Adaptation Strategy Options for a Climate Resilient Production of Agricultural Export Commodities in Ethiopia

By

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Addis Ababa, Ethiopia

July 2015
This research report is part of the research project on ‘Strategy options for a climate resilient production of cotton and sugarcane in Ethiopia”. The project is financed by the SCIP Fund, which is financed by the governments of the United Kingdom (UK), Norway and Denmark.
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1. Introduction

Adaptation assessments that include both top-down assessments of biophysical climate changes and bottom-up assessments of what makes people and natural systems vulnerable to those changes will help to deliver local solutions to globally derived risks. In addition, assessments that are linked more directly to particular decisions and that provide information tailored to facilitate the decision making process appear to have most consistently led to effective adaptation measures.

A number of different but related concepts are discussed in the literature on assessment of adaptation that aims to identify effective adaptation strategy designed to build climate resilient pathways. These involve identifying current and future climate change risk (hazards and extremes); climate and non–climate drivers of vulnerabilities to climate change impacts; and adaptation capacity (assessing opportunities and constraints) that reduces the risk and effective adaptation strategy to cope with or reduce the anticipated risk. Identifying effective adaptation strategy involves assessment of adaptation needs and options; assessment of adaptation opportunities and constraints, assessment of the costs and benefits, the different adaptation options and planning and implementation of effective adaptation strategies. Depending on the magnitude and rate of climate change, these adaptation strategies can either be incremental or transformative. If the magnitude and rate of climate change is kept minimal or moderate, incremental adaptation may be a sufficient response to consequences in many locations and contexts. However, in cases where vulnerability is currently high, transformational adaptation may be needed to respond to changes in climate and climate variability. Transformational change can be considered a means of reducing risk and vulnerability, not only by adapting to the impacts of climate change, but also by challenging the systems and structures, economic and social relations, as well as beliefs and behaviours that contribute to climate change and social vulnerability1.

Given this as a brief background, this study focuses on identifying adaptation options, from which effective adaptation strategies can be identified for building a climate resilient production of cotton and sugarcane in Ethiopia. The adaptation options are identified based on the findings of different research components whose findings feed into producing the adaptation options. The different research components help to answer the following three basic questions. The first question is ‘what is the knowledge on climate change impacts, vulnerabilities and prospects of adaptation in the context of cotton and sugarcane in Ethiopia?’. The second question is ‘what are the anticipated climate change risks and impacts that Ethiopia need to worry about in its cotton and sugarcane commodities i.e. what are the key risks and key vulnerabilities that we need to worry about?’. The third question which is addressed in this part of the study tries to answer is ‘what should Ethiopia do to respond to the key risk and key vulnerabilities in the

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1 Transformation is defined as a change in the fundamental attributes of a system, often based on altered paradigms, goals, or values. It can occur in technological, biological or financial systems, or regulatory, legislative, or administrative regimes.
context of the two commodities? i.e. what are the adaptation options that reduce the impact or build a climate resilient production of the two commodities?

The report is organized in four sections. The next section summarizes the findings on climate change hazards and impacts so as to give a summary of the response for the first question. It discusses key drivers of vulnerability and key risks associated with current and future climate change. The reasons for concern and the need to identify adaptation options are also discussed in section two. Section three presents adaptation options for the cotton and sugarcane commodities. The section discusses conceptual issues, the criteria for selection of adaptation options and the identified adaptation options. The last section summarizes the report.

2. Reason for Concern

Reasons for concern are related to the observed and projected climate change and climate related hazards and key vulnerabilities and risks to the anticipated hazards in cotton and sugarcane producing regions of Ethiopia. That is, one needs to worry about climate change once the first and second questions raised in previous section are adequately answered. Accordingly, the aim of this section is to provide scientific evidence on these two fundamental policy questions. It is based on the findings of the different research components of the project. Thus, the section is organized to provide information on the historical and projected climate change in cotton and sugarcane producing regions of Ethiopia and the anticipated climate related extremes based on the findings of the climate modelling part of the project study. This will be followed by the key vulnerability and risks of the anticipated climate related impacts. Both of these subsections will produce some fundamental issues that can be reasons for concern in relation to climate change in the textile and sugar export commodities.

2.1. Projected climate change and extremes

A climate modelling study has been conducted in the cotton and sugarcane producing regions of Ethiopia (Geremew and Agizew, 2015). The study involved the use of observed and predicted daily rainfall, minimum temperature and maximum temperature time series. Predicted rainfall and temperature series were obtained from regional climate multi-model outputs of CORDEX-Africa for three RCP scenarios (RCP2.6, RCP4.5 and RCP8.5). Regional climate model

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2 As a glimpse on these scenarios, RCP stands for “Representative Concentration Pathways”. It is a set of climate scenarios constructed that contain emission, concentration and land-use trajectories. The word “representative” signifies that each of the RCPs represents a larger set of scenarios in the literature. This implies that this set of RCPs should be compatible with the full range of emission scenarios (with and without climate policy) available in the current scientific literature. The word “concentration pathway” emphasizes that these RCPs are not the final new, fully integrated scenarios (i.e. they are not a complete package of socio-economic, emission and climate projections), but instead are internally consistent sets of projections of the components of radiative forcing that are used for the input to climate models. The word “concentration” also emphasizes that instead of emissions, concentrations are used as the primary product of the RCPs designed as input to climate models. Four RCPs scenarios named according to radiative forcing target level for 2100 are used. These are RCP2.6, RCP4.5, RCP6 and RCP8.5. In the terminology of climate change policy, RCP8.5 scenario gives predictions that correspond to the
outputs of each scenario were aggregated and/or averaged to characterize rainfall and temperature at monthly, seasonal, and annual time scales. Characterizations at four different periods were also made—historical, near-term (2016-2035), mid-term (2046-1965) and long-term (2081-2100). The rainfall was characterized in terms of inter-annual variability, seasonal and monthly rainfall amounts, number of rainy days, mean wet/dry spell lengths and number of extreme daily rainfalls. The temperatures of the study sites were characterized in terms of inter-annual variability, mean monthly and seasonal values and change in temperature with respect to the historical. Bias corrections to the predicted rainfalls and minimum and maximum temperatures were made to minimize model tendencies to underestimate or overestimate the observed means. The results are summarized as follows.

2.1.1. Rainfall

Amount/Distribution

The inter-annual pattern of rainfall in the Central Rift Valley for both bias corrected and uncorrected projection does not show a distinct trend. However, the monthly and seasonal distribution when observed for the near (2020s), medium (2050s) and long term (2090s) period considering various scenarios show changes. On the other hand, the inter-annual trend in the case of Northwest lowlands shows a decrease in RCP8.5 showing more pronounced decrease.

The monthly and seasonal distribution of Central Rift Valley region for bias uncorrected version shows a decrease of rainfall in the rainy seasons of Belg (43%) and Kiremt (8%) in the 2090s and for bias corrected projection the values are: Belg (25%) and Kiremt (3%) for RCP8.5. In Northwestern Lowlands, the decrease in the 2090s for the same scenario is: Belg (50%) and Kiremt (26%) for bias uncorrected Belg (29%) and Kiremt (16%) for bias corrected projection. In Bega, the increase for RCP8.5 in the 2090s is (97%), (18%), (113%) and (33%) for bias uncorrected and corrected projections in the Central Rift Valley and Northwestern Lowlands respectively (see table 1). Thus, one can conclude that there will be less rainfall in rainy seasons and more in the drier periods.

business-as-usual development pathways. The RCP2.6 outputs indicate possible future temperature and rainfall patterns with climate change policy. The RCP4.5 represents the middle situation.
Table 1: Projected Change in Rainfall for Kiremit Season by Scenario from Historical Mean for Central Rift Valley (%)

<table>
<thead>
<tr>
<th>Period</th>
<th>Kiremit Season</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RCBC2.6</td>
<td>RCBC4.5</td>
<td>RCB8.5</td>
</tr>
<tr>
<td>2016-2035</td>
<td>5.35</td>
<td>0.90</td>
<td>3.24</td>
</tr>
<tr>
<td>2046-1965</td>
<td>1.08</td>
<td>0.83</td>
<td>9.28</td>
</tr>
<tr>
<td>2081-2100</td>
<td>3.84</td>
<td>-3.83</td>
<td>-3.42</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Belg Season</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2016-2035</td>
<td>-2.89</td>
<td>25.78</td>
<td>-7.85</td>
</tr>
<tr>
<td>2046-1965</td>
<td>9.04</td>
<td>-35.31</td>
<td>1.81</td>
</tr>
<tr>
<td>2081-2100</td>
<td>-20.27</td>
<td>-5.04</td>
<td>-24.66</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Bega Season</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2016-2035</td>
<td>-14.23</td>
<td>-25.12</td>
<td>-40.78</td>
</tr>
<tr>
<td>2046-1965</td>
<td>5.25</td>
<td>2.67</td>
<td>2.58</td>
</tr>
<tr>
<td>2081-2100</td>
<td>-14.80</td>
<td>-15.85</td>
<td>18.43</td>
</tr>
</tbody>
</table>

Source: Geremew and Agizew (2015)

In general, the change in rainfall quantity in whichever direction becomes significant when one moves from near term period (2020s) to the long term (2090s) and from RCP2.6 to RCP8.5. However, in some cases, the finding of the research for bias corrected shows variability - a decrease or increase in one period – 2050s and an opposite trend in the next, 2090s. The other important finding is a delay in the beginning and exit of rainy season showing shift of season particularly a drier June and extension of rainy period to October and November. A summary of the projected rainfall change over the historical period for Central rift valley and north West Low lands over short term (2016-2035), mid-term (2046-1965) and long-term (2081-2100) is shown in tables 1 and 2, respectively.

Rainy days

The number of rainy days in the Central Rift Valley region increases by 52% in Bega and decreases by 41% and 21% in Belg and Kiremt respectively for RCP8.5 in 2090s. In the Northwestern Lowlands, the increase in Bega is 67% and the decrease in Belg and Kiremt is 37% and 15% respectively. These values are in line with the results for the amount and distribution of rainfall. Thus, it is likely that there will be less rainy days in rainy seasons and more in drier ones.
Table 2: Projected Change in Rainfall for Kiremit Season by Scenario from Historical Mean for North West low land

<table>
<thead>
<tr>
<th>Period</th>
<th>RCBC2.6</th>
<th>RCBC4.5</th>
<th>RCB8.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016-2035</td>
<td>2.74</td>
<td>6.82</td>
<td>9.73</td>
</tr>
<tr>
<td>2046-1965</td>
<td>-1.19</td>
<td>-3.81</td>
<td>1.33</td>
</tr>
<tr>
<td>2081-2100</td>
<td>0.58</td>
<td>-6.13</td>
<td>-15.63</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Period</th>
<th>RCBC2.6</th>
<th>RCBC4.5</th>
<th>RCB8.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016-2035</td>
<td>-0.34</td>
<td>9.43</td>
<td>13.07</td>
</tr>
<tr>
<td>2046-1965</td>
<td>-16.70</td>
<td>-6.59</td>
<td>-4.43</td>
</tr>
<tr>
<td>2081-2100</td>
<td>12.05</td>
<td>-7.84</td>
<td>-28.64</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Period</th>
<th>RCBC2.6</th>
<th>RCBC4.5</th>
<th>RCB8.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016-2035</td>
<td>9.15</td>
<td>1.02</td>
<td>-27.12</td>
</tr>
<tr>
<td>2046-1965</td>
<td>-9.49</td>
<td>22.37</td>
<td>10.17</td>
</tr>
<tr>
<td>2081-2100</td>
<td>-6.78</td>
<td>14.24</td>
<td>32.88</td>
</tr>
</tbody>
</table>

Source: Geremew and Agizew (2015)

**Wet spell length**

The number of days showing consecutive rainy days – wet spell length – in Central Valley Region decreases by 27% in Kiremt and by 20% in Belg for RCP8.5 in the 2090s which is more or less in line with the decrease in rainfall quantity if not identical. However, in the case of Bega, the wet spell length is not increasing though the amount of rainfall increases in the season. This shows that though the total number of rainy days is higher, it is not continuous and is characterized by alternative dry and wet days. In the Northwestern Lowland, the average wet spell length indicates a decrease in all season and between periods which is not in line with the Bega season as the quantity of rainfall and rainy days increase in this season. The increase in quantity can be explained with a high intensity of rainfall.

### 2.1.2. Temperature

Unlike the rainfall pattern which sometimes is difficult to determine the long term trend for both bias uncorrected and corrected projection clearly shows an increase though the value might differ for the two projections. The conclusions on the inter-annual, monthly and seasonal trends are briefly summarized as follows.

**Average temperature**

The inter-annual increases in average temperatures in the 2090s for scenarios RCP2.6, RCP4.5 and RCP8.5 are 2 °C, 3°C and 6 °C respectively for the Central Rift Valley region and while the corresponding values for Northwestern Lowlands is nearly zero, 3°C and 5 °C. Thus, the
inter-annual pattern shows an increase for both areas and the increase is significant in the higher scenarios and long term periods.

The monthly pattern shows the same characteristics of an increase as the scenario and periods reach RCP8.5 and 2090s where the maximum temperature difference is 7 °C in the months of December and January for Central Rift Valley region and the corresponding value for Northwestern Lowlands is 6°C in the months of December, January and May. These results show that the temperature increase is significant in the dry periods for both regions. See table 3 and 4.

With regard to seasonal variation, in the Central Rift Valley region, all seasons – Kiremt, Bega and Belg show an increase of over or about 6°C in RCP8.5 in 2090s though the highest is in Bega about 6.5 °C. However, in the Northwestern Lowlands, there is a significant temperature increase of 7 °C in Kiremt for RCP8.5 in the 2090s. Projected change in mean temperature for the three seasons by scenario over the historical period is shown in table 3 and for central rift valley and North West low lands, respectively.

Table 3: projected Change in temperature for the three seasons by Scenario from historical mean (%) for Central Rift Valley

<table>
<thead>
<tr>
<th>Period</th>
<th>RCP2.6</th>
<th>RCP4.5</th>
<th>RCP8.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kiremit season</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016-2035</td>
<td>1.1</td>
<td>1.2</td>
<td>1.4</td>
</tr>
<tr>
<td>2046-2065</td>
<td>1.6</td>
<td>2.3</td>
<td>2.9</td>
</tr>
<tr>
<td>2081-2100</td>
<td>1.2</td>
<td>2.7</td>
<td>5.9</td>
</tr>
<tr>
<td>Belg season</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016-2035</td>
<td>1.0</td>
<td>1.1</td>
<td>1.4</td>
</tr>
<tr>
<td>2046-2065</td>
<td>1.4</td>
<td>2.2</td>
<td>3.0</td>
</tr>
<tr>
<td>2081-2100</td>
<td>1.1</td>
<td>2.5</td>
<td>5.7</td>
</tr>
<tr>
<td>Bega season</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016-2035</td>
<td>2.0</td>
<td>2.0</td>
<td>2.2</td>
</tr>
<tr>
<td>2046-2065</td>
<td>2.1</td>
<td>3.0</td>
<td>3.7</td>
</tr>
<tr>
<td>2081-2100</td>
<td>2.0</td>
<td>3.3</td>
<td>6.3</td>
</tr>
</tbody>
</table>

Source: Geremew and Agizew (2015)
Table 4: Projected Change in temperature for three seasons by Scenario from historical mean (%) for North west low land

<table>
<thead>
<tr>
<th>Period</th>
<th>RCP2.6</th>
<th>RCP4.5</th>
<th>RCP8.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kiremit season</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016-2035</td>
<td>3.9</td>
<td>2.0</td>
<td>2.2</td>
</tr>
<tr>
<td>2046-2065</td>
<td>6.1</td>
<td>3.2</td>
<td>3.8</td>
</tr>
<tr>
<td>2081-2100</td>
<td>4.9</td>
<td>3.6</td>
<td>7.0</td>
</tr>
<tr>
<td>Belg season</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016-2035</td>
<td>-0.4</td>
<td>0.7</td>
<td>1.2</td>
</tr>
<tr>
<td>2046-2065</td>
<td>-0.6</td>
<td>1.8</td>
<td>2.8</td>
</tr>
<tr>
<td>2081-2100</td>
<td>0.0</td>
<td>2.3</td>
<td>5.4</td>
</tr>
<tr>
<td>Bega season</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016-2035</td>
<td>0.9</td>
<td>1.6</td>
<td>1.9</td>
</tr>
<tr>
<td>2046-2065</td>
<td>0.5</td>
<td>2.4</td>
<td>3.5</td>
</tr>
<tr>
<td>2081-2100</td>
<td>2.2</td>
<td>2.9</td>
<td>6.0</td>
</tr>
</tbody>
</table>

Source: Geremew and Agizew (2015)

Minimum temperature

The inter-annual bias uncorrected increase in minimum temperature in the 2090s for scenarios RCP2.6, RCP4.5 and RCP8.5 is 2°C, 3.5°C and 7°C respectively in the Central Rift Valley region and the corresponding bias corrected projection is 2°C, 3°C and 5°C. The corresponding values for bias uncorrected and corrected projections in Northwestern Lowlands are 2, 3°C and 7°C; and 1°C, 3°C and 7°C respectively. Thus, the inter-annual pattern shows an increase for both areas and projections; and the increase is significant in the higher scenarios and long term periods.

The monthly pattern in the bias uncorrected projection in the Central Rift Valley region shows an increase of nearly 8°C for RCP8.5 in the 2090s in the month of December and January and the minimum difference is 1°C in June for RCP2.6 in the same period. However, the bias corrected projections do not show significant difference in any scenario or period. The bias uncorrected corresponding value for Northwestern Lowlands is 7°C in the months of December and January and the minimum difference is less than 1°C for all periods in RCP2.6. These results show that the temperature increase is significant in the dry periods for both regions.

With regard to seasonal variation, in the Central Rift Valley region, in the bias uncorrected projection a maximum difference of about 6.5°C occurs in Bega and Belg seasons for RCP8.5 in 2090s and the minimum difference of 1°C for the same period occurs in Kiremt for RCP2.6. In the case of the bias corrected the temperature difference is insignificant with a maximum of 0.2°C in Belg season. The corresponding bias uncorrected values in Northwestern Lowlands is
over 6°C in Bega and a minimum difference of 1 °C in Kiremt as in the Central Rift Valley Region. The corresponding bias corrected value is 5 °C in Belg with a decrease of 0.5°C in Bega in the 2090s.

**Maximum temperature**

The inter-annual bias uncorrected increase in maximum temperature in the 2090s for scenarios RCP2.6, RCP4.5 and RCP8.5 is 2 °C, 3.5°C and 7 °C respectively in the Central Rift Valley region and the corresponding bias corrected projection is 1 °C, 2°C and 5 °C. The corresponding values for bias uncorrected and corrected projections in Northwestern Lowlands is 1.5, 2.5°C and 6°C; and 3°C, 4°C and 7.5°C respectively. Thus, the inter-annual pattern shows an increase for both areas and projections; and the increase is significant in the higher scenarios and long term periods.

The monthly pattern in the bias uncorrected projection in the Central Rift Valley region shows an increase of nearly 7°C for RCP8.5 in the 2090s in the month of July and the minimum difference is 1°C in March for RCP2.6 in the same period. In the case of bias corrected projections, the temperature difference is insignificant in RCP2.6 for the whole period and the maximum difference is 6°C and 5°C in May and August for RCP8.5 in the 2090s. The bias uncorrected corresponding value for Northwestern Lowlands is 8°C in the months of July and the minimum difference is less than 1°C in February and March for RCP2.6. For the bias corrected projections, the maximum increase 6.5°C in July for RCP8.5 and the minimum difference is almost zero for RCP2.6 in all months of the year. These results show that the temperature increase is significant in the wet periods for both regions.

Regarding seasonal variation, in the Central Rift Valley region, in the bias uncorrected projection a maximum difference of over 6 °C occurs in Kiremt seasons for RCP8.5 in 2090s and the minimum difference 1 °C for the same period occurs in Belg season for RCP2.6. In the case of bias corrected projections the temperature difference is 5.5°C in Belg season for RCP8.5 in the 2090s and the minimum is 0.5°C in the same season for RCP2.6. The corresponding bias uncorrected values in Northwestern Lowlands is over 7°C in Kiremt with a minimum difference of 1 °C in Belg as in the Central Rift Valley Region. The corresponding bias corrected increase is 5 °C in Kiremt and a decrease of 0.5°C in Bega in the 2090s for RCP8.5. The seasonal maximum temperature increase for both regions is in Kiremt in the same period and scenario while the minimum temperature difference is in Belg for Central Rift Valley Region and Bega for Northwestern Lowlands.

**2.1.3. Extremes and impacts**

The historical and projected climate change revealed the likelihood of the occurrences of extreme events. The extreme value analysis carried out for wet days during which the rainfall quantity is greater than the mean plus one and two times standard deviation shows a general
trend of increase from 6 to 9 days (50%) and 3 to 4 days (33%) respectively in the Central Rift Valley region. The analysis for dry extreme events shows that most of the days of the year will have a rainfall less than the mean minus one times standard deviation. Thus, in the Central Rift Valley region there will be an increase in both extreme wet and dry event indicating the possible occurrence of flooding and drought. The extreme value analysis in the Northwestern Lowlands for one or two times standard deviation above the mean value shows decrease as one goes from RCP2.6 to RCP8.5 and from the 2020s to 2090s. On the contrary, the extreme dry days with rainfall less than the mean value increase up to 7%. Overall, the findings of the research show that there will be a combination of decrease on overall rainfall quantity for Northwestern Lowlands and with no clear indication for Central Rift Valley Region. But monthly and seasonal findings show drier periods have more rain while in wetter periods it decreases. On the other hand, there is a consistent indication of an increase of temperature of more than 2°C in the RCP4.5 and RCP8.5 in the 2050s and 2090s. This shows there is a combination of decrease in rainfall and increase in temperature which is not favorable for both sugarcane and cotton farming.

2.2. Key Vulnerabilities

The last subsection tells us that there will be change in long term mean temperature and precipitation which affects the inter–annual and seasonal amount and distribution of temperature and rainfall. As a result, it is likely that climate related hazards including drought and flooding will occur. In addition, the change in these climate variables will have strong implications for cotton and sugarcane growth. This subsection will discuss the extent of the vulnerability of the actors along the value chain of the two commodities based on the findings of the agronomic and economic analyses.

Vulnerability assessment has been conducted using household level data collected in both cotton and sugarcane producing regions of Ethiopia (Firew and Alebel, 2015). The result revealed that non-climate factors have contributed to the vulnerability of communities to climate related hazards in these regions. These non-climate factors include economic, social, institutional, infrastructure and technological (Alebel et al, 2014). A summary of the key factors and issues are shown in Table 3 below. For instance, one of the non-climate factors that increase the vulnerability of communities to climate-related hazards is the type of livelihood on which the community depends for their survival. This livelihood is characterized by the dominance of subsistence crop production, which accounts for more than 90% of households' annual average income. Non–farm income contributes to very small proportion of their annual income. This type of livelihood is very sensitive to climate related impacts and increase their vulnerability to any negative impact associated with future climate change. Asset holding is also another factor that contributes to their vulnerability as their asset is not only climate sensitive such as livestock but also has low value that may not enable the community to cope up with sudden occurrence of climate related hazards. Their low level of education and skill also make them vulnerable since they cannot help them to change their livelihood to non–climate sensitive

3 Interested readers can access the detail results from a research report on vulnerability at www.edri.org.et
livelihoods such as involving in small trading, wage employment, etc. Institutional and governance system also contribute to their vulnerability as there are limited institutional services such as provision of crop and livestock extension services for better or improved practices. In addition, the governance system in cotton producing region along its value chain is so weak that there is no established arrangement that provides any systematic service such as climate related information or technology to improve the adaptive capacity of the different actors and reduce their vulnerability. In addition, there is also low institutional capacity for cotton that can produce information for building the resilience of the commodity at different level of its value chain (Berihu, et al, 2015). Though the institutional and governance system is relatively better for sugar as there are well established corporation and linkage among the policy making (sugar corporation), producers (out growers, factory owners), sugar distributors (marketing department at Sugar corporation), retail traders (such as consumer association) and consumers, the sector has low capacity in terms of producing, processing and regulating climate related information for sugar. Overall, the key vulnerabilities of these actors are due to low income, limited technology use in key livelihood, weak institutions, low level of education, unequal consideration particularly biased against women, limited access to public services such as water, sanitation, energy and limited access to finance. These factors, together with change in climate, make the vast majority of the households/communities in both cotton and sugarcane producing regions of the country vulnerable. Characteristics of vulnerability and key determinants of non–climate factors for vulnerability including economic, social, technological, infrastructure, institutional and governance, engineering as well as agronomic factors are discussed in detail in respective research reports and can be found at footnote 2.

2.3. Key risks
The above discussions on observed and projected change in climate parameters, climate related hazards and key vulnerability suggests that there will be climate related risk associated with the interaction of climate-related hazards and key vulnerabilities of societies, communities, or the economy as a whole. The findings from climate modelling show that there will be a combination of decrease on overall rainfall quantity for Northwestern Lowlands and with no clear indication for Central Rift Valley Region. But monthly and seasonal findings show that drier periods have more rain while wetter periods decrease. In addition, the findings show that there is a consistent indication of an increase of temperature of more than 2°C in the RCP4.5 and RCP8.5 in the 2050s and 2090s. This shows that there is a combination of decrease in rainfall and increase in temperature. These findings will not only induce the occurrences of climate related hazards such as flood and drought but will also have an impact on the agronomic aspect of the two crops. The vulnerability study also shows that the human systems in the two regions are vulnerable to the anticipated climate related hazards. Thus, the key risks may arise from the interaction of these climate-related hazards and key vulnerabilities of the human system including societies, communities, or economy exposed to the anticipated impact. These key risks are identified based on the agronomic and economic implications of these findings. Agronomic analyses is done to understand the implications of the future projection of change in climate for the growth and production of the two crops based on their agro ecological, water and soil requirements. In identifying the key economic risks, the dynamic aspect of socioeconomic
development of the country is taken into consideration since vulnerability is not only region specific but it also varies over time depending on the development process of the country. In this regard, the key economic risks are categorized into productivity of specific crop, welfare of the most vulnerable groups and the economy wide impact. This subsection presents the key climate change risks for cotton and sugarcane producing regions of Ethiopia.
Table 5: Key vulnerability factors and issues for cotton and sugarcane producing region of Ethiopia.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Key issues in cotton growing region</th>
<th>Key issues in sugarcane producing region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Livelihood</td>
<td>Dominance of subsistence crop production, small share of income from non-farm business; low annual average income; lack of alternative sources of income; low adoption of improved technology such as fertilizer and improved seed;</td>
<td>Dominance of subsistence crop production, small share of income from non-farm business; low annual average income; lack of alternative sources of income; low adoption of improved technology such as fertilizer and improved seed;</td>
</tr>
<tr>
<td>Asset</td>
<td>Liquid asset including livestock, which is sensitive to climate change; durable items not only whose market price is low but also shallow in kind and magnitude; farm land as key asset</td>
<td>Liquid asset including livestock, which is sensitive to climate change; durable items not only whose market price is low but also shallow in kind and magnitude; farm land as key asset</td>
</tr>
<tr>
<td>Demography</td>
<td>Large family size, high dependency ratio, limited/shortage of access to land for new coming generation; limited non – farm business opportunities</td>
<td>Large family size, high dependency ratio, limited non – farm business opportunities;</td>
</tr>
<tr>
<td>Human capital</td>
<td>Low literacy level, low skill, low year of schooling</td>
<td>Low literacy level, low skill, low year of schooling</td>
</tr>
<tr>
<td>Institutional service</td>
<td>limited extension service; low improved technology supply such as fertilizer and improved seed, low market information, low access to finance;</td>
<td>limited extension service; low improved technology supply such as fertilizer and improved seed, low market information, low access to finance;</td>
</tr>
<tr>
<td>and Governance system</td>
<td>Major institutional and capacity gaps, including agro-meteorological information, management of key areas (e.g. watershed management), skill constraints, lack of private sector investment, etc.</td>
<td>Major institutional and capacity gaps, including agro-meteorological information, management of key areas (e.g. watershed management), skill constraints, lack of private sector investment, etc.</td>
</tr>
<tr>
<td></td>
<td>Absence of linkages among the different actors along the value chain;</td>
<td>Low levels of existing adaptive capacity are an important barrier to the successful uptake of resilience plans.</td>
</tr>
<tr>
<td></td>
<td>Low levels of existing adaptive capacity are an important barrier to the successful uptake of resilience plans.</td>
<td></td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Inadequate transport network including poor access to road to nearest market; poor basic social services including access to potable water supply, sanitation,</td>
<td>Inadequate transport network including poor access to road to nearest market; poor basic social services including access to potable water supply, sanitation,</td>
</tr>
<tr>
<td>Inequality</td>
<td>Inequality between male – headed and Female headed households;</td>
<td>Inequality between male – headed and Female headed households;</td>
</tr>
<tr>
<td>Technology</td>
<td>Limited use of improved technology such as irrigation, sowing and harvesting technology</td>
<td>Irrigation infrastructure for sugarcane production is vulnerable to flood; limited use of improved technology</td>
</tr>
<tr>
<td>Engineering</td>
<td>Awash river bank, main canal in sugarcane plantation are vulnerable to flood</td>
<td></td>
</tr>
<tr>
<td>Agronomic factors</td>
<td>Water stress for crop growth due to drought and decrease in rainfall; decrease in soil moisture, etc</td>
<td>Water stress for crop growth due to drought and decrease in rainfall; decrease in soil moisture, etc</td>
</tr>
<tr>
<td>Macroeconono</td>
<td>Challenge from substitute crops such as sesame for cotton</td>
<td></td>
</tr>
<tr>
<td>mic production; as a result, textile sector is vulnerable for shortage of input from domestic source; Textile sector is vulnerable to risk of dependency on foreign sources for its input;</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The key risks in sugarcane producing region are the following:

**Extreme events**: The climate modelling study revealed that the project mean annual rainfall will not have distinct trends in Central Rift Valley but decreasing in North West Lowland in RCP8.5 climate change scenario. However, a distinct trend is observed in the projected seasonal rainfall. In addition, more number of rainy days in Bega & a decrease in Kiremt and Belg will likely be observed. With regard to mean annual temperature, the finding shows that it has an increasing trend over the study period from 2020 to 2090s. It also increases as one goes from RCP2.6 to RCP8.5. Overall, mean annual temperature is likely to increase by at least 2°C in 2090s for RCP8.5 scenario, and maximum temperature increase is observed in Kiremt season. A combined trend in rainfall and temperature is also observed during crop growing season: A decrease in rainfall with increase in maximum temperature, and an increase in rainfall with increase in minimum temperature in dry season. In terms of climate change related hazards, it is likely that the overall projected change in climate variables will likely result in increase of extreme events including flood and drought in central rift valley and dry extreme event in North West lowland (Geremew and Agizew, 2015; Alebel et al, 2014).

**Agronomic implications**: the findings from climate modelling in Central Rift valley over the medium and long terms revealed that though the inter–annual rainfall will not show distinct trend, which also confirms previous findings done for Ethiopia, the study findings show a decrease in rain during growing season of cotton and an increase in the dry season, which will have important agronomic implications. The simultaneously observed trends in rainfall decrease and increase in maximum Temperature in growing seasons will likely result in water stress for crop growth. In addition, delay and/or extension of rain in rainy season will likely affect planting time. A decrease in consecutive rainy days in all season & an increase in mean annual Temperature will have effect on the type of Seed Variety for both crops. On the other hand, the findings of the climate modelling on the projected change that will likely result in the increase of rainy days in Bega season may be an opportunity to have access to water for plant growth at later seasons (Kidane G, 2015).

These findings will have direct effect for crop growth and total production since the changes induce water stress, shorter growing season as well as uncertainty in planting dates for cotton. In addition, the finding in northwest lowlands shows that there will be a decrease in rainfall, which will have a similar effect. In relation to change in temperature, the findings also revealed an increase in temperature, which will have important agronomic implications for plant growth through moisture stress and water availability and thereby pose climate risk for cotton and sugarcane production. Therefore, the key risks associated with these findings include yield and production decrease, change in seed variety, less water availability for plant growth, loss of farm land due to higher run off during Bega, during which there will be an increase in rain. Thus, these key climate risks call for the need to identify adaptation options to minimize the risk and build a climate resilient production of cotton and sugarcane.
Economic implications: The economic implications of the observed and projected climate variables are briefly summarized as follows based on the findings of the different research components of the project.

- **Decrease in yield**: one of the key risks is a reduction in sugarcane and cotton productions as a result of climate change risk of change in temperature and rainfall. The productivity impact study revealed that climate change will reduce sugarcane yield\(^4\). The risk is associated with increase in temperature, which induces water stress for crop growth. When this is coupled with a decrease in rainfall, the reduction in crop yield will be significant. While the Productivity impact of rainfall varies with scenario and period of analyses, projected change in mean temperature will likely reduce productivity (Alebel et al, 2015). The productivity analyses revealed that projected impact in rainfall may result in improving productivity though it may also likely result in reduction. Temperature is likely to reduce productivity. The largest negative effect will likely result from seasonal change in temperature (T) and rainfall (RF). Overall, projected impact of climate change will likely reduce sugar productivity by 10% to 70% depending on the period and climate scenario. It will also likely decrease revenue from output by almost the same percentage in both sugarcane and cotton growing regions. The climate modelling result indicated that it is likely that flooding may occur and pose water logging problems in sugar plantation and resulted in reduction of the yield. This is also true in cotton production. Besides, the increase in rainfall, which causes flooding, may induce the expansion of the Beseka lake, which may pollute river Awash and thereby affect sugarcane production.

- **Increased in price of sugar and cotton**: the reduction in sugarcane yield may pose risk of shortage of sugar supply which, as a result, may increase the price of sugar. Similarly, the reduction in cotton yield may also cause shortage of domestic supply of cotton which may affect textile factories in increasing their production cost.

- **Risk of food insecurity**: the value chain analyses revealed that the different actors along the textile industry value chain are not well mainstreamed whereas the sugar industry operates in a relatively well streamlined and vertically integrated environment. However, in both commodities, not all actors are equally vulnerable to climate change risks. The findings on the vulnerability and welfare impact studies shows that it is likely that poor households will fall below the poverty line due to their vulnerability and low income or welfare status. The vulnerability analyses revealed that, on average, 72.5% & 78.0% of producers in sugarcane and cotton producing regions are vulnerable to climate change risks, respectively (Firew and Alebel, 2015). This impact may be due to risk of the breakdown of food systems linked to warming and precipitation which may induce the occurrences of extremes including drought and flooding. The impact may also be severe for female – headed households who are more vulnerable to the impact due to their current welfare situations.

- **Loss of asset**: The vulnerability and welfare studies revealed that asset holdings such as access to land and livestock have significant relations with welfare and probability of failing below poverty line. For instance, access to resources (Land), demography characteristics (family size), literacy and income source crucially determine vulnerability to climate change

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\(^4\) See research report on ‘productivity and welfare impact of climate change on cotton and sugarcane producing regions. Available at www.edri-et.org
risk. This implies that with increase in rainfall amount, pattern and intensity, which may result in sudden flooding, climate change may pose key risk of losing assets due to its effect on the occurrence of flood. The associated adverse event may also further cause reduction in asset since households may sell their durable asset to cope up the flood event. Drought may also be a cause for asset loss since households may be forced to sale their durable assets as coping mechanism for the reduction in crop yield as a result of drought (Firew and alebel, 2015; Alebel et al, 2014).

- **Loss of basic infrastructure**: welfare analyses revealed that access to infrastructure has significant effect in welfare of the household. Besides, the likelihood of households falling below the poverty line is less for those households with access to infrastructure compared to those with low access. On the other hand, climate change may also pose risk to infrastructure due to climate associated extreme events leading to the breakdown of infrastructure networks such as road and critical services such as electricity, water supply, and health and emergency services. In addition, flooding may damage existing irrigation infrastructure particularly in sugarcane producing areas, where large scale farms are producing sugarcane using irrigation (Alebel et al, 2014).

- **Reduction in welfare of households**: The reduction in sugarcane and cotton yield and production as a result of climate change induced events crucially affects the welfare of producers and laborers working in sugar and textile factories as well as other families involving along the value chain of the two commodities including processing, distributing and consuming. The reduction in production of sugarcane reduces the welfare of the out-growers due to yield reduction and loss of asset of assets. However, the effect on producers’ welfare due to the increase in the price of sugar depends on the revenue they obtain from higher demand and sale of lower quantity of sugar as well as the loss of assets. On the other hand, consumers’ welfare will substantially decrease as a result of reduction in yield in sugar. In addition, the welfare of laborers’ employees of sugar factory may also decrease if their income/wage is associated with volume of production of sugar. In relation to cotton, smallholder and large scale producers are the major actors whose welfare is affected as a result of reduction in cotton production though the level of the impact varies depending on their adaptive capacity. Similar to sugarcane, the effect on cotton producers also depends on the substitution and income effects of the increase in price of cotton. Others whose welfares are likely to be affected by reduction in cotton production are wage laborers in textile factories and smallholder ginners whose livelihood is strongly linked to cotton. Overall, the welfare analyses revealed that, like its effect on productivity, rainfall has no distinct trends in its impact on welfare of households, as it depends on the period of analyses and climate scenario used. However, the findings indicated that compared to inter–annual rainfall, projected mean seasonal rainfall will likely result in significant change in welfare. For instance, the long term mean change in Bega season rainfall will likely have the maximum negative impact on welfare. It will reduce welfare by 15%. On the other hand, long term mean change in Belg season will likely improve welfare by almost the same percent. On the other hand, unlike rainfall, projected mean inter-annual temperature will likely reduce welfare consistently. The reduction in welfare ranges from 0.05% to 0.2% due to mean annual temperature (Alebel et al, 2015).
• **Economy wide impact:** The reduction in cotton and sugarcane as a result of climate change will also have an economy-wide impact. The effect is reflected on the export of textile and sugar due to shortage of domestic supply of cotton and sugarcane input, respectively, as well as on the overall economy or Gross Domestic Production (GDP). The dynamic CGE analyses indicated that it is likely that Ethiopia will loss in its export earnings as a result of climate change impact on cotton and sugarcane production. The result shows that projected rainfall change will increase quantity of export of sugar by 46% and change in mean annual temperature will decrease export of sugar by 55% within the next two years. Total GDP at factor cost slightly increases by about half percentage point over the 2016-2035 period due to the projected rainfall change. Conversely, GDP declines by 0.77 percent as compared to the baseline scenario due to change in mean annual temperature within the same period. In the long run, mean annual change in rainfall and temperature will reduce GDP at factor cost by about 1.52 percentage point and 3.12 percentage points, respectively in 2080 – 2100 due to the impact on sugarcane production. Similarly, projected change in mean annual rainfall and temperature will have an impact on export of textile, and, thereby, GDP. While projected change in mean annual rainfall will decrease export of textile by 0.6 percentage point, temperature will reduce textile export by about 248 percentage point. These changes in export of textile will have an impact on GDP. Rainfall will increase GDP by about 0.39 and 1.52 percentage points over the 2016-2035 and 2081-2100 periods respectively. Conversely, predicted change in mean annual temperature will decrease GDP by 1.52 and 3.12 percentage points for medium and long term periods, respectively, as compared to the baseline scenario (Seneshaw and Alebel, 2015).

2.4. **Reason for concern**

The discussions in the previous subsections indicated that there are good reasons to worry or be concerned about climate change impact on the two commodities studied. Thus, effective adaptation strategies are required to adapt to the anticipated climate change impacts. This requires identification of adaptation options from which effective adaptation strategies can be selected based on the planning and implementation capacity of the different actors. Before we will discuss the adaptation options, we will summarize the risks, drivers of vulnerabilities and concerns based on the findings of the different components of the project activities.

Summary of observed and projected climate risk, key vulnerability and key risk in the two commodities’ growing regions can be summarized as follows.

• **Risks to unique and threatened systems:** key risk of future cc are increase average annual temperature, more hot days, decrease in rainfall, change in rainfall pattern and increase in rainfall intensity. Impacts of such climate-related extremes include reduction in discharge of Awash river, damage to river bank infrastructure of Awash river due to flood, damage of irrigation infrastructure; reduction in sugarcane production/yield, reduction in cotton yield/production, increase in soil moisture, water stress for crop growth; reduction in food production and income, loss of assets, displacement of community; migration. In addition, these cc risk can have effects on reduction in yield, negatively affect their income
and make them fail below poverty line. On the other hand, producers, labourers, women and children depend on the production and marketing of cotton and sugarcane. Thus, they are threatened as a result of their exposure and vulnerability to current and future cc risk. In addition, the export economy is threatened due to risk on the textile and sugar sectors, which is threatened as a result of reduction in yield of sugarcane and cotton.

- **Risks associated with extreme weather events**: key risk of future cc are increase average annual temperature, more hot days, decrease in rainfall, change in rainfall pattern and increase in rainfall intensity. This future cc can bring about the occurrences of extreme weather events including drought and flood. These can trigger key risks to societies who depend on activities along the value chain of these two commodities. Producers including smallholder cotton producers and large scale private cotton producers; weavers, ginners are social groups who will be more vulnerable to the impact of climate change on cotton as these are directly dependent on the production of cotton. Female headed households are also more vulnerable. Smallholder sugar out-growers are also more vulnerable to climate change related impacts on sugarcane production as they are majorly dependent on its production. Second level vulnerable groups due to climate change impact on cotton and sugar productions are textile and sugar factory wage workers, respectively, and families’ whose livelihood solely dependent on the market value chain of textile products. Rural and urban consumers are also vulnerable to the impact of sugarcane production due to shortage of supply of sugar, which induce an increase in the price of sugar.

- **Risks associated with the distribution of impacts**: Differences in non - climate change drivers are attributed to differences in vulnerability of these climate change related hazards and to their impacts. These non – climate change drivers include economic, infrastructure, institutional, governance, etc. Besides, the cotton sector will be more vulnerable due to absence of well-organized institutional arrangement and lack of governance system that regulates the different actors along its value chain. As vulnerability also vary over time due to the dynamic nature of poverty, future climate change impact will also vary across time and geographic regions. Changes in poverty or socioeconomic status, age structure, and governance will have a significant influence on the outcome of future crises associated with climate-related hazards. Thus, the distributional impact of the key risk associated with current and future cc disproportionately affect different societies. Among those affected, smallholder producers, large scale private cotton producers, smallholder out-growers and female – headed households are more vulnerable to cc risk due to their economic status.

- **Risks associated with global aggregate impacts**: as a result of decrease in yield in sugar, there may be shortage of supply of sugar or sugar may be imported. Both cases will increase in the price of sugar domestically, which will affect poor households. Besides, some of the adaptation mechanisms that will be used to cope up with the future cc risk may also increase input cost for cotton and sugarcane producers. If price is constant, such adaptation strategy may decrease the welfare of producers due to reduction in revenue. This may pose key risk to producers. Otherwise, if price is proportionately increased,
consumers will face higher price for sugar and thus will be negatively affected. Together with their level of vulnerability, this may pose key risk to consumers.

- **Risks associated with large-scale singular events:** A sudden occurrence of flood due to climate change may pose particular risk to sugarcane or cotton producers which may result in loss of lives, property or crop on farm. These pose immediate key risk to producers. Drought may also occur which induces migration or change in livelihood. This may also pose key risk. The future projection of climate change on sugar and cotton will also have an overall economy wide impact. Reduction in cotton production will have a negative effect in reducing the foreign currency reserve of the country as the country either may loss export earning or consume its reserves as it will be forced to import cotton from abroad if it should opt to continue to produce and export textile. The same is true for sugar commodity.

### 3. Adaptation options

In the previous section, the change in climate and its related hazards are presented together with the exposure and vulnerability of the different actors along the value chain of the cotton and sugarcane commodities. The observed and expected impacts have also discussed. The information generated from the previous section indicated that there are enough reasons to concern about future climate change and, thus, calls for the need to identify adaptation options. This section presents the adaptation options identified in order to reduce the risk and vulnerability, seek the opportunities and build the capacity of the local community, the different actors along the value chain and the export economy from the textile and sugar commodities. The study used the definition given by the fifth assessment report of the WGII of IPCC. It defined adaptation options as the array of strategies and measures available and appropriate to reduce the anticipated climate change risks and build the adaptive capacity. As it has been stated the overall aim of the project is to identify adaptation options. This does not mean that all the options need to be implemented when the need arises. The later requires other works including the need to assess the challenges in planning and implementations of the options, and assessments of their costs and benefits. Therefore the identified adaptation options are broad set of strategies that will help to identify effective adaptation strategies which will be selected, planned and implemented to build a climate resilient export of the textile and sugar commodities in Ethiopia. The section is organized as follow. The next subsection will briefly discuss the approach used to identify the adaptation options, followed by criteria used to identify the options. Finally, the adaptation options will be presented.

#### 3.1. Approach for identifying adaptation options

Many adaptation frameworks or approaches have been published. They vary not only with their theoretical framework but also based on the goal each study aims to achieve and the type of data use. Most of the approaches were done using a risk – hazard framework, which is basically gives emphasis on the physical and biological aspects of impacts and adaptation (Burton et al.,
“Impacts-based” approaches focus primarily on the biophysical climate change impacts to which people and systems need to adapt. The risk-hazard framework is drawn primarily from risk and disaster management. It focuses on the adverse effects that natural hazards and other climate impacts can have on a given location (Füssel and Klein, 2006). The emphasis in this approach is on the physical and biological aspects of impacts and adaptation (Burton et al., 2002). There are also others with some standard approach and share common characteristics. Such standard approach often described as top-down because it combines scenarios downscaled from global climate models to the local scale with a sequence of analytical steps that begin with the climate system and move through biophysical impacts toward socioeconomic assessment (IPCC, 2007b). The process of downscaling of global climate models leads to issues of uncertainty and limited statistical confidence (Fünfgeld and McEvoy, 2011). These approaches ignore the social vulnerability aspect of climate change impact studies. On the other hand, there are also approaches that focus on vulnerability and adaptation based assessment that are done separately. Vulnerability-based approaches focus on the risks themselves by concentrating on the propensity to be harmed, then seeking to maximize potential benefits and minimize or reverse potential losses (Adger, 2006; IPCC, 2007b). The social vulnerability framework focuses on the reasons and ways in which individuals, groups, and communities are vulnerable to climate impacts. Here, the focus is on how different factors, such as institutions, shape the socioeconomic conditions that place human populations at risk (Adger and Kelly, 1999; Preston et al., 2011b). “Adaptation-based” approaches examine the adaptive capacity and adaptation measures required to improve the resilience or robustness of a system exposed to climate change (Smit and Wandel, 2006). In practice these approaches are interrelated, especially with regard to adaptive capacity (O’Brien et al., 2007). An evolution in the conceptualization of risk and vulnerability in the past decade has led to more holistic and integrated approaches to assessment, aiming toward a more systemic understanding of the complexity of human environment interactions (Preston et al., 2011b). However, these two are interrelated and need not be assessed separately. A new approach that links scenario-based assessment with biophysical, economic and social analysis tools have been also used in different studies. Recently, researchers also used approach that combines vulnerability and adaptation assessment to generate information on vulnerability and inform decision makers on adaptation options to reduce risk and build adaptive capacity (Burton et al, 2002; Füssel and Klein, 2006; LDC Expert Group, 2012). These approaches are characterized by the intensive involvement of stakeholders and the participation of vulnerable groups in decision making around adaptation options. The literature on assessment of adaptation options shows that there are overlaps and complementarities between these frameworks, and the approach is still evolving as many researches will still be need to be done.

Given these brief review of the different approaches used in assessment of adaptation options, this study used a “top-down” and “bottom-up” assessments approaches based on the notion that identification of adaptation options requires assessments of the factors that determine the nature of, and vulnerability to, climate risks and assessment of adaptation option. The fifth assessment report of the IPCC stated that adaptation assessments best suited to delivering effective adaptation measures often include both top-down assessments of biophysical climate changes and bottom-up assessments of vulnerability targeted toward local solutions to globally
derived risks and toward particular decisions (IPCC, 2013). This approach combines the
different approaches discussed above including scenario – based, impact-based assessment,
vulnerability- and adaptation – based assessment approaches. Therefore, the identification of
the adaptation options are done based on the findings of the others studies including climate
modelling, agronomic and vulnerability – based assessments. The framework used in
identifying the adaptation options also considers the following basic characteristics of
adaptation. First, adaptation is place and context specific i.e. adaptation to one place may not
work for other due to the specific nature of the geographical, agro-ecological, socioeconomic,
institutional, governance and cultural values. Second, adaptation requires the involvement of
different stakeholders at different levels including international, national and sub national
governments, regional and local communities. This consideration is taken since there is an
increasing recognition in the literature that while many adaptation actions are local and build on
past climate risk management experience, adaptation will often require changes in institutional
arrangements and policies to strengthen the conditions favourable for effective adaptation
including investment in new technologies, infrastructure, information, and engagement
processes (WGII IPCC, 2013). As a result, the literature identifies adaptation practices at
policy and implementation levels by international organizations, national and regional
governments, private sectors and non-governmental organizations. For instance, the fifth AR of
the IPCC reported with high confidence that in Africa, most national governments are initiating
governance systems for adaptation (IPCC, 2014). Progress on national and subnational policies
and strategies has initiated the mainstreaming of adaptation into sectoral planning, but evolving
institutional frameworks cannot yet effectively coordinate the range of adaptation initiatives
being implemented. Disaster risk management, adjustments in technologies and infrastructure,
and livelihood diversification are reducing vulnerability, although efforts to date tend to be
isolated. There are also evidences that shows climate change impacts have pronounced due to
absence of early actions to adapt due to lack of adaptation capacity, which are attributed to
adaptation constraints including lack of access to credit, land, water, technology, markets,
information, and perceptions of the need to change. The third point that needs to be considered
in identifying adaptation options is the dynamic nature of vulnerability due to the change in
development or poverty levels over time. Building adaptive capacity by decision makers at all
scales is an increasingly important part of the adaptation discourse which has also further
addressed costs, benefits, barriers, and limits of adaptation (Adger et al., 2009; Nelson et al.,
2008).

There are different categories of adaptation options that are discussed in the literature. These
categories are classified based on the different needs or constraints identified for adaptation of
climate change impacts on the natural or human systems. For instance, the fifth assessment
report of the IPCC classifies these in to Structural and Physical Options, Social Options, and
Institutional Options (IPCC, 2014). In this study, the categorization of the adaptation options is
made based on the key climate and non – climate change determinants of vulnerabilities to the
impact of climate change on the different actors along the value chain of the two commodities
since the foundation for identifying adaptation options the specific information generated from
the characterization of climate change risk, vulnerability and adaptation capacity in the study
regions.
3.2. Selection of adaptation option

Selection and prioritization of adaptation options is important because not all adaptation options will be possible due to constraints such as insufficient local resources, capacities, and authority. The fundamental issue here is ‘what should be the Considerations when selecting adaptation options?’ This is a challenging question due to the uncertainty of the change in climate and its impact is cumulative. While there are a variety of systematic techniques used for selection and prioritization of adaptation options in the literature, the techniques are not free of weakness. For instance, quantification of the options does not account for a range of critical factors such as leadership, institutions, resources, and barriers (Smith et al., 2009). Risk management approaches: no-regrets measures both reduce climate risk and provide other social, economic or environmental benefits (Hallegatte, 2009). Risk management approaches often lead to no-regrets, low regrets or win-win options. While multi-criteria analysis (MCA) allows assessment of options against different criteria, as was used in the preparation of NAPAs (UNFCCC, 2011), they are not free from shortcomings. Recently, iterative risk management technique is considered as most suitable in situations characterised by large uncertainties, long time frames, the potential for learning over time, and the influence of both climate as well as other socio-economic and biophysical changes.

In this study, the following considerations have been taken to select the different adaptation options that are expected to build a climate resilient production of cotton and sugarcane, which are key inputs in the production of textile and sugar, the two key export commodities of Ethiopia.

- **Effective in reducing vulnerability and increasing resilience**: this study used the findings from the study made to identify the fundamental drivers of vulnerability to climate change. As it has been stated previously, a number of non-climate factors significantly increased the vulnerability of the key actors including smallholder producers to anticipated climate change related hazards and adverse effects. Thus, in identifying the adaptation options, addressing these fundamental drivers of vulnerability is believed to have significant positive effect in building the adaptive capacity and become resilient to climate change impacts.

- **Equitable, especially to vulnerable groups**: One of the key findings of the value chain analyses and vulnerability as well as welfare impact analyses is the different actors along the value chain of the two commodities have different level of exposure and vulnerability due to their heterogeneity in their level of dependency for their livelihood, socioeconomic, human capital, etc. As a result, the anticipated climate change will have different level of impacts. For instance, while smallholder producers in cotton producing regions are entirely dependent on the production of rain fed crop production, large scale cotton producers are entirely dependent on the production of cotton. Their livelihood is very sensitive to climate change. Similarly, sugarcane outgrowers and sugar factories are dependent on irrigated sugarcane production whose main source of water is Awash river. Climate change
negatively affects this river both in reducing its water flow during less rain season and increase flooding during increased rainy season. Thus, these people are more vulnerable to climate change. On the other hand, female-headed households are more vulnerable to climate change. These considerations are taken in identifying adaptation options.

- **Mainstreamed / integrated with broader social goals, programs, and activities:** another important consideration given due emphasis in selecting the adaptation options is the long term development path of the country, which is a climate resilient green economy strategy to achieve sustained economic growth and reduced poverty under the intervention of the state to fill a missing market gap along the development path. In this regard, the findings from the institutional assessment and characteristics of vulnerability and adaptation studies have been utilized. Here the coherences and synergies of the adaptation options with other climate change objectives such as mitigation is considered. However, as the main goal of the study is to identify adaptation options, we give priorities to those actions/interventions that build the resilience of the two commodities even if these will have a negative effect in increasing emissions.

- **Stakeholder participation, engagement, and support:** one of the key findings of the institutional assessment study is that there are many stakeholders involved along the value chain of the two commodities that have direct influence on formulation, planning and implementation of effective adaptation strategy for a climate resilient production of export commodities in Ethiopia. These stakeholders have roles that can feed-in to achieve a common goal of a climate resilient cotton and sugarcane production and export. Thus, considering the key roles, a strong institutional and governance arrangement is crucial in identifying the adaptation options. Accordingly, issues including the roles of actors at different levels including international, national and regional governments as well as local communities are taken into consideration.

- **Resources available (including information, finance, leadership, and management capacity):** as the different actors along the value chain of the two commodities differ in their level of exposure and vulnerability, climate change poses different levels of impact. In addition, their vulnerability also differs overtime depending on the development path and goal of the country. This different level of vulnerability means that the different groups of actors have different adaptation needs, which shows the need to identify adaptation options that builds the adaptive capacity of the different groups of actors according to their adaptation needs. We assumed that resource is limited. Thus, the study gives due consideration to fundamental characteristics of key vulnerability and key risks to climate change and give priority to more vulnerable groups. Accordingly, adaptation options are identified both from the ‘affected’ and ‘policy and implementation’ sides. From the ‘affected’ side, actors involved in production/processing, distribution and consumption are considered while from the ‘policy and implementation’ side, the institutional and governance system at national, regional and local community levels is considered.
• **Sustainable (environmental and institutional sustainability):** it is also crucial to develop adaptation options that provide sustainable solutions. In this respect, two issues are essential. The first is the sustainable utilization of the natural resource base as well as institutional arrangements that can provide appropriate leadership in identifying strategies, implementing and coordination so that the adaptation options can be effectively implemented to build the resilience of the sector to climate change impact. Sustainability is important since vulnerability and adaptation are dynamic in nature due to the dynamic nature of the development path of a country. Thus, in selecting adaptation options, such consideration is also made.

3.3. **Adaptation options**

The findings of the observed current and future climate change, the key vulnerability and key risks to these projected climate changes in both areas call for identifying adaptation options to reduce the anticipated impact of climate change and building the resilience of the commodities. The information generated from the different project study components are used to identify the adaptation options. Over the years, a number of categories of options have been identified. The fifth assessment report of the IPCC categorized adaptation options into Structural /physical, social and institutional. There are subcategories under each of these three main categories. However, we have categorized the adaptation options into five including structural/physical, social, economic, infrastructure and institutional and governance. Thus, the proposed adaptation options are discussed under each of these categories as follows. Table 5 summarizes the proposed adaptation options.

1. **Physical structure:**

Adaptation options under this category are characterized by clear outputs and outcomes. They can be improvements of the existing practices, plans and structures and/or developing new ones. Adaptation options under this category include:

1.1. **Engineering and built environment:**

- **Upgrading the existing infrastructure** of the Awash river bank to improve flooding resilience of the river so as to protect sugarcane farms/plantation and its irrigation infrastructure. When there is increase in rain and there will be extended rainy days during bega, there may be flood that damages the existing Awash river bank and irrigation infrastructure. Thus, this option will help to build the resilience of the river bank and irrigation infrastructure at the time of flooding.

- **New engineering infrastructure development:** Construction of multi-purpose reservoirs and rainwater harvesting systems. The increase in rainy days in Bega during the dry season will naturally lead to high water runoff which could give the opportunity for water harvesting and conserve water and use it for supplemental irrigation. This will give opportunity to
conserve water that will be used at the time of stress. This option will have a benefit to use supplemental irrigation during a decrease in rainfall in Belg and Kiremit by conserving the excess water during increase in rain due to increase in the amount of rain and rainy days in Bega. Thus, this option is important to deal with a decrease in rainfall and delay in rainy season in Belg and Kiremit.

1.2. Technological:

The engineering options can be combined with technological options so as to reduce adverse impacts of climate change on production of cotton and sugarcane. These technological options include the following.

- **Efficient irrigation method**: use of water efficient irrigation technologies to improve water use. This option is particularly advantageous to deal with a decrease in rainfall in Bega and Kiremit.

- **Drought resistant varieties**: use of drought resistant varieties is also essential to get reasonable yield. This option is recommended when there will be a significant decrease in rainfall and the change in climate (both reduction in rainfall and increase in temperature). These two climate events induce water stress and drought and significantly affect the existing varieties to give reasonable yield. The use of drought resistant/tolerant varieties is also advisable during the period of a decrease in consecutive rainy days for all seasons including Bega.

- **Adjusting planting time and intercropping**: Adjusting planting time based on long-term rainfall analysis depending on the onset of rainfall and late rainfall season. This option is used to deal with delay in rainy season and extension of rainy period, which may induce shift in planning and growing season. In addition, in such events (delay in rain and extension of rainy season), intercropping of legumes or forage crops with sugarcane crop is the best practice to deal with the problem. This practice is also important in both cotton and sugarcane areas since the farming system in the two regions is characterized by mixed farming (both crop and livestock production systems).

- **Improved practices**: When the total number of rainy days is higher but the distribution is poor, adaptation options to deal with such climate change impact include using water conservation practices, improving the soil fertility through building up the soil organic matter to improve soil water holding capacity and water use efficiency, and infiltration of water. Other best practices suggested as adaptation options to deal with a decrease in rainfall and an increase in temperature include use of conservation tillage practices, integrated nutrient management and integrated pest management. Use of appropriate land preparation techniques based on the specific area’s soil and climatic conditions.

- **Use of Information Technology**: recent advances in information technology such as mobile phone, internet and radio and television can facilitate the efforts to reduce unprecedented climate change impacts. This is because the speed at which information is produced and shared is an essential part of building the adaptive capacity of the human system. Such technologies provide opportunities not only to disseminate relevant
information from top to bottom such as weather forecasts, hazard warnings, market information, etc but they can also be used to generate and disseminate information through bottom–up processes. This is particularly important for adaptation since technologies such as those used to improve irrigation efficiency, new varieties, etc that are generated and used elsewhere can easily be transferred to the study regions. In addition, mass media such as radio, TV, etc are the major channels used to disseminate climate related information to the cotton and sugarcane growing regions.

1.3. Ecosystem based services:
Adaptation options under this category are those that use biodiversity and ecosystem services as an overall adaptation strategy to build the capacity of the natural and human system to adapt to the adverse effects of climate change. The ecosystem services that are suggested as adaptation options are used to deal with extreme events including drought and flooding in both regions. They are identified to work with nature’s capacity to improve efficiency or effectiveness to absorb or control the impact of climate change in the two commodities’ growing regions. These include the following:

- **Natural resource conservation and management** including soil and water conservation, afforestation, community based natural resource management, adaptive land use management.
- **Watershed management approach** which integrates agricultural, soil and water conservation, efficient use of resources

2. Social:
The social options are identified to reduce the climate change impact and build the adaptive capacity of vulnerable groups. These options include improving human development, access to information and gender gap that are found to have significant effect on increasing their vulnerability to climate related hazards. Therefore, the following adaptation options are suggested:

- **Educational**: awareness raising and integrating into education, knowledge sharing and learning platforms, communication through media
- **Informational**: early warning and response system, provision of meteorological information, developing well organized longitudinal dataset system, integrating indigenous climate observation, adaptation action and participatory scenario development
- **Gender equality**: promote gender equality among both male and female; behavioural change,

3. Economic:
The adaptation options under this category include those options used to reduce the impact of climate change and build adaptive capacity at household level, community, and sectoral levels.
- **livelihood diversification**, skill development, promoting saving behaviour for investment; promoting market oriented business practices;

- **Public service**: One of the key vulnerability factors to smallholder producers in the growing regions of the two commodities is lack of access to basic public services, which constrain their adaptive capacity. Thus, the provision of basic services including water, sanitation, solid waste disposal, power, and public transportation are crucial to increase adaptive capacity. Transport links enable households to take part in trade, for example, to access agricultural markets.

- **Infrastructure**: road development to integrate farm area with market;

4. **Institutional and governance:**

   **4.1. Institutional**

   - Ensure appropriate land preparation based on the specific area’s soil and climatic conditions
   - Establish functional and robust climate change monitoring system,
   - Develop Flood and Drought early warning systems,
   - Use Weather index-based insurance system,
   - Establish functional collaboration among cultivators, relevant industries, agricultural universities and research institutions and water resources management,
   - Extension service; access to finance for micro business development; weather–based insurance; financial incentives for large scale cotton producers;
   - System approach in research and development including livestock, crop, tree management;
   - Landscape in research and development and involving people in the system with a better participation is needed.
   - Strengthening the research in developing heat and drought resistant cotton and sugar cane varieties for the production areas. The model used clearly indicated that there will be an increase in temperature in both study areas conforming previous studies done in Ethiopia regarding climate change and variability. Thus, from agronomy point of view, the modeling exercise is important in suggesting the following recommendations:
     - Capacity building:
       - Establishing center of excellence for dryland research, forestry, soil and water conservation
       - Streamlining the existing higher learning institutions, research institutions to get involved in research and development work
       - Developing human power building through training both long and short-term

   **4.2. Governance**

   - Establishing water user associations
   - Create strong linkage among cotton producers, textile processors, organize smallholder weavers and ginner association; research system in cotton; research system in sugarcane.
### Table 6: Adaptation options for building a climate resilient agricultural export commodities in Ethiopia

<table>
<thead>
<tr>
<th>Adaptation options</th>
<th>Purpose/Advantage</th>
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<tbody>
<tr>
<td><strong>Structural /physical</strong></td>
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| **1.1. Infrastructure/Engineering and built environment** | A. Upgrading the existing infrastructure of the Awash river bank to improve flooding resilience of the river so as to protect sugarcane farms/plantation and its irrigation infrastructure.  
B. New engineering infrastructure development: Construction of multi-purpose reservoirs and rainwater harvesting systems,  
C. Road development. | a. help to build the resilience of the river bank and irrigation infrastructure at the time of flooding  
b. to supplement irrigation during a decrease in rainfall in Belg and Kiremit by conserving the excess water during increase in rain due to increase in the amount of rain and rainy days in Bega.  
c. Increase access to market |
| **1.2. Technological** | a. Efficient irrigation method:  
b. Drought resistant varieties:  
c. Integrated improved practices. This includes Adjusting planting time and intercropping; Conservation tillage practice; integrated nutrient management and integrated pest management. | a. to improve water use efficiency to deal with a decrease in rainfall in Bega and Kiremit.  
b. used to deal with a decrease in rainfall and the change in climate (both reduction in rainfall and increase in temperature).  
c. used to deal with delay in rainy season and extension of rainy period. It also deals with problems related to when the total number of rainy days is higher but the distribution is poor. Also, used during a decrease in rain and increase in temperature |
<table>
<thead>
<tr>
<th>Adaptation option</th>
<th>Purpose/advantage</th>
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<tbody>
<tr>
<td><strong>Technological</strong></td>
<td><strong>d. Use of Information Technology</strong></td>
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<td></td>
<td><strong>d.</strong> disseminate climate and other relevant information from top to bottom such as weather forecasts, hazard warnings, market information, etc. It also used to disseminate information from bottom-up process.</td>
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<tr>
<td><strong>1.3 Ecosystem</strong></td>
<td><strong>based services</strong></td>
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<td></td>
<td><strong>a. Natural resource conservation and management</strong></td>
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<td><strong>b. Watershed management approach</strong></td>
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<td></td>
<td><strong>- Build the natural asset</strong></td>
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<td></td>
<td><strong>- Used for sustainable use of the natural capital</strong></td>
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<tr>
<td><strong>2</strong></td>
<td><strong>Social</strong></td>
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<tr>
<td><strong>2.1 Educational</strong></td>
<td><strong>a. Awareness raising and integrating in to education, knowledge sharing and learning platform, communication through media</strong></td>
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<td></td>
<td><strong>- Used to build the adaptive capacity of actors</strong></td>
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<tr>
<td><strong>2.2 Informational</strong></td>
<td><strong>a. Provide early warning and response system,</strong></td>
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<td></td>
<td><strong>b. Provision of meteorological information,</strong></td>
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<td></td>
<td><strong>c. Develop well organized longitudinal dataset system,</strong></td>
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<td></td>
<td><strong>d. Integrating indigenous climate observation</strong></td>
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<td></td>
<td><strong>- Minimize risk specially at the time of climate related hazards such as drought and flood</strong></td>
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<tr>
<td></td>
<td><strong>- Generate systematic information for decision making and build the adaptive capacity of the different actors and create a resilient</strong></td>
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<tr>
<td><strong>2.3 Gender equality</strong></td>
<td><strong>- Used to minimize risks to more vulnerable groups like female headed households and build the resilience of women working in textile factory, rural women</strong></td>
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<td></td>
<td>Adaptation option</td>
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<tr>
<td><strong>3</strong></td>
<td><strong>Economic</strong></td>
</tr>
</tbody>
</table>
| 3.1. | Livelihood diversification | a. skill development,  
b. promote saving behaviour for investment;  
c. promote market oriented business practices | - build the resilience of vulnerable groups by increasing their adaptive capacity  
- Diversify their income sources  
- Shift in livelihood strategy from climate sensitive to less sensitive sectors |
|    |                     | 3.2 | Public services | a. Provision of basic services (water, sanitation, solid waste disposal, power, and public transportation). | - Increase adaptive capacity by minimizing the non–climate change drivers of vulnerability |
| 4 | **Institutional and governance** | |
| 4.1 | Institutional | a. Establish functional and robust climate change monitoring system  
b. Develop Flood and Drought early warning systems | - Improve information generation and minimize risk |
|    |                     | c. Establish functional collaboration among key stakeholders: cultivators, industries, agricultural universities and research institutions | - Build a strong institutional linkage and facilitate information exchange and work to a common goal |
|    |                     | c. Improve institutional support: access to extension service; access to finance for micro business development; weather – based insurance; financial incentives for large scale cotton producers; | Deals with drivers of non – climate vulnerability by increasing productivity, non – farm income; build a competitive market power for producers |
| 4.2 | Governance | Create strong linkage among cotton producers, textile processors, Organize smallholder weavers and ginner association; Research system in cotton; research system in sugarcane. Build institutional capacity of the research system by establishing/strengthening cotton and sugarcane research, train human resources and linking with producers, processors & distributors Create water users’ association where there does not exist | Build adaptive capacity along the value chain by creating strong linkage and build their capacity through generating and disseminating relevant information |
4. Summary

This report presents the adaptation options for building a climate resilient production of agricultural export commodities. The adaptation options are identified based on the findings of different research components whose findings are fed into this part of the study. Accordingly, a climate modelling study was made in cotton and sugarcane producing regions of Ethiopia with the aim of estimating the historical and projected trends in key climate variables including rainfall and temperature. The observed and projected climate variables revealed that there will be an increase in mean annual temperature and an overall decrease in mean annual precipitation. The analysis was done based on downscaling for three scenarios for the short term, medium term and long term periods. Climate related hazards are also identified. Based on the findings of the climate modelling, an agronomic implication of the two commodities has been studied in relation to agronomic practices, water management, technology requirement and so on. From the vulnerability side, a value chain analysis was made with the aim of identifying the different actors involved along the value chain of the two commodities and their role has been identified. Besides, the governance system that affects the resilience of the two commodities for climate change impacts have been analysed and an institutional arrangement for conducive governance system has been identified. The vulnerability study is conducted with the aim of identifying the extent of the vulnerability of the different actors to the anticipated climate change impact and to identify the most vulnerable groups along the value chain. Then, productivity and welfare impact of climate change has been done with the aim of estimating the magnitude of the impact on the productivity of the two commodities as well as in the change in welfare using key indicators for the productivity and welfare.

Overall, the findings of all these studies feed into identify the adaptation options, which are identified, based on certain basic criteria which arise from the findings of the different studies. The following key findings of the different studies of the project were crucial to identify the different selection criteria. First, there is variation in observed and projected trends in T & RF between CRV and NWL though both regions can grow both cotton and sugarcane. This implies that adaptation strategies need not solely be commodity-based. Second, both inter–annual and seasonal variations in CV are important for adaptation. Third, the impact of climate change is very sensitive to period of analyses and type of climate scenarios. Fourth, productivity is not the only channel through which climate change impact is reflected. Its impact on other channels such as resource-base and price may change the overall impact. Fifth, not all actors along the value chain of the two commodities are equally vulnerable to climate change. Sixth, non–climate factors and the heterogeneity or specific features of a particular system also determine the type of adaptation options to be adopted to build a climate resilient system. Accordingly, Physical, Social, Economic & Institutional options are identified as adaptation strategy to build a climate resilient export of sugar & textile commodities in Ethiopia.
References


