is to reach 9.3°C (See Synthesis Report). Withering and drying are affected by low temperatures as the air is more humid during the rainy season, requiring more energy while less energy is used when the air is drier.

Second disaster is unpredictable rain patterns, including uneven spread of rainfall across the tea growing areas, longer dry periods, destructive rainfall which can damage tea bushes and erode tops soils, and these occurrences are on the rise (Cracknell, 2013). Historical climate data indicated that the highest total monthly rainfall during May 1987 was 450 mm. The midterm projection for the period of 2040-2060 shows that the total monthly rainfall

is predicted to increase throughout the year (See Synthesis Report). This will have negative impact on tea production at farm level as well as the withering and drying stages. For the same reason as described above for cold condition, the higher humidity in the air requires more energy for the withering and drying processes. Heavy rains make all-weather-purpose roads impassable hence delay in delivery of green leaves (Miriti, Bundi, 2003). Sustainable land use management practices such as mulching, minimum tillage, agroforestry and soil conservation methods mitigate against this problem at the local level.

Hail storm also affects the foreign trade earnings. For a country like Kenya which already suffers adaptation deficit, this scenario aggravates the socio-economic conditions of the country hence the need for strategies on low carbon and climate resilient industrial development. Hailstone is a form of precipitation that falls from the sky as pellets of ice. The pellets can range from small pea size to hailstones as large as grapes. It is damaging for the tea crop and can completely strip the branches of all the leaves thereby reducing the yields, and the crop takes a long time to regenerate (Ng'etich, et. al. 2001). Factories are closed and workers laid off for an extended period. It also affects plant husbandry, plucking and drying process significantly.

Next is drought which has effects not only at the farm level like land preparation, planting, plant husbandry and plucking process, but also spread across the entire value chain especially withering, cut-tear-curl and fermentation. Drought results in reduced production of green leaf, stunted growth, low leaf quality and susceptibility to fire hazards (Cheruiyot, et. al. 2007). The totality of these outcomes exposes the tea sector to reduced productivity by undermining the change competitiveness and the communities' ability to withstand climate change effects.

Lastly, frost occurs when temperatures fall below freezing point causing formation of small white ice crystals. It causes withering of the tea leaves therefore reducing productivity hence less tea export which reduces foreign trade for the country (DW, 2015). It is prevalent in hilly areas such as Nandi, Kericho, Bomet and Kisii. During such times the tea plantations lay off workers. The practice of agroforestry alleviates the situation as livelihood diversifying income. Looking at the entire value chain, this problem is more accentuated at the farm level. Kenya suffered the worst frost in the period of late 2011 and early 2012 (OCHA, 2011). The frost effect is expected to extend into the future following the adverse effects of climate change and this justifies the need for low carbon and climate change resilient industrial development in Kenya.

“ There are several climate change disasters in the tea sector. First of these is cold condition. ”



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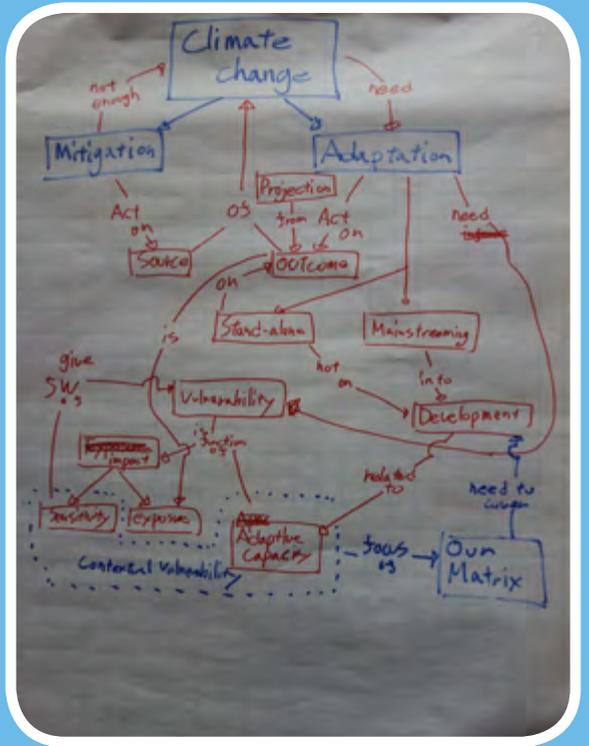
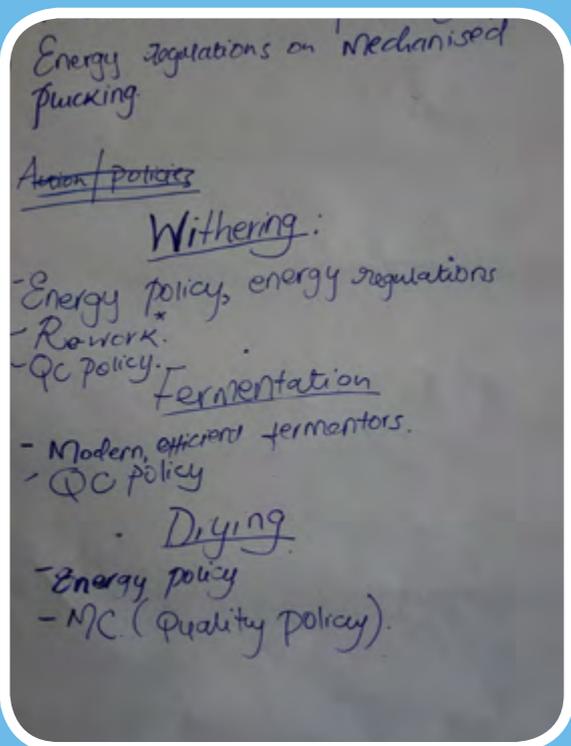
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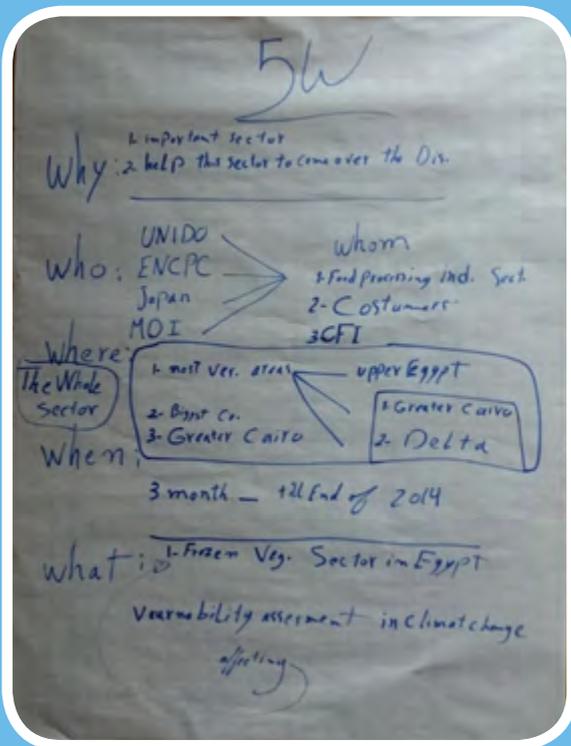


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In order to create awareness and demonstrate the opportunities, as well as benefits, of low-carbon growth and climate resilient development in the productive industries in Africa, UNIDO applies Green Industry policy instruments, practices and techniques in 4 countries in this project:

EGYPT



KENYA



SENEGAL



SOUTH AFRICA



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