Economics of Climate Adaptation

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Vulnerability Report

Ethiopia

Drought Risk

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Table of Contents

List of Tables

List of Figures

List of Acronyms

ACI	Adaptive Capacity Indicator
AEZ	Agro-ecological Zone
APARI	Afar Pastoral and Agro-pastoral Research Institute
ARC	African Risk Capacity
BMZ	German Ministry for Economic Cooperation and Development
BUA	Build-up Area
CBD	Convention on Biological Diversity
CCIP	Complementary Community Investment Program
CMIP5	Coupled Model Intercomparison Project Phase 5
CORDEX	Coordinated Regional Climate Downscaling Experiment
CRU	Climate Research Unit of the University of East Anglia
CSA	Central Statistical Agency of Ethiopia
DMP	Dry Matter Productivity
ECA	Economics of Climate Adaptation
EIAR	Ethiopian Institute of Agricultural Research
EM-DAT	Emergency Events Database
EVSD	Ecosystem Services Valuation Database
IGAD	Intergovernmental Authority on Development
IRI	the International Research Institute for Climate and Society of the Columbia University, New York
ISF	InsuResilience Solutions Fund
KfW	German Development Bank
KII	Key Informant Interview
LSMS	Living Standards Measurement Study
MCA	Multi-Criteria Analysis
MDD	Mean Damage Degree
MFI	Micro-finance Institute
MoANR	Ministry of Agriculture and Natural Resources of the Federal Democratic Republic of Ethiopia
MoARD	Ministry of Agriculture of the Federal Democratic Republic of Ethiopia
MoWIE	Ministry of Water, Irrigation and Energy of the Federal Democratic Republic of Ethiopia
MSDI	Multivariate Standardized Drought Index
NAP	National Adaptation Plan
NAP-ETH	Ethiopia's National Adaptation Plan

NbS	Nature-based Solutions
PDSI	Palmer Drought Severity Index temperature
RCA4	Rossby Centre regional atmospheric model, 4th version
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
SDG	Sustainable Development Goals
SIIPE	Satellite Index Insurance for Pastoralists Ethiopia Programme by WFP Ethiopia
SLA	Sustainable Livelihoods Approach
SPEI	Standard Precipitation Evapotranspiration Index
SPI	Standardized Precipitation Index
SPI-G	Standard Precipitation Index (Gamma distribution)
SPI-P	Standardized Precipitation Index (Polynomial distribution)
SSA	Small Settlement Area
SSD	Sub-surface Dam
TEEB	The Economics of Ecosystems and Biodiversity
TLU	Tropical Livestock Unit
UNU-EHS	The United Nations University - Institute for Environment and Human Security
WRSI	Water Requirements Satisfaction Index
Z Index	Palmer Z Index

1 Introduction

Storms, floods, droughts and other extreme weather events can threaten urban and rural areas, from small regions to entire nations. Along with growing populations and economies, losses from natural hazards are rising in the world's most exposed regions as our climate continues to change. The Economics of Climate Adaptation (ECA) is a decision-making support framework that integrates climate vulnerability and risk assessments with economic and sustainability impact studies to determine the portfolio of optimal adaptation measures for diverse climate risks.

The United Nations University - Institute for Environment and Human Security (UNU-EHS) in cooperation with and funded by the InsuResilience Solutions Fund (ISF), is implementing the Economics of Climate Adaptation (ECA) framework in the Afar and Somali regions in eastern Ethiopia to identify the most cost-effective measures to address drought hazards. The ISF is funded by the German Development Bank KfW and commissioned by the German Ministry for Economic Cooperation and Development (BMZ). Currently, the Economics of Climate Adaptation (ECA) methodology is being implemented in three different countries (Vietnam, Honduras and Ethiopia).

The two previous phases, namely the Inception Phase and the Base Data Phase, focussed on setting the scope, and compiling and validating necessary data with key stakeholders in order to run the modelling tool CLIMADA. This Vulnerability Report now presents the final recommendations for adaptation measures suited to enhance the resilience against drought events in the two observed regions.

The following chapters provide an overview of the inputs for CLIMADA in terms of hazards, assets, damage functions and adaptation measures. Assumptions made and encountered uncertainties involved in the processes are further discussed. The report closes with final conclusions and recommendations directed primarily at both, the national and regional governments as well as development partners engaging in related programmes, and an additional chapter introducing the last phase of this ECA study presenting a pre-feasibility analysis of the measures suggested for implementation.

Over the past months, a set of calls and workshops were organized for representatives of the Ministry of Agriculture of the Federal Democratic Republic of Ethiopia (MoARD), local governments, and further stakeholders to provide input and request clarification on the subjects of the asset valuation methods and the modelled adaptation measures. The drought model used for the ECA study was specifically developed by the study team including several drought indices covering different types of droughts since no specific drought module existed so far. Chapter 2 describes the developed drought model in further detail.

During the joined asset valuation and adaptation measures webinar, the valuation method was discussed and validated for each of the asset groups identified during the Inception Phase. The recommendations provided by representatives, local consultants, partners and other invited experts were incorporated and details of the results can be found in Chapter 3. Chapter 4 further presents the applied damage functions describing each asset group's sensitivity to drought events and thus the expected mean damage degree at different drought intensities. Facing the scarcity of historical data on damages, different sources were applied to construct and validate the assumptions made, including data gathered through a field survey in the course of the study and literature review before starting the iterative calibration process using CLIMADA. Following the same approach as was done with regard to the assets' valuation, the participants' knowledge and expertise was leveraged to coordinate a prioritisation methodology based on given criteria, scoring the adaptation measures to better reflect the local conditions.

A total of 13 short listed drought adaptation measures were identified following the approach described in Chapter 5. Those include nature/ eco-systems based solutions, technical and engineering solutions (grey measures), measures drawing from both categories, as well as risk transfer/ insurance solutions. The measure selection process including the longlist of measures and their corresponding scoring is described in Annex IV, and the final shortlist including a detailed description of those can be found in Annex V.

The final results as computed by CLIMADA, as well as a comprehensive discussion on their expected costs and benefits, and the related uncertainties, can be found in Chapter 6. Chapter 7 compiles the conclusions and recommendations of the report.

2 Drought Modelling

2.1 Introduction

In this chapter, we describe - at some points rather decanally- the assumptions and validity of the drought module developed and used in this report. Key findings are presented in section 2.5. The effects of droughts on crop productivity and chances of failure, as well as on wild dry matter production needed by pastoralists to feed their livestock, are amongst the highest contributors to food insecurity in Afar and Somali.[1] The 2017 Central Statistical Agency and Living Standards Measurement Study (LSMS) identified drought on its top of major shocks negatively affecting households, second only to an illness of a household member.[2] 21% from the nearly 5 000 surveyed households across Ethiopia identified negative impacts due to droughts in the last 12 months and 76% of those highlighted droughts as the most severe shock they encountered during that period.[3] These results coincide with the statistics reported by EM-DAT on historical damages which linked over 97% of the people impacted by natural disasters in Ethiopia to droughts.[4]

Finally, and in addition to the precedent left by past droughts supporting the urgency of addressing drought risks to protect the communities in the study regions, there is a general concern for the effects of climate change in pastoral livelihoods in the Ethiopian lowlands. As recent droughts appear to be having larger impacts than previous ones, a factor that seems to be playing a major role is the fragmentation of natural resource bases linked to the changes in precipitation patterns. This fragmentation closes off the mobility and flexibility needed by pastoral communities to manage risk.[5]

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[1] WFP Ethiopia and Central Statistical Agency (2019*). Comprehensive Food Security and Vulnerability Analysis (CFSVA)*. Addis Ababa, Ethiopia: CSA.

[2] World Bank and Central Statistical Agency (2017). LSMS—Integrated Surveys on Agriculture Ethiopia Socioeconomic Survey (ESS) 2015/2016. Addis Ababa, Ethiopia: CSA.

[3] Ibid.

[4] EM-DAT. (2020). *EM-DAT Data Base*. Retrieved from EM-DAT: https://www.emdat.be/

[5] Birch, I. (2018). *Economic growth in the lowlands of Ethiopia.* K4D Helpdesk Report. Brighton, UK: Institute of Development Studies.

In this section, we describe how we address the modelling of drought risk in Ethiopia and how the new module is integrated within CLIMADA.

2.2 The CLIMADA Drought Risk Model

This section presents the setup of the drought model as introduced in CLIMADA. To date, no specific drought module existed, and we present here how we addressed the challenges of drought modelling in CLIMADA.

Drought risk often consists of different types of drought events such as meteorological drought, agricultural drought and socio-economic drought.[6] We therefore have induced different indices in CLIMADA that cover different types of drought. Using different indices helps adapting the methodology to different climatic regions.

To date six (6) indices have been encoded in CLIMADA (a python version will be available after the final report is delivered). These indices reflect the state of the art on literature relegated to drought and are applicable in a large amount of countries for various situations. In Table 1 we describe these indices in terms of strengths and weakness as well as the kind of input data needed to operate them. Please note that the input data is not provided by the code to run the indices but needs to be incorporated by the end user. All data used for drought modelling in this report are open source and free to use for non-commercial purposes.

Table 1: Description of drought Indices included in CLIMADA

Acronym	Name	Advantages	Limitation	Type of drought	Data needed
SPI-G	Standard Precipitation Index (Gamma distribution)	Low data requirement Easy to compute Allow gridded and station data Global	Do not consider Temperature Needs a distribution selection	Meteorological Hydrological Agricultural	Precipitation
SPI-P	Standard Precipitation Index (Polynomial distribution)	Low data requirement Easy to compute Allow gridded and station data Global	Do not consider Temperature Needs a distribution selection	Meteorological Hydrological Agricultural	Precipitation
SPEI	Standard Precipitation & Evapotranspiration Index	SPI including temperature	Only monthly index Limited by data needed No missing values allowed	Meteorological Hydrological Agricultural	Precipitation Temperature Evapotranspiration
MSDI	Multivariate Standardized Drought Index	Ease of Use Good when no station data is available	No time scales	Hydrological Agricultural	Precipitation Soil Moisture MERRA-Land (0.66°x0,55°)

[6] Wilhite, D.A.; and M.H. Glantz. (1985). *Understanding the Drought Phenomenon: The Role of Definitions*. Water International 10(3):111–120.

PDSI	Palmer Drought Severity Index temperature	Robust Global	Not easy to use No NaN allowed Input data	Hydrological	Precipitation Temperature Water holding capacity
Z Index	Palmer Z Index	Robust Global	Not easy to use Input data	Hydrological	Precipitation Temperature Water holding capacity

In the case of Ethiopia, numerous studies recommend the use of the standardized precipitation index (SPI) to determine drought risk.[7] It is a globally recognized index, with limited data input required that reflects well a variety of drought types such as meteorological, agricultural and hydrological. Consequently, in this section, we describe SPI in detail, as applied in this case study. The SPI is commonly used to describe different type of droughts, with a predilection for meteorological drought. It expresses the gap between a given period and the average observed values on standard deviation units.[8] This index is the most commonly used for studying droughts in Ethiopia as well[9], mainly due to the restricted amount of data collected on the ground by weather stations, particularly in the study area.[10]

A number of advantages are associated with the use of the SPI index. First, the index is based on precipitation alone making its evaluation relatively easy. Secondly, the index makes it possible to describe drought on multiple time scales. A third advantage of the SPI is its standardization which makes it particularly well suited to compare drought conditions among different time periods and regions with different climates. It makes SPI particularly well suited for drought forecasting. Either for short-term or long term probabilistic forecasts.[11] The index is based on an equi-probability transformation of aggregated monthly precipitation into a standard normal variable. In practice, computation of the index requires fitting a probability distribution to aggregated monthly precipitation series (e.g. 3, 6, 12 months, etc.), computing the non-exceedance probability related to such aggregated values and defining the corresponding standard normal quantile as the SPI. Table 2 provides a drought classification based on SPI.

[7] See McKee TB, Doesken NJ, Kleist J. (1993). *The relationship of drought frequency and duration to time scales*. In: Paper presented at 8th conference on applied climatology. American Meteorological Society, Anaheim and Degefu MA, Bewket W (2015) Trends and spatial patterns of drought incidence in the Omo-Ghibe River basin, Ethiopia. GeografiskaAnnaler: Ser A, Phys Geograph 97(2):395–414. https://doi.org/10.1111/geoa.12080 and Viste E, Korecha D, Sorteberg A (2013) Recent drought and precipitation tendencies in Ethiopia. Theor Appl Climatol 112(3–4):535–551. https://doi.org/10.1007/s00704-012-0746-3

[8] Wilhite, D.A.; and M.H. Glantz. (1985). *Understanding the Drought Phenomenon: The Role of Definitions*. Water International 10(3):111–120.

[9] Ibid.

[10] Fazzini M, Bisci C, Billi P. (2015). *The Climate of Ethiopia. Landscapes and Landforms of Ethiopia.* World Geomorphological Landscapes. Springer Science

[11] Cancelliere, A., Mauro, G.D., Bonaccorso, B. *et al.* Drought forecasting using the Standardized Precipitation Index. *Water Resour Manage* **21,** 801–819 (2007). https://doi.org/10.1007/s11269-006-9062-y

Table 2: Wet and drought period classification according to the SPI index (after McKee et al., 1993)[12]

SPI values	Class
>2	Extremely wet
1.5–1.99	Very wet
1.0–1.49	Moderately wet
−0.99 to 0.99	Near normal
−1 to −1.49	Moderately dry
−1.5 to −1.99	Very dry
<−2	Extremely dry

There are some limitations related to the use of the SPI especially in arid areas like Afar and Somali. In regions where the average precipitation is low but there are periods of significant rainfall, both indices can miss small decreases in rainfall which are nevertheless significant for the local population. CLIMADA enables the user to select the length of the period to compensate for this issue. Prior to modelling, a variable running window of 1 to 12 months can be selected. However, given the limited precipitation volumes in Ethiopia it is meaningful to consider the 3-month for seasonal drought and 12-month accumulated precipitation at the end of the year as a collective drought measure.[13]

2.3 Input Data

As in most regions with ungauged catchments, several assumptions are necessary to represent physical processes. However, in this ECA study, we strived to collect the best available data. All input data were carefully quality checked and discarded or improved if necessary. The following sections describe the main inputs.

2.3.1 Precipitation Time Series for Validation

A wide range of satellite-derived precipitation products have emerged in the last decades, providing a spatial coverage that is superior to gauge products, considering that rain gauges had the obvious queries such as the density of site networks, the continuous time series, or financial limitation. To satisfy the demand of studies and applications of climate and drought, some of these satellite-based estimations provide long-term precipitation records. Unfortunately, most of previous satellite precipitation products had short historical record (less than 30 years) and lower spatial resolution. Accurate long-record (at least 30 years) precipitation data are helpful to deal with natural studies like droughts. Fortunately, the Climate Research Unit of the University of East Anglia (CRU) offers a viable option for estimating precipitation and drought forecasting. It has long time-series records (more than 50 years) and high spatial resolution (0.5°). Compared to other products, the CRU showed the highest

[12] McKee TB, Doesken NJ, Kleist J. (1993). *The relationship of drought frequency and duration to time scales*. In: Paper presented at 8th conference on applied climatology. American Meteorological Society, Anaheim

[13] Viste, E., Korecha, D. & Sorteberg, A. Recent drought and precipitation tendencies in Ethiopia. *Theor Appl Climatol* **112,** 535–551 (2013). https://doi.org/10.1007/s00704-012-0746-3

agreement with gauge observations and has been shown to be a useful substitute for gauge data in Ethiopia.[14,15]

Monthly re-analysis rainfall data from the Climate Research Unit is used to assess the seasonal rainfall performance of Ethiopia. The CRU version TS4.01 data set is discussed at length by the University of East Anglia Climatic Research Unit from gridded at 0.5° latitude by 0.5° longitude resolution.[16,17] This dataset merges three types of information: global climatology, satellite estimates, and in situ observations, generating monthly precipitation, temperature, wind speed and other meteorologically relevant products between 1901 and 2020.

2.3.2 Precipitation Time Series for Simulation and Future Scenarios

In this study, we suggest using runs from RCA4 driven by the Had-CGCM2-ES circulation model for present and future simulation of precipitation within the drought model. RCA4, a regional climate model, offer high resolution simulation of precipitation, taking into account the local topography for higher accuracy. As discussed in the data report, the climate scenarios RCP4.5 (weak climate change signal) and RCP8.5 (strong climate change signal) are selected simply because they are most consistent.

2.4 Results and Validation

2.4.1 Drought Module Simulation Performance

In this section we compare how SPI 3-month (SPI3) and SPI 12-month (SPI12) simulated by CLIMADA and with the CRU dataset perform when compared to other SPI calculations. To do so, we have selected the IRI SPI [18] calculations (0.5°) from the International Research Institute for Climate and Society of the Columbia University, New York (IRI). The data are compared for the 1998-2020 time period for the Afar and Somali regions. For the sake of clarity we present the results only for the medium longitude in Afar (41.25°) and Somali (43.75°). Results are presented in Figure 1 and Figure 2. Anomalies (or differences between two datasets) are compared in terms of distribution of anomalies for SPI3 (a) and SPI12 (b) and across the region over the 1998-2020 time period (c and d). Figures for the Afar and Somali regions show a very good agreement between the simulation in CLIMADA with the CRU data set and the IRI control data.

[14] Temam D, Uddameri V, Mohammadi G, Hernandez EA, Ekwaro-Osire S. (2019). *Long-Term Drought Trends in Ethiopia with Implications for Dryland Agriculture*. *Water*.; 11(12):2571.

[15] Asaminew Teshome, Jie Zhang (2019). *Increase of Extreme Drought over Ethiopia under Climate Warming, Advances in Meteorology*, vol. 2019, Article ID 5235429, 18 pages. https://doi.org/10.1155/2019/5235429

[16] Harris, I., Osborn, T.J., Jones, P. *et al.* (2020) Version 4 of the CRU TS monthly high-resolution gridded multivariate climate dataset. *Sci Data* **7,** 109. https://doi.org/10.1038/s41597-020-0453-3

[17] Accessed from https://data.ceda.ac.uk//badc/cru/data/cru_ts/cru_ts_4.01/data/

[18] IRI (2021) IRI Analyses SPI. SPI-PRECL0p5 dataset, IRI Data Library, Columbia University. Accessed in Dec 2020 from https://iridl.ldeo.columbia.edu

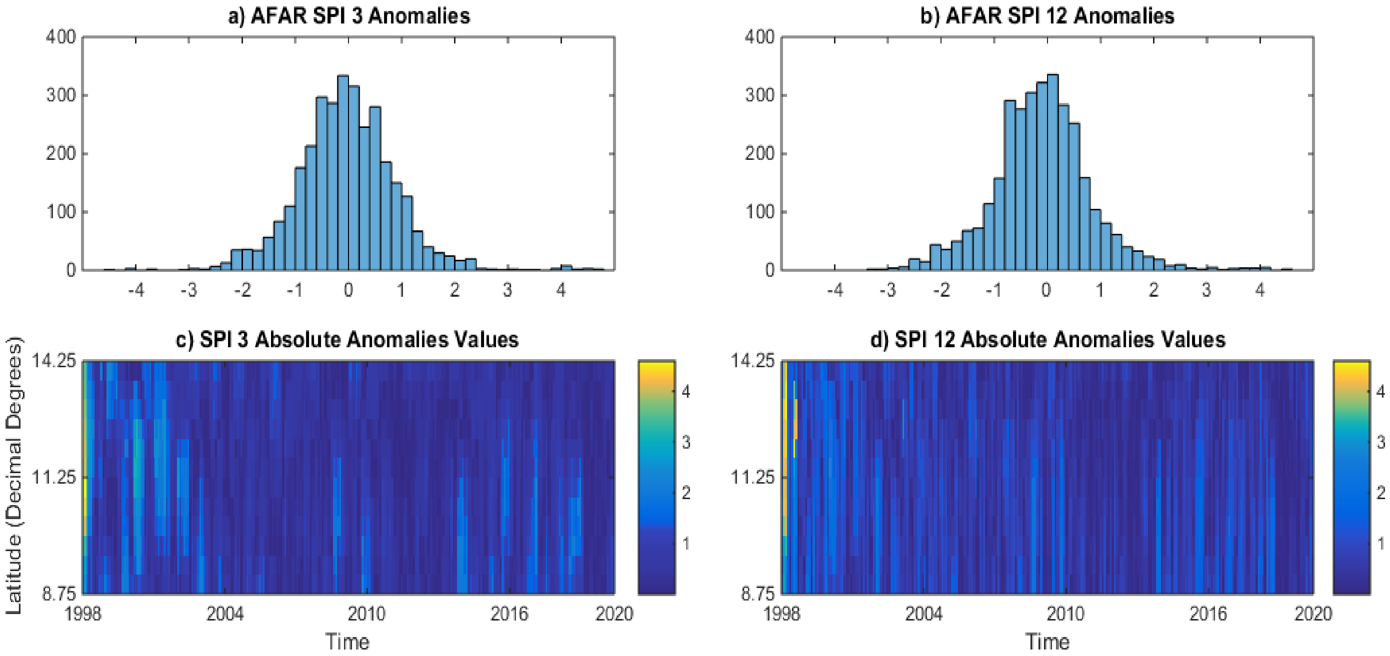

Figure 1: SPI anomalies calculation for the Afar region (41.25°) between CRU (CLIMADA) and IRI datasets

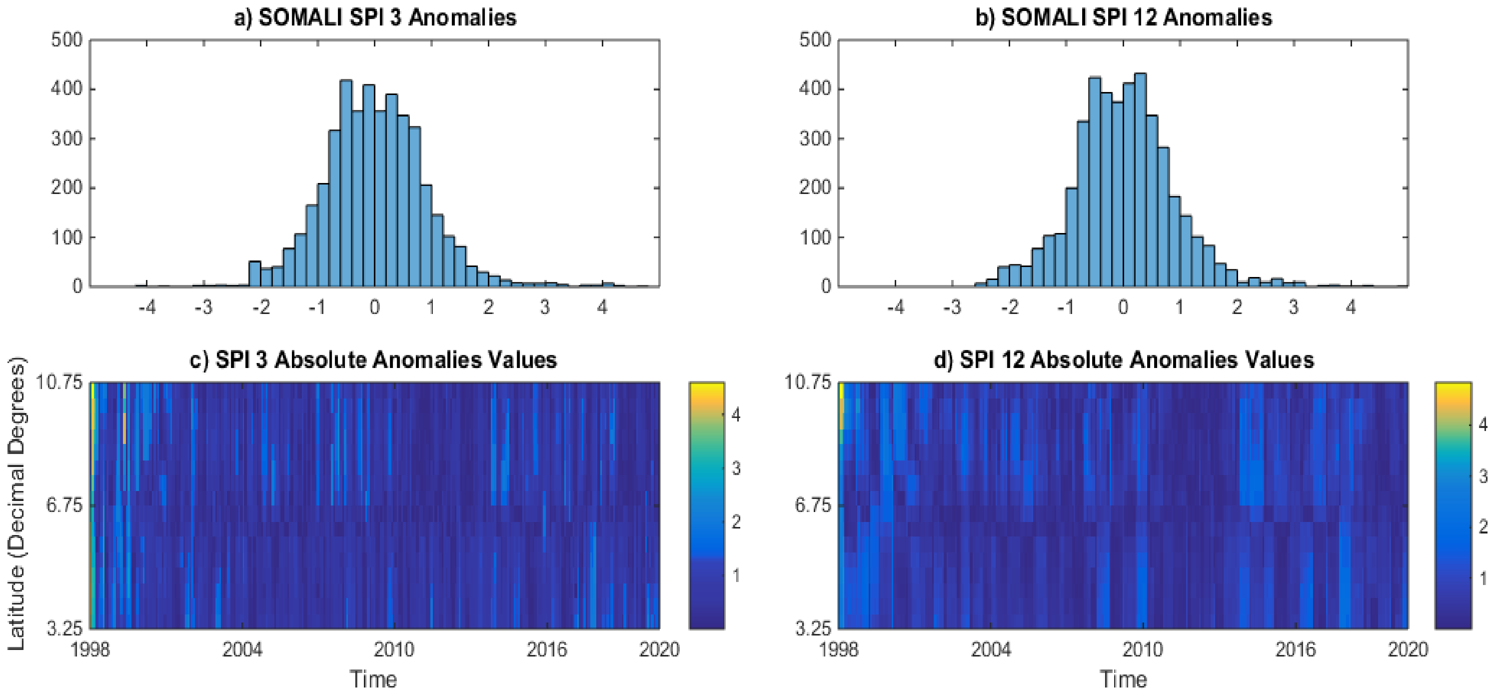

Figure 2: SPI anomalies calculation for the Somali region (43.75°) between CRU (CLIMADA) and IRI datasets

In Table 3, we summarize the performance indicators for the Afar and Somali regions for normal conditions and moderate conditions where the simulation offers a high confidence level in their ability to reproduce SPI in the region. As displayed already above, the CRU simulations show no differences (anomalies close to 0) or little differences for moderate conditions and normal conditions.

Table 3: Performance indicator for agreement between CRU (CLIMADA) and control data set in Afar and Somali

	Normal Conditions (-0.99<SPI<0.99)		Moderate conditions (-1.49<SPI<1.49)	
	SPI 3	SPI 12	SPI 3	SPI 12
AFAR	77.0%	77.1%	95.8%	95.6%
SOMALI	77.5%	78.6%	91.4%	90.8%

2.4.2 Stochastic Modelling of Future Drought Events

From a stochastic point of view, the problem of forecasting future values of a random variable is equivalent to the determination of the probability density function of future values conditioned by past observations. Once the conditional distribution is known, the forecast is usually defined as the expected value or a quantile of such distribution, and confidence intervals of the forecast values can be computed.

In this case the SPI-P model is selected to simulate drought for Afar and Somali using the RCA4 historical time series. The 1951-1991 time period is used to determine the probability density function. The validation of 1 000 CLIMADA simulations is done for the period 1991-2020 for SPI-3 and SPI-12 values. The CLIMADA SPI simulations are presented in Figure 3 for Afar and Somali. 1 000 stochastic simulations are represented by the boxplots showing the median (line), the 75% quantile (box) and the 95% quantile (whiskers). The CLIMADA SPI values are plotted (green line) against SPI-3 and SPI-12 calculated with the RCA4 historical values, assimilated to observations and therefore constituting a control time series. In both regions, the CLIMADA simulations are in strong agreement with observations reflection the robustness of the drought module, for short term (SPI-3) and long term (SPI-12) drought prediction.

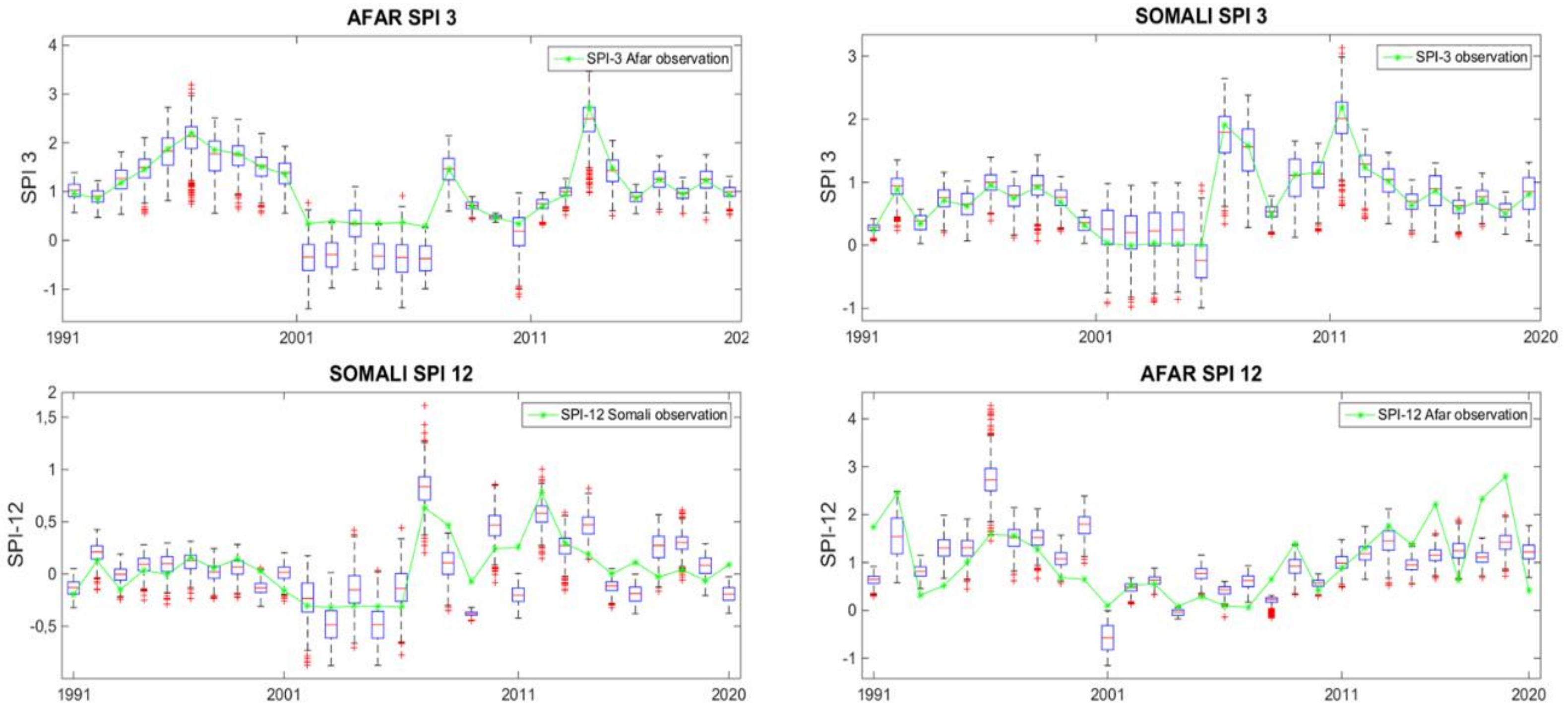

Figure 3: Probabilistic simulations (boxplots) of the new CLIMADA drought module against observations (RCA4 historical time series) for Afar and Somali regions

2.5 Limitations and Conclusion

This section presents the methods, data and parameters used for the setup of the drought model for Ethiopia. This new module constitutes a significant advance in terms of drought modelling in Ethiopia but also for other regions. Nevertheless, an honest and careful discussion regarding limitations and uncertainties linked with the forecasting exercise is necessary to further improve future iterations of the model.

Uncertainties within drought modelling generally arose due to the quality of the precipitation in some regions. In our case, the RCA4 data has proven highly reliable in Ethiopia.[19] Nevertheless, bias due to overestimation of rainfall in certain cases has been demonstrated.

Another source of uncertainty lies in the difficulty to grasp drought in its complexity. While we decided to use SPI for its flexibility, its outcome is limited by record length and the time scale calculation. Some minor drought events might be overestimated, whereas short but strong events can be underestimated.

Finally, climate scenarios, GCM and downscaled data offer a series of biases due to resolution, orographic changes and temporal issues which impair the forecasting power of drought models in general.

In conclusion, the outputs of the study included drought estimations for five return periods (5, 10, 25, 50 and 100 years) for the present and the future (RCP4.5 and RCP8.5). As a new module for drought risk in CLIMADA, significant improvements have been made, which can be applied in other regions. The results of this modelling exercise are explicitly fit for purpose for the scope of this study and, beyond, are also to be considered for a basis to further planning in the regions of Afar and Somali.

[19] Dinku, T, Funk, C, Peterson, P, et al. Validation of the CHIRPS satellite rainfall estimates over eastern Africa. Q J R Meteorol Soc. 2018; 144 (Suppl. 1): 292– 312. https://doi.org/10.1002/qj.3244

3 Assets Valuation

3.1 Methodology

The following chapter describes how the different types of assets and their values were estimated. CLIMADA relies on georeferenced data and hence, both risk scenarios and damage to assets have to be simulated based on georeferenced information. Therefore, all assets were previously geo-located and partitioned where necessary, e.g. larger environmental assets such as waterbodies or rivers, as described in further detail in the corresponding subchapters below.

In general, the methodologies used in this study to estimate asset values, including probabilities of being affected by climate hazards, were

- Field survey and Key Informant Interviews, especially regarding population and livestock,
- Literature review,
- Discussions with experts.

Additional to the data available online at different research centres and databases as well as data made available by various Ethiopian authorities, some Key Informant Interviews with several experts on the national and regional level were conducted. Further, a field survey targeting 90 household in each of the two region was implemented to gain further understanding especially with regard to living conditions, livestock and crop values as well as experienced losses caused by drought events in the past, and experiences and opinions on so far implemented adaptation measures.[20]

3.2 Assets Categories

The assets examined in this study were confirmed during an iterative process through (a) the inception workshop and the corresponding report and (b) through the validation webinar and its report. Hence, the final list of assets, and simultaneously the order in which they and their corresponding valuation method and results will be more closely described in this chapter, is as outlined below.

[20] For further detail see Annex I - Field Survey and Key Informant Interviews and Annex III - Household survey questionnaire.

1. People
2. Livestock
3. Natural Resources (incl. Crop lands)

Based on the initial results from literature review and the provided data, a data webinar was conducted with national and international experts and representatives from the Ministry of Agriculture of Ethiopia. During the webinar, follow-up discussions and based on results of the implemented field survey, recommendations were made regarding the updating and refining of the values for some asset categories.

The following sub-chapters will provide further insights into the respective assets location, the finally selected valuation method and the valuation results. The chapter will be concluded with an overview of all the assets in the study region.

3.3 People

As the first asset group 'people' were identified. People and their level of vulnerability are defined here according to the definition of the Intergovernmental Panel on Climate Change[21] based on the three components of vulnerability, namely

- exposure,
- adaptive capacity, and
- sensitivity.

Other than the other assets considered in this study, people are not valued in financial terms but simply as individual human beings of equal worth.

The following paragraphs provide a brief insight into how each of the three components is being accounted for in this analysis.

Exposure, although most likely with local differences, e.g. based on differing altitudes, is assumed in this case to be relatively uniform across each of the two regions as droughts are slow on-setting events and are experienced across wide and differing areas, unlike e.g. floods or storms that take very distinct paths.

Adaptive Capacity, as by the 5th IPCC report[22] defined as 'the ability to adjust, take advantage of opportunities, or cope with consequences' has the potential to differ greatly between individual

[21] IPCC. (2014). Impact, adaptation and vulnerability. Part A: Global and sectoral Aspects Working Group (WG) II Report. P. 118.
[22] Ibid.

households, communities, and livelihood zones at different locations. With that bearing in mind, for this study a normalised indicator was calculated.

Following the approach[23] using and adopting the Sustainable Livelihoods Approach (SLA)[24] to assess the adaptive capacity of the European agricultural sector to droughts, an indicator to estimate the adaptive capacity was developed. The SLA initially interprets welfare as a function of multiple forms of capital, or capacity, that actors can use to recover and increase their resilience. In general, the framework relies on five types of assets:

1. **Human capacity**, e.g. health and education
2. **Social capacity**, e.g. close social bonds aiding cooperative actions
3. **Natural capital**, e.g. natural resource base, water and biological resources, and actions to sustain the productivity
4. **Physical capacity**, e.g. items produced through economic activity including infrastructure and equipment
5. **Financial capacity**, e.g. access to financial resources combining or contributing to wealth.

Based on these categories, the index was developed taking all but the 'social capacity' category into account since no quantitative data of sufficient quality and resolution was available. In this study, the proxies used are presented in Table 4.

[23] Williges, K., Mechler, R., Bowyer, P., & Balkovic, J. (2017). *Towards an assessment of adaptive capacity of the European agricultural sector to droughts.* Climate Services, 7, 47-63. doi:10.1016/j.cliser.2016.10.003
[24] Ellis, F. (2000). Rural Livelihoods and Diversity in Developing Countries. Oxford: Oxford University Press.

Table 4: Proxies used to estimate the Adaptive Capacity of households for this Study.

Human capacity	Natural capital	Physical and Financial capacity
Number of enrolled pupils [25]	Proximity (5 km) to water, natural flows as well as manmade e.g. canals [26]	Percentage of people living below USD 1 005 per year [27]
Number of hospital beds per 1 000 people[25]	Dry Matter Productivity (DMP)[28,29] of the surroundings	Per person livestock holding (Camel, Cattle, Sheep, Goat) aggregated in Tropical Livestock Units (TLU)[30,31].
		Access to financial services[32]

All categories are given equal weights to reach the final (normalised) adaptive capacity index (ACI).

In order to highlight especially vulnerable people, an ACI value of 0.7 was defined as a cut-off, with values below 0.7 reflecting 'vulnerable people' and people with a score of 0.7 or higher defined as the sub-group 'people'.[33]

Finally, **sensitivity** describes to which degree a system is affected, in this case by drought. This parameter will be defined by the modelling exercise in CLIMADA.

Since exposure is assumed to be distributed uniformly in this analysis and sensitivity is being defined only during the modelling exercise only the adaptive capacity component, i.e. the ACI, is being applied as a proxy to distinguishing between the two sub-groups 'vulnerable people' and 'people'.

[25] UNISDR (2015). *GAR15 Global Exposure Dataset for Ethiopia*. Ethiopia. Retrieved 16.06.2020 from https://data.humdata.org/dataset/gar15-global-exposure-dataset-for-ethiopia

[26] Humanitarian OpenStreetMap Team (2020). *HOTOSM Ethiopia Waterways (OpenStreetMap Export)*. Retrieved 16.06.2020 from https://data.humdata.org/search?q=hotosm_eth

[27] UNISDR (2015) *GAR15 Global Exposure Dataset for Ethiopia*. Ethiopia. Retrieved 16.06.2020 from https://data.humdata.org/dataset/gar15-global-exposure-dataset-for-ethiopia

[28] Dry Matter Productivity describes the increase in dry biomass of the vegetation in kg of dry matter per hectare per day. For more information see Smets, B., Swinnen, E., & van Hoolst, R. (2019). *Vegetation and Energy. Product User Manual. Dry Matter Productivity (DMP) Gross Dry Matter Productivity (GDMP) Collection 300m*. (I1.22), 1. Copernicus Global Land Operations.

[29] Copernicus Global Land Service. (2020). Dry Matter Productivity. DMP and GDMP 300m.

[30] The Tropical Livestock Unit is defined by a weight equivalent of 250kg living weight. Conversion factors for the four relevant livestock types here are: Camel: 1.0 TLU, Cattle: 0.7 TLU, Sheep and Goat: 0.1 TLU. For further details see e.g. Jahnke, H. E. (1982). *Livestock Production Systems and Livestock Development in Tropical Africa*. Kiel: Kieler Wissenschaftsverlag Vauk.

[31] USAID and the Government of Ethiopia. (2010). *An Atlas of Ethiopian Livelihoods*. The Livelihoods Integration Unit. USAID and the Government of Ethiopia, Disaster Risk Management and Food Security Sector, MOARD.

[32] Central Statistical Agency. (2016). *Socioeconomic Survey 2015-2016, Wave 3. Living Standards Measurement Study*. Retrieved on 01.06.2020 from https://microdata.worldbank.org/index.php/catalog/2783/

[33] The score of 0.7 does not follow a specific formula but much rather is based on the notion that most people in the regions can be assumed to be vulnerable. In order not to under-estimate the number of vulnerable people a rather high value of 0.7 was chosen.

Figure 4 (Afar) and Figure 5 (Somali) below display the distribution of people, both vulnerable and non-vulnerable, living within the three different categories of settlements: build-up areas (BUA), Small Settlement Areas (SSA), and Hamlets.[34] Although the figures show each individual settlement for better visualisation, for the modelling both a 1km and a 5km raster were constructed with the corresponding population of each pixel in order to reduce data points for the calibrations and calculations.[35] Reducing the spatial resolution to a 5km raster inevitably results in loss of some information but decreases computing time and thus usability significantly. However, both rasters were deemed suitable in the light of the rather widespread drought hazard.

[34] BUA: areas of urbanization, around 400 000 m^2 and larger; SSA: permanently inhabited structures and compounds with roughly a few hundred or thousand inhabitants in smaller housing patterns (50+ houses); Hamlets: low-density collection of compounds/ sleeping houses in isolation of settlements, <50 houses. For more information see Center for International Earth Science Information Network (CIESIN), Columbia University and Novel-T. 2020. *GRID3 Ethiopia Settlement Extents Version 01, Alpha*. Palisades, NY: Geo-Referenced Infrastructure and Demographic Data for Development (GRID3). Source of building Footprints "Ecopia Vector Maps Powered by Maxar Satellite Imagery"© 2020. Accessed 05.09.2020.

[35] Reducing the resolution led to a reduction from 37 888 and 212 207 (each individual settlement) to 16 493 and 84 782 (1km raster) to finally 2 571 and 9 741 (5km raster) data entries for population alone in Afar and Somali respectively. Through that the computing time can be reduced significantly. This was also done in light of the prospect of handing over the model and data to the partners in Ethiopia who may have limited computing capacities.

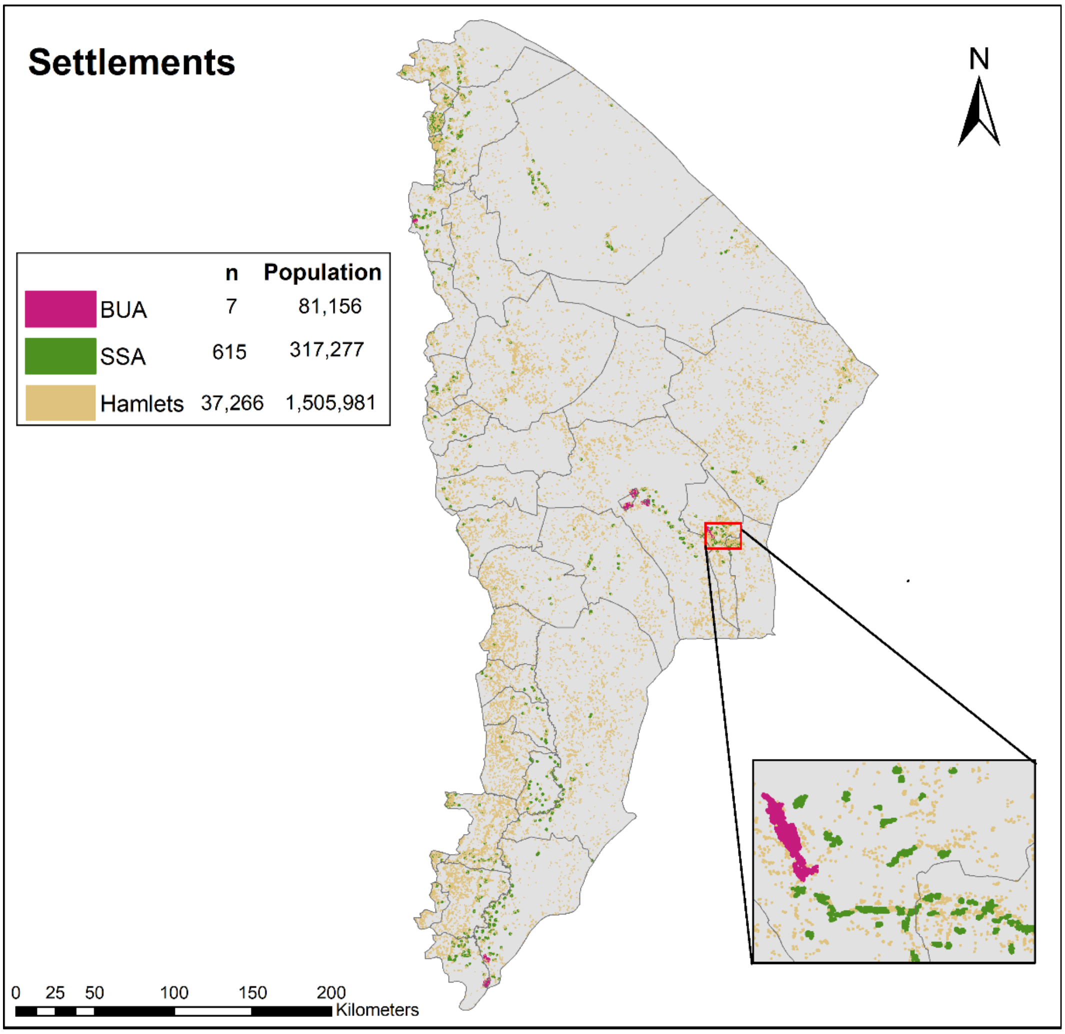

Figure 4: Settlements and Population in Afar. Source: own compilation based on data provided by CIESIN (2020)

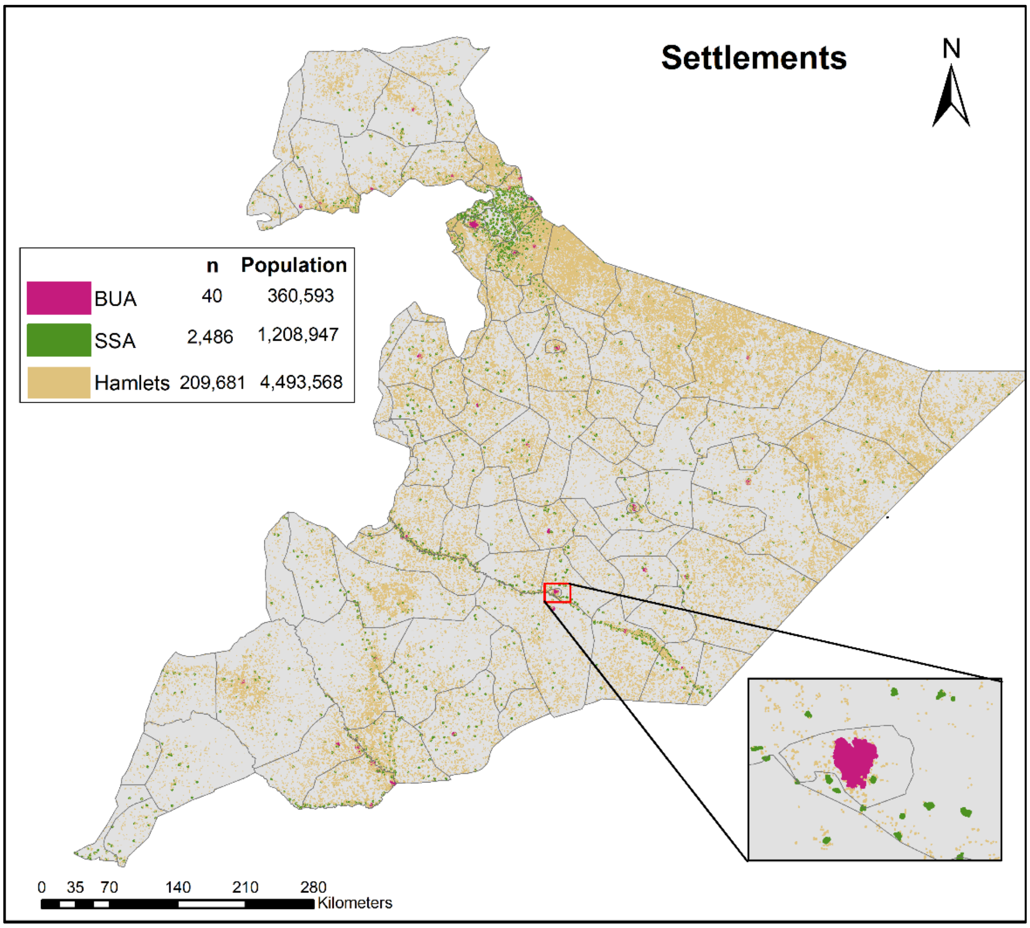

Figure 5: Settlements and Population in Somali. Source: own compilation based on data provided by CIESIN (2020)

Table 5 below summarises the distribution of the population per region and settlement classification. Table 6 summarises the division between the population considered as being vulnerable and those not being vulnerable.

Table 5: Population distribution by settlement type and region. Source: Authors' own compilation.

	Build- up areas (%)	Small settlement areas (%)	Hamlets (%)	Total
Afar	81 156 (4.3%)	317 277 (16.7%)	1 505 981 (79.1%)	1 904 414
Somali	360 593 (5.9%)	1 208 947 (19.9%)	4 493 568 (74.1%)	6 063 108
Total	**441 749 (5.5%)**	**1 526 224 (19.2%)**	**5 999 549 (75.3%)**	**7 967 522**

Table 6: Population divided into vulnerable and non-vulnerable by region. Source: Authors' own compilation.

	Vulnerable (%)	Non-Vulnerable (%)	Total
Afar	1 228 852 (64.5%)	675 562 (35.5%)	1 904 414
Somali	4 970 353 (82.0%)	1 092 755 (18.0%)	6 063 108
Total	**6 199 205 (77.8%)**	**1 768 317 (22.2%)**	**7 967 522**

3.4 Livestock

With most of the population in Afar and Somali being dependent on a pastoralist or agro-pastoralist lifestyle, livestock, namely the four key species camel, cattle, sheep, and goats, were chosen for this study. Due to data limitations sheep and goats were combined to the *Shoats* category.

Figure 6 and Figure 7 exemplary showcase the random distribution of livestock within a given *woreda* based on data on livestock held per person per *woreda*, each spot represents 500 respective animals. The livestock estimation is based on both, population data per *woreda* as described above as well as animal ownership per adult person as adopted from USAID and the Government of Ethiopia (2010).[36,37]

As a basis to evaluate the damages and losses caused by drought events, most recent average annual prices for each of the animal classes shall be applied in order to capture the potential value of the animal when it was first purchased and when the animal could have been sold. The values applied in this study are drawn from the UN Food and Agricultural Organisation's online database for the year 2017 in USD since no consistent national or regional data were available. An average (79.08 USD/shoat) was applied to account for the grouping of sheep and goats with the (slight) differences in price estimates (79.93 USD/sheep and 78.22 USD/goat).[38]

Table 7 provides a condensed overview of livestock per region and the applied value estimates in USD.

Table 7: Total livestock counts and value estimates by region and livestock type. Source: UNU-EHS based on USAID and the Government of Ethiopia. (2010).

	Camel	Cattle	Shoat	Sum
USD/Animal	348.14	285.17	79.08	
Afar, Animals	802 711	2 946 525	1 384 287	5 133 523
Somali, Animals	4 959 645	4 969 608	11 401 070	21 330 323
Sum Animals	**5 762 356**	**7 916 133**	**12 785 357**	**26 463 846**
Afar, m USD	279.5	840.3	109.5	1 229.2
Somali, m USD	1 726.7	1 417.2	901.6	4 045.4
Sum, m USD	**2 006.1**	**2 257.4**	**1 011.1**	**5 274.6**

36 USAID and the Government of Ethiopia. (2010). *An Atlas of Ethiopian Livelihoods*. The Livelihoods Integration Unit. USAID and the Government of Ethiopia, Disaster Risk Management and Food Security Sector, MOARD.

37 For details on the estimation please see the previous report: Waldschmidt, F, Rojas, A, Behre, E, Daou, D, Sebesvari, Z, Kreft, S, Souvignet, M. (2020). *Base Data Report – Ethiopia – Drought Risk*. Report 02. Bonn. UNU-EHS.

38 FAOSTAT (2020). FAOSTAT. Food and Agriculture Organisation of the United Nations, Rome, Italy

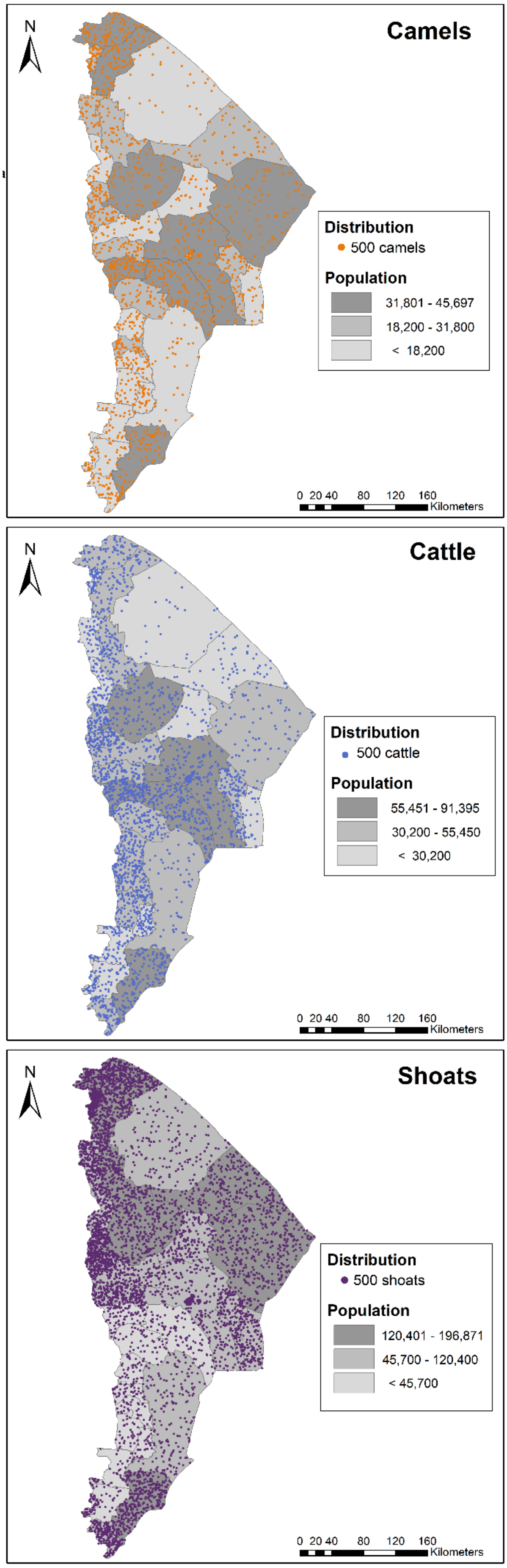

Figure 6: Livestock distribution, Afar. Source: Authors' own compilation.

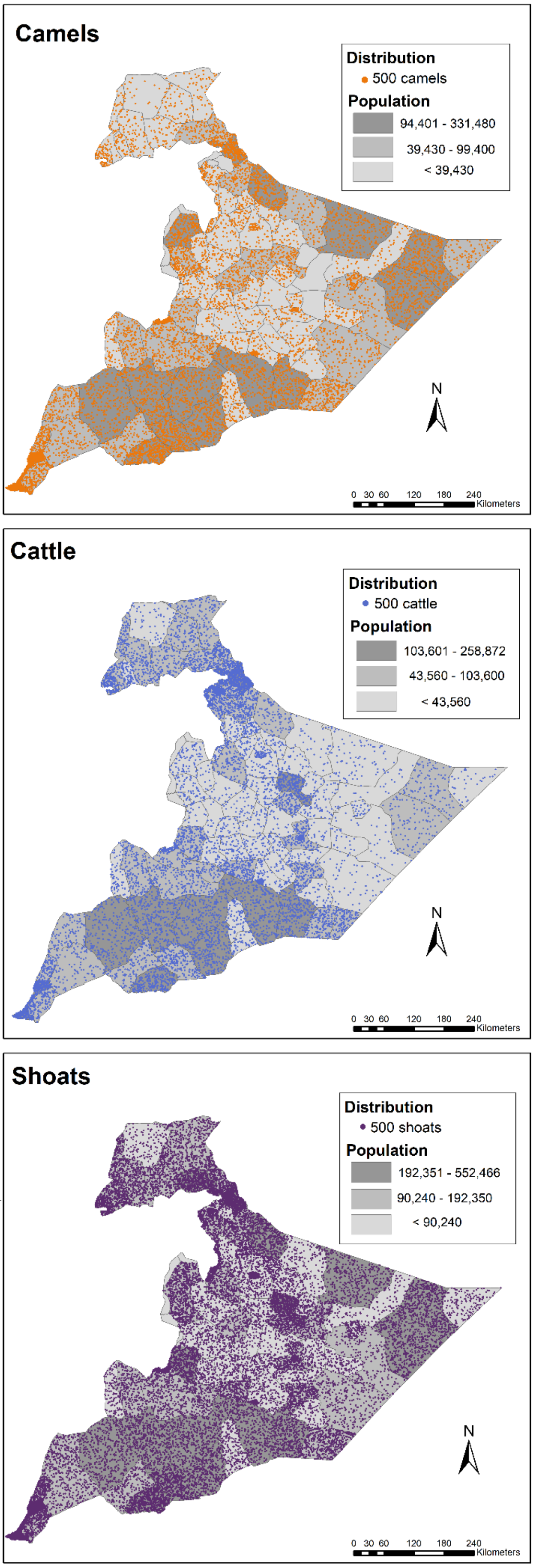

Figure 7: Livestock distribution, Somali. Source: Authors' own compilation

3.5 Natural Resources and Crop Land

Natural resources, e.g. environmental assets such as water resources, range- and forage lands, and crop lands are described within the same sub-chapter as similar data sources were applied for both, the value and damage/ loss estimations.

As the base to determine the type of natural resource at a specific location, or in other terms the land cover, remote sensing images provided by the Copernicus Global Land Service[39] were used. Since the field of evaluating natural resources provides a plethora of approaches, in this study a rather broad approach is being applied reflecting a variety of ecosystem services provided by different biomes. Considering this variety of ecosystem services however leads inevitably to higher value estimates than considering for instance the market value of the material of the respective ecosystem or peoples' willingness to pay or most other common valuation methodologies. The Ecosystem Services Valuation Database (ESVD) considers a wide range of ecosystem services (23) based on one of the most widely used ecosystem service classification systems as a follow up to the "The Economics of Ecosystems and Biodiversity" (TEEB) database.[40] As becomes clear from the selected assets, the regions' and their populations' welfare is largely dependent on functioning ecosystems and ecosystem services. In that light, the EVSD provides the advantage of aiming to represent the 'true value' of nature, biodiversity and corresponding ecosystem services. Table 8 below summarises the corresponding values per ha (or km for rivers and streams) and per region while Figure 8 displays the distribution of the different land covers at a resolution of 5km x 5km as used for the modelling exercise[41]; Figure 9 showcases the

[39] Copernicus Global Land Service. (2019). *Vegetation and Energy. Moderate Dynamic Land Cover Change*. Collection 100m. Version 2.1.. Retrieved on 23.06.2020 from https://land.copernicus.eu/global/products/lc.

[40] The 23 ecosystem services considered are: food, water, raw materials, genetic resources, medicinal resources, ornamental resources, air quality regulation, climate regulation, moderation of extreme events, regulation of water flows, waste treatment, erosion prevention, maintenance of soil fertility, pollination, biological control, maintenance of life cycles of migratory species, maintenance of genetic diversity, aesthetic information, opportunities for recreation and tourism, inspiration for culture, art and design, spiritual experience, information for cognitive development, existence and bequest values. Each represented ecosystem service is being valued with regard to different biomes based on over 600 independent studies evaluating those. Selected studies are examined for relevant ecosystem services valuated and the respectively applied valuation methodology. Values are subsequently standardized considering price levels, currencies, and spatial and temporal dimensions. Further, the project team undertakes a beneficiary standardization in order to be able to compare value observations to the same specific beneficiary. The chosen common specification is the total population of beneficiaries, i.e. the 'market size' or 'economic constituency' for the respective ecosystem. The database hence aims to summarise and condense the existing knowledge and data to a handier overview.
As the database comprises data and values from many different countries and contexts values are standardized and reported in international USD (Int USD) and are not converted into Birr as this analysis too is done in USD.
For further information see: R. De Groot, Brander, L., Solomonides, S. (2020). *Ecosystem Services Valuation Database (ESVD). Update of global ecosystem service valuation data*. FSD report No 2020-06 Wageningen, The Netherlands (58 pp).

[41] Although available at higher resolution this resolution was deemed as a reasonable compromise between higher resolution and limiting individual asset entities, and hence computing power needed to run the CLIMADA model. However, as expected some information was lost in the process of rescaling as the majority land cover within each 5x5km pixel was assumed as the total land cover of the corresponding pixel. That way, for instance, some smaller water bodies were 'swallowed' in Somali, while in both regions build up areas are no longer represented in the land cover map (as compared to a 1x1km resolution.)

water streams within the two regions separately for better visibility. According to the United Nations Educational, Scientific and Cultural Organization (UNESCO)-Intergovernmental Hydrological Programme (IHP), water is one of the most under-valued resources on the planet.[42] To account for that, we have deliberately attributed the same value per kilometre to main streams, tributaries and channels.

[42] Verbist, K (2021). Water - one of the most undervalued Resources on Earth. UNESCO article available at https://en.unesco.org/news/water-one-most-undervalued-resources-earth (accessed on 12th April 2021)

Table 8: Natural resources and crop land and corresponding value estimates. Source: Authors' own compilation based on data provided by Copernicus Global Land Service (2019) and De Groot and Solomonides (2020).

		Afar		Somali		Total	
	USD/ha	'000 Hectare	m USD	'000 Hectare	m USD	'000 Hectare	m USD
Permanent water bodies	108 361	55	2 675.6	-	-	55	2 675.6
River in km	108 361	3 501 km	379.3	6 734 km	729.7	10 235 km	1 109.0
Wood land	769	85	65.4	1 377.5	1 059.3	1 462.5	1 124.7
Shrub land	769	2 230	1 714.9	26 980	20 747.6	29 210 000	22 462.5
Herbaceous vegetation	1 597	2 230	3 561.3	2 387.5	3 812.8	4 617.5	7 374.1
Herbaceous wetlands	48 647	10	486.5	2.5	121.6	12.5	608.1
Un- & sparsely vegetated areas	337	5 392.5	1 817.3	1 725	581.3	7 117.5	2 398.6
Crop lands	8 026	120	963.1	237.5	1 906.2	357.5	2 869.3
Total			11 663.4		28 958.6		40 622

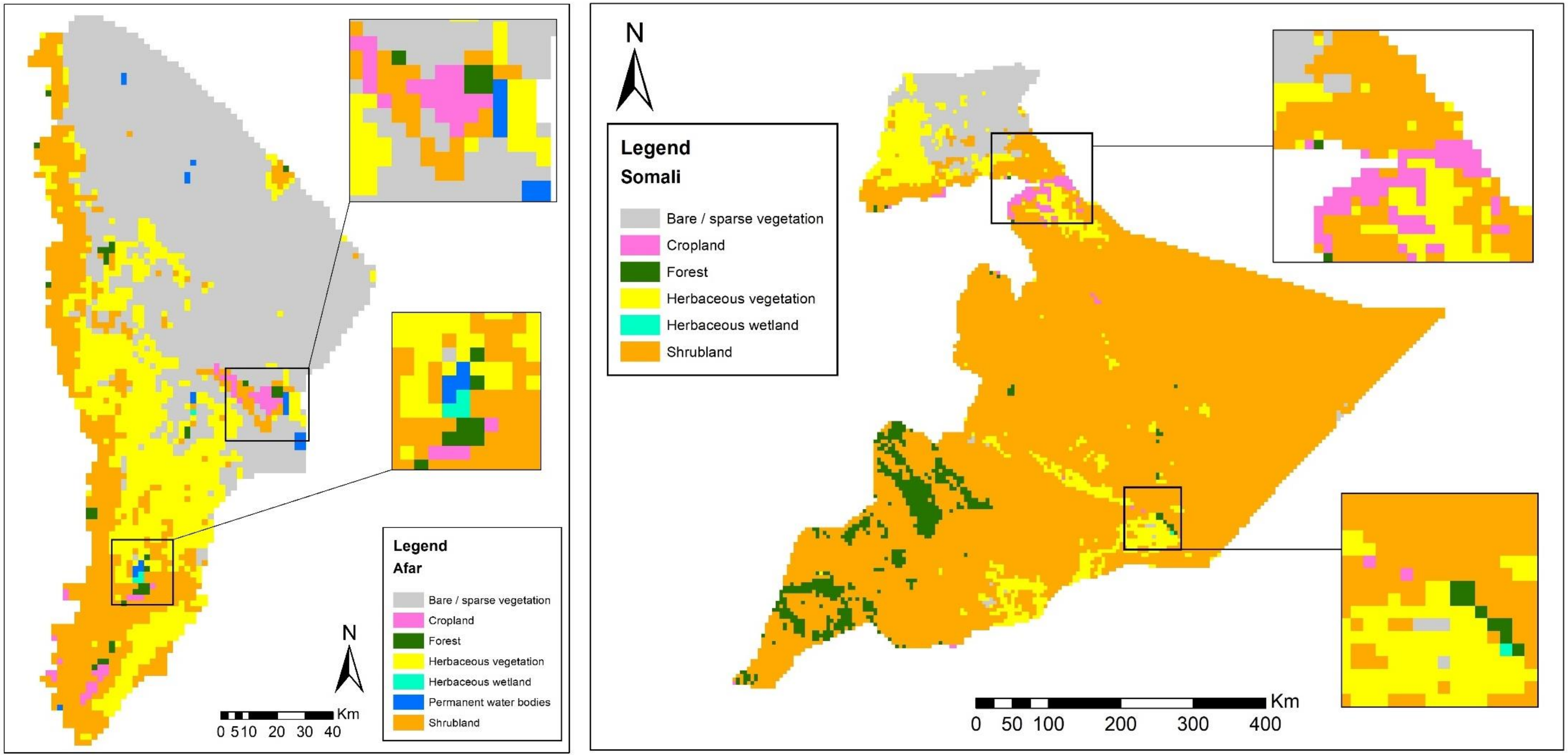

Figure 8: Land cover in Afar (left) and Somali (right). Source: Authors' own compilation.

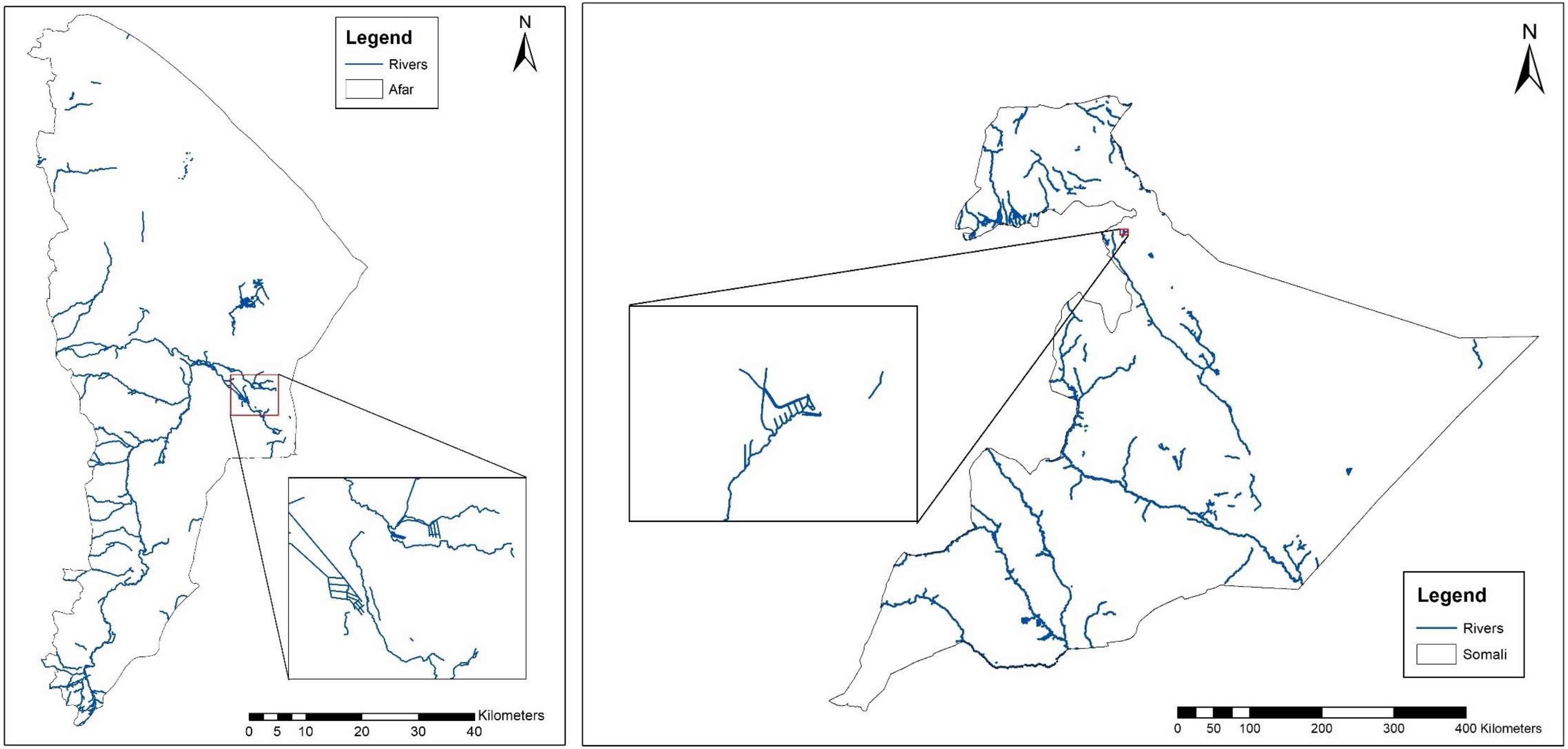

Figure 9: Rivers and streams in Afar (left) and Somali (right). The magnifications highlight manmade waterways, i.e. irrigation systems, which are considered as well as valuable water resources in this study. Source: UNU-EHS based on data provided by the Humanitarian OpenStreetMap Team (2020)..

3.6 Results

Since this study considers two regions, the value estimation results will be summarised by region in order to allow for different conclusions drawn by the reader.

Table 9: Asset Value Summary – Afar

Afar Asset Category	Total Value	Unit	Total Number
People	1 904 414	People	1 904 414
Camel	279 455 647	USD	802 711
Cattle	840 260 403	USD	2 946 525
Shoat	109 469 406	USD	1 384 287
Permanent water bodies	2 675 585 000	USD	55 000 ha
River	379 348 428	USD	3 501 km
Wood land	65 365 000	USD	85 000 ha
Shrub land	1 714 870 000	USD	2 230 000 ha
Herbaceous vegetation	3 561 310 000	USD	2 230 000 ha
Herbaceous wetlands	486 470 000	USD	10 000 ha
Un- & sparsely vegetated areas	1 817 272 500	USD	5 392 500 ha
Crop lands	963 120 000	USD	120 000 ha
Total Asset Value	12 892 526 385	USD	

Table 10: Asset Value Summary – Somali

Somali Asset Category	Total Value	Unit	Total Number
People	6 063 108	People	6 063 108
Camel	1 726 650 692	USD	4 959 645
Cattle	1 417 183 005	USD	4 969 608
Shoat	901 596 598	USD	11 401 070
Permanent water bodies	-	USD	-
River	729 698 928	USD	6 734 km
Wood land	1 059 297 500	USD	1 377 500 ha
Shrub land	20 747 620 000	USD	26 980 000 ha
Herbaceous vegetation	3 812 837 500	USD	23 875 00 ha
Herbaceous wetlands	121 617 500	USD	2 500 ha
Un- & sparsely vegetated areas	581 325 000	USD	1 725 000 ha
Crop lands	1 906 175 000	USD	237 500 ha
Total Asset Value	33 004 001 723	USD	

Table 11: Asset Value Summary – Both regions

Total Asset Category	Total Value	Unit	Total Number
People	7 967 522	People	7 967 522
Camel	2 006 106 339	USD	5 762 356
Cattle	2 257 443 408	USD	7 916 133
Shoat	1 011 066 005	USD	12 785 357
Permanent water bodies	2 675 585 000	USD	55 000 ha
River	1 109 047 356	USD	10 235 km
Wood land	1 124 662 500	USD	1 462 500 ha
Shrub land	22 462 490 000	USD	29 210 000 ha
Herbaceous vegetation	7 374 147 500	USD	4 617 500 ha
Herbaceous wetlands	608 087 500	USD	12 500 ha
Un- & sparsely vegetated areas	2 398 597 500	USD	7 117 500 ha
Crop lands	2 869 295 000	USD	357 500 ha
Total Asset Value	45 896 528 108	USD	

3.7 Limitations

While the worth of a human life can be estimated in financial terms by a multitude of approaches, in this ECA study it was decided to consider every person's life as exactly the same, not just in the underlying study but also across different ECA studies. However, the estimation of the remaining observed assets' values in a given context is oftentimes challenging. Although many different approaches for most of the potential assets are described in the literature, all those approaches rely on high- quality data. This makes data availability and quality the key bottleneck in assets valuation.

In the case of tradable assets, prices often change and are determined by numerous factors. Contrary to the fluctuating nature of prices and values, an ECA study aims at estimating expected costs and damages. Consequently, seasonal fluctuations of assets, such as for instance livestock, cannot be reflected. Therefore, reasonable estimates have to be applied, such as e.g. annual average values or the typical price at time of purchase as an estimate for replacement cost, or the maximum expected value expected within a given year. These different approaches provide different advantages and disadvantages. The underlying study applied the replacement cost approach, i.e. the average purchasing value, for livestock. Similar approaches can be taken for crops, including the estimation of probable harvest. As mentioned in the introductory paragraph of the sub-chapter, the availability of high quality data can decide over success and failure of reliable crop value estimation. Given the available data, no reasonable estimates for crops in the two regions could be produced and hence, the value estimation followed the same approach as chosen for natural resources.

Natural resources present a special challenge in the exercise of value estimation, as they and their ecosystem services are public goods. In this field, approaches were developed to estimate natural resources, or environmental assets, with different foci. For instance, one could use the resell value of the material, e.g. wood or water, as a value estimate. In this case, we chose an approach that specifically includes a multitude of ecosystem services beyond resell values as to reflect the value of natural resources and biodiversity that are essential for the predominant (agro-) pastoral livelihood of the population in the research area. Consequently, this leads to higher values as compared to rather simple resell values of corresponding materials.

4 Damage Functions

4.1 Introduction

Drought is a complex slow-onset natural hazard with (indirect) effects accumulating over time, while time horizons can vary widely from a few weeks to several years. Multiple types of drought, e.g. meteorological, agricultural, hydrological, or socio-economical droughts are defined and measured differently and with various indices.[43]

In the light of this complexity drought can still be considered a hidden hazard. Damage caused by weather-related hazards, such as drought, is commonly assessed using damage curves (also called damage functions or vulnerability curves) which express the degree a certain asset type can be expected to be affected or damaged for different hazard intensities. In the case of drought different drought indicators can be applied for this such as the Standardised Precipitation Index (SPI) as has been done in this study.[44]

Different approaches can be used to design damage functions. One approach relies on historical data on both hazard intensity and recorded damages, reconstruction cost or depreciated values of the assets. With sufficient data available this approach is very precise within a reference context. Alternatively, it is possible to estimate probable damages based on expert opinions regarding materials, animals' and plants' water requirements and other characteristics of the respective assets. This method is particularly helpful when no or insufficient historical records are available. Lastly, one can rely on generic or empirical damage functions and subsequently calibrate them using (household) surveys such as the one performed in the course of this study.[45] The calibration using (household) surveys can be done by comparing the generic or empirical damage functions with the specific local data obtained through the survey and adjusting for observed differences, e.g. in human or livestock mortality data. In any case, an

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[43] For details please see the preceding report: Waldschmidt, F, Rojas, A, Behre, E, Daou, D, Sebesvari, Z, Kreft, S, Souvignet, M. (2020). *Base Data Report – Ethiopia – Drought Risk*. Report 02. Bonn. UNU-EHS.

[44] For further information on drought indices see e.g. UNDRR (2019). *Global Assessment Report on Disaster Risk Reduction*. Geneva. Switzerland. United Nations Office for Disaster Risk Reduction (UNDRR).

[45] For further details see Annex I (Field Survey and Key Informant Interviews), Annex II (Key Informant Interview – Guiding questions), and Annex III (Household survey questionnaire).

iterative calibration process of the resulting damage functions is necessary to ensure that the damages simulated by CLIMADA reflects historical damages in the region (e.g. obtained from international databases, national and local statistical offices/agencies, or individual surveys and case studies).

Little research has been done into the quantification of damages and losses caused by different drought events, especially since the context of each case, e.g. regional context, populations' habits, or specific plant and animal species, matter significantly. Hence, little, but indicative conclusions could be drawn based on literature review focussing on pre-existing damage functions. However, data on losses, damages and (indirectly) affected people were used to estimate the below presented damage functions which in turn went through an iterative calibration process when applied in CLIMADA. [46,47,48,49,50] In order to reach more detailed and targeted results the study area was split into the two regions along the regional boundaries. However, as the regions are quite similar with the same assets being considered and to keep results comparable the same damage functions are being applied in both regions.

For the sake of clarity, all figures are displayed in the same format. As displayed, the mean damage degree (MDD) on the ordinate cannot exceed 100%. Additionally one needs to bear in mind that the intensity of the drought hazard is measured using the Standardised Precipitation Index (SPI), its values can be interpreted as the number of standard deviations by which the observed precipitation deviates from the long term mean of the same period. Hence, negative values represent a drought. Based on this, the abscissa uniformly reaches from -3.5 (extreme drought) to 0.5 while actually a value of -2.0 is considered as extremely dry and 0, i.e. no deviation from the long term mean, is defined as no drought.

4.2 Population

Following the premise outlined in this chapter's introduction the academic literature reviewed provided very little insights into direct effects of droughts on human beings. Using the available literature two damage functions in the shape of exponential functions, i.e. a steadily increasing rate of change with increased drought intensity as displayed in Figure 10. With an increasing Mean Damage Degree (MDD) for both vulnerable and non-vulnerable people no maximum value was defined. Hence, the percentage of people being affected consistently increases with drought intensity with only slightly above and below 1% affected at a mild drought indicated by and SPI of -1, but reaching a level of about 20% and 17% at an already quite severe drought of -2.5 SPI, respectively.

[46] EM-DAT. (2020). *EM-DAT Data Base*. Retrieved on 10.12.2020 from EM-DAT: https://www.emdat.be/

[47] Annual versions of the *Agricultural Sample Survey. Report on Livestock and Livestock Characteristics.* Published by the Central Statistical Agency of the Federal Democratic Republic of Ethiopia.

[48] United Nations Office for Disaster Risk Reduction (UNDRR). (2020). *DesInventar Sendai*. Retrieved on 10.12.2020 from https://www.desinventar.net/DesInventar/profiletab.jsp

[49] Abraham, A., Suryabhagavan, K., Balakrishnan, M. (2018). Multi-model and Vegetation Indices for Drought Vulnerability Assessment: A Case Study of Afar Region in Ethiopia. Remote Sensing of Land. 2. 1-14.

[50] Catley, A., Admassu, B., Bekele, G., Abebe, D. (2014). *Livestock mortality in pastoralist*. Disasters. 38: 500-516.

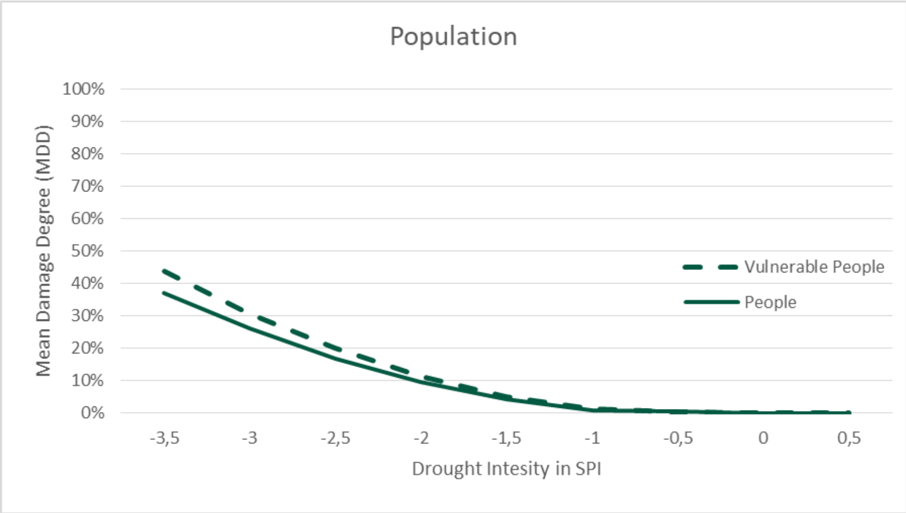

Figure 10: Damage functions for population: vulnerable people (dash) and non-vulnerable people (solid)

4.3 Livestock

Analysing different sources, including data obtained by the specifically conducted field survey[51] and studies with related content, let again to exponential damage functions for livestock.[52,53,54] Although one has to assume different levels of vulnerability and hence different damage functions for goat and sheep, due to data limitations and in line with summarising them into the asset group *shoat*, this approach was followed here too. Figure 11 displays the damage functions for all livestock subgroups: camel, cattle, and shoat. Based on the consulted sources the damage functions were constructed in order to represent the different vulnerability levels with cattle being the most vulnerable species reaching an MDD of about 17% at an extreme drought at an -3.0 SPI while at the same level of drought Camel and Shoats reach an MDD of about 9% and 12% respectively.

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[51] See Annex I - Field Survey and Key Informant Interviews and Annex III - Household survey questionnaire

[52] Annual versions of the *Agricultural Sample Survey. Report on Livestock and Livestock Characteristics.* published by the Central Statistical Agency of the Federal Democratic Republic of Ethiopia.

[53] Catley, A., Admassu, B., Bekele, G., & Abebe, D. (2014). Livestock mortality in pastoralist. Disasters. 38: 500-516.

[54] Huho, Julius. (2010). Drought severity and their effects on rural livelihoods in Laikipia district, Kenya. Journal of Geography and Regional Planning. 3. 035-043.

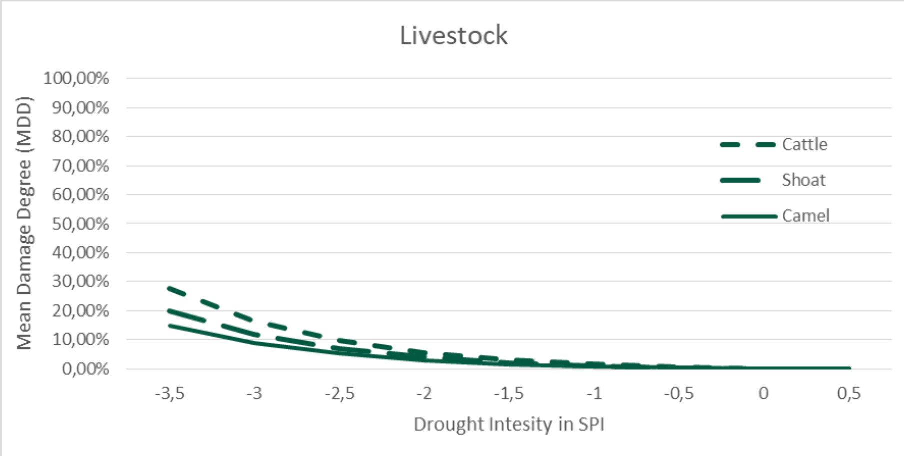

Figure 11: Damage functions for livestock: Cattle (dash), Shoat (long dash), and Camel (solid)

4.4 -Natural Resources and Crops

The information and literature available on quantifiable damages on natural resources and crops is quite limited. However, as drought, independent from any specific definition, denotes the scarcity of water similarly damage curves following, at least partially, an exponential pattern can be expected. Especially for crops and subsequently other flora this has been confirmed by limited data provided by e.g. a study on drought and its effects on rural livelihoods in Kenya.[55]

Based on those information the in Figure 12 displayed damage functions for the different vegetation classes where constructed. Crops were considered the most vulnerable and assumed to experience a substantial loss (MDD = 50%) at a severe drought of an -2.5 SPI while a MDD of 20% is already reached a mild drought with -1.5 SPI. Grassland / rangeland, wood- and shrub land, and un- or sparsely vegetated areas are considered less vulnerable and follow a stepwise less severe damage function respectively. The three types are considered to reach their plateau of maximum MDD of 42%, 33%, and 17% respectively at an extreme drought of -3.0 SPI from which no further damage with increased drought intensity as measured by SPI is expected.

[55] Huho, Julius. (2010). Drought severity and their effects on rural livelihoods in Laikipia district, Kenya. Journal of Geography and Regional Planning. 3. 035-043.

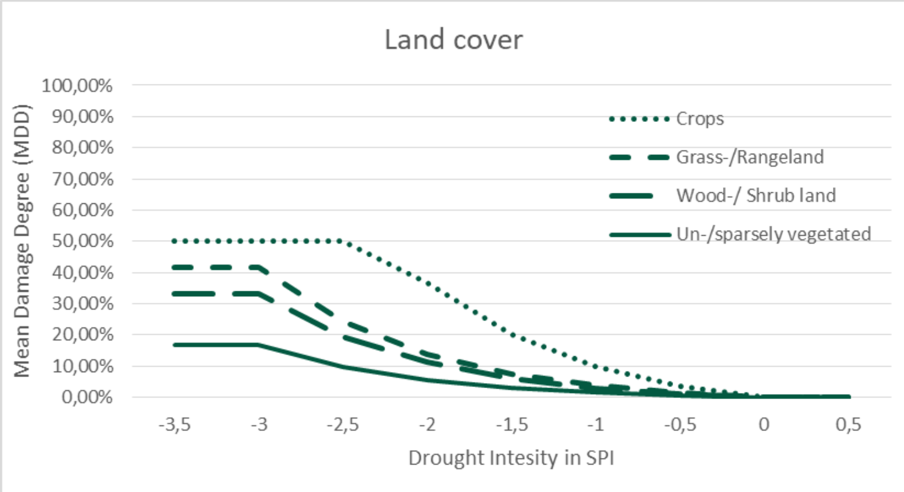

Figure 12: Damage functions for Land cover: Crops (dotted), Grass-/Rangeland (dash), Wood-/ Shrub land (long dash), and Un-/sparsely vegetated areas (solid).

In the case of water bodies, e.g. lakes, rivers and streams, and wetlands an increasing lack of precipitation and drought severity can have quite substantial effects of the fragile ecosystems relying on the presence of water. With decreasing water level higher concentrations of pollutants can be expected, especially communal waste water and washouts from agricultural and animal breeding areas can cause microbiological pollution. Further, warming water is one of the main factors in decreasing oxygen concentrations in water bodies during drought conditions affecting water quality and resulting in potential further knock-on effect on e.g. livestock and people.[56] Accordingly, the constructed damage functions (see Figure 13) represent the increasing damage on water resources considered here with increasing drought intensity. As wetland ecosystems are considered specifically fragile the corresponding damage function is assumed to follow an exponential pattern up until an MDD of 45% at an -3.0 SPI from which it increases comparatively slight onward with increasing drought intensity. Other waterbodies, i.e. lakes and rivers, follow the same pattern but reach an MDD of 36% at -3.0 SPI.

[56] T. Hrdinka et al. (2012). *Possible impacts of floods and droughts on water quality*. Journal of Hydro-environment Research 6 (2012) 145 - 150

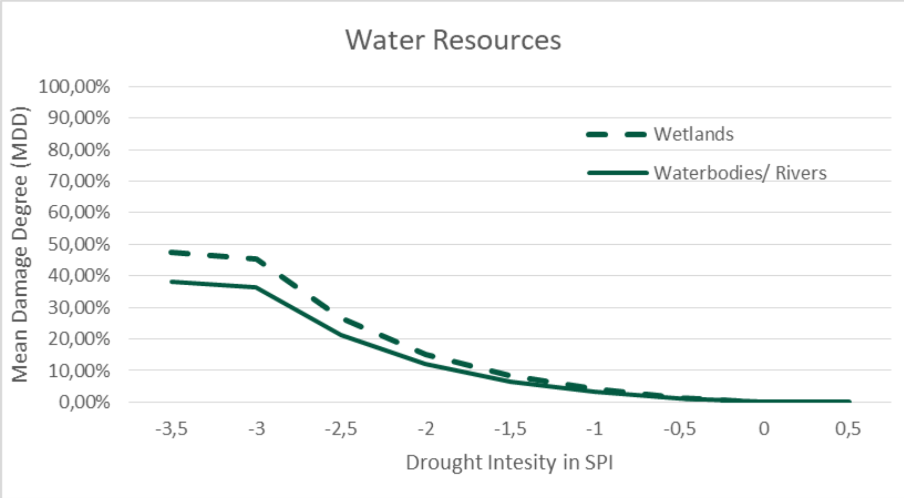

Figure 13: Damage functions for Wetlands (dash) and Waterbodies & Rivers (solid)

4.5 Limitations

Although there is a vast literature on drought and drought risk, drought remains a vastly complex weather-related hazard. Its intrinsic nature of taking different shapes with regard to time extent, geographical extent as well as intensity makes the estimation of its potential damages a special challenge. A lack of properly detailed documentation of drought events, especially longer term lingering drought events (or *hidden drought* events), and their specific characteristics as well as damages underlines this notion. Moreover, although the SPI is an accepted measure for drought, there are further capable indices that could be chosen as an alternative for drought measurement.[57,58]

The here presented damage functions largely rely on literature and data produced and gathered without the intention on construction drought damage curves. However, they do provide reasonable estimates for potential damages caused by drought in the given setting as confirmed through several calibration rounds within CLIMADA using e.g. global datasets such as EM-DAT[59] and DesInventar[60]. One has to note that these damage functions are to represent the aggregation of each asset category as a whole *in the given context* rather than e.g. an individual maize field or one specific herd of livestock and hence should be handled with care when applied in other settings without calibration.

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[57] See Chapter 2 - Drought Model for an overview of examples further of drought indices that were included in the newly developed drought model.

[58] For further information see e.g. UNDRR (2019). *Global Assessment Report on Disaster Risk Reduction*. Geneva. Switzerland. United Nations Office for Disaster Risk Reduction (UNDRR).

[59] EM-DAT. (2020). *EM-DAT Data Base*. Retrieved on 10.12.2020 from EM-DAT: https://www.emdat.be/

[60] United Nations Office for Disaster Risk Reduction (UNDRR). (2020). *DesInventar Sendai*. Retrieved on 10.12.2020 from https://www.desinventar.net/DesInventar/profiletab.jsp

5 Adaptation Measures

5.1 Introduction

This chapter presents the list of drought adaptation measures identified for the Afar and Somali Region in Ethiopia. These measures will serve to reduce the vulnerability of the key assets and population groups selected during the Inception Workshop, by reducing either the number of assets expected to be affected, the intensity of the impact, or in some cases both. The benefit of each measure was linked to the potential averted damage.

The adaptation measures were selected based on a comprehensive literature review, and a consultation process with key experts and government representatives. In total 37 adaptation measures were initially identified (referred to as a “long list”) and reduced to 13 (referred to as a “short list”), which have been introduced to CLIMADA.

Reducing the list of measures from 37 to 13 involved a transparent and participative selection process, including stakeholder validation workshops and a concluding Multi-Criteria Analysis. A detailed description of the measures selection procedure can be found in Annex IV.

5.2 Drought Adaptation Measures

For both study areas, the Afar and Somali Regions, 13 drought adaptation measures have been identified based on specific selection criteria (see Annex IV). The selection of measures is classified into different adaptation types, of which four are categorized as Nature-based Solutions (NbS), two as ‘Hybrid’, indicating a mix of NbS elements combined with ‘Grey’ infrastructure interventions. Five measures can be considered as solely ‘Grey’ adaptation types, referring to engineered solutions. In addition, two types of ‘Insurance’ solutions focusing on agriculture and livestock have been selected. All measures have been introduced to the CLIMADA modelling tool. The list of selected measures is shown below in Table 12.

Table 12: Overview List of Drought Adaptation Measures for the Afar and Somali Region. 'Grey' measures refer to technological and engineering solutions. 'NbS' measures refer to ecosystem-based (or nature-based) solutions and make use of multiple services provided by ecosystems. 'Hybrid' solutions indicate a combination of NbS and Grey types of measures. 'Insurance' solutions cover residual risks, which remain after alladaptation measures have been implemented

#	Name of Measure	Type of Measure
1	Wetland restoration and rehabilitation	NbS
2	Intercropping of trees with crops (Agroforestry)	NbS
3	Replanting of indigenous and improved fodder trees and grass species (Fodder Banks)	NbS
4	Management of protected environmental areas	NbS
5	Establishment of fodder tree and grass nursery sites	Hybrid
6	Subsurface Dams in Riverbeds (Micro-Reservoirs)	Hybrid
7	Riverbank restoration	Grey
8	Improvement of water storage systems	Grey
9	Improved forage storage & treatment	Grey
10	Establishment of communal seed banks	Grey
11	Establishment & Rehabilitation of small- & medium sized irrigation systems	Grey
12	Livestock Index Insurance	Insurance
13	Crop Index Insurance	Insurance

The identified drought adaptation measures have been allocated to the respective agro-ecological zones (AEZ) of the Afar and Somali Region. The Ministry of Agriculture (MoARD) developed a system of agro-ecological zonation based on temperature and moisture regimes. Each AEZ has characteristic crops found within it. These two main factors used to characterizing AEZ in the country are mainly governed by elevation (altitude). Additionally, elevation is the prime determinant of agricultural land-use in Ethiopia influencing the temperature and rainfall considerably. The country has very diversified agro-ecologies that are difficult to describe correctly. Hence, the agro-ecology of the country has been divided into 33 major zones.[61] Based on these zones, five different AEZs have been identified for both regions: Hot arid lowland plains (A1), Warm semi-arid lowland plains (A2), Very cold sub-moist mid highlands (A3), Warm moist lowlands (M2), and Warm sub-moist lowlands (SM2) (see Figure 14).

[61] EIAR (Ethiopian Institute of Agricultural Research). 2011. Coordination of National Agricultural Research System, Ethiopia. English and Amharic Version. EIAR, Addis Ababa.

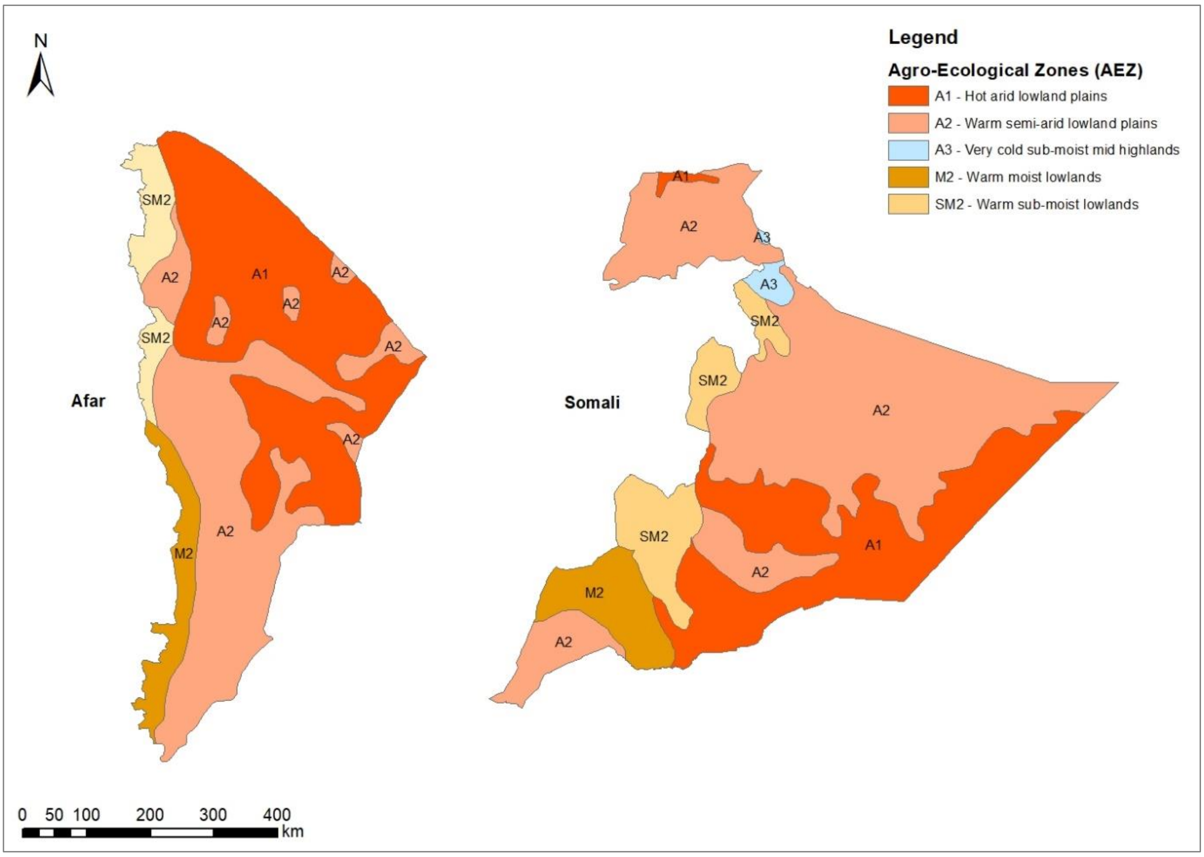

Figure 14: Overview of Agro-Ecological Zones (AEZs) for the Afar and Somali Region. The AEZs serve as zoning in which the drought adaptation measures be allocated. Source: UNU-EHS.

The adaptation measures are described in brief in the following overview, Table 13. Each box provides information about the cost per assigned location (A1, A2, A3, M2, SM2), the implementation time, expected life span, complexity, and maintenance intensity. A more precise description of each measure can be found in Annex V. Table 14 summarises the measures' cost and impact reduction.

Table 13: Description of intended drought adaptation measures (13 measures).
For each measure the table provides the cost per assigned location, implementation time, expected life span, complexity of the measure (in high, medium, low) and maintenance intensity (in high, medium, low).

1. Wetland restoration and rehabilitation

Prioritizing wetland protection and restoration can enhance climate adaptation and resilience, and stabilize and maintain local water cycles, water supply, and local microclimates. Incentives for local communities to apply sustainable wetland management practices efficiently should be encouraged in alignment with relevant institutions to facilitate an appropriate planning for the implementation of wetland conservation and restoration interventions. Actions to restore and sustainably manage wetlands for resilient livelihoods and sustain ecosystems include:

I. Restoration and management of wetland hydrology and associated forests/shrub land
II. Improved agricultural practices and alternative livelihood options in wetland catchments
III. Enhancing knowledge management and information sharing to facilitate community-based wetland restoration activities

Total Cost (USD)	834 750 (Afar, Awash Basin), 834 750 (Somalia, Ayisha & Shebelle Basin)		
Implementation Time	2 years	Complexity	Medium
Life Span	20-30 years	Maintenance	Low

2. Intercropping of trees with crops (Agroforestry)

In this scenario it is assumed to plant maize hedgerow intercropped with trees, taking a 10x10 meter spacing, representing 100 trees planted per hectare on a rectangular grid. It is intended to plant the tree species *Sesbania sesban* in agroforestry systems for contour forage banks or hedgerows. It is aimed to promote 1450 ha of agroforestry systems in each region, reaching circa 4 000 households, assuming an average field size per household of 0.25 ha. For this *Sesbania sesban* trees are interplanted in 10 meter wide alleys (10x10 meters = 100 trees/ha) in combination with maize (2x2.5 meters = 2 000 plants/ha). Generally, either in the long-term or short-term, agroforestry practices have an attractive financial incentive for the improvement of the livelihood of the farm households or minimizing the prevailing ecological problems such as land degradation.

Total Cost (USD)	546 530 (Afar Region), 546 530 (Somali Region)		
Implementation Time	1 year	Complexity	Low
Life Span	>30 years	Maintenance	Low

3. Replanting of indigenous and improved fodder trees and grass species (Fodder Banks)

It is advised to establish high-quality fodder trees, such as *Sesbania sesban* and Napier grass (*Pennisetum purpureum*) as a fodder grass for smallholder dairy production in a cut-and-carry production system. The aim of the introduction of Napier grass and *Sesbania sesban* is to increase feed quantity and quality especially during the dry season to subsequently improve animal health, and stabilize and increase milk yields under climate change. It is intended to establish in both regions 400 ha of fodder banks (800 ha both regions). Fodder banks should be ideally maintained through community members, either in organised agricultural or livestock associations or other systems abundant in communities or villages. It is also advised to support the establishment and maintenance of fodder banks with agricultural extension services, at least for a certain time shortly after the introduction.

Total Cost (USD)	628 400 (Afar Region), 628 400 (Somali Region)		
Implementation Time	1 year	Complexity	Low
Life Span	>30 years	Maintenance	Low

4. Management of protected environmental areas (Exclosures)

Exclosures are areas closed from humans' and domestic animals' interferences with the goal of promoting natural regeneration of plants and reducing land degradation of formerly degraded communal grazing lands. The effects of exclosures on the recovery of woody species diversity, population structure, and regeneration status, restoration of soils, and restoration of ecosystem carbon stocks have been well studied in the past. Exclosures are often managed within a rotational system, which defines the closure and accessibility for livestock activities. In both regions, Afar and Somali are 1 000 ha of exclosure areas planned.

Total Cost (USD)	907 986 (Afar Region), 907 986 (Somali Region)		
Implementation Time	1 year	Complexity	Low
Life Span	5-10 years	Maintenance	Low

5. Establishment of fodder tree and grass nursery sites

Nurseries with the focus on productive and drought tolerant indigenous and introduced seeds of forage and tree species are established. In Ethiopia, *Sesbania sesban* is the most important planted fodder tree and is generally grown in home gardens. Other species could include: *Panicum*, Rhodes, *Acacia polysantha*, others such as pigeon pea, cow pea, papaya, bamboo, elephant grass, various *acacia* species (*Acacia Abysinica*, *Acacia Tortois*, *Acacia Seyal*). Fodder tree and grass nursery sites are established and managed accordingly, ideally by communities. Nursery sites should be fenced and appropriately equipped with nursery tools and planting materials. Each nursery site should include the construction and rehabilitation of irrigation canals, water storage ponds to enable a permanent production of seedling and fodder seeds. It is intended to implement 100 ha of nurseries in each region with 12 species and two types of germplasm.

Total Cost (USD)	3 007 000 (Afar Region), 3 007 000 (Somali Region)		
Implementation Time	1 year	Complexity	Medium
Life Span	>30 years	Maintenance	Medium

6. Subsurface Dams in Riverbeds (Micro-Reservoirs)

A Subsurface dam (SSD) in a riverbed is also referred to as groundwater or sand storage dam, and is a micro-catchment technology to harvest and store rainwater, which is built on seasonal sandy streams in rural arid and semi-arid areas. SSDs can be considered as hydraulic retention structures built on underground dikes in order to block shallow groundwater flow during wet periods. They are designed to increase the water yield of an already existing shallow groundwater reservoir, thereby, increasing the volume of water yielded during dry periods and their accessibility for local communities. The most common way of constructing a subsurface dam is to build a dam in a trench excavated across a valley or riverbed. It is planned to realise 50 subsurface dam projects in reach region, i.e. in the Awash (Afar) and Shebelle basin (Somali).

Total Cost (USD)	502 871 (Afar Region), 502 871 (Somali Region)		
Implementation Time	2 years	Complexity	Medium
Life Span	20-30 years	Maintenance	Low

7. Riverbank restoration

Various techniques and methods exist to prevent or control the loss of valuable land and to ensure a stable water conveyance without losses in water quantities. In order to strengthening banks engineered revetments are advised, such as gabions and mattresses. The word Gabion is French derived from the Italian word *gabbia* meaning cage. Gabions are rectangular wire boxes filled with small stones, stacked on steep slopes and provide higher resistance for high water velocities in which small riparian stones are unstable or vegetated cover unable to establish. Gabions can be linked together to form terracing, retain river banks, or support earth banks. Gabions and gabion mattresses should be designed to resist hydraulic conditions notably the velocity of water flow. They may be used for water velocities of up to 6 m/s. In each region, it is intended to plan with the following dimensions of gabions for riverbanks:

- Length: 10 000 meters
- Height: 3 meters
- Mesh Type: 3 mm
- 45 025 500 m^3 of stone

Total Cost (USD)	1 176 622 (Afar Region) 1 176 622 (Somali Region)		
Implementation Time	1-2 years	Complexity	Medium
Life Span	>30 years	Maintenance	Low

8. Improvement of water storage systems (Cisterns)

Cisterns should be located as close as possible to areas where the water is to be used. To be effective, a cistern should have an adequate catchment under specific rainfall conditions and a suitable underlying geological formation. Normally, the cistern's capacity will depend on the quantity of runoff, which in turn depends on catchment size and rainfall. They may be built above or below ground, however, below-ground cisterns are recommended due to the increased protection. Underground cisterns also have the advantage of providing relatively cool water even during the dry season. A cistern should be located where the surrounding area can be graded to provide good drainage of surface water away from the cistern and should be located slightly upslope, away from any sewage disposal facilities. Concerning the environment, it is advised to use either concrete or steel-made materials. For a below-ground concrete block-walled version, walls and floors should be at least 15 centimetre thick and reinforced with steel rods. The top of a cistern may consist of individual panels, and at least a manhole to allow access to the storage tank. It is intended to reach 4 000 people in both regions combined and to establish cisterns with a total capacity of 2 246 000 litres (2 246 m^3).

Total Cost (USD)	188 475 (Afar Region), 188 475 (Somali Region)		
Implementation Time	1-2 years	Complexity	Medium
Life Span	20-30 years	Maintenance	Low

9. Improved forage storage & treatment (trench silos)

In dry seasons, the supply of forage decreases and the available forage is low in protein. Lack of quality forage can lead to decreased conception and growth rates or increased livestock mortality. Therefore, the basis of feeding in livestock and ruminant production systems is surplus forage stored in growing seasons. It is advised to establish improved forage storage systems using roofed trench (bunker) silos in combination with storage polythene bags (e.g. 50 kg capacity). Trench (or bunker) storages are permanent structures constructed above ground and are commonly used in flat areas. Above ground walls are constructed using concrete, earth, or steel. Bag silos show several advantages, since these systems are very flexible. Bags are suited to crops where fluctuating amounts harvested can be sealed. For each region, two (2) concrete trench silos are planned. Each trench silo has a capacity of 2 000 tons.

Total Cost (USD)	874 880 (Afar Region), 874 880 (Somali Region)		
Implementation Time	1-3 years	Complexity	Medium
Life Span	20 years	Maintenance	Low

10. Establishment of communal seed banks

It is intended to establish a network of seed banks providing affordable and high quality seed of grass and fodder tree varieties to ensure constant accessibility and quality, especially for nurseries. Seed banks could be managed under communal systems and supervised under regional or national agencies. The aim of seed banks is to increase local seed security and contributing to the possibilities to continued utilization of locally important genetic diversity. Community seed banks are collections of seeds that are maintained and administered by the communities themselves. In Ethiopia, community seed banks contribute to sustainable conservation strategies and support seed exchange of traditional varieties among farmers. Banks are managed by the local farmers, who use them to exchange seeds of traditional varieties from diverse crops, such as wheat, teff, barely, lentil, beans, and chickpeas. Having registered in crop conservation associations, farmers borrow and return seeds from the community seed banks. It is planned to build communal seed banks where each has the capacity to store 4-6 tons of seed supply, able to cover at least 1 200 households. In each, the Afar and Somali region, 50 communal seed banks are planned (in total 100).

Total Cost (USD)	1 938 000 (Afar Region), 1 938 000 (Somali Region)		
Implementation Time	2-5 years	Complexity	High
Life Span	>30 years	Maintenance	Medium

11. Establishment & Rehabilitation of small- & medium sized irrigation systems

It is intended to promote and establish small- and medium sized irrigation schemes, promoting solar-powered drip irrigation systems or sprinkler systems. This measure allows a shift from gravity irrigation to modern pressurized systems (e.g. drip irrigation), contributing towards sustainable intensification for food and nutrition security. Such irrigation systems are comprised of a tank of water connected to hoses or plastic pipes that are laid on the ground along field crops. The use of such drip irrigation system permits reduction of water loss (up to 50%) as compared to flood irrigation, showing water savings of 50% and a yield increase of 30%, with no substantial differences with the conventional drip irrigation systems.[62] In each region, a 60 ha irrigation project is planned within the Awash River and Shebelle River basin.

Total Cost (USD)	12 724 998 (Afar Region), 12 724 998 (Somali Region)		
Implementation Time	1-3 year	Complexity	High
Life Span	>30 years	Maintenance	Medium

12. Livestock Index Insurance
13. Crop Index Insurance[63]

Although with limited capabilities, CLIMADA includes a module focusing on insurance, more precisely, resembling parametric insurance. This is being used in this analysis in two ways to represent two different potential insurance schemes, one being directed at crop, one being directed at livestock. Parametric, or Index-based insurance schemes make use of modelling and satellite imagery with other data to predetermine drought thresholds, which could trigger rapid compensation pay-outs. The advantage of triggering pay-outs using observable indices such as rainfall or vegetation cover rather than actual losses (as an indemnity based insurance scheme would do), is the elimination of costly damage and loss assessment. However, this advantage leads to the common challenge of basis risk: The risk of either experiencing and actual (qualifying) damage but not receiving a pay-out based on the index not triggering it, or on the other hand a pay-out being triggered by the index even though no (qualifying) damage is experienced.[64]

For modelling purposes it was assumed that a potential insurance product gets triggered at a drought level of SPI -1.8. This means once a relatively severe drought is measured with an SPI value of -1.8 pay-outs to the insured are automatically triggered. Secondly, a cut-off value was included from which on-ward, with increasing drought intensity, no further pay-out is being made. This cut-off is set at a quite severe level of SPI -3. Although setting a cut-off limit may seem counter intuitive from a humanitarian point of view, it is necessary to limit the risk and cost for the insurance provider and hence ensure economic viability. Finally, as the model considers a 5 x 5km raster as the unit for land cover and 500 of each livestock at each randomised location, values entered into CLIMADA for pay-outs (or the 'tick value') relate to those scales. Hence, 1m USD were used as tick value for crops and 15 000 USD were are applied for livestock.

[62] Yemenu, F., Hordofa, T., & Abera, Y. (2014). Review of water harvesting technologies for food security in Ethiopia: challenges and opportunities for the research system. *Journal of Natural Sciences Research*, *4*(18), 40-49.

[63] Although measures targeting economic resilience did not rank high enough to be included in the short list of measures in Annex VI a brief summery overview presents additional approaches targeting e.g. financial inclusion of the target population. Further information on insurance is presented in Annex V.xiii 12 & 13. Livestock & Crop Index Insurance.

[64] As the field of insurance is quite extensive and many more factors have to be taken into account when designing an insurance product within this report the information is being kept on this rather simplistic level in order to keep it both readable and not to go too far beyond the scope and goal of the study. A more thorough overview and useful tools to assess the respective needs can be found for instance in: Ramm, Gaby, Balogun, Kehinde, Souvignet, Maxime and Range, Matthias (2018). *Integrating Insurance into Climate Risk Management: Conceptual Framework, Tools and Guiding Questions: Examples from the Agricultural Sector*. UNU-EHS.

Insurance Premium (USD)	42 000 USD per unit (crops), 5 000 USD per 500 livestock (camel, shoats, cattle)		
Implementation Time	1-3 year	Complexity	High
Life Span	>30 years	Maintenance	Medium

5.3 Overview of Costs

Table 14: Overview of all measures applied in the Afar and Somali Region incl. location in the respective agro-ecological zone. The total cost until year 2050 (incl. construction & maintenance) and the respective impact reduction are listed.

AFAR REGION		
Measure	Location (AEZ)	Total Cost in USD (for 30 years, incl. construction & maintenance)
Wetland restoration and rehabilitation	A2, M2, SM2	834 750
Intercropping of trees with crops (Agroforestry)	A1, A2, M2, SM2	546 530
Replanting of indigenous and improved fodder trees and grass species	A1, A2, M2, SM2	628 400
Management of protected environmental areas	A2, M2, SM2	907 986
Establishment of fodder tree and grass nursery sites	A2, M2, SM2	3 007 000
Subsurface Dams in Riverbeds	A2, M2, SM2	502 871
Riverbank restoration	A1, A2, M2, SM2	1 176 622
Improvement of water storage systems	A2, M2, SM2	188 475
Improved forage storage & treatment	A2, M2, SM2	874 880
Establishment of communal seed banks	A2, M2, SM2	1 938 000
Establishment & Rehabilitation of small- & medium sized irrigation systems	A1, A2	12 724 998
Livestock Index Insurance	ALL	5 000 per 500 of each livestock/a
Crop Index Insurance	ALL	42 000 per 5x5km raster /a
TOTAL		23 330 512

SOMALI REGION		
Measure	Location (AEZ)	Total Cost in USD (for 30 years, incl. construction & maintenance)
Wetland restoration and rehabilitation	A2, A3, M2, SM2	834 750
Intercropping of trees with crops (Agroforestry)	A1, A2, A3, M2, SM2	546 530
Replanting of indigenous and improved fodder trees and grass species	A1, A2, A3, M2, SM2	628 400
Management of protected environmental areas	A2, A3, M2, SM2	907 986
Establishment of fodder tree and grass nursery sites	A2, A3, M2, SM2	3 007 000
Subsurface Dams in Riverbeds		502 871
Riverbank restoration	A1, A2, A3, M2, SM2	1 176 622
Improvement of water storage systems	A1, A2, A3, M2, SM2	188 475

Improved forage storage & treatment	A2, A3, M2, SM2	874 880
Establishment of communal seed banks	A2, A3, M2, SM2	1 938 000
Establishment & Rehabilitation of small- & medium sized irrigation systems	A1, A2	12 724 998
Livestock Index Insurance	ALL	5 000 per 500 of each livestock/a
Crop Index Insurance	ALL	42 000 per 5x5km raster /a
TOTAL		23 330 512

Region	Total Cost in USD (for 30 years, incl. construction & maintenance)
AFAR Region	23 330 512
SOMALI Region	23 330 512
TOTAL	46 661 024

6 Results

6.1 Introduction

In this section, results from CLIMADA are presented and show i) the annual expected damage for different scenarios, ii) a cost-benefit analysis of selected measures for drought and iii) a comparison of measures according to their mitigation effect in the regions of Afar and Somali.

In the previous sections, asset values and population estimations have been presented and discussed thoroughly. Further, different climate and socio-economic scenarios have been introduced. Last, a list of measures, specific to the study region and dedicated to mitigation of drought risk have been designed and parameterized into CLIMADA. This data was processed by CLIMADA against the drought information described below.

In the ECA Methodology, the benefit of a given adaptation measure reflects the expected damage that can be averted by its implementation in the future. Because all measures are described on a monetary basis, results are comparable, and the efficiency of each measure (in terms of impact or investment) can be quantified. In doing so, a set of "best" measures can be considered for a feasibility study, prior to investment.

6.2 Annual Expected Damage

Annual expected damage represents the damage expected on assets and people in the region of Afar and Somalia on average annually. This annual expected damage is the percentage, or absolute value of asset or persons affected by the set of extreme events. The set of extreme events, or the value of assets or number of persons can be affected by climate change and socio-economic scenarios. Figure 15 and Figure 16 show annual expected damage in Afar and Somali regions for assets in USD (Graphs a) and b) below) and for people (vulnerable population and other) (Graphs c) and d) below). The first bar (today) in yellow represent annual expected damage today. The second bar (economic development) represents the increase of the expected annual damage over the next 30 years due to economic development (for persons, it represent the population growth).[65] The light red bar represents the additional annual expected damage due to climate change in Ethiopia. Last, the red bar represents the total aggregated expected annual damage in 2050, when economic growth (and population growth) and climate change are considered.

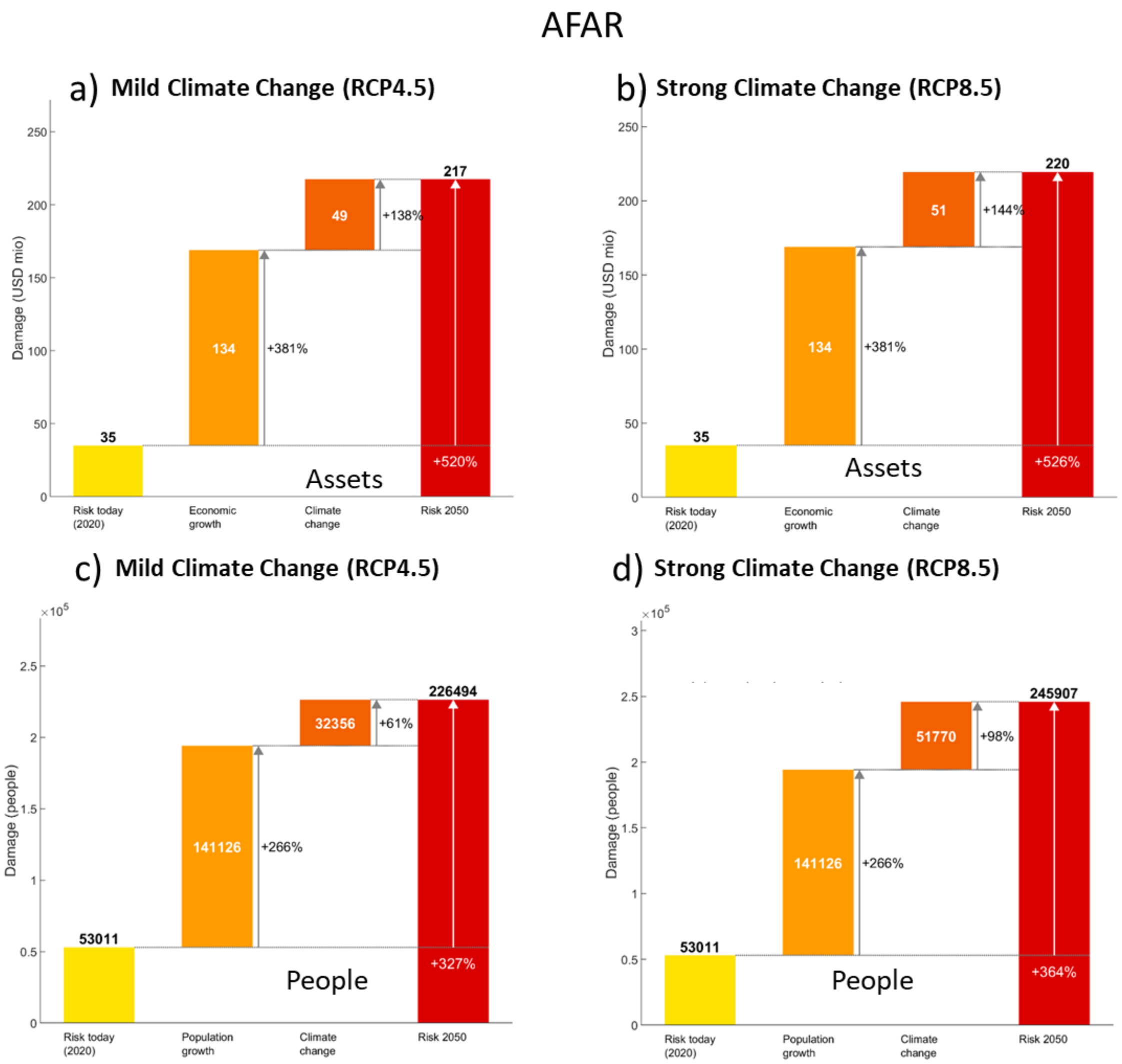

Figure 15: Annual expected damage (AED) in Afar for Assets (Graphs a) and b) in USD) and people affected (Graphs c) and d) in people).

[65] For Afar annual population growth rates of 3.02% in 2018 to 1.76% in 2030 and 1.35% in 2050, and a declining discount rate of 6.2% in 2018, 4.00% in 2030 and 2.22% in 2050 is being assumed. For Somali annual population growth rates of 2.63% in 2008 to 1.96% in 2030 and 1.40% in 2050, and a declining discount rate of 4.8% in 2018, 4.03% in 2030 and 2.23% in 2050 is being assumed. Since little local information was available on economic growth a national estimate of 5.82% annually had to be assumed. These growth rates lead to a constant increase in the value of existing assets as well as the continuous accumulation of further assets. In the case of natural resources it is too assumed that the relative value increases with the GDP.
For further details on the socio-economic scenario please see the previous report: Waldschmidt, F, Rojas, A, Behre, E, Daou, D, Sebesvari, Z, Kreft, S, Souvignet, M. (2020). *Base Data Report – Ethiopia – Drought Risk.* Report 02. Bonn. UNU-EHS.

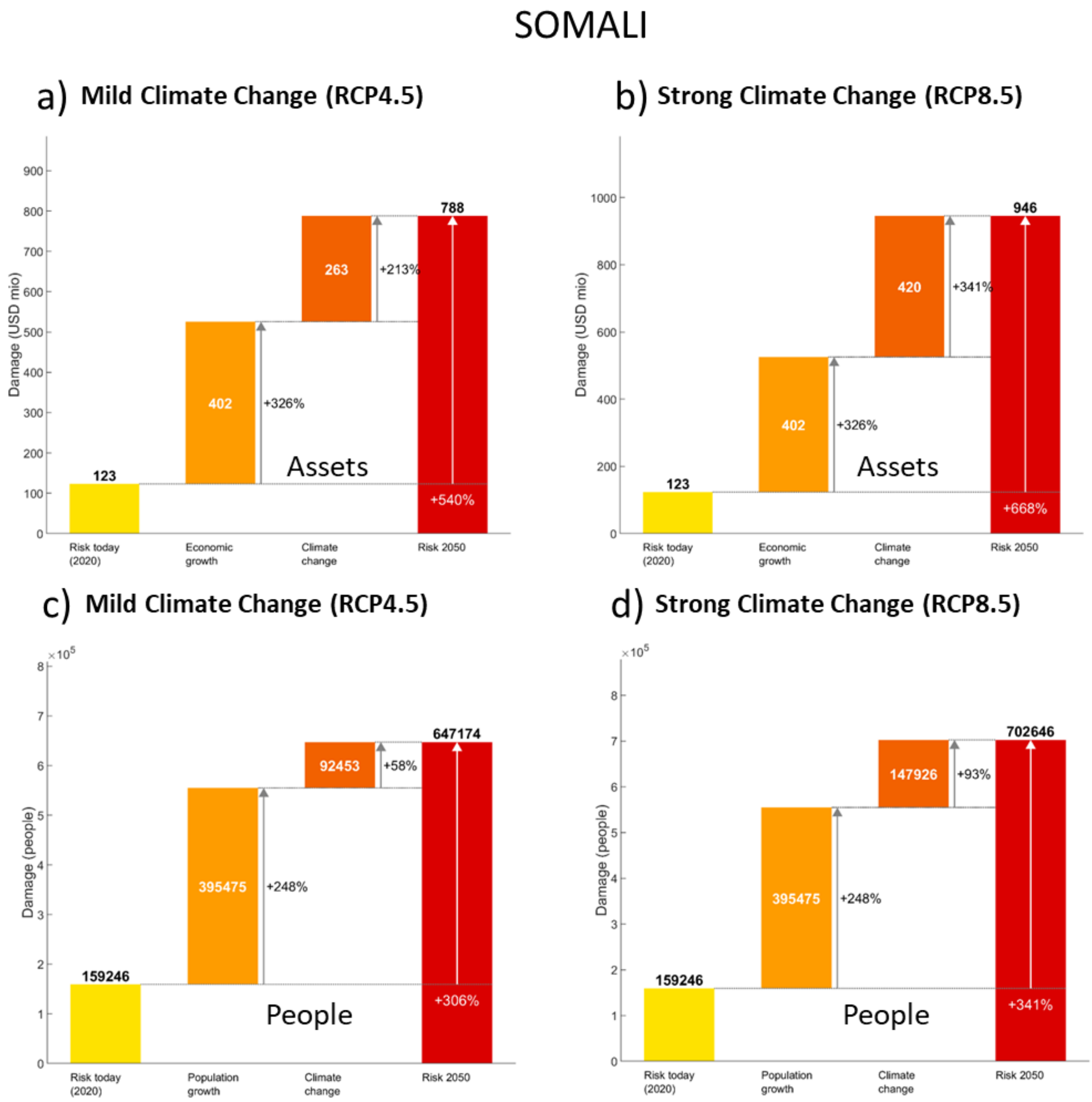

Figure 16: Annual expected damage (AED) in Somali for Assets (a,b in USD) and people affected (c,d in people).

Annual damage for assets and persons are summarized in Table 15 and

Table 16. Results are presented for all scenarios separately and aggregated with today's expected damage. Defining 2020 as today in alignment with discussions with stakeholders.

Afar: For the region of Afar, the total expected damage for assets of USD 35m (2020) is expected to rise to 381% due to economic growth and of 138% due to climate change (144% with extreme climate scenario). A total of USD 217m (USD 220m for extreme climate change scenario) are simulated for the time horizon 2050. The increase in annual expected damage in 2050 represents a raise of more than 520% in Afar, due both to economic growth (assets will be more valuable) and climate change (hazard will be more frequent and more intense). This large increase is mostly reflected by a strong economic growth prediction. In addition, drought events are expected to worsen in the coming decades. Regarding the population, more than 53 000 people are expected to be affected by drought annually in 2020. Despite a relatively low population growth in the area, an increase of 266% is expected in the future. More intensive climate, in return is expected to affect more persons with an increase of 61% for a moderate climate and 98% for extreme climate. A total of 226 000 (245 000 for extreme climate) are expected to be affected annual in 2050, i.e. an increase of 327% and 364% compared to 2020.

Table 15: Summary of annual expected damages in Afar for different scenarios

ID	Asset Categories	Units	Total Value (% of Total Sum)	AED Today (% of Total Sum)	AED Economic Growth (total) (% of Total Sum)	AED Moderate Climate Change (total) (% of Total Sum)	AED Extreme Climate Change (total) (% of Total Sum)
101	People	People	675 562 (35.5%)	21 148 (39.9%)	85 126 (43.8%)	99 314 (43.8%)	107 827 (43.8%)
102	Vulnerable People	People	1 228 852 (64.5%)	31 863 (60.1%)	109 011 (56.2%)	127 179 (56.2%)	138 080 (56.2%)
201	Camel	USD	279 455 647 (3.3%)	162 893.9 (0.5%)	5 056 614 (3.0%)	6 510 391 (3.0%)	6 573 598 (3.0%)
202	Cattle	USD	840 260 403 (9.9%)	247 223.7 (0.7%)	4 141 996 (2.5%)	5 332 820 (2.5%)	5 384 595 (2.5%)
203	Shoat	USD	109 469 406 (1.3%)	56 383.7 (0.2%)	1 312 697 (0.8%)	1 690 097 (0.8%)	1 706 506 (0.8%)
301	Waterbodies/ Rivers	USD	379 300 000 (4.5%)	856 125.0 (2.4%)	6 558 216 (3.9%)	8 443 704 (3.9%)	8 525 681 (3.9%)
302	Wetlands	USD	486 500 000 (5.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
303	Grass-/Rangeland	USD	3 561 300 000 (41.9%)	4 954 104.7 (14.1%)	33 136 968 (19.6%)	42 663 846 (19.6%)	43 078 058 (19.6%)
304	Wood-/ Shrub land	USD	65 400 000 (0.8%)	3 816 144.8 (10.9%)	31 912 746 (18.9%)	41 087 661 (18.9%)	41 486 570 (18.9%)
305	Un-/sparsely vegetated	USD	1 817 300 000 (21.4%)	209 134.1 (0.6%)	3 496 292 (2.1%)	4 501 477 (2.1%)	4 545 180 (2.1%)
401	Crops	USD	963 100 000 (11.3%)	24 780 697.9 (70.6%)	83 267 784 (49.3%)	107 207 272 (49.3%)	108 248 119 (49.3%)
All Assets		USD	8 502 085 456	35 082 708	168 883 314	217 437 267	219 548 309
All Persons		People	1 904 414	53 011	194 137	226 494	245 907

Somali: For the region of Somali, the total expected damage for assets of USD 123m (2020) is expected to rise to 326% due to economic growth and of 213% due to climate change (341% with extreme climate scenario). A total of USD 788m (USD 946m for extreme climate change scenario) are simulated for the time horizon 2050. The increase in annual expected damage in 2050 represents a raise of more than 540% in Somali, due both to economic growth (assets will be more valuable) and climate change (hazard will be more frequent and more intense). Regarding people, more than 159 000 people are expected to be affected by drought annually in 2020. Despite a relatively low population growth in the area, based on the analysis the number of people expected to be affected will increase by248% in the future. More intensive climate, in return is expected to affect more persons with an increase of 58% for a moderate climate and 93% for extreme climate. A total of 647 000 (702 000 for extreme climate) are expected to be affected annual in 2050, i.e. an increase of 306% and 341% compared to 2020.

Table 16: Summary of annual expected damages in Somali for different scenarios

ID	Asset Categories	Units	Total Value (% of Total Sum)	AED Today (% of Total Sum)	AED Economic Growth (total) (% of Total Sum)	AED Moderate Climate Change (total) (% of Total Sum)	AED Extreme Climate Change (total) (% of Total Sum)
101	People	People	1 092 755 (18.0%)	17 773 (11.2%)	71 438 (12.9%)	83 344 (12.9%)	90 488 (12.9%)
102	Vulnerable People	People	4 970 353 (82.0%)	141 473 (88.2%)	483 283 (87.1%)	563 830 (87.1%)	612 158 (87.1%)
201	Camel	USD	1 726 650 692 (14.1%)	1 617 556.5 (1.3%)	25 012 180 (4.8%)	37 518 271 (4.8%)	45 021 925 (4.8%)
202	Cattle	USD	1 417 183 005 (11.6%)	2 807 756.4 (2.3%)	23 446 658 (4.5%)	35 169 988 (4.5%)	42 203 985 (4.5%)
203	Shoat	USD	901 596 598 (7.4%)	1 241 653.8 (1.0%)	14 398 645 (2.7%)	21 597 968 (2.7%)	25 917 561 (2.7%)
301	Waterbodies / Rivers	USD	729 700 000 (6.0%)	3 943 352.7 (3.2%)	15 047 616 (2.9%)	22 571 425 (2.9%)	27 085 710 (2.9%)
302	Wetlands	USD	121 600 000 (1.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
303	Grass-/Rangeland	USD	3 812 800 000 (31.1%)	18 022 377.0 (14.6%)	60 060 754 (11.4%)	90 091 131 (11.4%)	108 109 356.7 (11.4%)
304	Wood-/ Shrub land	USD	1 059 300 000 (8.6%)	88 162 802.0 (71.5%)	366 996 585 (69.8%)	550 494 877 (69.8%)	660 593 852 (69.8%)
305	Un-/sparsely vegetated	USD	581 300 000 (4.7%)	1 206 436.4 (1.0%)	10 051 841 (1.9%)	15 077 761 (1.9%)	18 093 313 (1.9%)
401	Crops	USD	1 906 200 000 (15.6%)	6 223 623.1 (5.1%)	10 408 473 (2.0%)	15 612 709 (2.0%)	18 735 251 (2.0%)
All Assets		USD	12 256 330 295	123 225 558	525 422 753	788 134 129	945 760 955
All Persons		People	6 063 108	159 246	554 721	647 174	702 646

Additionally, the elevation is the prime determinant of agricultural land-use in Ethiopia influencing the temperature and rainfall to a significant extent. The country has very diversified agro-ecologies that are difficult to describe correctly. Hence, the agro-ecology of the country has been divided into 33 major zones.[66] Based on these zones, five different AEZs have been identified for both regions: Hot arid lowland plains (A1), Warm semi-arid lowland plains (A2), Very cold sub-moist mid highlands (A3), Warm moist lowlands (M2), and Warm sub-moist lowlands (SM2) (see Figure 29 in Annex V). When no zones are specified, the whole region is considered equally impacted. Defining such zone, allows simulating how clusters of assets might or might not be affected by certain measures, and therefore offering a greater level of analysis. Nevertheless, these zones might change during project implementation, due to a higher level of details needed for the exact planning of each measure.

[66] EIAR (Ethiopian Institute of Agricultural Research). 2011. Coordination of National Agricultural Research System, Ethiopia. English and Amharic Version. EIAR, Addis Ababa.

In order to validate these results against existing events, the annual expected damage (AED) for the Afar and Somali was compared to damage from previous large drought events. Information about historical events can be found in the open-source EM-DAT data base.[67] Table 17 offers an overview of the last 55 years on record for drought events in Ethiopia. Although EM-DAT is an internationally recognized compilation of disaster damages, some local sources propose different figures[68] for overall damages for certain events, which were included in our database. The NGO Oxfam calculated that on average, Ethiopia has sustained over a billion USD annual loss over the last decades. Because of very few sources available with EM-DAT, we propose to use this figure as an orientation.

Table 18 summarizes historical events over the last decades in Ethiopia. Only drought will be considered in our analysis. Damages due to drought over the last 55 years averages USD 1.493, a figure that seems extremely underestimated, due to the lack of records in EM-DAT (4 records in 55 years). We therefore suggest to use the Oxfam figure of 1.1 bn USD of annual damages due to drought.

Table 17: Drought events in Ethiopia from the EM-DAT international disaster database. Source: EM-DAT, The International Disaster Database (2020)

Year	Disaster Type	Country	Total People Affected	Total Damages (USD m)
1965	Drought	Ethiopia	1 500 000	-
1969	Drought	Ethiopia	1 700 000	1
1973	Drought	Ethiopia	3 000 000	76
1983	Drought	Ethiopia	7 750 000	-
1987	Drought	Ethiopia	7 000 000	-
1989	Drought	Ethiopia	6 500 000	-
1997	Drought	Ethiopia	986 200	-
1998	Drought	Ethiopia	-	15.6
1999	Drought	Ethiopia	4 900 000	-
2003	Drought	Ethiopia	12 600 000	-
2005	Drought	Ethiopia	2 600 000	-
2008	Drought	Ethiopia	6 400 000	-
2009	Drought	Ethiopia	6 200 000	-
2010	Drought	Ethiopia	4 805 679	-
2011	Drought	Ethiopia	1 000 000	-
2015	Drought	Ethiopia	10 200 000	1 400

In a recent publication[69] describing the effects of drought in Ethiopia, it was documented that 10% of the Ethiopian population was affected by the drought in 2017. At this time, in Afar and Somali, 21% and 25% received food aid, underlining the vulnerability of the two regions. Calculated for the population

[67] http://www.emdat.be/country_profile/index.html

[68] Oxfam (2011) Briefing on the Horn of Africa Drought 2011, Disaster risk reduction. Oxfam. 17pp

[69] Mera, Getachew. (2018). Drought and its impacts in Ethiopia. Weather and Climate Extremes. 22. 10.1016/j.wace.2018.10.002.

ratios of the two regions, it means that 4% (Afar) and 11% (Somali) of the total population of Ethiopia were affected. Without further (or better) values for comparison between the regions, we propose to use these ratios for population and for USD damages in Afar and Somali. Based on these proxies, between 56 000 and 154 000 people are expected to be affected per year in Afar and Somali, with economic damages adding to 21m USD for the two regions. Results in CLIMADA simulations are in strong agreement with these figures.

Nevertheless, not all assets are captured in our study, and certain assets are captured that are not normally considered in damage calculation (such as environmental assets). AED today is therefore larger than historical damage in the records available.

Table 18: Annual damage calculation for Ethiopia, Afar and Somali regions

Catastrophe Type	Total damage per catastrophe type (USD m)/People (m)				
	Accumulated (55 years)	AED Ethiopia	AFAR	SOMALI	AFAR+SOMALI
Drought (USD m)	1.493	30	9	12	21
Drought (Oxfam (2011), USD m)	-	1 100	44	121	165
Drought (people)	77 141 879	1 402 580	56 103	154 284	210 387

6.3 Discussion on Uncertainties

In this section, we will discuss uncertainties associated with simulations done in this chapter. In a modelling exercise, uncertainties are inevitable and should be qualified whenever possible. In Figure 17, uncertainties associated with each component of the CLIMADA modelling chain is displayed.

The four components of CLIMADA are displayed in different colours in order to ease identification of the main sources of uncertainties. Within the component “drought modelling”, the quality of the observation data is key to reduce uncertainties. Tested re-analysis product such as the one used in this report are one example on how precipitation data from remote sensing can reduce uncertainties in data scarce areas. In terms of drought modelling, uncertainties lie in the conceptualisation of drought. Indeed, different indices return different drought signals. Nevertheless, to date there is no existing consensus on a uniform drought index. Nevertheless, there is a high confidence in the outputs of the drought model due to validation by existing observations. An important source of uncertainty in the ECA methodology is introduced by economic and climate scenarios. Indeed, producing scenarios always introduce uncertainty in a modelling exercise. The economic and population growth scenarios, although based on actual observations, are simple and do not reflect possible fluctuations. Nevertheless, they provide a good estimation of a mean trend and should be treated as such. Climate scenarios are more challenging to evaluate. Although the scenarios used are based on validated scientific data and models, not all climate scenarios are consistent in their conclusions. In addition, models are seldom calibrated for a certain region and especially precipitation simulations are sensitive to scale. Last, there is usually less confidence in extreme scenarios than in moderate scenarios, the latter being often the results of a consensus among different models.

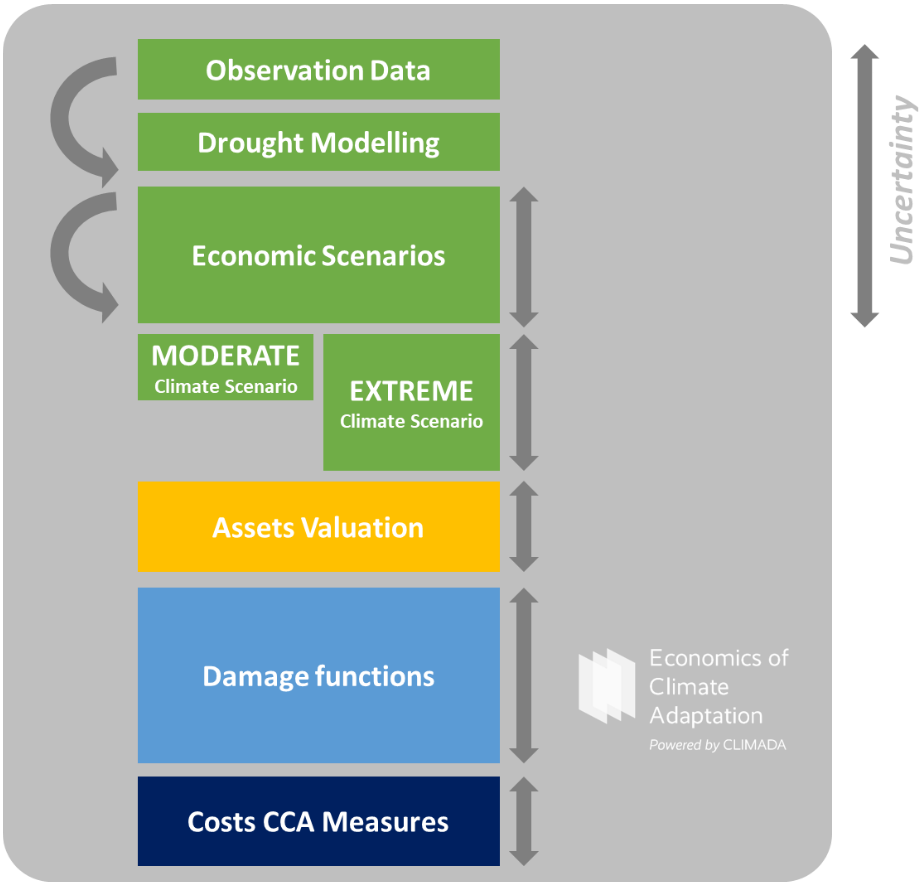

Figure 17: Uncertainty cascade for the CLIMADA modelling chain

Asset valuation is difficult at the regional level, and although more confidence is placed in these values, they are difficult to calibrate properly with observations.

Further, damage functions are the most sensitive parameter in the ECA methodology. Damage functions can be determined by mathematic formula or using expert knowledge. In our case, we have tried to reduce uncertainty in using both approaches. Nevertheless, as damage functions cannot be validated we assume a quantitative bias introduced by this component. There is also extremely few literature on drought damage curves.

The quantification, valuation and parameterization of adaptation measures is a challenging exercise for any type of risk. The location and exact size of a project might influence greatly the cost and benefit calculated. In this study, costs, maintenance costs and parameterization was done in close cooperation with local and international experts in order to achieve a reduced uncertainty related to measures. Nevertheless, unless using time-consuming modelling tools, the exact estimation of measures introduced in CLIMADA is difficult. We assume therefore a moderate confidence concerning the costs and impact of measures presented in this report.

6.4 Cost Benefit Analysis

In this section, the existing relationship between costs (investment costs and maintenance) and net averted damage of a given measure is analysed. In the case of climate change, net averted damage can be understood as the benefit of a measure. Therefore, this section presents a cost-benefit analysis of selected adaptation measures. The analysis of this relationship is twofold: the adaptation cost curve analysis and the adaptation bar chart.

First, a so called adaptation cost curve plots benefit/cost ratio (ordinate) against aggregated averted damages (abscissa) for each measure. The dotted line (at value 1) represents the threshold for the benefit/cost ratio, in other words, values above it are cost efficient where expected benefits exceed implied costs of the respective measure, and value below it are not cost efficient. On the vertical axis, the larger a measure, the larger the damage averted by a measure, therefore the larger the mitigation or adaptation impact of a measure. Hence, with this figure, each measure can be analysed in terms of mitigation/adaptation efficiency and cost efficiency and compared with one another. Figure 18 and Figure 19 display impacts of measures applied to assets in Afar and Somali. Figure 20 and Figure 21 display respectively for Afar and Somali impacts measures applied to persons as in 2050 under a moderate climate scenario. In the case of drought, a large number (13) of measures were selected for the cost benefit analysis.

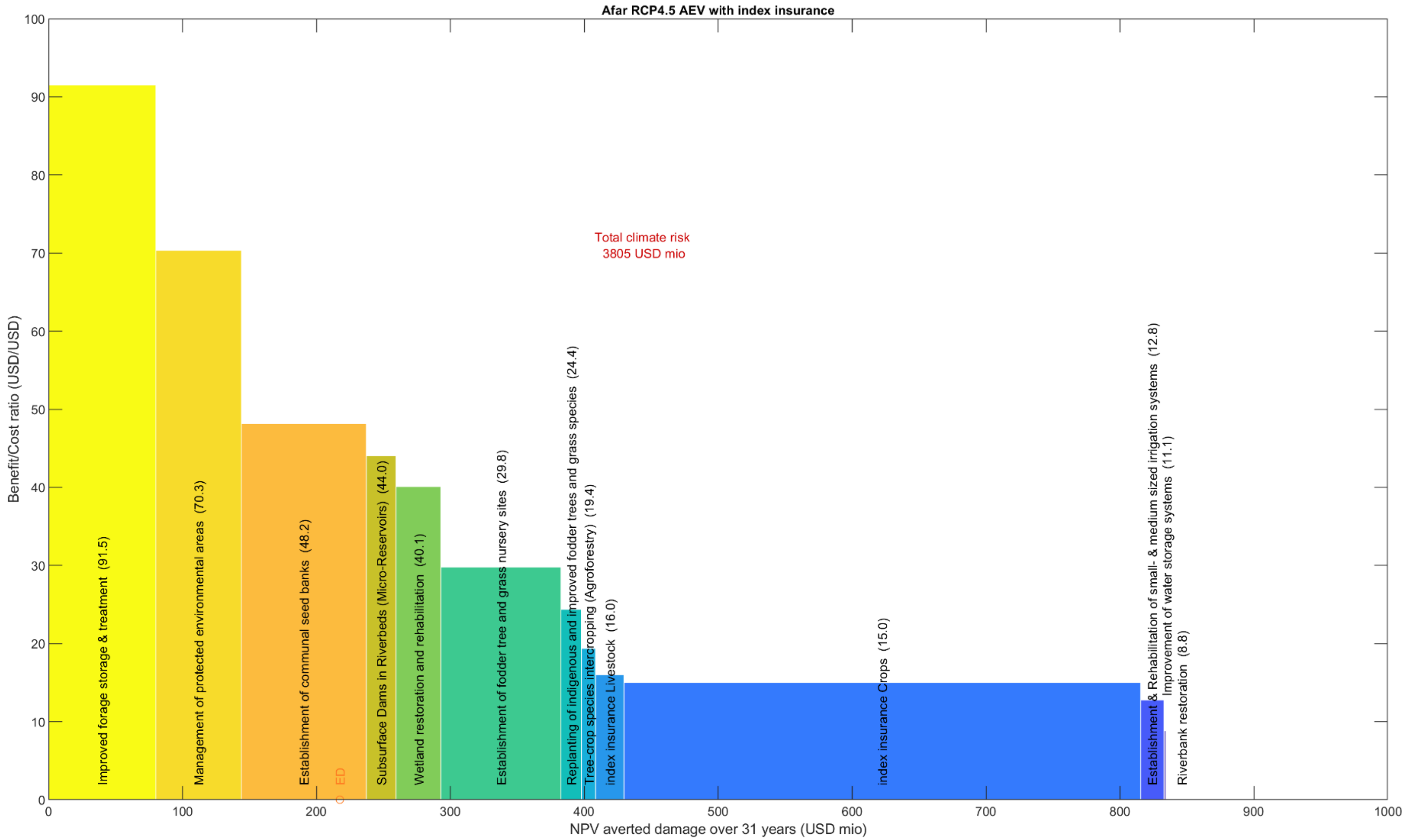

Figure 18: Mitigation cost curve for assets' damage for drought in USD for a moderate climate scenario (RCP4.5), AFAR

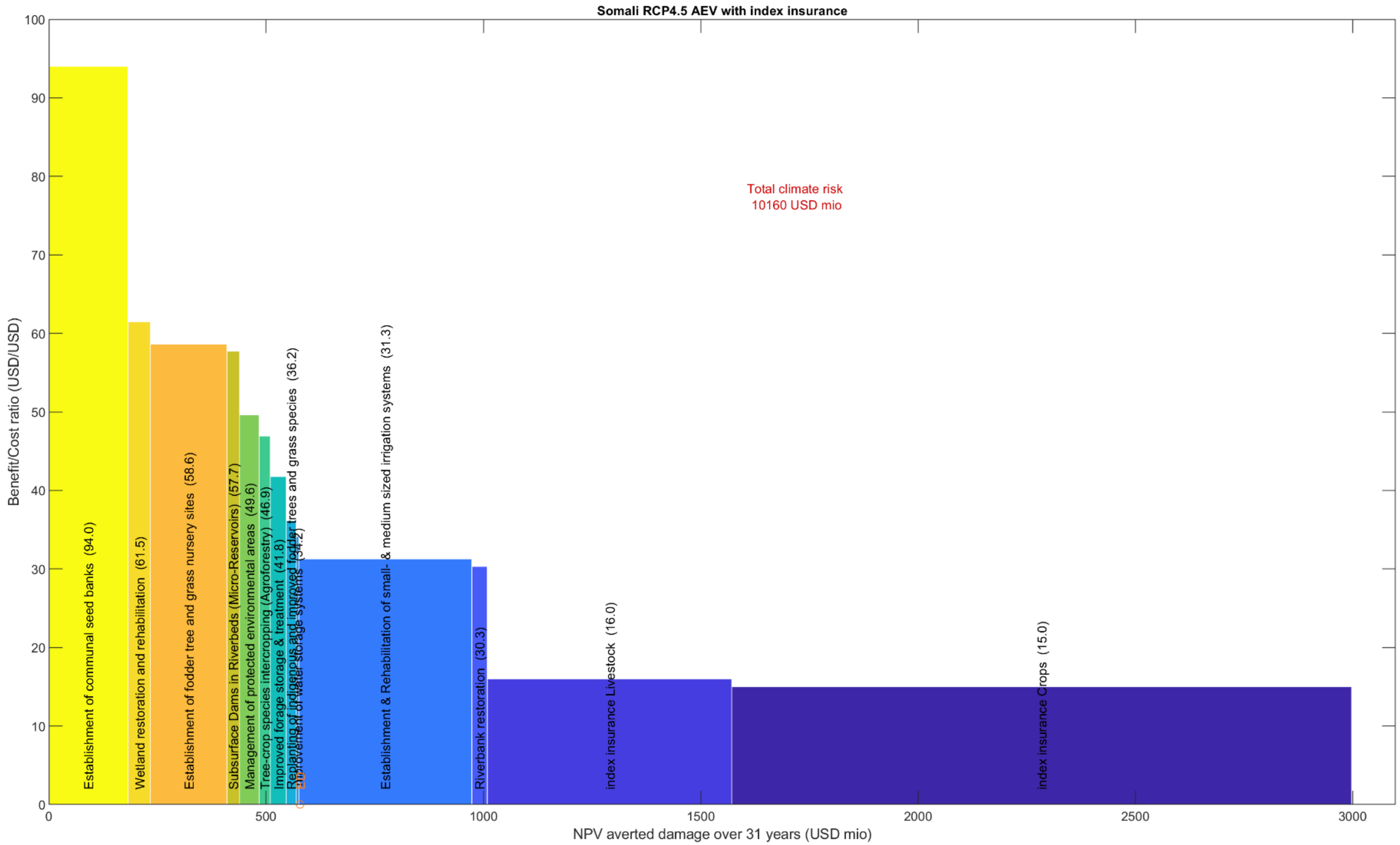

Figure 19: Mitigation cost curve for assets' damage for drought in USD for a moderate climate scenario (RCP4.5), SOMALI

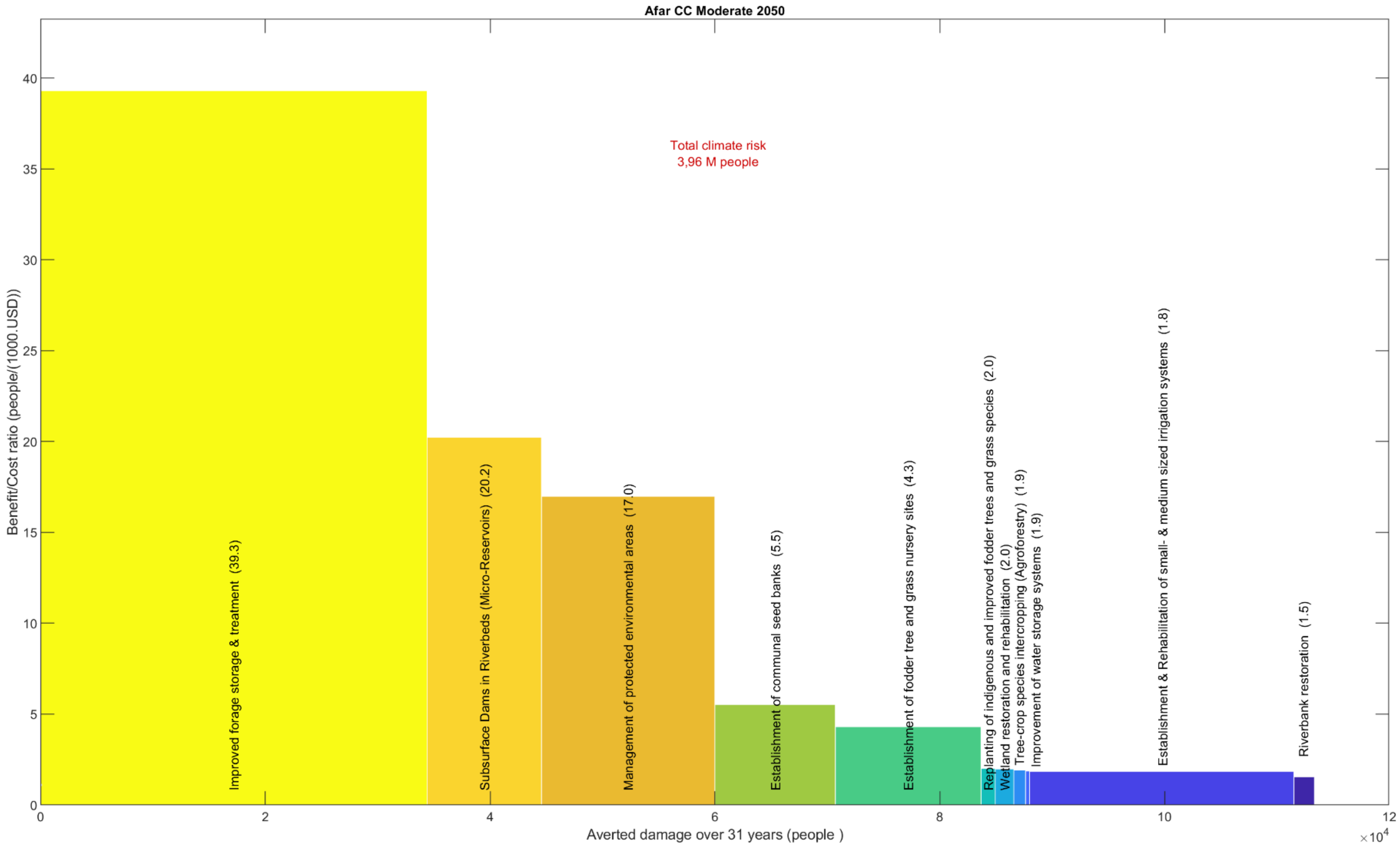

Figure 20: Mitigation cost curve for affected persons by drought for a moderate climate scenario (RCP4.5), AFAR

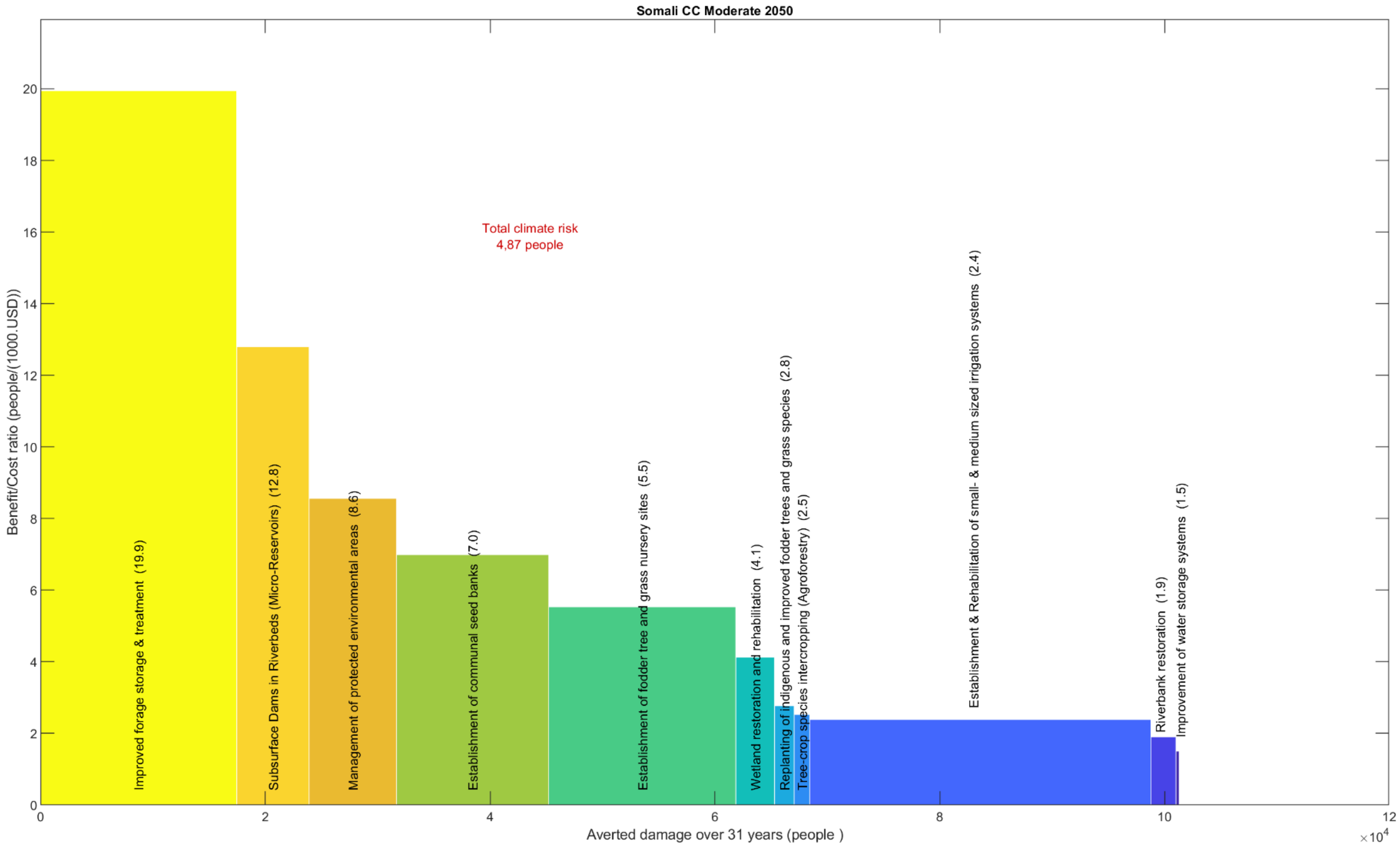

Figure 21: Mitigation cost curve for affected persons by drought for a moderate climate scenario (RCP4.5), SOMALI

In Figure 18 in Afar, all measures are cost efficient, and account altogether to more than 800 m USD of averted damage, if combined without overlapping effect. Selected measures offer therefore an efficient adaptation strategy against climate and economic change. Between measures, one can observe large differences, both in terms of cost efficiency and mitigation efficiency (averted damage). For instance, “improved forage” and “management of protected areas”, both typical green measures, offer a substantial benefit (>50m USD) and an excellent cost/benefit ratio, where each invested dollar accounts for more than 70 USD of averted damage.

Grey measures, such as “Riverbank restauration” or “improvement of water storage” are less efficient in terms of averted damage, but show a good cost/benefit ratio for each invested dollar. In Figure 19, for Somali, all measures are cost efficient, and account altogether to more than 1 000m USD of averted damage, if combined without overlapping effect and without insurance. These measures, although being cost efficient, have a low adaptation/mitigation impact with the notable exception of “communal seed bank” and “rehabilitation of irrigation system”. Nevertheless, some of them could be considered in combination with others in order to reach combined objectives such as “seed bank” and fodder tree and grass nursery sites”.

Figure 20 and Figure 21 present the impact of measures on affected persons in Afar and in Somali respectively. All measures, including insurance are cost efficient, and account altogether to a reduction of more than 110 000 affected persons per invested 1 000 USD. It is noteworthy that the ranking of different measures is not necessarily different from the one observed previously for assets. It means that measures selected for assets have the potential to protect population at risk too.

Although similar, the results of the separate cost-benefit analyses are not the same in the two regions. While the same assumptions about cost of adaptation measures were made, the regions’ respective portfolio of assets as well as the agro-ecological zones differ. For instance, the share of shrub land is much larger in Somali than it is in Afar while also the regions’ average herd composition differ.

In the same line, the benefit/cost ratios are relatively high in both regions. This is mainly due to the strong economic and population growth in the regions, which makes investments made today very efficient when damages are increasing in the future. In addition, the most efficient measures in the two regions are relatively cheaper than the others. In other studies and regions EbA measures are generally more cost efficient than traditional measures.

6.5 Parametric Insurance

Risk transfer measures, unlike other measures, do not directly reduce the impact of drought on assets. However, due to pay-outs, it reduces the financial impact on these assets, speeding up recovery. As displayed in Figure 18 and Figure 19, index-based drought insurance is an innovative approach to developing effective pay-out schemes for low-income, at-risk communities. Index insurance schemes make use of modelling and satellite imagery with other data to predetermine drought thresholds, which could trigger rapid compensation pay-outs. Effective end-to-end solutions will be developed in collaboration with a range of organizations and experts from central and state government bodies, private insurance firms, community-based organizations (CBOs) and non-governmental organizations (NGOs). Indices can be developed for crops and livestock. For both index insurance schemes, we have proposed similar attachment (SPI -1.8) and cover (-3.0), resulting in different impact reduction. Given the large amount of livestock considered, it seems an insurance scheme for livestock would be much more efficient. Notwithstanding, both schemes are cost efficient as forecasted benefits for the community are high. In general, combined with other adaptation measures, index insurance can help cover the resulting risk for large events. The choice to prioritize insurance over adaptation measures should be driven by the investment ability of the government. Adaptation measures require larger investment to be made, whereas insurance runs usually on yearly contracts. Nevertheless, one should bear in mind that the insurance premium should diminish with an increased number of adaptation measures (mainly because the total risk is reduced). In the case of Afar and Somali, index insurance seems to provide a significant coverage of the residual risk compared to other type of measures. Such a strong coverage comes with a large penetration (60% of all assets are covered in our simulation) and the relative high cost-benefit are due to the fact that commercial incentives (add-on on the premium to cover delivery, administration costs and profit) are not included. In addition, additional incentives such as subsidies can make insurance schemes even more attractive. Nevertheless, they introduce additional in term of sustainability of the product. In this report we only considered index insurance, as modelled by CLIMADA, but other types of risk transfer could also be considered (especially pooling risk with other cities or regions). This approach has been successfully implemented in Africa by the African Risk Capacity (ARC), of which Ethiopia is a member state.[70]

6.6 Spatial Distribution of Benefits

The figures below showcase exemplary the spatial distribution of benefits on a given assets resulting from the respective measure as indicated. Due to limitations in the hazard resolution the highlighted areas of benefit are only indicative and not to be understood as exact locations. The benefits are presented as the annual averted damages averaged over the here relevant period of 31 years. In Figure 22, for instance, the benefits of the establishment of communal seedbanks, one of the most cost-efficient in both regions as identified above, on cattle in both regions is being displayed. Figure 23 displays the benefits of the most cost-efficient measure in the Afar region, Improved Forage Storage, for cattle (left), shoats (middle), and vulnerable people (right). A final example is shown in Figure 24 with the measure of Wetland Restauration and Rehabilitation for the same three asset groups in the Somali region. Even though Wetland Restauration and Rehabilitation is only the 6th most cost efficient measure with regard to vulnerable people in Somali this example showcases the additional benefits a measure can have although it may have been implemented targeting e.g. livestock rather than people.

[70] Further information here: https://www.africanriskcapacity.org/

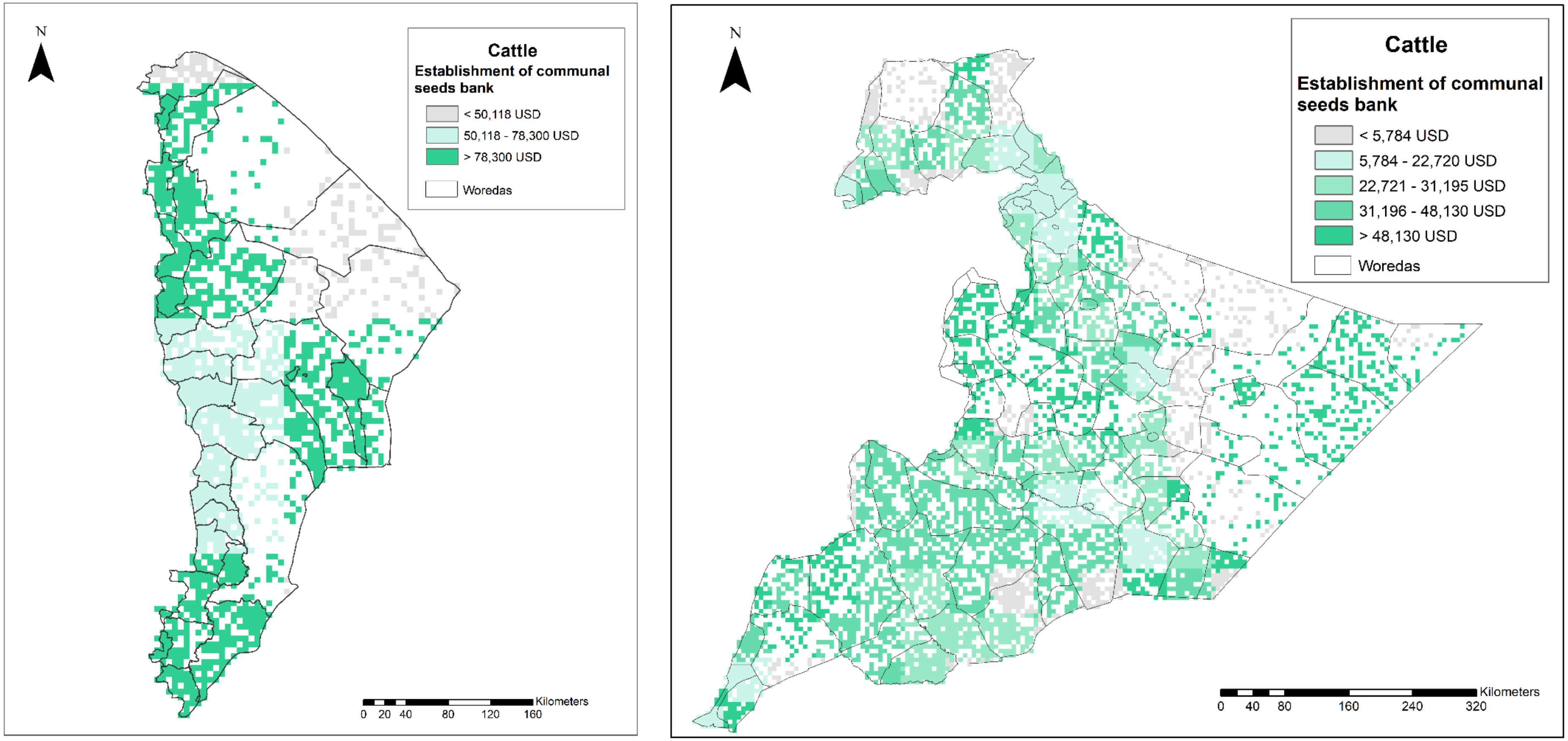

Figure 22: Benefits of 'Establishment of Communal Seed Banks' on cattle in Afar (left) and Somali (right)

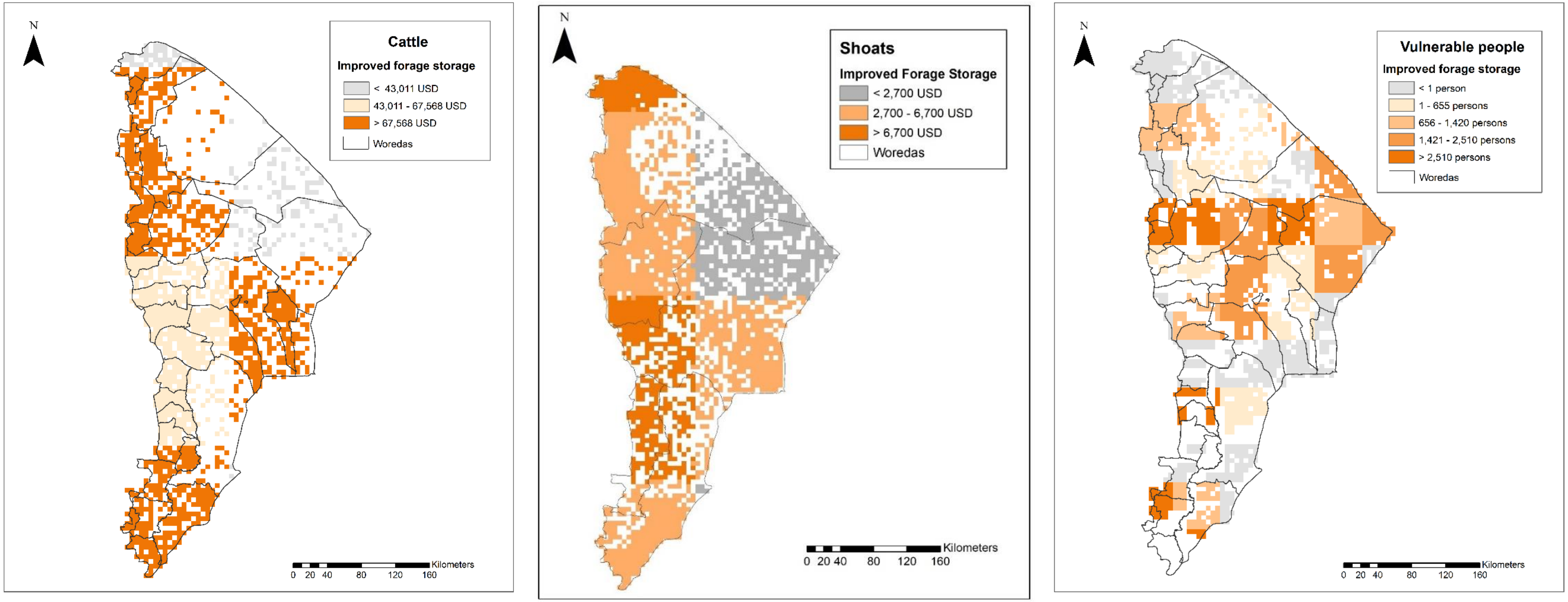

Figure 23: Benefits of 'Improved Forage Storage' in Afar on cattle (left), shoats (middle), and vulnerable people (right).

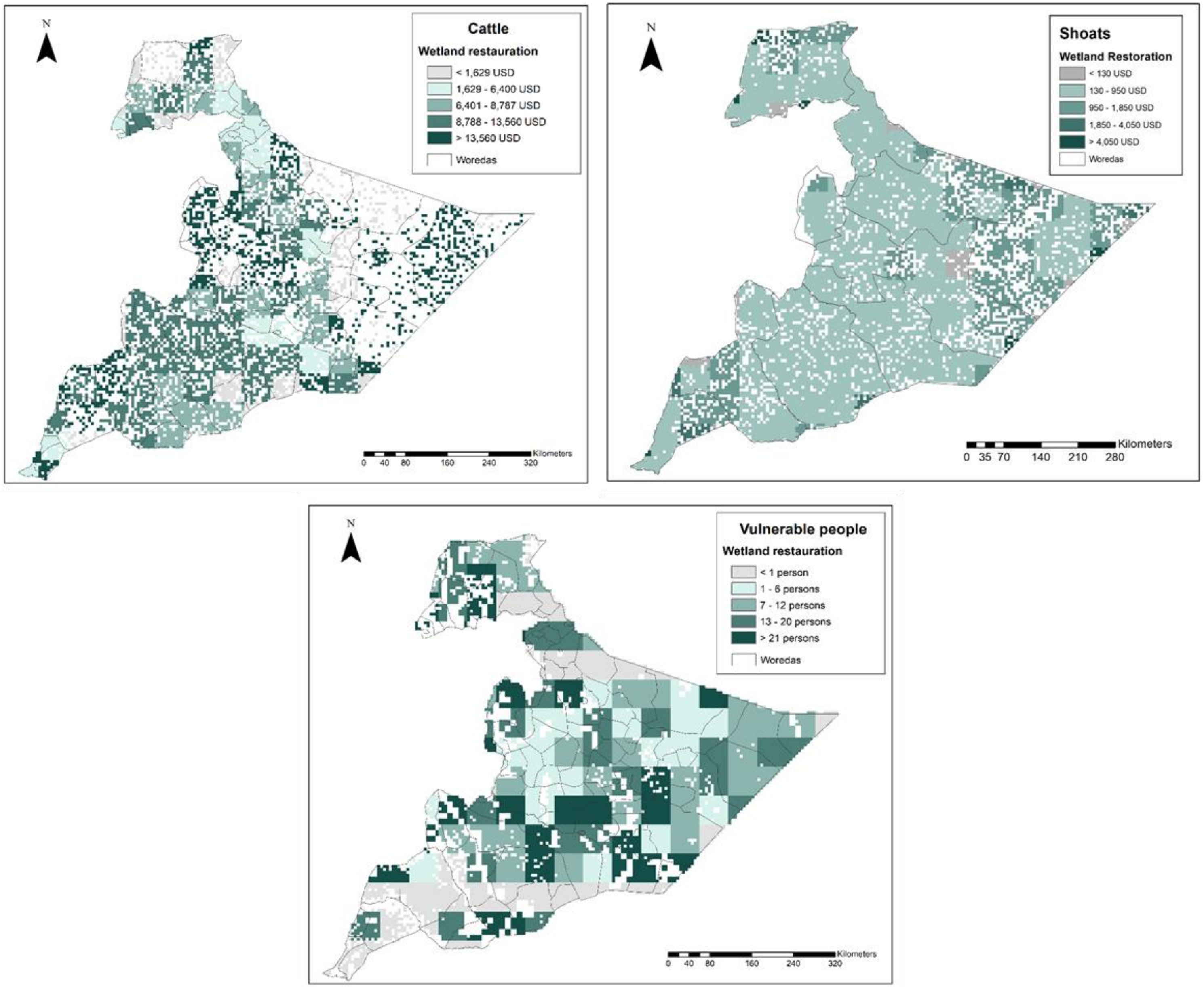

Figure 24: Benefits of 'Wetland Restauration' in Somali on cattle (top left), shoats (top right), and vulnerable people (bottom).

6.7 Conclusions

In this section, drought measures were analysed in the Afar and Somali regions in terms of cost-efficiency and adaptation/mitigation efficiency. A total of 26 measures (13 measures in Afar and 13 in Somali regions) were successfully introduced in CLIMADA. The main findings are summarized below:

1) All selected measures are cost efficient for the asset selected;
2) All measures combined are not sufficient to account for the total climate risk. In Afar and Somali, respectively 22% and 29% of the total climate risk in 2050 is covered by the measures presented in this report. Significant higher investment are needed to address the issue at this scale;
3) Climate index insurance for crops and livestock are cost-efficient and can help cover partly the remaining risks, so called residual risks, after the most effective physical adaptation measures have been implemented;
4) By 2050 all measures for drought will be cost-efficient, with co-benefits for population at risk; under extreme climate conditions;
5) The top three cost-efficient measures for Afar are:
    a. Improved forage storage
    b. Management of protected areas
    c. Establishment of communal seeds bank
6) The top three cost-efficient measures for Somali are:
    a. Establishment of communal seeds bank
    b. Wetland Restauration
    c. Establishment of fodder tree and grass nursery

7 Conclusions and Proposal for Pre-Feasibility Study

7.1 Conclusions

Afar and Somali Region, as other arid areas in the world, are threatened by droughts and other extreme weather events. Along with growing populations and economies, losses from natural hazards are rising. In this report, we applied the Economics of Climate Adaptation (ECA), a decision-making support framework, to integrate climate risk assessments and optimal adaptation solutions.

In its first part, this report recalls decisions made in coordination with all stakeholders regarding the scenarios (climatic and economic) to be applied and what assets should be considered in the analysis. During several workshops and webinars, a portfolio of measures (from a long list to a short list) have been discussed. Values have been validated by stakeholders' concertation and expert interview.

Further, this report presents the results, assumptions and limitations of the development of a drought model for the region of Afar and Somali. The drought model developed for the purpose of this report provides unique improvement in resolution and quality to the simulation of drought in the region. Its integration into CLIMADA, a modelling platform, provide an estimation of impacts of future drought risk impact for the selected assets. These results for future damages have been successfully validated against existing historical observations. By 2050, drought damages in Afar and Somali are expected to rise by a threefold, due to both, economic growth (assets will be more valuable) and climate change (hazards will be more frequent and more intense).

The introduction of a selection of adaptation measures provide insights for the development of a sound climate adaptation portfolio under the selected scenarios. Green measures and grey measures such as communal seed banks provide the best return on investment, while offering a good protection against future climatic risks.

Finally, the quantification, valuation and parameterization of adaptation measures is a challenging exercise. The location and exact size of an engineering project might influence greatly the cost and benefit calculated. Although great care has been given to the modelling exercise, the outcome of the study are not meant to replace a more detailed engineering screening of the measures to be introduced and offer a decision support, to be added to other tools and discussion already on-going within the municipality. It is important to consider these uncertainties while making climate impact decisions.

Building on these conclusions, this section contains the work plan for the pre-feasibility analysis that will be carried out as the last stage of the ECA study in Afar and Somali. With the goal of facilitating the implementation of the identified adaptation measures discussed in the vulnerability report, the analysis will cover the technical, economic, environmental, social and regulatory frameworks relevant for this case study. These further analyses meets the demands of international donors, such as KfW, to evaluate possible investments.

Regarding the scope of the pre-feasibility study, it will include: a background, beneficiary and feasibility analysis, an institutional analysis of the executing agencies and a budget and execution schedule. The following sections provide some further details.

7.2 Recommendation for a Pre-feasibility Study

7.2.1 Background Analysis

For this study the background analysis covers the institutional context, ongoing programs and initiatives, challenges and opportunities relevant to Disaster Risk Management (DRM) and its interdependence, both at the regional and local levels. These items entail:

- **Institutional context:** Identification of the institutions best equipped to carry out the adaptation measures suggested by the ECA study, in terms of efficiency, effectiveness and accountability.
- **Ongoing programs and initiatives:** Verification of the ongoing programs and activities related to climate change, of the Government of Ethiopia and regions of Somali and Afar in cooperation with international organizations, such as KfW, the World Bank for Economic Integration, the United Nations Development Program, etc.
- **Problems and potentials for DRM:** Preliminary risk classification through the analysis of available information on drought hazards in the region.

7.2.2 Beneficiary Analysis

This analysis will include both direct and indirect beneficiaries, considering for aspects of gender, poverty, peace and conflict.

- **Direct beneficiaries:** Defined by local population in the intervention area, and disaggregated by gender, age group, socio-economic characteristics, etc.
  It will also include the institutions that have received, are receiving or will potentially receive institutional strengthening and actively participate in the implementation of the proposed measures.
- **Indirect beneficiaries:** Constituted by the general population, disaggregated as well by gender, socio-economic characteristics, etc. Existing equipment and infrastructure will also be considered.

7.2.3 Feasibility Analysis

This analysis will be carried out to establish the feasibility of at least three of the priority measures proposed by the ECA Vulnerability Report for Afar and Somali. Considering technical, economic, environmental, social and legal aspects.

- **Technical feasibility:** Assessment of the availability of technical and technological means within the beneficiary to carry out the measures. The following four topics will be included:
  - Applicable regulations, guidelines of good design practices and other instruments that regulate the technical aspects of the project.

- Existence of base studies of the land in terms of topography, geotechnics and hydrology, among others.
- Available technology in terms of accessibility to technological knowledge to implement and operate the measures, as well as the capacity to supply inputs, capital goods including civil work and equipment, labour and maintenance services.
- Sustainability, which includes the identification of possible failure modes, as well as the ability to obtain funding sources to cover project costs throughout its life cycle.

- **Identification of co-benefits:** Assessment of co-benefits that could occur during the design, implementation and operation of the proposed priority measures. That are, additional positive impacts such as increased employment, increased income, reduction of negative health effects and other qualitative co-benefits.
- **Environmental and social risks:** Assessment of possible negative social and environmental impacts that could occur during the implementation and operation of the proposed measures will be identified, as well as the methods available to mitigate or prevent them.
- **Legal feasibility:** Assessment of the current Ethiopian legal framework that the measures of infrastructure and institutional strengthening, as well as of education-communication and citizen organization that will be proposed in the pre-feasibility study.

7.2.4 Proposed Executing Entity

In this section, an analysis of the institution identified as executing agency for the proposed measures and the recommended strengthening needs will be carried out. This analysis will ensure that such an institution has the proven capacity to manage the infrastructure project cycle and citizen management, as well as the adequacy of its procurement and contracting rules and procedures, accounting records and accountability. However, the study will also identify the types of support it needs as an executing agency to successfully implement the proposed measures.

In order to establish the execution structure, a matrix of roles and responsibilities will be prepared to assign these functions to each of the actors involved in the planning, execution and operation of the measures.

7.2.5 Budget and Execution Schedule

This section will define the scope of the program through a broken-down work structure, to which time and resources will be allocated to develop the schedule and budget for its implementation.

1. **Breakdown of work structure:** It will consist of the hierarchical decomposition of the work to be done to achieve the program objectives and the required products.
2. **Project schedule:** It will consist of the presentation of all the logical sequence and the steps to be followed to deliver the program's outcomes or results.
3. **Program budget:** It will consist of the allocation of the financial resources of the program, to complete and achieve the objectives and products.

7.2.6 Feasibility Report

The feasibility report will be the final step of the study, for which a vulnerability webinar will be held online beforehand.

8 Annexes

Economics of Climate Adaptation

List of Annexes

Annex I *Field Survey and Key Informant Interviews*

I.i Introduction

To gain valuable insights into the lives and livelihoods of the population in the research area and their specific experiences with applied adaptation practices, a field survey covering households from all livelihood and agro-ecological zones was conducted. Additional to qualitative data, a variety of quantitative data on the subjects such as crops, livestock, and health and sanitation were gathered to complement and verify data gathered from other sources, such as values and prices, or livestock death and crop loss data.

Additional to the field survey, key informant interviews (KII) were conducted. The primary goals of those KIIs was to gain a comprehensive overview of the policy setting and ongoing relevant projects to refine the study's time horizon.

I.ii Key Informant Interview

For the KIIs, individuals were contacted representing the following authorities:

- Ministry of Agriculture and Natural Resources (including the Department of Pastoralism and Agro-pastoralism, Department of Meat, Hide and Skin Directorate, Department of Natural Resources, Department of Climate Change and Climate Resilient Green Economy Unit, SDR Project);
- Ministry of Peace (Department for Pastoral Development Affairs);
- Environment, Forest and Climate Change Commission (Forest Sector Transformation Unit).
- Somali Regional Bureaus for Agriculture and Natural Resources, Water sector, Pastoral Development, Disaster Risk Management Commission
- Afar Regional Bureau for Land and Rural Development (Planning and Budget Preparation, CRGE Coordination, Agricultural Input and Marketing, Livestock Resource Development); Range Land management;
- Afar Pastoral and Agro-pastoral Research Institute (APARI)

Key challenges identified regarding livestock and crop production and recommendations on policy interventions are presented in Table 19; Annex II and Annex III display the interview guideline used for the Key Informant Interviews and Household Survey respectively. Regarding the second objective to gain insight into relevant policies and strategies potentially influencing the choice of the study's time horizon the results are summarized in Table 20. Most reviewed policies and strategies are periodically renewed while current phases last until 2025 or 2030. Based on the results, it was recommended to use a 10-year time horizon from 2020 to 2030. However, it was agreed among the stakeholders to focus on a longer term horizon of 31 years (2020-2050), while also presenting the 10-

year interim results. Thus, both the short and the medium perspective was taken into account. This allows to include the medium term recommendations in policy renewals for a longer time period.

Table 19: Challenges identified through Key Informant Interviews in livestock and crop production and recommended interventions

Key challenges	Recommended Technical policy measures to address challenges	Institutions and initiatives addressing the challenges.
Livestock sector		
• Lack of awareness creation /knowhow in the pastoral areas,	Implement the newly developed pastoral and agricultural policy and strategy,	MoANR,
• Pastoral policy and strategy,	National feed strategy organized,	MoP,
• Undermining the pastoral life style and recognize them as poor,	Water development schemes such as dam, community pond, Birka, Rige etc for livestock breeding policy and dairy strategy	EIAR,
• Limited herd mobility due to demarcated political boundary,	Proclamation of breeding policy,	MoWIE,
• Low carrying capacity,	Construction of animal clinic and health center,	Feed development directorate with
• Food and feed shortage,	Construction marketing center,	Different projects (RPLRP,DRSLP,LFSDP.AGP),
• Frequent drought,	Proclamation livestock marketing,	National Artificial Insemination Centre (NAIC),
• Low human capacity caused by high staff turnover,	Agricultural Marketing Strategy,	Dairy development directorate,
• Low human resource management,	Establishment of chalking point for animals	National Veterinary Institute,
• Lack of project follow up,	Task force establishment to control black market,	Disease control directorate,
• Negligence for project resources such as heavy duty machinery,	FTC and training centers establishment,	The Livestock and Fishery Marketing directorate,
• Lack of leadership role and commitment,	Extension system establishment.	Ministry of Trade & Industry,
• Lack of commitment /support in federal Ministries,	Training of DAs and experts	Extension and Training Department,
• Poor project monitoring and evaluation system,	Training of farmers and pastoralist.	Pastoral areas development project,
• Lack of synergy among sector Bureaus,	As much as possible assign Qualified personnel	Low land livelihoods Resilient Project,
• Poor project management,	Supply quality improved inputs	Feed the future project,
• Capacity limitation: Both in terms of leadership and qualified experts in the field to perform the livestock sector	Avail the appropriate technology with credit facility	Livestock and rural development bureau,
• Institutional arrangement	Soil and water conservation,	Justice Bureau,
• Limitation of improved Agricultural Input: Forage seed and improved breed	Improve the livelihood to substitute the charcoal production for their income generation	Ministry of Livestock,
• Poor animal genetic performance,	Improve Vaccination and drug supply	
• Poor animal health status and no livestock disease treatment,	Develop pastoral extension system	
• Replacement of native grass land by invasive species,	Hay conservation,	
• Small town development introduced cultural changes,	cattle and sheep fattening,	
• Technology: Unavailability, access, expensiveness etc.	Effective Pastoral policies,	

• Irrigation infrastructure and knowledge of irrigation system,	Early warning and information sharing,	
• Degradations of rangelands,	Climate change Adaptation interventions,	
• Natural resource degradation:	Area closures and seasonal grazing,	
o Wind erosion specially lowland areas	Clean water policy,	
o Water erosion such as Gully erosion	Environment policy	
o Charcoal making	Conflict management strategies should be effective and government should bring peace,	
o Deforestation	Strengthening urban development sectors such as market, energy, school, health centers, infrastructure to transform the pastoral life style to sedentary livestock sector,	
• Animal Diseases and forage pests,	Establishing product-market-industry linkage,	
• Prevalence of Livestock disease,	Implementing 2011 pastoral development policy.	
• Limitation of pastoral extension system,	Bring pastoral representatives to federal level government positions and leadership,	
• Market (Live animal and processed animal product market problems Value chain),	Reconciliation and peacemaking efforts, integration through development projects,	
• Traditional marketing system,	Asset accumulation, natural resource management and environmental protection,	
• Political stability and conflict among ethnic groups,	Implementations of food security Program such as PSNP	
• Credit, subsidy and insurance problem both for pastoralist and agrarian,		
• Insufficient agricultural package technology,		
• Land fragmentation due to population increase,		
• Shrinkage of grazing land		
Key challenges	**Recommended Technical policy measures to address challenges**	**Institutions and initiatives addressing the challenges.**
Crop production		
• Unreliable rain fall/Erratic rainfall,	Assign qualified personnel,	MoANR,
• Water scarcity,	Approve/implement land use policy,	EIAR,
• Vulnerability to climate change,	Foreign direct investment (FDI) policy,	MoWIE,
• Lack suitable crop variety,	Integrated pest management policy,	Agriculture, Research institute, Basin and irrigation development Bureau,
• soil and water salinity,	Agricultural and capacity development policy,	MoP,
• Food culture i.e, milk as staple food,	Implementing already launched Pastoral and agro pastoral policy,	Woreda pastoral offices,

• Cultural attitude to crop farming activities,	Facilitate access to quality inputs in time	NGOs,
• Extension knowledge is not fitting to pastoral life style,	Implement Appropriate water shade management,	Cross country projects by development partners such as EU, GIZ, WB, IGAD,
• Gender issues as females are taking all responsibilities,	Improve the range land management	Universities, colleges and research institutes for capacity building and knowledge management,
• Capacity limitation: Both in terms of leadership and qualified experts in the field to perform the livestock sector	Strategies of crop protection should be implemented,	Relevant region sector Bureaus,
• Institutional arrangement	Create synergy among sector Bureaus with clear mandate and task to pastoral area development,	Bureau of Agriculture and Natural Resources, Bureau of livestock resources, Bureau of Water resources,
• Limitation of improved Agricultural Input:	Rehabilitate irrigation schemes,	Irrigation and Basin development Bureau,
• improved breed	Range land management in avoiding invasive species,	Bureau of Disaster risk management,
• fertilizer and chemicals	To establish different Area closures in different areas,	Bureau of Environmental Protection,
• Technology:	Eradicating the effect of invasive species,	Bureau agriculture, bureau water development, Somali research institutions and bureau of livestock,
o Unavailability, access, expensiveness etc.	Dig large scale wells for dry Zones in the region,	
o Low Irrigation infrastructure and lack of knowledge to tap irrigation potential,	Forage development,	
o Irrigation canals failed with siltation,	Access to international market for the livestock production,	
• Natural resource degradation:	Develop Vaccination and treatment of the livestock,	
o Wind erosion specially lowland areas	Develop the infrastructure of the region(Telephone, Electronics and roads),	
o Water erosion such as Gully erosion	Establishing Beef and leather industrial park/scheme,	
• Rehabilitation with human labor is difficult,	Physical and biological treatment (water spread, soil bund, stone bund Gabion, Nursery…..),	
• Crop pests (Diseases and insect pest,	Conflict management strategies should be effective and government should bring peace,	
• Limitation of pastoral extension system,	Private sector engagement in feed and fodder supply,	
• Lack of access to market and Value chain,	Studying impact of COVID 19 on pastoral area development,	
• Political instability and conflict among ethnic groups,	Special support to pastoral,	
• Lack of alignment between federal ministries and corresponding region sector Bureaus,	Drought resistant wheat development,	
• Luck encouragement from federal and region institutions,	Leadership change,	
• Lack of access to credit, subsidy and insurance problem both for pastoralist and agrarian,	Updating and keep on practical oriented tailored made trainings,	
• Youth and women unemployment,	ICT development	

• Un poor weather prediction and expected flooding,	Implementing Joint support mission consisting of MoA, MoWIE, MoF, and Donor with a quarterly report,	
• Environmental setting forces freehand give aid without deliverables of public work,	Developing pastoral specific watershed management,	
• Luck of infrastructures in the region,		
• Postharvest loss and sanitary,		
• Food insecurity		

Table 20: Feedback on national and international agendas relevant to setting a relevant time horizon of the ECA study

National and global climate change adaptation and mitigation agendas	Time horizon (years)	Time horizon
CRGE (2010-2015; 2015-2020; 2020-2025): 20 -years' time horizon	20	Assuming renewal 2030 or 2050
NDC (2016-2030): 15-years' time horizon	15	2030
GTP1-2 (2011-2020): 5-years' time horizon	5	Potentially 2030 or 2050
PDP (2020-2030): 10-years' time horizon	10	2030
Agenda 2063 (2013 - 2063): 50-years' time horizon	50	2063
SDGs (2015-2030); 15-years' time horizon	15	2030
Sandi Framework 2015-2030: 15-years' time horizon	15	2030
RCP Scenarios and Paris agreement on limiting warming to 1.5 to 2 degrees C (Post 2020): decadal-century scale time horizon	100	2100

I.iii Field Survey

The implemented survey was aimed to gain valuable insights into the research area's population, their livelihoods, and perception as well as practiced adaptation measures. To get a reasonably comprehensive overview in each region, *woredas* of each of the three respective livelihood zones[71] were selected in which three villages/ *kebelles* were randomly selected. In those selected *kebelles,* five households were randomly selected for the survey. Hence, in each region 30 surveys were planned in each livelihood zone resulting in a total 90 surveys per region and 180 surveys overall. Due to respondents not being available, the final survey number in Afar was 87 and 90 in Somali.

The selected villages are shown in the maps Figure 25 and Figure 26 and summarized in Table 21 below.

Table 21: Selected villages/ kebelles.

Livelihood zone	Afar	Somali
Agro-pastoral	• Abaála • (4 households from Awash Fentalia)	• Dhaghabur • Kebribayah
Pastoral	• Teru	• Kohle • Lasdankayre
Sedentary Agriculture	• Argoba / Argoba Special • Awash Fentalia • Ayssita	
Riverine		• Dolo Ado • Godey

[71] In both regions there are livelihood zones labelled "Agro-pastoral" and "Pastoral". The respective third livelihood zones "Sedentary Agriculture" and "Riverine" are reported separately. Even though they share quite similar characteristics, the labels should not be used interchangeably. The gaps in Table 21 do not represent missing data or villages.

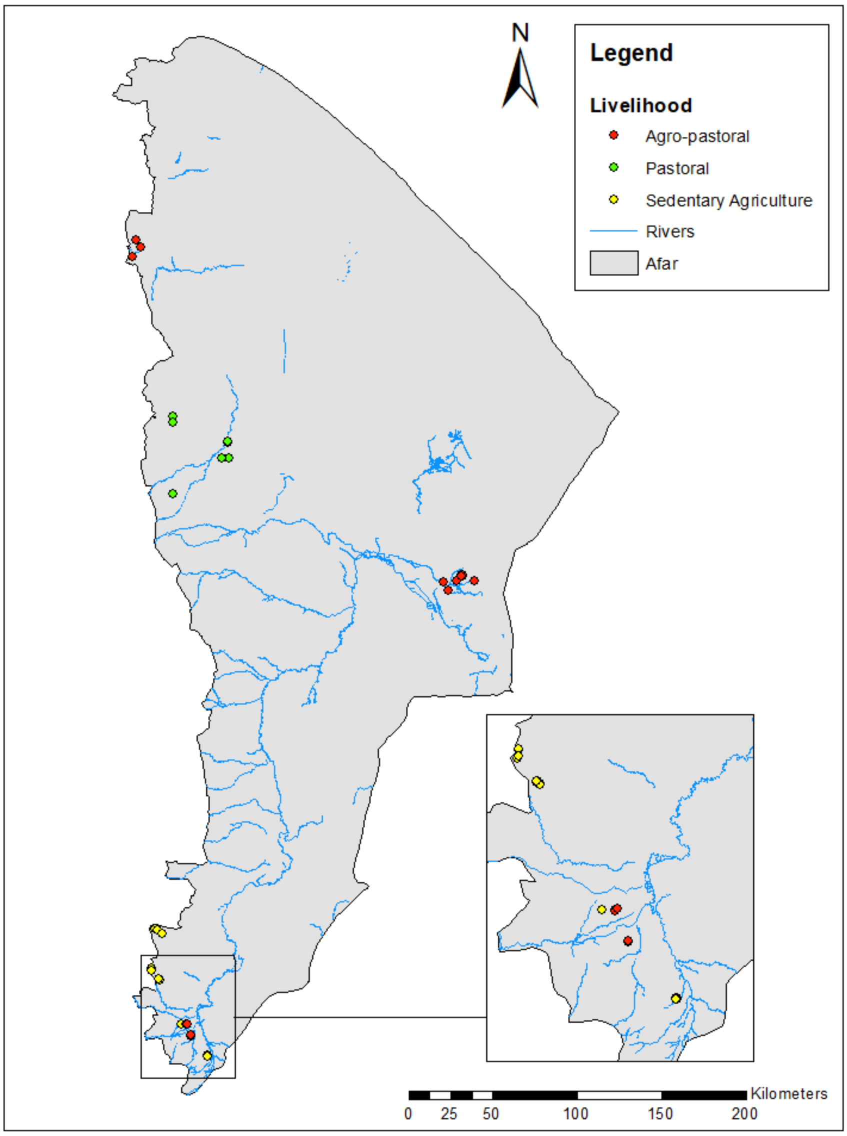

Figure 25: Surveyed villages/ kebelles in Afar Region. Livelihood zones: Agro-pastoral (red), pastoral (green), Sedentary Agriculture (yellow).

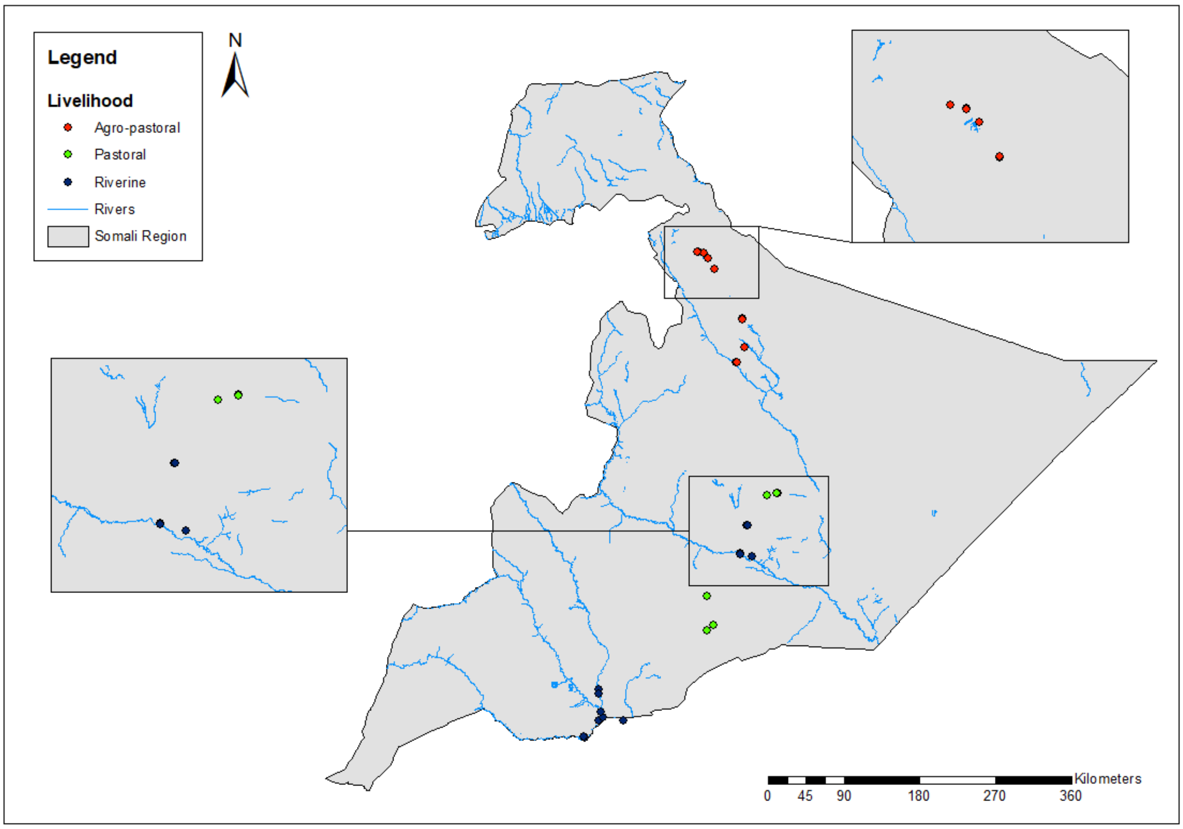

Figure 26: Surveyed villages/ kebelles in Somali Region. Agro-pastoral (red), pastoral (green), Riverine (blue).

To limit the extent of this annex, only selected key results will be summarised while the raw data are available on request.

I.iii.i Somali Region

In Somali, the average household size varied averaging for agro-pastoral, pastoral and riverine households at 7, 10, and 9 household members. Although no substantial difference in housing conditions was identified across the livelihood zones, it became apparent that more than 90% of all the observed dwellings used soil as floor materials, the majority further relies on mud and poles, and thatch and straw as materials for their walls.

Four major income sources were identified among the respondents: livestock, petty trading, wage employment, and subsistence farming. Although subsistence farming, unsurprisingly, was not found among the pastoral respondents, who rather concentrated on wage employment as a second source of income. The dominant livestock held within all livelihood zones are goats and sheep. While people kept on average more sheep (18) than goats (13) in pastoral households, it was the reverse case in riverine households (13 and 24, respectively) while the average numbers where equal (12) in agro-pastoral households. The average cattle and camels owned in agro-pastoral, pastoral and riverine households were 6 and 2, 3 and 0, and 7 and 1, respectively. The majority's main feed source for their herd was natural grazing areas for both, agro- pastoral (90%) and pastoral (97%) households while riverine households used larger set of primary feed sources: natural grazing areas (43%), crop residue

(24%) and standing hay (14%). Improved forages where only the secondary choice for 10 of agro-pastoral households, while among riverine households 10% used improved forage as their main source and 29% as the secondary feed source. Regarding water sources for livestock, permanent and temporary rivers are key to all households while a large share of riverine households mentioned bore holes as their primary source.

The main constraints of livestock rearing among agro-pastoral farmers were recurring droughts (83%) and feed shortage (14%). For pastoral households, feed (37%) and water shortages (33%) while only 23% mentioned recurrent droughts as their main constraint. Among the riverine respondents 26% reported recurring droughts to be the key constraint, closely followed by feed shortage (22%) and invasion of rangelands invasive plant species (17%). While the sole strategy to tackle those (temporary) constraints for pastoral farmers is to migrate, riverine farmers tend to migrate (57%) or use reserve feed from enclosures or crop resides (39%). Agro-pastoral farmers rather focus either on commercial destocking (31%), purchasing hay (30%) or purchasing cultivated improved forages and use reserve feed from enclosures and crop residues (17%).

Overall, the coping strategies to reduce drought impacts during the drought events of 2008/09, 2011/12 and 2015 in agro-pastoral households focuses on destocking of livestock, although that involves selling as well as consumption, as well as eating less preferred foods, and borrowing food or money. Pastoral and riverine households relied heavily on eating less preferred food and reducing the overall number of meals and intake, but also enrolled in food-for-work programmes and engaged into casual labour or sold and consumed livestock. In all three livelihood zones, the preferred choice of grazing and browsing grounds were either communal or tribal grazing lands, or public/ government owned lands.

Finally, the following responses where collected focusing on the respondents' strategies to cope and to adapt to perceived adverse impacts due to climate change, extreme weather events, and environmental stresses such as increased temperatures, increased drought and decreased rainfalls, as well as increased flooding due to more erratic rainfalls (see Table 22).

Table 22: Adverse impacts and coping and adaptation strategies as per the respondents in Somali region.

Adverse impacts	Physical measure to be taken	Behavioural change	Adaptation measures for compensation
• Increased crop pest • Crop loss • Increased Livestock disease • Livestock death • Increased human disease • Increased land degradation	• Building weirs • Building dams • Water harvesting schemes • Weeding/cull out invasive species	• Adjusting livestock management • Adjusting seasonal cropping calendar • Seasonal movement • Limiting food intake • Migration • Spent on saving	• Sold or consumed livestock • School dropout • Worked for food • Change herd composition • Reduced expenditures on health & education • Change crop type • Food aid • Change income source • Sold agricultural inputs (tools, seeds etc.) • Loan

I.iii.ii Afar Region

The average household size in the surveyed households in the agro-pastoral, pastoral, and sedentary agricultural livelihood zones in Afar were 7.6, 7, and 6.8 respectively. Just as in Somali, the main material used for the floor of people's housing in Afar was either soil or soil mixed with cow dung in all livelihood zones. However, contrary to agro-pastoral households in Somali about 20% of the corresponding households in Afar used cement instead. Regarding wall materials, a parallel can be drawn with the Somali as most households use mud and wood or thatch and straw while some few agro-pastoral and sedentary agricultural households use cement blocks or stones.

For the respondents of all livelihood zones livestock plays a major role as income source being mentioned as primary or secondary income source by 94%, 100%, and 100% of agro-pastoral, pastoral and sedentary agricultural households, respectively. Organisational support from e.g. NGOs is key for most households with 85%, 93%, and 95% respectively while subsistence farming is of high importance for agro-pastoral (91%) and sedentary agricultural (85%) households as well.

Goats are the most kept livestock type in all the livelihood zones with on average 13.5, 15.3, and 11 animals per surveyed agro-pastoral, pastoral and sedentary agricultural households, respectively. Cattle were the second most kept with 4.6, 1.1 and 7.5 animals, sheep the third with 2.3, 1.4, and 2.8 animals per household in the respective zones. Agro-pastoral household on average kept the most camels (2.2), but only slightly more that pastoral households (2) while households in the sedentary agricultural zone only kept 0.5 camels on average. To feed the kept animals natural grazing areas was the main source while crop residues are of high importance for agro-pastoral and sedentary agricultural households. Improved forage is not widely used by any group of respondents. Regarding water sources for their herds respondents from agro-pastoral and pastoral households heavily rely on permanent rivers while seasonal rivers play an important for all respondents.

Main constraints in livestock production for pastoral respondents are both the shortage of animal feed as well as recurring droughts. Contrary to that, for households based in the sedentary agricultural livelihood zone, water shortage and invasive plant species are the key constraints. Agro-pastoral respondents reported both invasive species and animal feed shortage as the major constraints. Coping strategies to tackle those and other challenges primarily include migration (all groups) as well as the use of reserve feed such as crop residues and enclosures (sedentary agricultural and agro-pastoral), while a large share of the sedentary agricultural respondents highlighted the entrusting of livestock to shepherds as coping strategy.

With regard to general coping strategies, sedentary agricultural households mostly reverted to eating less preferred foods as well as reducing the number of meals per day as main strategies during the drought events of 2008/09, 2011/12 and 2015. For agro-pastoral households spending savings played a bigger role in coping than the second most mentioned eating of less preferred foods. Although the data show some gaps for pastoral households, the responses shows that eating less preferred food as well as reducing meals in overall were mentioned most. Other strategies such as reducing expenditure on education and health played only minor roles for all groups.

For the households of all three livelihood zones are natural grazing areas the most important source of animal feed, while crop residues are an important secondary feed source for the two agricultural livelihood zones. For all groups communal or tribal owned grazing lands are the preferred choice of grazing and browsing ground for their livestock while for some sedentary agricultural households private grazing lands played a key role, too.

The respondents' coping and adaptation strategies targeting perceived adverse impacts due climate change, extreme weather events and experienced environmental stresses are presented in Table 23.

Table 23: Adverse impacts and coping and adaptation strategies as per the respondents in Afar region.

Adverse impacts	Physical measure to be taken	Behavioural change	Adaptation measures for compensation
• Increased crop pest • Crop loss • Increased Livestock disease • Livestock death • Increased human disease • Increasing invasive species (e.g. Prosopis Juliuofora) • Shortage of rangelands / land degradation • Water scarcity	• Re-& afforestation • Agroforestry • Water catchments • Building water weirs	• Adjusting livestock management • Adjusting seasonal cropping calendar • Changing the diet • Limiting food intake	• Sold or consumed livestock • Changing grazing land/ rangeland places • Reduced expenditures on health and education • Change crop type • Food aid • Change income source • Sold agricultural inputs (tools, seeds etc.) • (temporary) migration • Continuous monitoring (livestock and crop pests/ diseases)

Annex II *Key Informant Interview – Guiding questions*

1. What are biggest challenges facing in keeping livestock and crop productive and sustainable; and most relevant policy and institutions addressing the challenges?

Livestock		**Crop**		**Policy and Intuition meeting addressing challenges**	
List biggest challenges to keep livestock	Measures taken to overcome challenges	List biggest challenges to keep crop production	Measures taken to overcome challenges	Most relevant policy to overcome challenge	Most relevant Institutions to overcome the challenge

2. Determining Appropriate time horizon

Complete the following table for determining appropriate time horizon for ECA studies using milestones of national, regional and global climate change agenda framework and development goals. Rank/score appropriateness of the milestones for ECA time horizon with a 5-point scale (1-5 score).

Programs/ strategies/ projects/ frameworks	Implementation time frame /horizon (years)	Implementation target years within 100 years period (2000-2100)	Targets achieved	Appropriateness for ECA studies (rank 1-5)
National Strategies				
CRGE	20	2011-2030	emission reduction by 64%	
INDC	10	2020-2030	Reducing vulnerability and emission	
GTP I-II	10	2011-2020	Low middle income status	
A 10-year Perspective Development Plan	10	2020 - 2030	Line-up with SDGs	
Regional and Global Strategies/frameworks				
Africa 63	50	2020-2063		
SDGs				
Sandi Framework				

RCP 2.6		2020-2040 (400 ppm; 1 ºC)		
RCP 4.5		2070 (520 ppm; 2 ºC)		
RCP 6.0		2100 (620 ppm;)		
RCP 8.5		2100 (>950 ppm; 3-5.5ºC)		
Paris climate Change Agreement				
Others				
Reasons for high rank				

Annex III *Household survey questionnaire*

Questionnaires

I. Household Level Questionnaire

Name of data collector: ____

1. Household roster

1.a. Region _____________________; Zone ___________________ ; Woreda _______________________; Kebele_____________________;

Project (e.g. KfW, GIZ, PSNP, SDR1, SDR2, WB etc)______________________________;
Livelihoods zone (Mark "X" where appropriate: Pastoral ___; Agro-pastoral ___; Riverine ___; Sedentary agriculture

1.b. GPS Location of the Household

Latitude (Degrees°, Minutes', Seconds"): ___________________________
(UTM)________________________________

Longitude (Degrees°, Minutes', Seconds"): ___________________________
(UTM)________________________________

Altitude (Degrees°, Minutes', Seconds"): ______________________________
(UTM)________________________________

1.c. Name of KII (Household head): ____________________________________, (Male, Female); Age (years) ______, Education _________, Disability (Mark "X" if yes___

Complete list of Household members (list includes household members during the last 12 months)

No	Name	Relationship to household head?	Sex	Age (years)	Marital Status	Educational level	Persons with disability.
		1= Head 2= Spouse 3= Son/daughter 4= Grand child 5= Step child 6= Parent of head or spouse 7= Sister/Brother of head or spouse 9= Other relatives 10= Servant 11= Other (specify)	1=M 2=F		1= Married 2= Divorced/ Separated 3= Widow/ Widower 4= Never married	1=BSc Degree and above 2=Certificate or Diploma 3=High School (School year) 4=Elementary (school year) 5= literate but no formal Schooling 6=Illiterate	If yes- Mark" X" corresponding to the household member
1							
…							

1.d. What was the household's most important source of income? (select the number from the alternative(s) – prioritize by Ranking using 1-5 point scale

Source of income	Scale (1-5)[72]
1=Livestock keeping 2=Subsistence farming 3=Wage employment 4=Transfers (pension, any other) 5=Remittances 5=Property income 6=Organizational support (e.g. food aid – PSNP, WFP, NGOs, etc) 7=Petty trade (Informal) 8=Other, specify	

[72] Score 1- Very low or non-income, 2- low income, 3- moderate income, 4- high income, 5- full scale income

1.e. Housing conditions

Floor	Wall	Roof Material	Age of the house in years	No of rooms	Is the kitchen in a separate room	Is there separate area for animals
1=Earth 2= Earth painted with cow dung 3= Cement 4= Ceramic tiles 5=Plastic tiles 6= Other (specify)	1=Thatch, Straw 2= Mud and poles 3= Timber 4= Cement blocks 5= Stone 6= Other (specify)	1=Thatch/straw 2=corrugated iron sheet 3= tiles 4=other (specify)			1=yes 2=no	1=yes 2=no describe the condition: If yes, circle (Barn within homestead area or in the range land) If No , circle (separate room or same room);

1.f. Drinking Water (human)

Main source of water	Walking distance to the source in hours	How much water does the household use (for all purposes) (Jerican per day)
1=Public tap 2=Ponds 3=Traditional well (Birka), 5=Protected spring 6=Unprotected spring 7 =traditional well (Ella), 8=Cisterns 9=Deep well 10=River 11=Other (specify)		

1.g. Toilet (Select the appropriate alternative(S) and put the numbers in the blank column)

What is the type of toilet used by the household?	Do you have a hand washing facility at the toilet?	With how many other households do you share the toilet?
1=Covered pit latrine private 2= Covered pit latrine shared 3= Uncovered pit latrine 4= Flush toilet private 5= Flush toilet shared 6= Bush/forest 7=Other (specify)	1= No 2= Yes with water only 3= Yes with water and soap	

1.h. Source of cooking fuel (Select the appropriate alternative(s) and put the numbers in the blank column)

What is the main source of cooking energy in your house?	Consumption per month (Kg, liter, KW)	What kind of cooking stove?	How did you get your cooking energy?	If collected how often per month?	If purchased select the appropriate alternatives from the list in the 1st column.	How much do you pay in total/month?
1=Charcoal 2=Firewood/ branches 3=Dung 4=Biomass (agriculture waste, shrubs, roots) 5=Kerosene 6=Biogas 7=Liquefied petroleum gas (LPG) 8=Electricity 9=Other, specify		1=Three stone stove 2=Improved charcoal stove 3= Improved firewood stove 3=Kerosene stove 4=Biogas stove 5=Electric plate /cooker 6= Other (specify)	1=Purchased 2=Collected	1=1x per month 2=2x per month 3=3x/month 4=4x/month 5=more than 4x/month 6=other (specify)		

1.i. Source of lighting (Select the most appropriate alternative(S) by ranking using 1-5 point scale

What is the main source of lighting in your house?	Scale (1-5)[73]
1=Electricity-Grid 2= Electricity-Generator 3= Electricity-Solar 4= Paraffin lantern 5= Torch 6= Firewood 7= Other (specify)	

[73] Score 1- Very low or non, 2- low source, 3- moderate source, 4- high source, 5- full scale source

1J. Changes in energy sources before and after 2015: Rank role of actors in establishment and maintenance of energy sources using a 5-point scale (1-5 score)

	Before 2015												
	Purpose				Actors of establishment				Actors of maintenance				Establishment years
Source	Cooking	Lighting	Heating	Cooking stove type	GOV	Community	NGO	Household	GOV	Community	NGO	Household	
National Grid													
Solar													
Biogas													
Biomass													
Kerosene													
Hurricane lamp													
Generator													
Wood													
Charcoal													
Others													

	After 2015												
	Purpose				Actors of establishment				Actors of maintenance				Establishment years
Source	Cooking	Lighting	Heating	Cooking stove type	GOV	Community	NGO	Household	GOV	Community	NGO	Household	
National Grid													
Solar													
Biogas													
Biomass													
Kerosene													
Hurricane lamp													
Generator													
Wood													
Charcoal													
Others													

1.h. Household assets (select from the alternatives)

Type of Assets	Estimated cash Value (ETB)	Year of service in good condition
Furniture/Furnishings		
Household Appliances e.g. Kettle, Flat iron, etc.		
Electronic Equipment e.g. TV., Radio, Cassette, etc.		
Generators		
Solar panel/electric inverters		
Bicycle		
Motor cycle		
Motor vehicle		
Other Transport equipment		
Jewelry and Watches		
Mobile phone		
Other (specify		

1.k. Loans borrowed (select the numbers from the alternatives and put the figures corresponding to the loan in the other columns)

Loan Source	Total amount borrowed	For what purpose	Amount repaid	Repayment period	Main Collateral
1= Friends/ relatives 2= Private money lender 3=Employer 4=Bank 5=Microfinance institutions 6=Input trader/shop keeper 7=Others (specify) 8=Not borrowed					1=None 2 = Land 3 = Livestock 4 = House 5 = Future harvests 6 = Vehicle 7 = Group lending) 8 = Other (specify)

2. Livestock

2.a. Livestock herd composition, milk production and products

Type of Livestock	Number	Estimated value (ETB)	Milking period (Days)	Milk production (liters/day)	Estimated cash value from milk (ETB)	Estimated value (ETB) from milk products		
						Butter	Yoghurt	Others specify
Cattle								
Sheep								
Goats								
Donkey								
Horse								
Mule								
Camel								
Chicken								
Other (specify)								

2b. Livestock-related annual cash income (ETB/year) from sell of live animals, milk, egg, chicken.

Type of Livestock	Sell of livestock (ETB)	Sale of Livestock products (ETB)						Rent for transport
		Milk	Butter	Yoghurt	Egg	Meat	Hide & skin	
Cattle								
Sheep								
Goats								
Donkey								
Horse								
Mule								
Camel								
Chicken								
Other (specify)								

2c. Livestock source of feed: Rank the sources and strategies by ranking using 1-5 point scale

Feed source	Scale (1-5)[74]	Livestock water source	Scale (1-5)[75]	Strategies used during critical feed shortage period	Scale (1-5)[76]
1=Natural grazing area 2=Standing hay (enclosure) 3=Crop residues 4=Improved forages 5=Other (specify)		1=Permanent rivers 2=Temporary rivers 3=Ponds 4=Traditional wells 5=Other (specify)		1=Migration 2=commercial destocking 3=Use reserve feed (enclosure; crop residues) 4=Supplementing cultivated improved forages 5=Supplementing cultivated improved forages and use reserve feed (enclosure; crop residues) 6=Other (specify) 7= Feed rationing 8= water rationing	

[74] Score 1- Very low or non, 2- low source, 3- moderate source, 4- high source, 5- full scale source

[75] Score 1- Very low or non, 2- low source, 3- moderate source, 4- high source, 5- full scale source

[76] Score 1- Very low or non, 2- low, 3- moderate, 4- high, 5- full scale

2d. Commonly used Source of Water for Livestock: Prioritize most commonly used water sources by ranking using 1-5 point scale

Water Source	Scale (1-5)[77]
1=Bore hole	
2=Dug wells	
3-Stream seasonal	
4=Stream permanent	
5=River	
6=Pond	
7=Dam	
8=Pipe	
9=Other (specify)	

2e. Major livestock production and productivity constraints: Rank level of constraints using 1-5 point scale

Production Constraint	Scale (1-5)[78]
1=Shortage of animal feed	
2=Water shortage in the rangelands	
3=Recurrent drought	
4= Invasion of rangelands by bushes and other invasive plants	
5=Lack of Veterinary service (clinical, AI)	
6=Lack of awareness about livestock management	
7=Market linkage	
8= Other (specify)	

[77] Score 1- Very low or non, 2- low, 3- moderate, 4- high, 5- full scale

[78] Score 1- Very low or non-constraints, 2- low constraint, 3- moderate constraint, 4- high constraint, 5- full scale constraint

2f. Major drought impact on livestock and human life and year perceived by the respondents

Drought impact	Drought years							
	2008/9	Number affected	2011/12	Number affected	2015	Number affected	Other drought years (specify year)	Number affected
1=Death of livestock								
2=Famine								
3= Migration								
4=Poor grass growth								
5=Death of human being								
6=human disease epidemic								
7=livestock disease epidemic								
8=other (specify)								

2g. What coping mechanism(s)/strategy (ies) have your HH adapt to mitigate these drought impact? Rank the coping mechanisms using Rank level of constraints using 1-5 point scale

Coping strategy	Drought years (Scale 1-5)[79]			
	2008/9	2011/12	2015	Other drought years (specify year)
1=Eating less preferred foods				
2=Borrowing money/food				
3=Reducing number of meals and intake				
4=Enrolled in FFW program				
5=Spent savings				
6=Engaged in casual labor				

[79] Score 1- Very low or non-coping, 2- low coping mechanism, 3- moderate coping mechanism, 4- high coping mechanism, 5- full scale coping mechanism

7=Destocking of livestock (sold, consumed)				
8=Being temporarily displaced from the village				
9=Sold agricultural tools, seeds, or other inputs				
10=Reduced expenditures on health and education				
11=Other (specify)				

2h. Forage and water requirements of different livestock type, minimum needed to survive during droughts (kg/day/head) vs good years

Livestock type	Feed (kg[80]/day/head)		Water (liter/day/head)	
	during drought years	During good years	during drought years	During good years
Cattle				
Sheep				
Goats				
Camel				
Donkey				
Horse				
Mule				
Chickens				
Others				

[80] State a traditional unit equivalent to a kg

2i. Extension support? What kind of support are provided? Score level of support with a 5-point scale (1-5 score[81])

Livestock type	Vet service (Clinical and Artificial Insemination/AI)					Feed and water supply				Market access
	Availability of animal clinic	Availing livestock experts (vet, management)	Drug, vaccine and AI	Training and awareness	Traditional Vet experts	Traditional Livestock feed & rearing experts	Feed supply	Pasture	Water supply	
Cattle										
Sheep										
Goat										
Camel										
Donkey										
Horse										
Mule										
Chickens										
Others										

[81] Score 1- Very low or non, 2- low support, 3- moderate support, 4- high support, 5- full scale support

2j. What is/are factor(s) affecting production and productivity of livestock? Score level of adverse impacts of the factors with a 5-point scale (1-5 score).

Livestock type	Vet service (Clinical and Artificial Insemination/AI)					Feed and water supply				Market access
	Lack of animal clinic	Lack of livestock experts (vet, management)	Lack of Drug, vaccine and AI	Lack of training and awareness	Lack of traditional Vet experts	Lack of traditional Livestock feed & rearing experts	Lack of feed supply	Lack of Pasture land	Lack of Water supply	
Cattle										
Sheep										
Goat										
Camel										
Donkey										
Horse										
Mule										
Chickens										
Others										

1= very low/no impact; 2= low impact; 3= moderate impact; 4= high impact; 5= full scale/very high impact

2k. Access to grazing/browsing areas: Rank level of access and restrictions with a 5-point scale (1-5 score)

Livestock type	Public/government land			Communal/Owned by a Tribe			Private/household land		
	Score (1-5)	Restriction		Score	Restriction		Score	Restriction	
Cattle		Long distance	Competition		Long distance	Competition		Long distance	Competition
Sheep									
Goat									
Camel									
Donkey									
Horse									
Mule									
Chickens									
Others									

1= very low/no access; 2= low access; 3= moderately; 4= high access; 5= full access .

2L.i. Herd mortality during droughts of 2008/9 and 2011/12 (How much deaths and destocking/year):
Mark “X) for causes of death (starvation, thirst, disease).

Livestock type	Drought year 2008/9 and normal year before 2008/9										Drought year 2011/12 and normal years before 2011/12									
	Drought years		Normal years		Causes of death						Drought years		Normal years		Causes of death					
	Death	Destocking	Death	Destocking	Drought years			Normal year			Death	Destocking	Death	Destocking	Drought year			Normal year		
					Starvation	Thirst	Disease	Starvation	Thirst	Disease					Starvation	Thirst	Disease	Starvation	Thirst	Disease
Cattle																				
Sheep																				
Goat																				
Camel																				
Donkey																				
Horse																				
Mule																				
Chickens																				
Others																				

2L. ii. Herd mortality during droughts of 2015 and others (How much deaths and destocking/year):
Mark (X) for causes of death (starvation, thirst, disease)

Livestock type	Drought year 2015 and normal year before 2015										Other drought year (specify year_____) and normal years before the drought year									
	Drought years		Normal/good years		Causes of death						Drought years		Normal/good years		Causes of death					
	Death	Destocking	Death	Destocking	Drought years			Normal year			Death	Destocking	Death	Destocking	Drought year			Normal year		
					Starvation	Thirst	Disease	Starvation	Thirst	Disease					Starvation	Thirst	Disease	Starvation	Thirst	Disease
Cattle																				
Sheep																				
Goat																				
Camel																				
Donkey																				
Horse																				
Mule																				
Chickens																				
Others																				

2m. Herd mobility during droughts and Normal years: (How much kms away from settlement areas)

Livestock type	2008/9		2011/12		2015		Other Drought year (Specify	
	During Drought (mobility in km)	During normal year before 2008 (mobility in km)	During Drought (mobility in km)	During normal year before 2011 (mobility in km)	During Drought (mobility in km)	During normal year before 2015 (mobility in km)	During Drought (mobility in km)	During normal year before drought (mobility in km)
Cattle								
Sheep								
Goat								
Camel								
Donkey								
Horse								
Mule								
Chickens								
Others								

3. Crop

3a. When did crop farming started in the area (Approximate years)? ______________________

3b. What types and amount of crops/vegetables/fruits does your family grow; and level of family members engagement?

Crop type	Land area (ha)	Total Yield (Kg)	Estimated cash value (ETB)	Who is in charge of crop production: Rank level of engagement using point Scale 1-5)[82]					
				Husband	Wife	Boys	Girls	Children	Aged
1=Sorghum									
2=Maize									
3=Wheat									
4=Teff									
5=Vegetables									
6=Root crops									
7=Fruit crops									
8=Other (specify)									

3c. What are the main constraints to low production and productivity of your Crops/vegetables/ fruits? Rank level of degree of constraint impact using point Scale 1-5)[83]

Crop type	Types of Constraints (score 1-5)				
	1=Moisture	2=Farming practice	3=Improved seeds,	4=Pests/diseases,	5=Others (specify)
1=Sorghum					
2=Maize					
3=Wheat					
4=Teff					
5=Vegetables					
6=Root crops					
7=Fruit crops					
8=Other (specify)					

[82] Score 1- Very low or no impact, 2- low impact, 3- moderate impact, 4- high impact, 5- fully scale impact,

[83] Score 1- Very low or no constraint, 2- low constraint, 3- moderate constraint, 4- high constraint, 5- fully scale constraint,

3d. Crop management schedule: Who is involved at most in crop management? Score level of involvement with scale point 1-5, with 1= very low/no responsibility; 2= low; 3= moderate; 4 = high; 5= full responsibility. Indicate activity date (month)

Crop type	Management	Responsible persons of household members						Activity month(s)
		Men (score 1-5)	Women (score)	Young men(score)	Young women(score)	Children (score)	Aged	
1=Sorghum	Land prep./plowing							
	Seeding							
	weeding							
	Harvesting							
	Storage							
2=Maize	Land prep./plowing							
	Seeding							
	weeding							
	Harvesting							
	Storage							
3=Wheat	Land prep./plowing							
	Seeding							
	weeding							
	Harvesting							
	Storage							
4=Teff	Land prep./plowing							
	Seeding							
	weeding							
	Harvesting							
	Storage							
5=Vegetables	Land prep./plowing							
	Seeding							
	weeding							
	Harvesting							
	Storage							
6=Root crops	Land prep./plowing							
	Seeding							

	weeding							
	Harvesting							
	Storage							
7=Fruit crops	Land prep./plowing							
	Seeding							
	weeding							
	Harvesting							
	Storage							
8=Other (specify)	Land prep./plowing							
	Seeding							
	weeding							
	Harvesting							
	Storage							

3e. i. Crop damage during droughts of 2008/9 and 2011/12 vs normal years: How much is damaged during drought and normal years, and mark “X” for cusses of losses.

Crop type	Drought year 2008/9 and normal year before 2008								Drought year 2011/12 and normal year before 2011							
	During drought year		During normal year before 2008		Causes of loss (Mark “X”)				During drought year		During normal year before 2011		Causes of production loss (Mark “X”)			
	Production gain (Quintal)	Production Loss if any (Quintal)	Production gain (Quintal)	Production Loss if any (Quintal)	Drought year		Normal year		Production gain (Quintal)	Production loss if any (Quintal)	Production (Quintal)	Production loss if any (Quintal)	Drought year		Normal year	
					Moisture scarcity	Disease/ pest	Moisture scarcity	Disease/ pest					Moisture scarcity	Disease / pest	Moisture scarcity	Disease /pest
1=Sorghum																
2=Maize																
3=Wheat																
4=Teff																
5=Vegetables																
6=Root crops																
7=Fruit crops																
8=Other (specify)																

3e. ii. Crop damage during droughts of 2015 and other drought years vs normal years: How much is damaged during drought and normal years, and mark “X” for cusses of losses.

Crop type	Drought year 2015 and normal year before 2015								Other Drought year (specify_______) and normal year before the drought							
	During drought year		During normal year before 2015		Causes of loss (Mark “X”)				During drought year		During normal year before ____		Causes of production loss (Mark “X”)			
	Production gain (Quintal)	Production Loss if any (Quintal)	Production gain (Quintal)	Production Loss if any (Quintal)	Drought year		Normal year		Production gain (Quintal)	Production loss if any (Quintal)	Production (Quintal)	Production loss if any (Quintal)	Drought year		Normal year	
					Moisture scarcity	Disease/ pest	Moisture scarcity	Disease/ pest					Moisture scarcity	Disease / pest	Moisture scarcity	Disease /pest
1=Sorghum																
2=Maize																
3=Wheat																
4=Teff																
5=Vegetables																
6=Root crops																
7=Fruit crops																
8=Other (specify)																

3f. Crop-related Cash Income and household consumption/year during non-drought years.

Crop type	Growing season, I (Main rain season)				Growing season II (Short rain season)				Growing season by Irrigation			
	Total Production (Quintal)	Production Sold (Quintal)	Cash income (Birr)	Production consumed (Quintal)	Total Production (Quintal)	Production Sold (Quintal)	Cash income (Birr)	Production consumed (Quintal)	Total Production (Quintal)	Production Sold (Quintal)	Cash income (Birr)	Production consumed (Quintal)
1=Sorghum												
2=Maize												
3=Wheat												
4=Teff												
5=Vegetables												
6=Root crops												
7=Fruit crops												
8=Other (specify)												

3g. Extension support? What kind of support are provided? Score level of support with a 5-point scale (1-5 score)

Crop type	Improved seed	Fertilizer	Herb/Insecticide	Irrigation	Market linkage	Other support
1 Sorghum						
2 Maize						
3 Wheat						
4 Teff						
5 Vegetables						
6 Root crops						
7 Fruit crops						
8 Others (specify)						

*Score 1- Very low or none, 2- low support, 3- moderate support, 4- high support, 5- full scale support

4. Water, Sanitation and Health

4.a. Source of water for human consumption and changes in the supply coverage before 5-10 years ago (before 2015) and after 5-years ago (after 2015-2020): Rank level of actors role in water supply support with a 5-point scale (1-5 score[84]).

		Before 2015										After 2015										
			Installment				Maintenance and upgrading				Establishment year (EC)	Installment						Maintenance and upgrading				Establishment year (EC)
Water source	Number	Distance (km)	Community	Gov	Household	NGO	Community	Gov.	Household	NGO		Number	Distance (km)	Community	Gov.	Household	NGO	Community	Gov.	Household	NGO	
Bore hole																						
Stream seasonal																						
Stream permanent																						
Pond																						
Dam																						
Pipe																						
Roof harvesting																						
Others																						

[84] Score 1- Very low or non, 2- low support, 3- moderate support, 4- high support, 5- full scale support

4b. Who is in charge of fetching water? Men, women, young men, young women, children, animal labor[85]. Rank level of household members engaged in water fetching before and after 2015 with a 5-point scale (1-5 score[86])

	Before 2015											
	Without animal labor						With animal labor					
	Distance	Men	Women	Young men	Young women	Children	Distance	Men	Women	Young men	Young women	Children
Bore hole												
Stream seasonal												
Stream permanent												
Pond												
Dam												
Pipe												
Roof harvesting												
Others												

85 Animal labor: Fetching a barrel of water by loading on donkey or camel.

86 Score 1- Very low or non, 2- low support to fetch, 3- moderate support to fetch, 4- high support to fetch, 5- full scale support to fetch

	After 2015											
	Without animal labor						With animal labor					
	Distance	Men	Women	Young men	Young women	Children	Distance	Men	Women	Young men	Young women	Children
Bore hole												
Stream seasonal												
Stream permanent												
Pond												
Dam												
Pipe												
Roof harvesting												
Others												

4c. Health facilities: Changes in health service provision, actors etc and rank services and actors role in maintenance and installment of health centers intensity using a 5-point scale (1-5 score[87])

	Before 2015												Establishment year (EC)
					Actors of Installment/ establishment				Actors of Maintenance and upgrading				
Health center type	Number	Use intensity (1-5)	Distance (km)	Health workers (Nr)	Community	Gov	Private	NGO	Community	Gov.	Private	NGO	
Health post													
clinic													
Health center													
Hospital													
Pharmacy													
Traditional healers													
Others													
	After 2015												Establishment year (EC)
					Actors of Installment/ establishment				Actors of Maintenance and upgrading				
Health center type	Number	Use intensity (1-5)	Distance (km)	Health workers (Nr)	Community	Gov	Private	NGO	Community	Gov.	Private	NGO	
Health post													
clinic													
Health center													
Hospital													
Pharmacy													
Traditional healers													
Others													

[87] Score 1- Very low or non-functional, 2- low, 3- moderately used, 4- highly used, 5- fully used and functional

4d. Prevalent diseases and level of treatment and drug supply before and after 2015: Rank availability of health facilities, prevalence of the disease and rank level of treatment and drug supply and medication fee and most affected community/family members with a 5-point scale (1-5 score[88]).

Before 2015																				
Type of prevalent disease	Health center type						Medicine supply		Medical coverage						Most affected groups					
	Health post	Clinic	Health center	Hospital	Traditional	Others	Pharmacy	Unknown sources	Community	Gov	Self	NGO	Free	Insurance	Men	Women	Young men	Young women	Children	Infant babies
1=Malaria																				
2=dengue fever																				
3=cholera																				
4=dysentery																				
5=T.B.																				
6=HIV																				
7=Other Sexually Transmitted Disease (STD)																				
8=Other (specify)																				

[88] Score 1- Very low or none, 2- low, 3- moderately, 4- high, 5- fully used and functional

After 2015																				
Type of prevalent disease	Health center type						Medicine supply		Medical coverage						Most affected groups					
	Health post	Clinic	Health center	Hospital	Traditional	Others	Pharmacy	Unknown sources	Community	Gov	Self	NGO	Free	Insurance	Men	Women	Young men	Young women	Children	Infant babies
1=Malaria																				
2=dengue fever																				
3=cholera																				
4=dysentery																				
5=T.B.																				
6=HIV																				
7=Other Sexually Transmitted Disease (STD)																				
8=Other (specify)																				

5. Education

5a. Changes in the coverage of education before and after 2015: Rank role of different actors engaged school establishment and maintenance with a 5-point scale (1-5 score[89]).

	Before 2015													
									Establishment cost		Maintenance / upgrading cost		Status	
Level of education	Number	Distance (km)	Number of enrollment	Number of Teachers	Community	Gov	Private	NGO	Community	Gov.	Private	NGO	Mobile	Stationery
Pre-school														
1-4th														
5-8th														
9-12th														
TVET														
University														
Specialized training center														
Boarding schools														
AFTER 2015														
Pre-school														
1-4th														
5-8th														
9-12th														
TVET														
University														
Specialized training center														
Boarding schools														

[89] Score 1- Very low or none, 2- low, 3- moderately, 4- high, 5- fully used and functional

6. Access to transport

6a. Changes in access to transport before and after 2015 and year of road construction. Rank level of access and vehicle availability using a 5-point scale (1-5 score[90]).

Before 2015													
Road type	Access to road (km)	Rank (1-5)	Public transport						Private transport				
			Bus	Mini-bus	Motor bike three wheel	Motor bike Two wheel	Distance from home to station (km)	Distance between stop points (km)	Automobile	Motor bike (three wheel)	Motor bike (two wheel)	Cycle
Highway												
Asphalt												
All weather Gravel road												
Dry weather Gravel road												
Others												
After 2015												
Road type	Access to road (km)	Rank (1-5)	Public transport						Private transport			
			Bus	Mini-bus	Motor bike three wheel	Motor bike Two wheel	Distance from home to station (km)	Distance between stop points (km)	Automobile	Motor bike (three wheel)	Motor bike (two wheel)	Cycle
Highway												
Asphalt												
All weather Gravel road												

[90] Score 1- Very low or none transport service , 2- low transport service, 3- moderate transport service, 4- high transport service, 5- full scale transport service

Dry weather Gravel road												
Others												

7. Telecommunication and ICT:

7a. Changes in telephone and ICT coverage before and after 2015.

Rank level of availability and access with a 5-point scale (1-5 score[91])

Type	Before 2015								After 2015							
	Purpose								Purpose							
	Network availability	Social media	ICT	E-mail	Market information	Weather information	Hazard information	Current affairs	Network availability	Social media	ICT	E-mail	Market information	Weather information	Hazard information	Current affairs
Mobile																
Landline																
Other (Neighbors, public pool)																
Hotels/shops																
Others (specify)																

[91] Score 1- Very low or non, 2- low, 3- moderately available, 4- highly available, 5- fully available and functional

8. Environmental stresses

8a. Perceived Climate Change and its impact

<table>
<tr><td colspan="2">Temperature: Have you noticed any long-term Shifts in temperature?
Mark “X”
Temperature Increases?___ Temperature decreases?___</td><td colspan="2">Precipitation: Have you noticed any long-term shifts in rainfall?
Mark “X”
Rainfall increases?___ Rainfall decreases?____
Season shifts?: Yes ______; No_____</td></tr>
<tr><td></td><td>Increasingly recurrent drought? Mark “X”
Yes___, No__</td><td></td><td>Increasingly recurrent flood? Mark “X”
Yes___, No__</td></tr>
<tr><td>Adverse impacts of Temperature shifts? Mark “X”</td><td>Adverse impact of recurrent drought
Mark “X”</td><td>Adverse impacts of precipitation shifts
Mark “X”</td><td>Adverse impacts of recurrent flood
Mark “X”</td></tr>
<tr><td>1=increased crop pest
2=crop loss
3=increased livestock disease
4= livestock death
5=Increased human disease
6=Human death
7=land degradation
8=infrastructure damage
9=other (specify)</td><td>1=increased crop pest
2=crop loss
3=increased livestock disease
4= livestock death
5=Increased human disease
6=Human death
7=land degradation
8=infrastructure damage
9=other (specify)</td><td>1=increased crop pest
2=crop loss
3=increased livestock disease
4= livestock death
5=Increased human disease
6=Human death
7=land degradation
8=infrastructure damage
9=other (specify)</td><td>1=increased crop pest
2=crop loss
3=increased livestock disease
4= livestock death
5=Increased human disease
6=Human death
7=land degradation
8=infrastructure damage
9=other (specify)</td></tr>
</table>

8b. Environmental stresses and behavioral changes as coping mechanisms: Rank all the available hazards according to their adverse impacts on their livelihoods, note reasons for high adverse impacts and behavioral changes as adaptation mechanisms.

	Ranking adverse impact (Score 1-5)	Adverse Impacts of livelihood bases rank (score 1-5)					Measures taken to adapt environmental stress (list)		Actor Supporting to deal with environmental shocks/stresses rank (1-5)		
Types of Environmental hazard		ability to acquire food	Ability to maintain livestock	Ability to maintain non-farm income generating activities	Ability to maintain school activity	Ability to maintain health and sanitation access	Physical changes[92]	Behavioral changes[93]	Gov	NGO	CBOs
Drought											
Flood											
Rangeland encroachment by invasive species											
Pest and disease (Desert locust)											
Rangeland encroachment by investment											
Others											

[92] Physical change e.g. migration or seasonal movement,

[93] Behavioral change e.g. limiting food intake, diet change etc.

8c. Losses and damages of environmental stress and mechanisms of compensating losses and damages indicating behavioural changes as option of adaptation. Rank degrees losses and compensating mechanisms with a 5-point scale (1-5 score)

Types of Environmental stress	Losses and damages		Compensating losses and damages															
	Crop loss	Livestock loss	Reduced expenditures on health and education	Spent savings	Sold or consumed livestock	Sold agricultural tools, seeds, or other inputs	Worked for food	Sold crop before harvest	Other, specify	Sold wood products	Loan	Change livestock composition	Change crop type	Change income source	Food aid	School meal	School dropout
Drought																	
Flood																	
Rangeland encroachment by invasive species																	
Pest and disease (Desert locust)																	
Rangeland encroachment investment																	
Biodiversity loss																	
Famine																	
Others																	

Annex IV *Measures' Selection Process*

IV.i Background

A set of drought adaptation measures had to be identified and tailored to the existing and projected drought risk for the selected assets and population in the Afar and Somali Region in Ethiopia. The selection and introduction of adaptation measures is an essential part of the ECA framework and requires specific steps of engagement and participation with key stakeholders in order to determine and validate their economic viability and sustainability. The following sections describe the process of selecting appropriate drought adaptation measures, starting from a pre-selection (*long list*) of measures up to a final selection of measures (*short list*) that are parameterised and introduced to the probabilistic modelling tool CLIMADA.

IV.ii Defining a long list of Adaptation Measures

The initial phase of identifying adaptation measures has been based on comprehensive literature review, consultations with key experts and project partners of the ECA study. The following key aspects have been considered in the process of selecting a long list of adaptation measures:

- Include international best practice of drought mitigation and adaptation.
- Include and respect local and national master plans on climate adaptation and/or regional interventions of international development and humanitarian corporations, i.e. what drought adaptation interventions are being implemented or included in national climate strategies and action plans?
- Include best practice from the local context, i.e. what adaptation designs are built upon local knowledge, and/or respect local customs and traditions?

As a result, and considering the mentioned key aspects the following list of measures has been compiled, covering 37 measures in total, classified into 7 adaptation categories and types (see Table 24).

Table 24: Long list of identified drought adaptation measures for the Afar and Somali Region. Measures are listed according to their adaptation category and type. There are four classification types, Grey, NbS, Hybrid and Insurance. 'Grey' measures refer to engineered solutions. 'NbS' measures refer to ecosystem-based (or nature-based) solutions and make use of multiple services provided by ecosystems. 'Hybrid' solutions indicate a combination of NbS and Grey types of measures. 'Insurance' solutions cover residual risks, which occur when adaptation measures are not cost-efficient.

Category	Type	Measures
1. Water Conservation & Infrastructure	Grey	1) Deep Boreholes
	Grey	2) Shallow Boreholes
	Grey	3) Construction of cisterns for livestock

	Grey	4) Construction of cisterns for agriculture
	Grey	5) Shallow watering ponds/wells for livestock
	Grey	6) Portable Water Treatment Plants
	Grey	7) Motorized Solar Pumps
	Grey	8) Improvement of water storage systems
	Grey	9) Improvement of water distribution facilities
	Grey	10) Establishment of small- & medium sized irrigation systems
	Grey	11) Establishment and strengthening of existing small- & medium sized irrigation systems
	Grey	12) Riverbank restoration
	Hybrid	13) Watershed Protection with bunds
	Hybrid	14) Subsurface Micro-Reservoirs in Riverbeds
	NbS	15) Wetland restoration and rehabilitation
2. Range- & Cropland Management	Grey	16) Establishment of seed banks
	Grey	17) Improved forage (incl. seed) storage & treatment
	Grey	18) Community based rangeland management / rehabilitation
	Grey	19) Establishment of forage hay producers' groups
	NbS	20) Livestock enclosures
	NbS	21) Crop switching
	NbS	22) Replanting of indigenous and improved fodder trees
	NbS	23) Replanting of indigenous and improved grass varieties
	NbS	24) Management of protected environmental areas
	Hybrid	25) Large-Scale Invasive Bush Clearing & Reseeding
	Hybrid	26) Establishment of fodder tree and grass nursery sites
3. Livestock Management	Grey	27) Improved veterinary health support
	Hybrid	28) Improved livestock production systems
4. Economic Resilience	Grey	29) Promotion of alternative farm and non-farm activities
	Grey	30) Capitalisation
	Insurance	31) Livestock Insurance
	Insurance	32) Crop Insurance

5. Market Access & Trade	Grey	33) Construction and rehabilitation of rural market and trade infrastructure
	Grey	34) Climate-resistant road infrastructure (road access)
6. Monitoring	Grey	35) Monitoring Scheme for Rangeland Quality
	Grey	36) Water Information System (WIS)
7. Agroforestry	NbS	37) Intercropping of trees with crops

Figure 27 below shows an overview of the amount of measures assigned to the different adaptation categories. The majority of measures focuses on 'Water Conservation & Infrastructure', followed by measures targeting 'Range- & Cropland Management'.

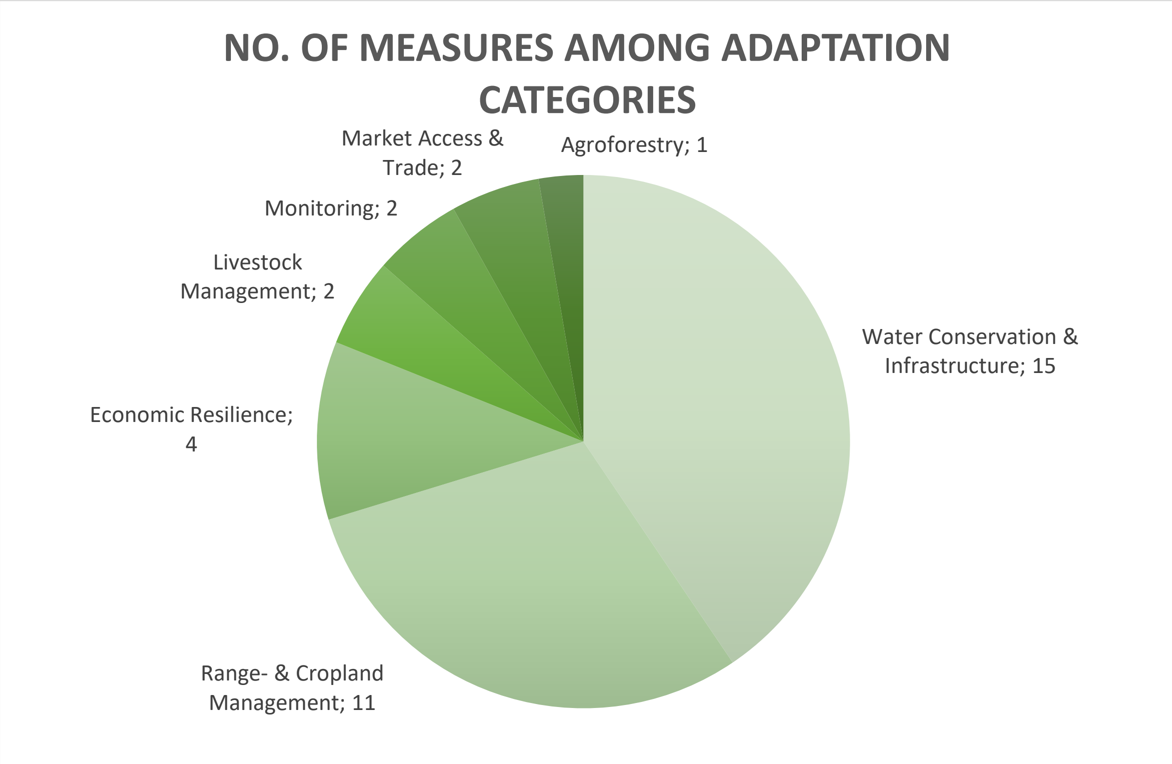

Figure 27: Number of measures according to their adaptation category, as identified for the 'long list' of measures.

IV.iii Validation and Weighting of Selection Criteria

After identifying a long list of 37 measures, the most promising adaptation measures should be parameterised within CLIMADA. To do so, it is best practice to reduce the long list of adaption measures to a short list based on specific selection criteria. Selection criteria are attributes or characteristics that have been identified of being essential to address drought risk but also to satisfy requirements such as sustainability and economic relevance. The following selection criteria have been validated by 15 key stakeholders:

1. Cost-Effectiveness: Represents the absolute cost of measures, considering cost of planning, and implementing adaptation measures, including transition cost and operation and maintenance cost. Benefits/Effectiveness are the avoided damage cost or the accrued benefits following the adoption and implementation of adaptation measures.

2. Up-scaling Potential: It is considered how much further potential for different adaptation strategies can be exploited in Ethiopia, i.e. how to increase the usage of adaptation strategies. This is assessed & validated by local key stakeholders, experts and available data, where available.

3. No-Regret Options (Risk Gradient): Risk-independent vs. risk-specific: Adaptation strategies can be useful even in the absence of climate change or in case of uncertainty regarding future climate change impacts (= risk-independent) or they can be risk-specific, where their implementation is only sensible when a risk is actually present (e.g. insurances).

4. Co-Benefits (for SDGs): Many adaptation strategies do not only adjust systems to cope with climate risk, but have the potential to contribute to other development benefits as well. Here, this is indicated by referring to relevant Sustainable Development Goals (SDGs), which can also be addressed by specific strategies.

5. Potential of Mal-adaptation: Adaptation interventions may also produce undesired effects or maladaptive outcomes (e.g. biodiversity losses, increased energy demand, etc.), which need to be considered for each adaptation strategy.

6. Stakeholder Interest (Social Acceptance): Another indicator for assessing adaptation strategies is the interest that stakeholders show in a strategy, as this crucially determines future uptake/acceptance and implementation.

7. Institutional Support Requirements: Institution-led vs. autonomous: While most adaptation strategies can be initiated and implemented by different actors, depending on their concrete design, a distinction can be made between strategies that generally require high institutional support and those that can be initiated by (agro) pastoralists/ smallholders themselves.

8. Ecosystem-based Adaptation (EbA): EbA is officially defined by the Convention on Biological Diversity (CBD) as 'the use of biodiversity and ecosystem services [...] to help people to adapt to the adverse effects of climate change' which may include 'sustainable management, conservation and restoration of ecosystems, as part of an overall adaptation strategy that takes into account the multiple social, economic and cultural co-benefits for local communities'.[94]

9. Alignment with Ethiopia's Climate Resilient Green Economy (NAP): Ethiopia's National Adaptation Plan (NAP-ETH) focuses on the sectors that have been identified as most vulnerable, namely: agriculture, forestry, health, transport, power, industry, water, and urban. Within these sectors, 18 adaptation options have been identified for implementation at all levels and across different development sectors, recognizing the considerable diversity in context and vulnerability across Ethiopia's regions and social groups.

[94] Lo, V. (2016). Synthesis report on experiences with ecosystem-based approaches to climate change adaptation and disaster risk reduction. *Technical series*, *85*.

10. Alignment with existing country programs (e.g. German Financial Cooperation, Technical Cooperation Initiatives, IGAD, CCIP): The following structures and programs are linking humanitarian and development interventions (from both, national and international initiatives) in Ethiopia and are already in place.

After validating the above-mentioned selection criteria, key stakeholders were asked to *weigh the criteria* for further use in a Multi-Criteria Analysis. Stakeholders ranked the validated criteria by assigning a score varying from 10 (most important) to 1 (least important). For each criterion, the average value of all assigned scores represents the weight. This weight will be applied in the Multi-Criteria Analysis. The results of the ranking and the resulting weight of each criterion is shown in Table 25.

Table 25: Weighting of selection criteria. Rank from 10 (most important) to 1 (least important). Rank values could be used only once.

Criterion	Avg. Points	Weight
Cost-effectiveness	8.00	14.55%
Up-Scaling Potential	7.33	13.33%
No-Regret Options (Risk Gradient)	6.83	12.42%
Co-Benefits (SDGs)	5.67	10.31%
Potential of Mal-Adaptation	5.33	9.69%
Stakeholder Interest	5.17	9.40%
Institutional Support Requirements	5.00	9.09%
Ecosystem-based adaptation (EbA)	4.50	8.18%
Alignment with Ethiopia's NAP	3.67	6.67%
Alignment with Existing Country Programs	3.50	6.36%

As a result, the criterion *Cost-Effectiveness* and *Up-scaling Potential* were given the highest weight. The criterion *Alignment with existing country programs* has been given the lowest weight, hence less significance for a potential adaptation measure. These weights (as of Table 25) have been used in a Multi-Criteria Analysis, to further reduce measures from the long list.

IV.iv Multi-Criteria Analysis - Defining a short list of Adaptation Measures

A Multi-Criteria Analysis (MCA) describes a structured approach used to determine overall preferences among alternative options, where the options accomplish several objectives. MCA is a type of decision analysis tool that is particularly applicable to cases where a single-criterion approach falls short (e.g. cost-benefit), and where multiple criteria need to be included.

The MCA has been applied to further shorten the list of measures (i.e. 37) and to conclude a short list that can be introduced to CLIMADA. Results of the MCA are shown and explained in Figure 28. The final short list of measures, as a result of the MCA, is shown in Table 26.

Table 26: Short list of drought adaptation measures for the Afar and Somali Region, based on the results from the Multi-Criteria Analysis (Figure 28). Measures are listed according to their respective type. 'Grey' measures refer to technological and engineering solutions. 'NbS' measures refer to ecosystem-based (or nature-based) approaches and make use of multiple services provided by natural ecosystems. 'Hybrid' measures consist of components of both, grey and NbS measures. NOTE: Independent of their low rank, Livestock- & Crop Index Insurance were added to the short list. Insurance represents a measure that is already embedded into CLIMADA, and can therefore be included without additional effort.

#	Name of Measure	Type of Measure
1	Wetland restoration and rehabilitation	NbS
2	Intercropping of trees with crops (Agroforestry)	NbS
3	Replanting of indigenous and improved fodder trees and grass species	NbS
4	Management of protected environmental areas	NbS
5	Establishment of fodder tree and grass nursery sites	Hybrid
6	Subsurface Dams in Riverbeds (Micro-Reservoirs)	Hybrid
7	Riverbank restoration	Grey
8	Improvement of water storage systems	Grey
9	Improved forage storage & treatment	Grey
10	Establishment of communal seed banks	Grey
11	Establishment & Rehabilitation of small- & medium sized irrigation systems	Grey
12	Livestock Index Insurance	Insurance
13	Crop Index Insurance	Insurance

Multi-Criteria Analysis Decision Matrix

	Measures	Type	Category	Stakeholder acceptance	Cost-Effectiveness	Up-scaling Potential	Existing country programs	Institutional Support	Mal-adaptation	Co-Benefits (for SDGs)	Resilient Green Economy (NAP)	No-Regret Options	EbA	Total Score	Short List
			Criteria: Weight	14,5	13,3	12,4	10,3	9,7	9,4	9,1	8,2	6,7	6,4	100	
34	**Wetland restoration and rehabilitation**	NbS	Water Conservation & Infrastructure	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	**1**	
24	**Tree-crop species intercropping**	NbS	Agroforestry	1,0	1,0	1,0	1,0	1,0	1,0	0,5	1,0	1,0	1,0	**0,95455**	
17	**Replanting of indigenious and improved fodder trees**	NbS	Range- & Cropland Management	1,0	1,0	1,0	1,0	1,0	0,5	1,0	1,0	1,0	1,0	**0,953**	
18	**Replanting of indigenious and improved grass varities**	NbS	Range- & Cropland Management	1,0	1,0	1,0	1,0	1,0	0,5	1,0	1,0	1,0	1,0	**0,953**	
19	**Establishment of fodder tree and grass nursery sites**	Hybrid	Range- & Cropland Management	1,0	1,0	1,0	1,0	0,5	1,0	0,5	1,0	1,0	1,0	**0,90609**	
5	**Shallow watering ponds/wells for livestock**	Grey	Water Conservation & Infrastructure	1,0	1,0	1,0	1,0	1,0	1,0	0,5	1,0	1,0	0,0	**0,89091**	
7	**Subsurface Micro-Reservoirs in Riverbeds**	Hybrid	Water Conservation & Infrastructure	1,0	1,0	1,0	1,0	1,0	1,0	0,5	1,0	1,0	0,0	**0,89091**	
35	**Riverbed restoration**	Grey	Water Conservation & Infrastructure	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	1,0	0,0	**0,85455**	
36	**Management of protected environmental areas**	NbS	Range- & Cropland Management	0,5	1,0	1,0	1,0	0,0	1,0	1,0	1,0	1,0	1,0	**0,83036**	
15	**Livestock enclosures**	NbS	Range- & Cropland Management	0,5	1,0	1,0	1,0	1,0	0,5	1,0	0,0	1,0	1,0	**0,79845**	
10	**Improvement of water storage systems**	Grey	Water Conservation & Infrastructure	1,0	1,0	1,0	1,0	0,5	1,0	0,0	1,0	1,0	0,0	**0,797**	
16	**Crop switching**	NbS	Range- & Cropland Management	0,5	1,0	1,0	1,0	1,0	0,5	0,5	1,0	0,0	1,0	**0,76809**	
21	**Improved forage (incl. seed) storage & treatment**	Grey	Range- & Cropland Management	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	1,0	0,0	**0,76364**	
23	**Establishment of forage hay producers' groups**	Grey	Range- & Cropland Management	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	1,0	0,0	**0,76364**	
20	Establishment of seed banks	Grey	Range- & Cropland Management	1,0	1,0	1,0	1,0	0,5	1,0	0,5	0,0	1,0	0,0	**0,76064**	
11	Improvement of water distribution facilities	Grey	Water Conservation & Infrastructure	1,0	1,0	1,0	1,0	0,5	1,0	0,0	0,0	1,0	0,0	**0,71518**	
12	Establishment of small- & medium sized irrigation systems	Grey	Water Conservation & Infrastructure	1,0	1,0	1,0	1,0	0,5	1,0	0,0	0,0	1,0	0,0	**0,71518**	
13	Rehabilitation and strengthening of existing small- & medium sized irrigation systems	Grey	Water Conservation & Infrastructure	1,0	1,0	1,0	1,0	0,5	1,0	0,0	0,0	1,0	0,0	**0,71518**	
1	Deep Boreholes	Grey	Water Conservation & Infrastructure	1,0	1,0	1,0	1,0	0,0	0,5	0,0	1,0	1,0	0,0	**0,70155**	
2	Shallow Boreholes	Grey	Water Conservation & Infrastructure	1,0	0,5	1,0	1,0	0,5	0,5	0,0	1,0	1,0	0,0	**0,68336**	
3	Construction of cisterns (birkas) for livestock	Grey	Water Conservation & Infrastructure	1,0	0,5	1,0	1,0	0,5	0,5	0,0	1,0	1,0	0,0	**0,68336**	
4	Construction of cisterns (birkas) for agriculture	Grey	Water Conservation & Infrastructure	1,0	0,5	1,0	1,0	0,5	0,5	0,0	1,0	1,0	0,0	**0,68336**	
26	Improved veterinary health support	Grey	Livestock Management	1,0	0,5	1,0	1,0	0,0	0,5	0,5	1,0	1,0	0,0	**0,68036**	
22	Community based rangeland management / rehabiliation	Grey	Range- & Cropland Management	1,0	0,5	1,0	0,0	0,5	1,0	0,5	1,0	1,0	0,0	**0,67273**	
9	Motorized Solar Pumps	Grey	Water Conservation & Infrastructure	1,0	1,0	1,0	1,0	0,0	0,0	0,0	1,0	1,0	0,0	**0,65455**	
27	Construction and rehabilitation of rural market and trade infrast	Grey	Market Access & Trade	1,0	0,5	1,0	1,0	0,0	0,5	0,0	1,0	1,0	0,0	**0,63491**	
6	Watershed Protection with bunds	Hybrid	Water Conservation & Infrastructure	0,0	1,0	1,0	1,0	1,0	0,5	0,5	1,0	0,0	0,0	**0,63173**	
30	Water Information System (WIS)	Grey	Monitoring	1,0	0,5	1,0	0,0	0,5	1,0	0,0	1,0	1,0	0,0	**0,62727**	
37	Capitalisation	Grey	Economic Resilience	0,5	0,5	1,0	1,0	1,0	0,5	0,5	0,0	1,0	0,0	**0,62273**	
33	Promotion of alternative farm and non-farm activities	Grey	Economic Resilience	0,5	0,5	1,0	1,0	0,5	0,5	0,0	1,0	1,0	0,0	**0,61064**	
14	Large-Scale Invasive Bush Clearing & Reseeding	Hybrid	Range- & Cropland Management	1,0	0,5	1,0	1,0	0,0	1,0	0,0	0,0	1,0	0,0	**0,60009**	
29	Monitoring Scheme for Rangeland Quality	Grey	Monitoring	1,0	0,5	0,0	0,0	0,5	1,0	0,0	1,0	1,0	0,0	**0,50309**	
31	Livestock Insurance	Insurance	Economic Resilience	0,5	0,5	1,0	1,0	0,0	0,5	0,0	1,0	0,0	0,0	**0,49545**	
32	Crop Insurance	Insurance	Economic Resilience	0,5	0,5	1,0	1,0	0,0	0,5	0,0	1,0	0,0	0,0	**0,49545**	
28	Climate-resistant road infrastructure (road access)	Grey	Market Access & Trade	1,0	0,0	0,0	1,0	0,0	0,5	0,0	1,0	1,0	0,0	**0,44409**	
25	Improved livestock production systems	Hybrid	Livestock Management	1,0	0,0	1,0	1,0	0,0	0,5	0,0	0,0	0,0	0,0	**0,41973**	
8	Portable Water Treatment Plants	Grey	Water Conservation & Infrastructure	1,0	0,5	1,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	**0,41809**	

Figure 28: Results of the MCA. The selection criteria have been applied to the remaining measures of the long list. The following values were applied to the criteria: Stakeholder acceptance [High = 1, Medium = 0.5, Low = 0], Cost-Effectiveness [High = 1, Medium = 0.5, Low = 0], Upscaling Potential [Yes = 1, No = 0], Existing country programs [Yes = 1, No = 0], Institutional support [High = 0, Medium = 0.5, Low = 1], Mal-adaptation [High = 0, Medium = 0.5, Low = 1], Cost-Benefits [High = 1, Medium = 0.5, Low = 0], Resilient Green Economy (NAP) [Yes = 1, No = 0], No Regret Options [Yes = 1, No = 0], EbA [Yes = 1, No = 0]. Measures indicated in 'red' are considered to be merged with other measures marked in 'green' to further reduce the short list. Measures indicated in 'green' representing the short list of identified measures.

Annex V *Description of Drought Adaptation Measures*

For both study areas, the Afar and Somali Region, 13 drought adaptation measures have been identified based on specific selection criteria (see Annex IV). The selection of measures is classified into different adaptation types, of which four are categorized as Nature-based Solutions (NbS), two as ‘hybrid’, indicating a mix of NbS elements combined with ‘grey’ infrastructure interventions. Five measures can be considered as solely ‘grey’ adaptation types, referring to engineered solutions. In addition, two types of ‘Insurance’ solutions focusing on agriculture and livestock have been selected. All measures have been introduced to the CLIMADA modelling tool. The list of selected measures is shown below in Table 27.

Table 27: Overview List of Drought Adaptation Measures for the Afar and Somali Region. ‘Grey’ measures refer to technological and engineering solutions. ‘NbS’ measures refer to ecosystem-based (or nature-based) solutions and make use of multiple services provided by ecosystems. ‘Hybrid’ solutions indicate a combination of NbS and Grey types of measures. ‘Insurance’ solutions cover residual risks, which occur when adaptation measures are not cost-efficient.

#	Name of Measure	Type of Measure
1	Wetland restoration and rehabilitation	NbS
2	Intercropping of trees with crops (Agroforestry)	NbS
3	Replanting of indigenous and improved fodder trees and grass species (Fodder Banks)	NbS
4	Management of protected environmental areas	NbS
5	Establishment of fodder tree and grass nursery sites	Hybrid
6	Subsurface Dams in Riverbeds (Micro-Reservoirs)	Hybrid
7	Riverbank restoration	Grey
8	Improvement of water storage systems	Grey
9	Improved forage storage & treatment	Grey
10	Establishment of communal seed banks	Grey
11	Establishment & Rehabilitation of small- & medium-sized irrigation systems	Grey
12	Livestock Index Insurance	Insurance
13	Crop Index Insurance	Insurance

V.i Context

The identified drought adaptation measures have been allocated to the respective agro-ecological zones (AEZ) of the Afar and Somali Region. The Ministry of Agriculture (MOARD) developed a system of agro-ecological based on temperature and moisture regimes. Each AEZ has characteristic crops found within it. These two main factors used to characterizing AEZ in the country are mainly governed by elevation (altitude). Further, the elevation is the prim determinant of agricultural land-use in Ethiopia as it influences the temperature and rainfall to some extent. The country has very diversified agro-ecologies that are difficult to correctly describe. Hence, the agro-ecology of the country has been divided into 33 major zones.[95] Based on these zones, five different AEZs have been identified for both regions as displayed in Figure 29: Hot arid lowland plains (A1), Warm semi-arid lowland plains (A2), Very cold sub-moist mid highlands (A3), Warm moist lowlands (M2) and Warm sub-moist lowlands (SM2).

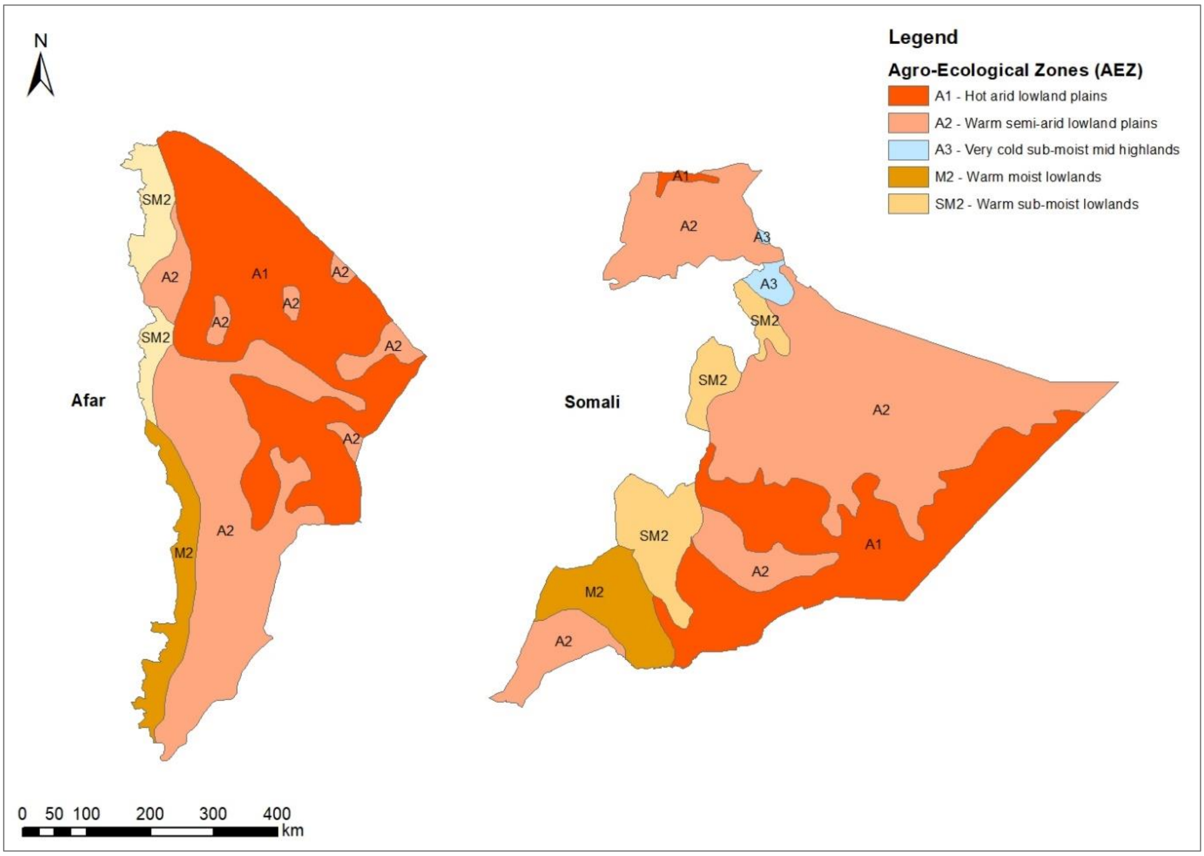

Figure 29: Overview of Agro-Ecological Zones (AEZs) for the Afar and Somali Region. The AEZs serve as zoning in which the drought adaptation measures be allocated. Source: UNU-EHS.

[95] EIAR (Ethiopian Institute of Agricultural Research). 2011. Coordination of National Agricultural Research System, Ethiopia. English and Amharic Version. EIAR, Addis Ababa.

V.ii Wetland restoration and rehabilitation

As of the Ramsar Convention definition[96], Wetlands can be defined as: "Areas of peatland, fen, marches, or water whether temporary, permanent, artificial or natural, with water that is flowing or static, salt, brackish, fresh or marine water, which does not exceed six meters at low tide." Further to this, in the Ethiopian context, floodplains, irrigation fields, valley bottoms, lake fringes, shallow vegetated areas, mountain seepages, plantations, and irrigation fields areas are categorized under 'wetlands'.[97]

Especially dryland wetlands are of key importance for regional biodiversity as they serve as habitat sanctuaries for aquatic and terrestrial biota in areas with very few resources. Periodical flooding events regulate the ecological diversity of wetlands as flows deliver water, sediment, and associated nutrients to the floodplain, flora, and fauna to reach floodplain environments or distant waterholes. During droughts, wetlands show resilience to limited water availability due to plant species either being drought-tolerant or able to re-establish when wet conditions return.[98] Dryland wetlands store water from precipitation and slowly release it to the surrounding environment, which can also recharge groundwater aquifers and maintain atmospheric water cycles. Evaporation and the transpiration of water from vegetation have a local cooling effect. Draining dryland wetlands reduce local water storage and can lead to increases in local daytime temperatures.[99]

Wetlands, either in their natural state or under wise use principles provide ranges of ecological and socio-economic benefits contributing in one way or another toward food security and poverty reduction. The role of wetlands is unique and vital with respect to food security as they save lives of humans, livestock and wildlife in the dry season and drought time.[100] Wetland edge springs are usually the only reliable sources of water both for domestic use and livestock especially in the dry months of the year, when many streams dry up. The value of wetlands ranges from tangible subsistence use and direct benefit such as providing drinking water. Generally, lack of awareness, draining for agriculture, overexploitation, deforestation, siltation, erosion and urbanization can be mentioned as major threats to wetlands in Ethiopia.[101] Many pastoral people and livestock herds flock and graze over the dry season in the Cheffa plain.

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[96] RAMSAR Convention, Art 1.1 and 2,1

[97] Giweta, M., & Worku, Y. (2018). "Reversing the Degradation of Ethiopian Wetlands": Is it Unachievable Phrase or A Call to Effective Action?. *International Journal of Environmental Sciences & Natural Resources*, *14*(5), 136-146.

[98] Sandi, S. G., Rodriguez, J. F., Saintilan, N., Wen, L., Kuczera, G., Riccardi, G., & Saco, P. M. (2020). Resilience to drought of dryland wetlands threatened by climate change. *Scientific reports*, *10*(1), 1-14.

[99] Erwin, K. L. (2009). Wetlands and global climate change: the role of wetland restoration in a changing world. *Wetlands Ecology and management*, *17*(1), 71.

[100] Jigar, N., Gebru, N., & Ayalew, N. (2016). Socio-economic values, threats and legal protection aspects of wetland ecosystem in Afar region, Ethiopia. *International Journal of Engineering Development and Research, 4*, 221-229.

[101] Ibid.

One of the major drivers of degradation in the Awash River Basin are excessive drainage of wetlands for agriculture purpose, e.g. for the expansion of development programs such as sugar or commercial cotton plantations and population and livestock increase. Additionally, groundwater abstraction, overgrazing, deforestation in the uplands and intensive agriculture in the lowlands and surface runoff are also the major causes for the decrease in the water table in the majority of wetlands that are found in the country.[102]

Prioritizing wetland protection and restoration can enhance climate adaptation and resilience and stabilize and maintain local water cycles, water supply and local microclimates. Incentives for local communities to apply sustainable wetland management practices efficiently should be encouraged, in alignment with relevant institutions to facilitate appropriate planning for the implementation of wetland conservation and restoration interventions. Actions to restored and sustainably managed wetlands for resilient livelihoods and sustain ecosystems include:

I Restoration and management of wetland hydrology and associated forests/shrub-land
  a) Strengthened wetlands management practices, such as control of invasive species vegetation
  b) Small-scale water storage and detention facilities designed and constructed or rehabilitated in critical waterways for communities to benefit from enhanced ecosystem functioning
  c) Degraded catchment areas rehabilitated and land productivity improved (e.g. with controlled and prevented pollutions)
  d) Effective wetland laws and policies
II Improved agricultural practices and alternative livelihood options in the wetland catchment
  a) Crop diversification and resilient agricultural best practice adopted
  b) Economically viable and sustainable agro-based livelihood and income-generating interventions introduced, promoted and supported in the wetland and immediate catchment
  c) Controlled extraction of environmental goods (harvesting)
III Enhancing knowledge management and information sharing to facilitate community-based wetland restoration activities
  a) Good practices and lessons learned in sustainable wetlands restoration, management and innovative livelihood options documented and disseminated

Potential costs for the above-mentioned components of wetland restoration are based on international funding proposals, e.g. Green Climate Fund. A brief overview of the costs are shown in Table 28 below.

[102] Giweta, M., & Worku, Y. (2018). "Reversing the Degradation of Ethiopian Wetlands": Is it Unachievable Phrase or A Call to Effective Action?. *International Journal of Environmental Sciences & Natural Resources*, *14*(5), 136-146.

Table 28: Overview of costs for wetland ecosystem restoration.[103]

Component	Costs in USD/ha
Restoration and management of wetland hydrology and associated forests/shrub-land	2 066
Improved agricultural practices and alternative livelihood options in the wetland catchment	1 306
Enhancing knowledge management and information sharing to facilitate community-based wetland restoration activities	466
TOTAL	3 838

In the **Afar Region**, the Awash Basin will subject to wetland ecosystem restoration. The Awash basin wetlands consist of a total area of 11 000 000 ha, incl. Lake Besaka and Gedebassa. Within the basin, the focus area will be the wetlands of Lake Afambo, Gamari and Abbe and the Gedebassa swamp. The Lake Abe wetland complex comprises several saline lakes such as Gamari, Afambo, Bario and Abe. All these lakes lie to the east of Asaita, the regional capital. Lake Afambo is about 30 km east of Asaita, and Lake Abe is on the eastern border with Djibouti, 600 km north-east of Addis Ababa (see Figure 30).[104] It is intended to define 150 ha for wetland restoration. The total establishment costs for 150 ha are 575 700 USD. Annual operation and maintenance costs represent 1.5% of total construction cost and are defined with 8 635 USD. Over 31 years until 2050, this represents 259 050 USD.[105] Both costs combined result in total costs of 834 750 USD.

[103] Source: GCF 2019, derived from https://www.greenclimate.fund/sites/default/files/document/funding-proposal-fp034-undp-uganda.pdf

[104] Mengistu, W. (2018). A First Directory of Ethiopian Wetlands: Description, Ecosystem Services, Causes of Degradation & Recommendations for Restoration and Sustainability.

[105] Costs for establishment: 1 919 USD * 150 ha = 287 850 USD. Operation and Management (1.5%): 4 317 USD*30 years = 129 510 USD.

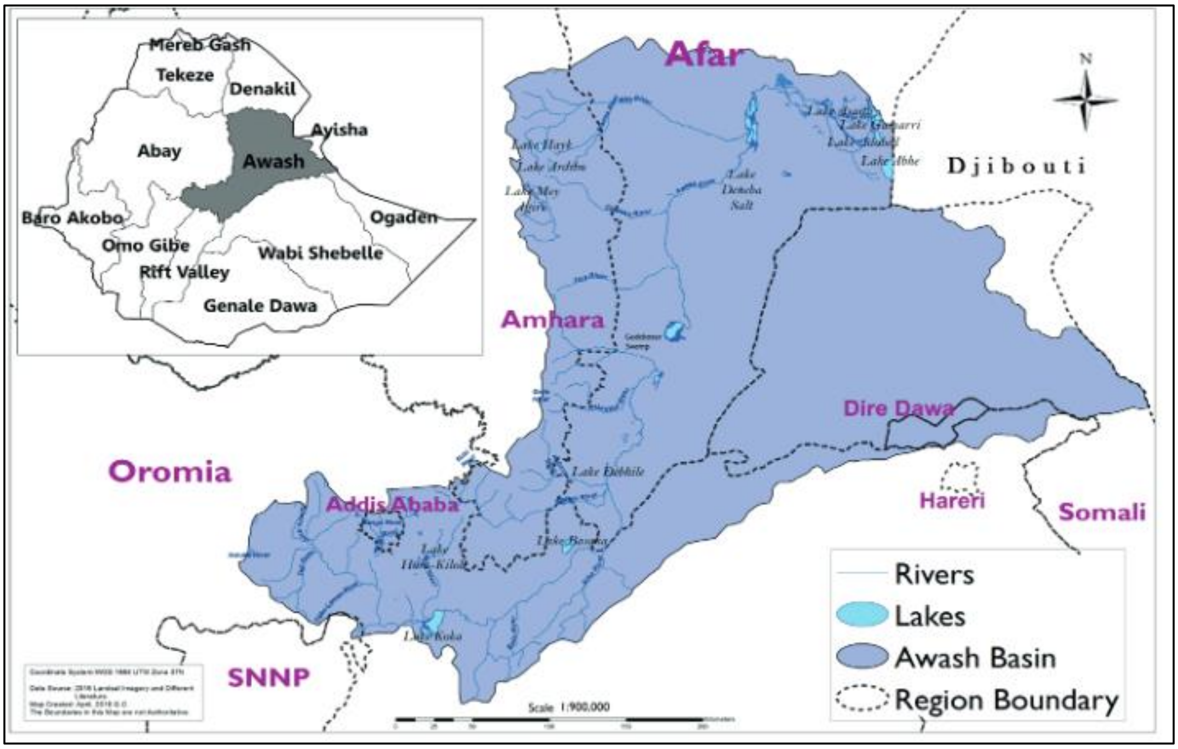

Figure 30: Overview of Lakes and Rivers in the Awash Basin. Source: Mengistu (2018).

In the Somali Region, two wetlands have been selected, the Ayisha and Shebelle Basin. The Ayisha basin (ca. 222 300 ha) is a dry basin and borders Djibouti in the north and Somalia Republic in the south and east (Figure 31). In the Ayisha basin, 50 ha are subject to restoration. The total establishment costs for 75 ha are 287 850 USD. Annual operation and maintenance costs represent 1.5% of total construction cost and are defined with 4 317 USD. Over 31 years until 2050, this represents 129 510 USD. Both costs combined result in total costs of 417 360 USD.

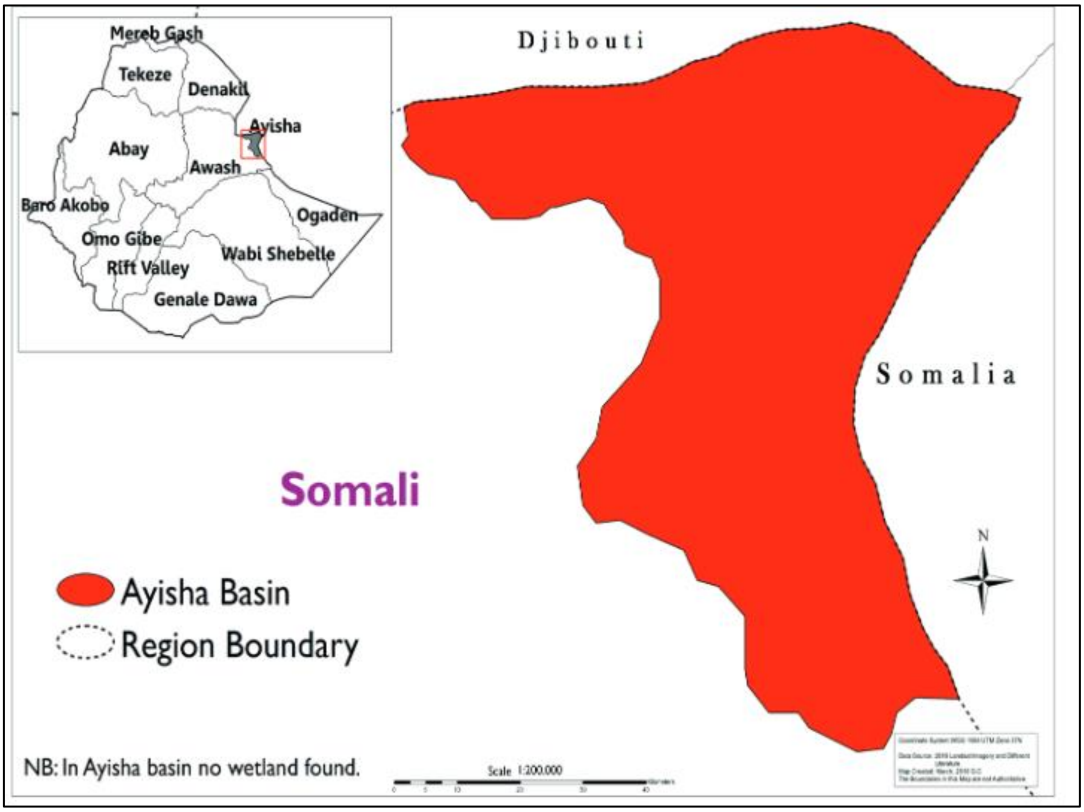

Figure 31: Overview of Rivers and Lakes in the Ayisha Basin. Source: Mengistu (2018).

The Shebelle River in central Somali Region forms the Shebelle basin. Rising between the Arsi and Bale mountains, it curves round the Bale massif and flows south-east to Somalia (Figure 32 and Figure 33). Without the Shebelle, vast areas of the southwestern Somalia Region would be devoid of plants, animals and life-forms, as such the river and its numerous wetlands are the only source of biodiversity and livelihoods in the region which is partially degraded due to increased water abstraction for irrigation agriculture. The Shebelle wetlands, situated in an arid environment, provide potable water, fish, vegetation and habitat for people, domestic animals and wildlife. The river and its floodplains are a rich source of biodiversity and have regulatory functions to maintain rainfall and moderate climate.106 In the Shebelle Basin, 75 ha are targeted to the restored. The total establishment costs for 75 ha are 287 850 USD. Annual operation and maintenance costs represent 1.5% of total construction cost and are defined with 4 317 USD. Over 31 years until 2050, this represents 129 510 USD. Both costs combined result in total costs of 417 360 USD.

[106] Mengistu, W. (2018). A First Directory of Ethiopian Wetlands: Description, Ecosystem Services, Causes of Degradation & Recommendations for Restoration and Sustainability.

Table 29: Overview of costs for wetland restoration in the Afar and Somali Region.

Region for Wetland Restoration	Total Cost in USD (for 3031 years, incl. construction & maintenance)
AFAR Region (Awash basin)	834 750
SOMALI Region (Ayisha & Shebelle basin)	834 750
TOTAL	**1 279 940**

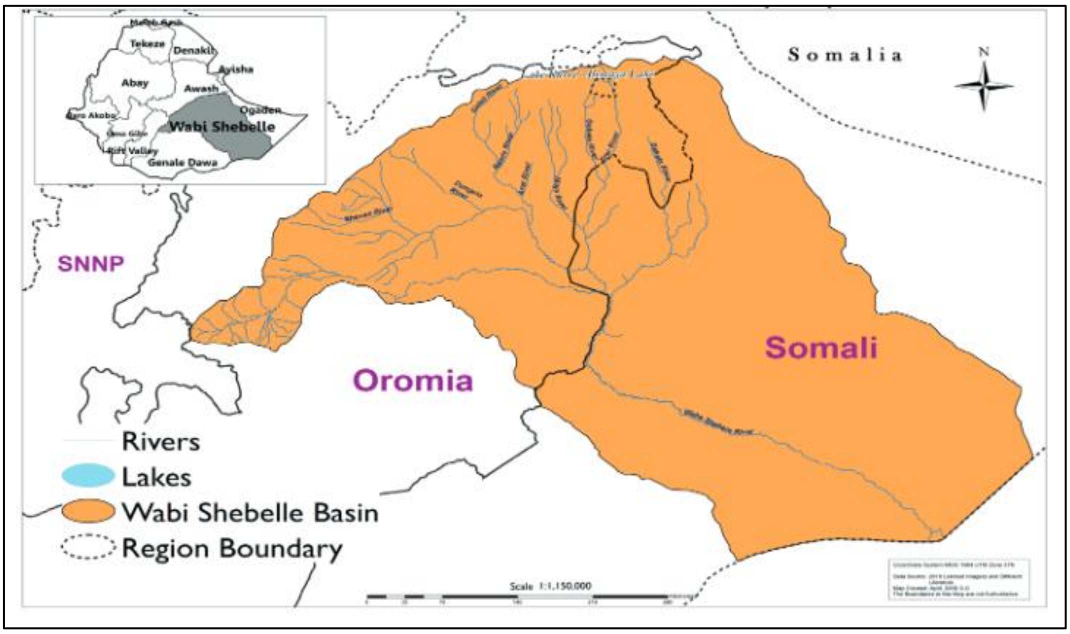

Figure 32: Overview of Rivers and Lakes in the Shebelle Basin. Source: Mengistu (2018).

Figure 33: Wetlands at lower plain areas of Shebelle River. Source: Mengistu (2018).

V.iii Intercropping of trees with crops (Agroforestry)

This measure promotes the introduction of an agroforestry system. In general, agroforestry is a collective name for land-use systems in which woody perennials (trees, shrubs, etc.) are grown in association with herbaceous plants (crops, pastures) or livestock, in a spatial arrangement, a rotation, or both; there are usually both ecological and economic interactions between the trees and other components of the system".[107] This measure will promote an agri-silvicultural system, referring to systems consisting of trees and crops.

In tree-crop land-management practices, trees are deliberately retained on or around farmlands, to support agriculture and other livelihood systems. Intercropping tree species within an agricultural system improves water use efficiency by reducing unproductive components of the water balance, such as run-off, soil evaporation and drainage. Incorporating trees into agricultural systems also shows effects on groundwater recharge. Some cropping systems in semi-arid areas often cannot fully utilize available rainfall due to losses by evaporation from the soil surface, runoff and drainage. Crop roots in drier surface soil may benefit from hydraulic lift of water by trees from wetter soil at depth. In semi-arid climates, soil water content under tree canopies can be higher than in open pasture due to reduced evapotranspiration in the tree shade out-weighing water uptake by plants.[108,109] Nonetheless, the success of agroforestry in semi-arid areas depends on efficient use of available water and effective strategies to limit tree/ crop competition.

Approximately 40% of the rainfall received by a watershed in Niger was lost to soil evaporation and 33–40% to deep drainage, with the smallest proportion of 6–16% being used for transpiration by pearl millet. Such studies indicate that high proportions of potentially available water, which are lost to biological production, might be captured by incorporating trees into land use systems, although effects on groundwater recharge may also need to be considered. In addition, many trees in agroforestry systems capture water resources that would not be put to productive use in the absence of trees, mainly from deep soil layers beyond the reach of annual crops. Crop roots in drier surface soil may benefit from hydraulic lift of water by trees from wetter soil at depth, either at night when transpiration is low or during the day along water potential gradients driven by variation in soil salinity. A particular challenge is the quantitative estimation of the combined effects of microclimate modification and shading on understory crop growth. While reduced photosynthetically active radiation through shading often has negative

[107] Lundgren, B., Introduction [Editorial].Agroforestry Systems, 1982. 1: p. 3-6.

[108] Benavides, R., G.B. Douglas, and K. Osoro, Silvopastoralism in New Zealand: review of effects of evergreen and deciduous trees on pasture dynamics. Agroforestry Systems, 2009. 76: p. 327-350.

[109] Joffre, R. and S. Rambal, How tree cover influences the water balance of Mediterranean rangelands. Ecology, 1993. 74(2): p. 570-582.

implications for crop growth, higher air humidity and reduced temperature have positive effects in hot climates.[110]

Generally, either in the long-term or short-term, agroforestry practices have an attractive financial incentive for the improvement of the livelihood of the farm households or minimizing the prevailing ecological problems such as land degradation.[111]

Many different tree species are used in Ethiopian agroforestry systems. The species composition of an agroforestry system in Ethiopia depends on characteristics of the respective household, e.g. gender, market access and local social capital, as different agroforestry systems require different amounts of labour and market access may determine whether high value crops, such as coffee are grown. Depending on the tree species, agroforestry systems also offer value for preserving biodiversity and offering ecosystem services.[112]

In this scenario it is assumed to plant maize hedgerow intercropped with trees, taking a 10x10 meter spacing, representing 100 trees planted per hectare on a rectangular grid. It is intended to plant the tree species *Sesbania sesban* in agroforestry systems for contour forage banks or hedgerows. It is aimed to promote 1450 ha of agroforestry system in each region, reaching circa 4 000 households, assuming an average field size per household of 0.25 ha. For this *Sesbania sesban* trees are interplanted in 10 meter wide alleys (10x10 meters = 100 trees/ha) in combination with maize (2x2.5 meters = 2 000 plants/ha). Based on this planting pattern, the costs for planting 100 tress/ha is 227 USD (incl. transport, site preparation, labour) and 150 USD for maize, resulting in a total cost of 377 USD/ha. In both, Afar and Somali region, 2 900 ha (1450 ha each) are planned to be converted into agroforestry systems.[113,114] This results in a total cost of 1 093 060 USD (546 530 USD per region). This already includes annual operation and maintenance (1.5%) costs of 8 197 USD over 31 years.

Table 30: Overview of costs for establishing agroforestry systems in the Afar and Somali Region.

Region for Agroforestry	Total Cost in USD (for 31 years, incl. construction & maintenance)
AFAR Region *(500 ha)*	546 530
SOMALI Region *(500 ha)*	546 530
TOTAL	**1 093 060**

110 Luedeling, E., Smethurst, P. J., Baudron, F., Bayala, J., Huth, N. I., Van Noordwijk, M., & Sinclair, F. L. (2016). Field-scale modeling of tree–crop interactions: Challenges and development needs. Agricultural Systems, 142, 51-69.

111 Duguma, L. A. (2013). Financial analysis of agroforestry land uses and its implications for smallholder farmers livelihood improvement in Ethiopia. *Agroforestry systems*, *87*(1), 217-231.

112 Murken, L., Cartsburg, M., Chemura, A., Didovets, I., Gleixner, S., Koch, H., & Gornott, C. (2020). Climate Risk Analysis for Identifying and Weighing Adaptation Strategies in Ethiopia's Agricultural Sector.

113 Iraola, J., Luis, J., & Moreira, E. (2012). Maize (Zea mays) intercropping in a silvopastoral system with Brachiaria hybrid cv. Mulato and Leucaena leucocephala cv. Peru. *Cuban Journal of Agricultural Science*, *46*(3).

114 Jenkins, G. P., Miklyaev, M., & Pankowska, K. (2014). A Cost-Benefit Analysis Of Small Scale Red Haricot Beans Production In Ethiopia: Intercropping As A Risk Diversification Mechanism (No. 2013-14). JDI Executive Programs.

Figure 34: Example of hedgerow intercropping systems with maize.

V.iv Replanting of indigenous and improved fodder trees and grass species (Fodder Banks)

Fodder and feed improvement is regarded as a promising adaptation strategy that, according to interviewed experts, has high potential for upscaling in Ethiopia. Fodder and feed improvement is an umbrella term subsuming different strategies and technologies to improve nutritional quality, digestibility, quantity and availability of fodder and feed resources for livestock production. This could include the implementation fodder banks with improved forages and fodder trees.

It is advised to establish high-quality fodder trees, such as *Sesbania sesban* and Napier grass (*Pennisetum purpureum)* as a fodder grass for smallholder dairy production in a cut-and-carry production system. The aim of the introduction of Napier grass and *Sesbania sesban* is to increase feed quantity and quality especially during the dry season to subsequently improve animal health and stabilize and increase milk yields under climate change. In addition, studies showed that supplementation of *Sesbania sesban* to grass or straw based diet fed to different ruminant animal species increased the dry matter (DM) intakes.[115] Fodder banks should be ideally maintained through community members, either in organised agricultural or livestock associations or other systems abundant in communities or villages. It is also advised to support the establishment and maintenance of fodder banks with agricultural extension services, at least for a certain time shortly after the introduction.

[115] Mekoya, A., Oosting, S. J., Fernandez-Rivera, S., Tamminga, S., Tegegne, A., & Van der Zijpp, A. J. (2009). Effect of supplementation of Sesbania sesban on reproductive performance of sheep. *Livestock Science*, *121*(1), 117-125.

It is intended to establish in every region 400 ha of fodder banks (800 ha in both regions). This involves the following costs[116]:

- Land preparation: 33 USD/ha
- 20 kg *Pennisetum purpureum* grass seed per ha (8.15 per kg): 163 USD/ha
- 3300 (2m x 1.5m) tree saplings of *Sesbania sesban* per ha: 227 USD/ha
- Annual weed and pasture management: 37 USD/ha
- Total costs: 461 USD/ha

The mean dry matter (DM) yield of *Sesbania sesban* is 4-12 tons/DM/ha/year.[117] Hence, we assume an average yield of 8 tons/DM/ha/year. In a cut-and-carry system, *Sesbania sesban* can be cut when it is 1-2 meters high, with a frequency of usually 5 times a year. For an area of 400 ha per region, it is expected to achieve DM yields of 3200 tons per year.

With no, or inadequate, fertilizer, yields for *Pennisetum purpureum* are in the range of 2-10 tons/DM/ha/year.[118] Hence, we assume an average yield of 6 tons/DM/ha/year Cuttings can be made at 45-90 day intervals. For an area of 400 ha per region, it is expected to achieve DM yields of 2400 tons per year.

In each region establishment costs for 400 ha consist of 184 400 USD. Annual weed and pasture management activities account for 444 000 USD for 31 years.[119] In total, fodder bank establishment in each region costs 628 400 USD (Table 31).

Table 31: Overview of costs to establish fodder banks in the Afar and Somali Region.

Region / Fodder Banks	Total Cost in USD (for 31 years, incl. construction & maintenance)
AFAR Region *(400 ha)*	628 400
SOMALI Region *(400 ha)*	628 400
TOTAL	**1 256 800**

[116] Manyeki, J. K., Kirwa, E. C., Ogillo, P. B., Mnene, W. N., Kimitei, R., Mosu, A., & Ngetich, R. (2015). Economic analysis of natural pasture rehabilitation through reseeding in the southern rangelands of Kenya. *Livestock Res. for Rural Development*, *27*(3), 49-61.

[117] Heering, J. H.; Gutteridge, R. C., 1992. *Sesbania sesban* (L.) Merrill. Record from Proseabase. Mannetje, L.'t and Jones, R.M. (Editors). PROSEA (Plant Resources of South-East Asia) Foundation, Bogor, Indonesia

[118] FAO, 2015. Grassland Index. A searchable catalogue of grass and forage legumes. FAO, Rome, Italy

[119] Construction: 200 ha * 461 USD = 92 200 USD. Annual weed and pasture management: 200 ha * 37 USD * 30 years = 222 000 USD.

Figure 35: Example of Napier grass (left) and Sesbania sesban (right).

V.v Management of protected environmental areas (Exclosures)

Exclosures are areas closed from the human and domestic animals interferences with the goal of promoting natural regeneration of plants and reducing land degradation of formerly degraded communal grazing lands. Exclosures are common land areas, which are traditionally 'open access', where woodcutting, grazing and other agricultural activities are forbidden or strictly limited to promote restoration and natural regeneration.[120] The effects of exclosures on the recovery of woody species diversity, population structure, and regeneration status, restoration of soils, and restoration of ecosystem carbon stocks have been well studied in the past.[121,122,123] Several studies show exclosures to be efficient tools in terms of soil and water conservation in enhancing water infiltration.[124]

Exclosures can range commonly from 1 ha to 700 ha in size.[125] Exclosures are normally established in eroded and degraded areas that have been used for grazing in the past. Normally exclosures are not fenced, in this case, guards are often hired by local administrations or managed by communal organizations. In many cases, exclosure management and protection have proven to be effective when the local community plays an active role under the overall authority of the local administration.[126] Exclosures are often managed within a rotational system, which defines the closure and accessibility for livestock activities. In some cases, so-called *Kallos* enclosures, are areas that are reserved for lactating, sick or young animals, so that these animals do not have to travel the much larger distances traveled by the rest of the herd for pasture particularly in the dry season.

In general, there are two exclosure management strategies for rehabilitation. The biological strategy simply protects an exclosure against livestock and human interference, with no additional management required. Ecological succession arises from buried or dispersed seeds. The assisted strategy involves planting seedlings and the construction of soil and water conservation structures, such as stone bunds

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[120] Atsbha, T., Wayu, S., Gebretsadkan, N., Giday, T., & Gebremariam, T. (2020). Exclosure land management for restoration of herbaceous species in degraded communal grazing lands in Southern Tigray. *Ecosystem Health and Sustainability*, *6*(1), 1829993.

[121] Kindeya, G. 2003. "Ecology and management of Boswellia papyearifera (Del.) Hochst. Dry forests in Tigray, Northern Ethiopia." Doctoral Dissertation. Georg-August University of Göttingen. Germany. pp. 182.

[122] Aerts, R. , T.Wagendrop, E.November, B.Mintesinot, J.Deckers, and B.Muys . 2004. "Ecosystem thermal buffer capacity as an indicator of the restoration status of protected areas in the Northern Ethiopian Highlands." Restoration Ecology 12 (4): 586–596. doi:10.1111/j.1061-2971.2004.00324.x.

[123] Tefera, M. , T.Demel, H.Hulten, and Y.Yonas . 2005. "The role of enclosure in the recovery of woody vegetation in degraded dryland hillsides of central and northern Ethiopia." *Journal of arid environments* 60 (2): 259–281.

[124] Birhane, E., Mengistu, T., Seyoum, Y., Hagazi, N., Putzel, L., Rannestad, M. M., & Kassa, H. (2017). Exclosures as forest and landscape restoration tools: lessons from Tigray Region, Ethiopia. *International Forestry Review*, *19*(4), 37-50.

[125] Nedessa, B.; Ali, J.; Nyborg, I. 2005. Exploring ecological and socio-economic issues for the improvement of area enclosure management: A case study from Ethiopia. DCG Report No. 38. Oslo, Norway: Drylands Coordination Group (DCG).

[126] Mekuria, W., Gebregziabher, G., & Lefore, N. (2020). Exclosures for landscape restoration in Ethiopia: business model scenarios and suitability (Vol. 175). IWMI.

and micro-basins, to speed up succession by modifying microclimatic and soil conditions. Grass harvesting is normally restricted in exclosures to restore the soil seed bank. The establishment of exclosures is relatively easy and inexpensive, requiring less investment in planting material, site preparation and management compared with plantation establishment.[127] The basic costs related to establishing and maintaining exclosures, other than the opportunity cost of setting land aside, are payments to guards employed to prevent incursion by people or livestock. Exlclosures should restrict access for at least 5 years to allow an optimum regeneration of trees, shrubs and grasses.

In both regions, Afar and Somali are 1 000 ha of exclosure areas planned. The costs for a 1 000 ha exclosure are as follows[128]:

Establishment Costs for 1 000 ha:

- Labour (85 person-days): 12 160 USD
- Equipment/Tools: 2 320 USD
- Construction material (fencing): 90 346 USD
- Total: 104 826 USD

Annual Operation and Maintenance Costs for 1 000 ha per year:

- Labour (guards): 6 346 USD
- Construction Materials (e.g. fencing, tools, etc.): 20 426 USD
- Total: 26 772 USD

For each region, construction costs consist of 104 826 USD. In addition, annual operation and maintenance costs are defined to be 26 772 USD, which represents 803 160 USD for 31 years. In total, for each region, the costs of exclosure management are 907 986 USD.

Table 32: Overview of costs for exclosure management in the Afar and Somali Region.

Regions for Exclosure Management	Total Cost in USD (for 31 years, incl. construction & maintenance)
AFAR Region *(1000 ha)*	907 986
SOMALI Region *(1000 ha)*	907 986
TOTAL	**1 815 972**

[127] Birhane, E., Mengistu, T., Seyoum, Y., Hagazi, N., Putzel, L., Rannestad, M. M., & Kassa, H. (2017). Exclosures as forest and landscape restoration tools: lessons from Tigray Region, Ethiopia. *International Forestry Review*, *19*(4), 37-50.

[128] FAO. 2008. Sustainable Land Use in Practice .Pastoralism and Rangeland Management. Derived from http://www.fao.org/3/i1861e/i1861e10.pdf (14.12.2020).

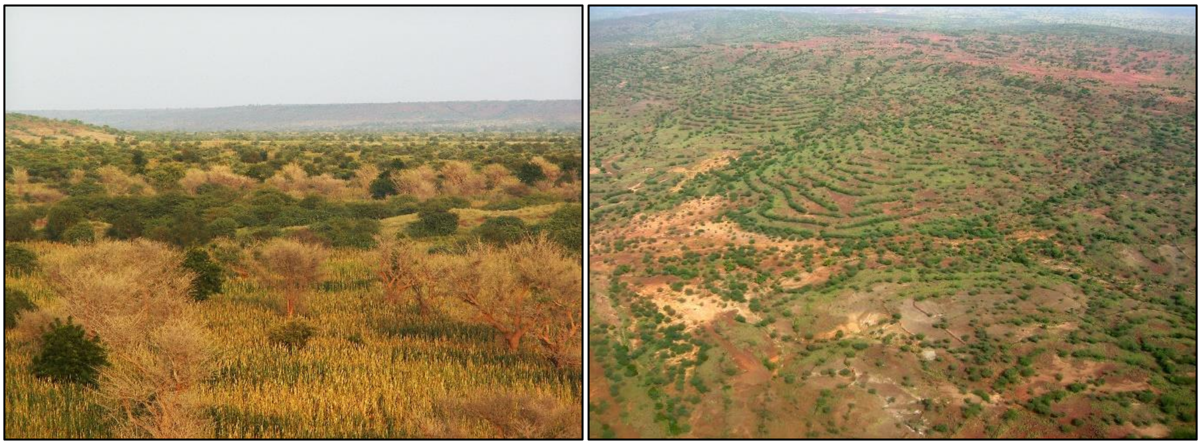

Figure 36: Examples of areas closed livestock and human interference for natural rehabilitation and regrowth.

V.vi Establishment of fodder tree and grass nursery sites

Livestock subsisting on rangelands often requires supplementation. Conventional bought-in supplements are expensive and fodder trees and shrubs have been integrated within some farming systems. The main constraint to improved livestock productivity is the poor quality and insufficient supply of fodder, particularly during the long dry season. The decrease in livestock numbers is partially also a result of reductions in forest and fodder resources. An important contribution of fodder trees to the farming system is in providing a store of green and nutritious fodder for the dry season as a supplement to crop residues which usually do not supply sufficient levels of nutrients to meet basic maintenance requirements. Hence, the actual and potential role of fodder trees to livestock production and productivity and the sustenance of farming systems is crucial.

Nurseries with a focus on productive and drought-tolerant indigenous and introduced seeds of forage and tree species are established. In Ethiopia, *Sesbania sesban* is the most important planted fodder tree and is generally grown in home gardens.[129] Other species could include *Panicum*, Rhodes, *Acacia polysantha*, others such as pigeon pea, cow pea, papaya, bamboo, elephant grass, various acacia species (*Acacia Abysinica*, *Acacia Tortois*, *Acacia Seyal*). Fodder tree and grass nursery sites are established and managed accordingly, ideally by communities. Nursery sites should be fenced and appropriately equipped with

[129] Franzel, S., Carsan, S., Lukuyu, B., Sinja, J., & Wambugu, C. (2014). Fodder trees for improving livestock productivity and smallholder livelihoods in Africa. Current Opinion in Environmental Sustainability, 6, 98-103.

nursery tools and planting materials. Each nursery site should include the construction and rehabilitation of irrigation canals, water storage ponds to enable a permanent production of seedlings and fodder seeds.

It is intended to implement 100 ha of nurseries in each region. The costs for a nursery include 12 species with two types of germplasm. Total costs per ha/year are as follows.[130]

Assuming 6 species as *seeds* in seedbeds with a density of 4 500 plants per hectare:

- Nursery materials, such as containers, media, fertilizer and rooting hormone: 218 USD/ha
- Labour: 100 USD/ha
- Sub-Total: 318 USD/ha

Assuming 6 species as *cuttings* in growing bags with a density of 2 500 plants per hectare

- Nursery materials, such as containers, media, fertilizer and rooting hormone: 552 USD/ha
- Labour: 100 USD/ha
- Sub-Total: 652 USD/ha

The total cost per hectare, incl. 6 species of seeds and 6 species of cuttings are 970 USD/ha/year. Hence, in each region, the construction and operation of nurseries with a total amount of 100 ha over 31 years cost 3 007 000 USD.[131]

Table 33: Overview of costs for the establishment of nurseries in the Afar and Somali Region.

Regions for Nurseries	Total Cost in USD (for 31 years, incl. construction & maintenance)
AFAR Region *(100 ha)*	3 007 000
SOMALI Region *(100 ha)*	3 007 000
TOTAL	**6 014 000**

[130] Neff, D., Kettle, C., & Gotor, E. (2019). Costs of tree seed and seedling supply systems. The cost of integrating genetic diversity into forest landscape restoration.

[131] 970 USD * 100 ha * 31 years = 3 007 000 USD

Figure 37: Example of tree and grass nursery sites in Ethiopia.

V.vii Subsurface Dams in Riverbeds (Micro-Reservoirs)

A key source in arid and semi-arid areas is shallow groundwater from seasonal sandy streams, especially during dry periods. During poor rainfall years, when all other water sources have dried up, water can still be found in seasonal sandy streams. Seasonal sandy streams collect runoff water during wet periods, which is naturally stores in the sandy sediments of the riverbed. A subsurface dam (SSD) in a riverbed is also referred to as groundwater or sand storage dam and is a micro-catchment technology to harvest and store rainwater, which is built on seasonal sandy streams in rural arid and semi-arid areas. SSDs can be considered as hydraulic retention structures built on underground dikes to block shallow groundwater flow during wet periods. They are designed to increase the water yield of an already existing shallow groundwater reservoir, thereby, increasing the volume of water yielded during dry periods and their accessibility for local communities. SSDs can raise the shallow groundwater level in seasonal sandy streams, but only up to one meter below the surface to minimize evaporation losses.[132] Subsurface dams are regularly applied to store alluvial groundwater. One of the most efficient ways of keeping and rationally utilizing the water in arid areas is to construct subsurface dams. This kind of structure, commonly located near the springs where the perennial or temporary streams originated, is regularly applied to store alluvial groundwater. Subsurface dams belong to specific groundwater storage structures.[133] Generally, well-designed subsurface dams in suitable locations, show high cost-efficiency. High volumes of water as low costs over a significant lifespan taking into account capital investment costs,

[132] De Trincheria, J. (2017). Best Practices on the Use of Rainwater for Off-season Small-scale Irrigation: Fostering the Replication and Scaling-up of Rainwater Harvesting Irrigation Management in Arid and Semi-arid Areas of Sub-Saharan Africa: AFRHINET: a Technology Transfer Network on Rainwater Harvesting Irrigation Management in Rural Arid and Semi-arid Areas of Sub-Saharan Africa. Hamburg University of Applied Sciences.

[133] Stevanović, Z. (2016). Damming underground flow to enhance recharge of karst aquifers in the arid and semi-arid worlds. *Environmental Earth Sciences*, *75*(1), 35.

and compared to other community-based rainwater harvesting technologies. Dams can ideally support communal livelihood models during dry periods, such as livestock, agriculture and horticulture. Also, dams have the potential to reduce the erosive action of floods and increase the retention and infiltration of runoff, mainly due to the reduction of the gradient of the original riverbed.[134] The most common way of constructing a subsurface dam is to build a dam in a trench excavated across a valley or riverbed. The earthwork involved may be carried out by manual labour since the excavation depths are generally not more than 3-6 meters. Subsurface dams are generally constructed at the end of the dry season when there is little water in the aquifer or stream. In most cases, the crest of a subsurface dam is kept at some depth from the surface. This is partly to avoid waterlogging in the upstream area, and partly to avoid erosion damage to the dam. A common distance from the dam crest to the surface is about one meter.[135] Each river is different and therefore the design of a dam has to be appropriate to the situation. The best situation is where the riverbed slopes gently and any dam installed will cause the water to be held up for a considerable distance upstream. Sand dams require high banks or wing walls to prevent floodwater from cutting around the side. Riverbanks must be well-defined and stable. Rocky banks and gorges are the best features. Wide meandering rivers in the sand are an indication that no lateral confinement is present and so the risk of lateral flow and leakages is high. A minimum topographic riverbed slope is required. Suitable gradients lie between 0.2% and 4%.[136] The dams can be constructed by using local materials such as clayey soil but also stone masonry or concrete.[137] Water can be drawn by wells (e.g. hand dug wells) constructed upstream to abstract the stored water from the aquifer. Wells should be situated on the inner side of bends in riverbeds to get a recharge through old sand deposits and for protection against floods. Insufficient recharge can be improved by an infiltration pipe.

It is planned to realize 50 subsurface dam projects in reach region, i.e. in the Awash (Afar) and Shebelle basin (Somali). The costs below are representing a concrete subsurface dam construction of 36 meters across a riverbed and a 1 meter wide strip which is excavated.

Table 34: Overview of costs for the construction of a concrete subsurface dam in 36 meters of length. Source: Frontieres (2006)[138].

Construction materials (concrete SSD)	Quantity	Cost (USD)
Ordinary cement	85 bags	1 532.60
Chicken mesh	15 rolls	1 185.86
Polythene sheet	120 m	249.66
Timber 8" x 1"	80 m	166.44

134 Trincheria, J., & Otterpohl, R. (2018). Towards a universal optimization of the performance of sand storage dams in arid and semi-arid areas by systematically minimizing vulnerability to siltation: A case study in Makueni, Kenya. *International Journal of Sediment Research*, *33*(3), 221-233.

135 Hanson, G., & Nilsson, Å. (1986). Ground-Water Dams for Rural-Water Supplies in Developing Countries. *Groundwater*, *24*(4), 497-506.

136 Frontieres, V. S. (2006). Subsurface Dams: A Simple. *Safe and Affordable Technology for Pastoralists*, 1-56.

137 Ethiopian Ministry of Water, Irrigation and Electricity. Operation and Maintenance Requirements for Pastoral areas Water Supply Facilities

138 Frontieres, V. S. (2006). Subsurface Dams: A Simple. *Safe and Affordable Technology for Pastoralists*, 1-56.

Timber 3" x 2"	30 m	41.60
Wire nails 4"	5 kg	9.70
Wire nails 3"	5 km	9.70
Binding wire	15 kg	41.60
Waterproof cement	85 kg	188.62
Hand tools		739.80
Skilled labour for 42 days		2 746.18
Community incentives for mobilization		668.52
Subtotal		**7 580.30**
Community contribution (concrete SSD)	**Quantity**	**Cost (USD)**
Hardcore	28 tons	388.34
Ballast	33 tons	485.44
Building sand	34 tons	485.44
Clay/Anthill soil	110 bags	305.14
1 security guard for 42 days		466.02
Storage structure		68.00
Access road clearing		277.40
Subtotal		2 477.12
TOTAL		**10 057.42**

The total cost of construction for each region and 50 projects is 502 871 USD.

Table 35: Overview of costs for the construction of concrete subsurface dams in the Afar and Somali Region.

Regions for Subsurface Dams	Total Cost in USD (for 31 years, incl. construction & maintenance)
AFAR Region (50 projects)	502 871
SOMALI Region (50 projects)	502 871
TOTAL	**1 005 742**

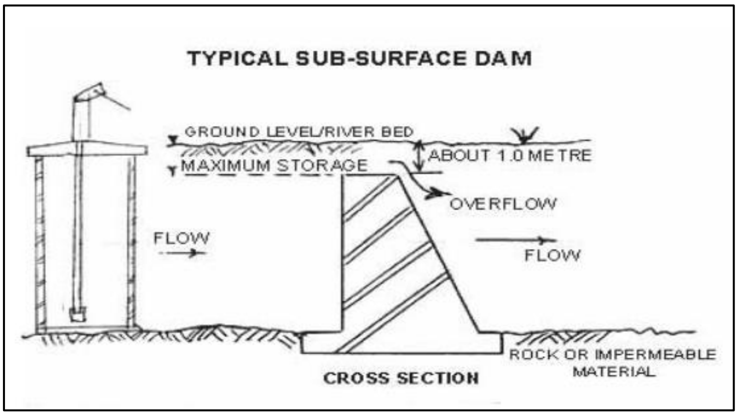

Figure 38: Examples of subsurface dams in sandy riverbeds.

V.viii Riverbank restoration

Riverbank erosion is a natural process in stable rivers, however, it can become accelerated and exacerbated by direct and indirect human impacts, such as livestock trampling, removal of riparian vegetation or channel incisions. Various techniques and methods exist to prevent or control the loss of valuable land and to ensure a stable water conveyance without losses in water quantities. To strengthening banks engineered revetments are advised, such as gabions and mattresses. The word Gabion is a French word derived from the Italian word *gabbia* meaning cage. Gabions are rectangular wire box filled with small stones, stacked on steep slopes and provide higher resistance for high water velocities in which small riparian stones are unstable or vegetated cover unable to establish. Gabions can be linked together to form terracing, retain river banks, support earth banks. Box gabions are principally used for retaining walls and spur-dikes, whereas mattresses are used for revetment and scour protection. Durability of the structures depends on the durability of the filling stones, and the wire mesh boxes. Gabions can be used for several types of works, combining erosion protection and retaining functions. Mattresses are a specialized form of gabion which are, unsurprisingly, mattress shaped, in that they have a relatively larger plan size and shallower depth. Their primary use is in protecting the bed of watercourses from excessive scour - they aim to prevent the water ripping up its bed, most commonly at weirs, waterfalls and other places where there is a sudden change in water level.[139] Gabions and gabion mattresses should be designed to resist hydraulic conditions notably the velocity of water flow. They may be used for water velocities up to 6 m/s.[140] Properly installed gabion baskets should have little need of maintenance. They should be monitored periodically during the first two years, especially after high water events. Additional vegetation should be established in any bare or sparse areas.

In each region, it is intended to plan with the following dimensions of gabions for riverbanks:

- Length: 10 000 meters
- Height: 3 meters
- Mesh Type: 3 mm
- 45 000 m^3 of stone

The costs[141] include a design[142] with three rows of gabions:

- Row 1, 3 mm mesh, 2m x 1m x 1m, 10 000 gabions: 510 480 USD
- Row 2**,** 3 mm mesh, 1.5m x 1m x 1m, 10 000 gabions: 410 902 USD
- Row 3**,** 3 mm mesh, 2m x 1m x 1m, 5 000 gabions: 255 240 USD
- Total cost of construction: 1 176 622 USD

139 Mississippi Watershed Management Organization (2010). A Guide to Bank Restoration Options for Large River Systems. Derived from: https://www.mwmo.org/wp-content/uploads/2017/11/Part-II_Installation_Manual_20171117.pdf (05.01.2021).

140 Wohl, E., Angermeier, P. L., Bledsoe, B., Kondolf, G. M., MacDonnell, L., Merritt, D. M., & Tarboton, D. (2005). River restoration. *Water Resources Research*, *41*(10).

141 Total cost of construction includes the following items:

(1) Gabion basket (1m³, 3 mm mesh) with an average cost of 8.10 USD (355 ETB) (based on Jan, 16, 2016). Hence total cost for 25 000 gabions represent 202 500 USD (8 378 437 ETB). Derived from: Nyssen, J., Gebreselassie, S., Assefa, R., Deckers, J., Zenebe, A., Poesen, J., & Frankl, A. (2017). Boulder-faced log dams as an alternative for gabion check dams in first-order ephemeral streams with coarse bed load in Ethiopia. *Journal of Hydraulic Engineering*, *143*(1), 05016005.

(2) Crushed stones (45 000 m³) from crusher site. 17.5 USD (720 ETB) per crushed m³ results in costs of 783 000 USD. Derived from: Material Prices at Crusher Sites, Ethiopia, https://con.2merkato.com/prices/material/2/23.

(3) Labour costs (incl. direct & indirect) of 69 USD (2 854 ETB) per month per capita. It is intended to plan with 30 days of labour works with 30 workers. This results in labour costs of 62 000 USD (2 565 250 ETB). Derived from: Caria, Stefano, Industrialization on a Knife's Edge: Productivity, Labor Costs and the Rise of Manufacturing in Ethiopia (August 13, 2019). World Bank Policy Research Working Paper No. 8980: https://ssrn.com/abstract=3437097.

(4) On-site machinery needs: 5 Hydraulic excavators of 120 hours during 30 days for 22 000 USD (910 250 ETB), 2 Mobile cranes of 120 hours during 30 days for 9 700 USD (401 337 ETB), 5 Transport trucks (15m³) for 30 days, 1500 tons stone per day with 5 trucks having 20 loads each day during 8 hours, 26 160 USD (1 082 400 ETB). Derived from: https://con.2merkato.com/prices/equipment/42; https://con.2merkato.com/prices/equipment/2; https://con.2merkato.com/prices/equipment/56.

(5) Unforeseen costs (ca. 6% of total construction cost): 71 262 USD.

142 Gabion Design Calculator. Derived from: https://www.gabionbaskets.co.uk/ (11.12.2020)

Table 36: Overview of costs for gabion riverbank restoration in Afar and Somali Region.

Regions for Gabion Riverbank restoration	Total Cost in USD (for 31 years, incl. construction & maintenance)
AFAR Region (10 000 meters)	1 176 622
SOMALI Region (10 000 meters)	1 176 622
TOTAL	**2 353 244**

Figure 39: Example of installed gabions to restore and stabilize riverbanks.

V.ix Improvement of water storage systems

Cisterns should be located as close as possible to areas where the water is to be used. To be effective, a cistern should have an adequate catchment under specific rainfall conditions, a suitable underlying geological formation. Normally, the cistern capacity will depend on, the quantity of runoff, which in turn depends on catchment size and rainfall. They may be built above or below ground, but below-ground cisterns are recommended due to the increased protection. Underground cisterns also have the advantage of providing relatively cool water even during the dry season months. A cistern should be located where the surrounding area can be graded to provide good drainage of surface water away from the cistern and should be located slightly upslope, away from any sewage disposal facilities. Cisterns can be constructed from a variety of materials including cast-in-place reinforced concrete, cinderblock and concrete, brick or stone set with a mortar and plastered with cement on the inside, or ready-made steel tanks. Concerning the environment, it is advised to use either concrete or steel-made materials. For a below-ground concrete block-walled version, walls and floors should be at least 15 centimetres thick and reinforced with steel rods. The top of a cistern may consist of individual panels, and at least a manhole to allow access to the storage tank. Manhole openings should have a watertight curb with edges projecting several inches above the level of the surrounding surface. To facilitate cleaning within the tank, a cleanout drain should be integrated in combination with a slightly sloped floor towards the drain.[143] Communities should take responsibility for the day-to-day operation, maintenance of the constructed cisterns. Community cisterns aimed to cover water needs for agricultural production during recurring dry spells during the rainy season and ensure an additional production cycle, if possible.

It is intended to reach 2 000 people in each region. We consider 8 people a household with water needs of 4 500 litres per month (ca. 3 600 litres) and additional 900 litres for agricultural/livestock use.[144] 2 000 people represent 250 households (with 8 people), with a need of 1 125 000 litres (1 125 m³). A concrete-built cistern costs 115.64 USD per m³.[145]

The total cost of construction for 1 125 m³ of concrete cistern costs 129 863 USD. Annual operation and maintenance costs represent 1.5% of total construction costs, which is 1 947 USD. Over a life span of 31 years, this represents 58 438 USD. The total cost over 31 years incl. construction and maintenance is 188 476 USD.

For both regions combined, 2 246 m³ of water storage capacities will be built, storing 2 246 000 litres of water for circa 4 000 people.

Table 37: Overview of costs for water storage cisterns in the Afar and Somali Region.

Regions for Water Storage Cisterns	Total Cost in USD (for 31 years, incl. construction & maintenance)
AFAR Region (1 125 m³) 2 000 People	188 475
SOMALI Region (1 125 m³) 2 000 People	188 475
TOTAL	**376 950**

[143] Akhtar Ali, A., Oweis, T., Salkini, A. B., & El-Naggar, S. (2009). Rainwater cisterns: traditional technologies for dry areas. *ICARDA, Aleppo, Syria. iv*.

[144] (1) Sutton, S., Butterworth, J. and Mekonta, L. 2012. *A hidden resource: household-led rural water supply in Ethiopia*. IRC International Water and Sanitation Centre, The Netherlands.
(2) Ethiopia: Ministry plans to raise water supply by 10 liter per day [News Article]. Derived from: https://reliefweb.int/report/ethiopia/ethiopia-ministry-plans-raise-water-supply-10-liter-day-gtp-2

[145] Akvopedia. Free, open-sourced water, sanitation & hygiene resource. *Sub-surface brick/cement tanks.* Derived from: https://akvopedia.org/wiki/Brick_cement_tank

Figure 40: Examples of cisterns made of reinforced concrete.

V.x Improved forage storage & treatment

In dry seasons, the supply of forage decreases and the availability is low in protein. Lack of quality forage can lead to decreased conception and growth rates or increased livestock mortality. Therefore, the basis of feeding in livestock and ruminant production systems is surplus forage stored in growing seasons.[146] Forage can be stored dry (hay) or as silage. Hay is dependent on good drying conditions, low humidity and air movement. It needs turning, to allow the air to penetrate the swath, or placing on racks or tripods. When dry (85-88% DM) it has to be stored under roof but with air circulation to avoid mold formation. It could be baling or stacking.[147] Silage is the storing, in anaerobic conditions. The process of ensilage involves the compaction of the material and exclusion of air, to allow the conversion of plant sugars to lactic acid. The correct stage for ensiling the crop (stage of maturity and dry matter content) will depend on whether the forage is needed as high energy or high protein feed. It advised to establish improved forage storage systems using roofed trench (bunker) silos in combination with storage polythene bags (e.g. 50 kg capacity). Trench (or bunker) storages are permanent structures constructed above ground and are commonly used in flat areas. Above ground walls are constructed using concrete, earth, or steel. Adopting ensilage technology has shown positive impacts. A study from Zimbabwe, where 63 ton of forage were ensiled in 4 771 bags, showed that cows fed with the silage showed improved body conditions and increase in body weight. Due to the improved storage system farmers also doubled their area planted for forage leading to a growth of herd's (60%) and increased nutrition uptake.[148] Bag silos show several advantages, since these systems are a very flexible. Bags are suited to crops where fluctuating amounts are harvested can be sealed.

For each region, two concrete trench silos are planned. Each trench silo will have a capacity of 2000 tons with the following cost dimensions.[149,150]

- Concrete flatwork (10 560 square feet at 4 USD) 1 000 m^2: 42 240 USD
- Precast concrete walls (12 by 400 feet) 40 m^2: 64 000 USD
- 830 tire sidewalls: 2 075 USD
- Total initial investment: 106 240 USD
- Total annual cost (incl. plastic bags): 11 040 USD for 2 000 tons of silage or 5.52 USD per ton per year. 331 200 USD over 31 year's operation.

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[146] A. Alvarez ARanguiz and J. Creemers, "Quick Scan of Ethiopia's Forage Sub-Sector, Working paper," Netherlands East African Dairy Partnership (NEADAP), Wageningen, Wageningen UR-Livestock Research, 2019.

[147] M. Titterton, O. Mhere, B. Maasdorp, T. Kipnis, G. Ashbell and Z. Weinberg, "Conservation of forages for dry season feeding of livestock in the semi-arid areas of the tropics," in *Proceedings of the Joint ZSAP/FAO workshop on Strategies for dry season feeding of animals, held by the Zimbabwe Society for Animal Production*, Harare, Zimbabwe, 2003.

[148] O. Mhere, B. V. Maasdorp, M. Titterton, S. M. Dube and G. Heinrich, "On-farm Assessment of Forage Yields and Silage Quality of Intercropped Drought Tolerant Cereal and Legume Forage Crops," in Sustaining livestock in challenging dry season environments: Strategies for Smallscale Livestock Farmers, Chatham Maritime, Kent, United Kingdom, Natural Resources International Limited, 2000, pp. 76-81.

[149] Forage Foundations. Silo Systems. https://www.vitaplus.com/blog/articles/ask-expert-walls-or-no-walls-randall-greenfield-vita-plus#.YA_bHbN7mHs (26.11.2020).

[150] Kansas State University. Silage Storage Economics for Diary. https://www.agmanager.info/silage-storage-economics-bunkers-piles-or-bags-dairy (26.11.2020).

- Total cost: 437 440 USD

Table 38: Overview of costs for forage trench silos in the Afar and Somali Region.

Regions for Forage Storage Systems	Total Cost in USD (for 31 years, incl. construction & maintenance)
AFAR Region (2 x 2 000 tons capacity)	874 880
SOMALI Region (2x 2 000 tons capacity)	874 880
TOTAL	**1 749 760**

Figure 41: Example of silage bags, filled for storage in roofed trench silos or shelters.

V.xi Establishment of communal seed banks

It is intended to establish a network of seed banks providing affordable and high quality seeds of grass and fodder tree varieties to ensure constant accessibility and quality for especially nurseries. Seed banks could be managed under communal systems and supervised by regional or national agencies.

Seed banks aim to increase local seed security and contributing to the possibilities to the continued utilization of locally important genetic diversity. Community seed banks are collections of seeds that are maintained and administered by the communities themselves. Seeds can be stored by a community either in large quantities to ensure that planting material is available, or in small samples to ensure that genetic material is available should varieties become endangered.[151] Community seed banks can serve as key local sources of germplasm allowing farming communities to exchange seeds in a decentralized manner through social networks and organized events, such a diversity fairs and participatory seed exchanges. As

[151] Kroglund et al. 2011. *Banking for the future saving security and seeds*. The Development Fund/ Utviklingsfondet.

such, community seed banks can operate as a central node in the local seed system and as a bridge to the supralocal level and the formal seed system, e.g., through links with other community seed banks, the national gene bank or other plant genetic resource institutions.[152]

In Ethiopia, community seed banks also contribute to sustainable conservation strategies and supporting the seed exchange of traditional varieties among farmers. Banks are managed by the local farmers, who use them to exchange seeds of traditional varieties from diverse crops, such as wheat, teff, barley, lentil, beans and chickpeas. Having registered in crop conservation associations, farmers borrow and return seeds from the community seed banks. As interest on their seed loan, they are obliged to return more seeds than they initially received, thereby helping to increase the banks' seed stock.[153]

It is planned to build communal seed banks with the following capacity and costs.[154]

- Initial seed fund: 400 USD
- Start-up fund to build social capital and initial physical infrastructure, including seed-storage units: 20 000 USD
- Total construction cost: 20 400 USD
- Ca. 4-6 tons seed supply
- Coverage of 1200 households

In Afar, it is planned to reach 30 000 people, which requires the establishment of 50 communal seed banks. The construction costs for 50 communal seed banks is 510 000 USD.[155] It is assumed that annual maintenance and operations costs will consist of 3% of the construction costs, representing 15 300 USD. During an operation over 31 years, this results in 459 000 USD. Hence, the total cost of a communal see bank with a life span of 31 years is 969 000 USD.

In Somali, it is planned to reach 30 000 people, which requires the establishment of 50 communal seed banks. The construction costs for 50 communal seed banks are 510 000 USD.[156] It is assumed that annual maintenance and operations costs will consist of 3% of the construction costs, representing 21 420 USD. During an operation over 31 years, this results in 459 000 USD. Hence, the total cost of a communal see bank with a life span of 31 years is 969 000 USD.

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[152] Wubeshet and Temam. 2020. Establishment and Current Status of Community Seed-Banks. JOURNAL LA LIFESCI.

[153] Kroglund et al. 2011. *Banking for the future saving security and seeds*. The Development Fund/ Utviklingsfondet.

[154] Vernooy, R., Shrestha, P., & Sthapit, B. (Eds.). (2015). *Community seed banks: Origins, evolution and prospects*. Routledge.

[155] Construction cost: 50 * 10 200 USD = 510 000 USD

[156] Construction cost: 70 * 10 200 USD = 714 000 USD

Table 39: Overview of costs for communal seed banks in the Afar and Somali Region.

Regions for Communal Seed Banks	Total Cost in USD (for 31 years, incl. construction & maintenance)
AFAR Region (coverage of 30 000 people, 50 Seed Banks)	1 938 000
SOMALI Region (coverage of 30 000 people, 50 Seed Banks)	1 938 000
TOTAL	**3 876 000**

Figure 42: Example of communal see banks. Storage of varieties in a shelving system.

V.xii Establishment & Rehabilitation of small- & medium sized irrigation systems

It is intended to promote and establish small- and medium sized irrigation schemes, promoting solar-powered drip irrigation systems or sprinkler systems. This measure allows a shift from gravity irrigation to modern pressurized systems (e.g. drip irrigation), contributing towards sustainable intensification for food and nutrition security. Such irrigation systems are comprised of a tank of water connected to hoses or plastic pipes that are laid on the ground along field crops.

The use of such drip irrigation system permits reduction of water loss (up to 50%) as compared to flood irrigation showing water savings of 50% and a yield increase of 30%, with no substantial differences with the conventional drip irrigation systems.[157]

According to Ministry of water, irrigation and electricity small scale irrigation projects cover an area less than 200 hectares, medium scale covers an area between 200 to 3 000 hectares. In Ethiopia such like

[157] Yemenu, F., Hordofa, T., & Abera, Y. (2014). Review of water harvesting technologies for food security in Ethiopia: challenges and opportunities for the research system. *Journal of Natural Sciences Research*, *4*(18), 40-49.

irrigation system classification is common. Hence about 46% of irrigation development is categorized under small scale irrigation project category.[158]

The cost dimensions for a solar-powered drip irrigation system (installation & annual cost) are as follows[159]:

- Solar-powered drip irrigation system (Installation) costs represent 39 583.33 USD/ha and include:
  - Solar PV System
  - Filter station and fertigation system
  - Dripping lines and filters
  - Pump system
  - Spare parts
- Inputs/Labour/Support (Annual costs/ha) represents 5 750 USD/ha.

In each region, a 60 ha irrigation project is planned within the Awash River and Shebelle River basin. The construction cost for each site, covering 60 ha is 2 5374 998 USD. Annual maintenance and operation costs over a life span of 31 years represent 10 350 000 USD.[160] In total, the cost for a 60 ha irrigation project with a life span of over 31 years is 12 724 998 USD.

Table 40: Overview of costs for solar-powered irrigation in the Afar and Somali Region.

Regions for solar-powered irrigation	Total Cost in USD (for 31 years, incl. construction & maintenance)
AFAR Region *(60 ha)*	12 724 998
SOMALI Region *(60 ha)*	12 724 998
TOTAL	**25 449 996**

[158] Kassa, M., & Andualem, T. G. Review of Irrigation Practice in Eth30iopia, Lessons from Israel.

[159] Burney, J., Woltering, L., Burke, M., Naylor, R., & Pasternak, D. (2010). Solar-powered drip irrigation enhances food security in the Sudano–Sahel. *Proceedings of the National Academy of Sciences*, *107*(5), 1848-1853.

[160] Annual maintenance and operation: 5.750 USD * 30 ha * 30 years = 5.175.000 USD.

Figure 43: Examples of solar-powered drip irrigation systems.

V.xiii 12 & 13. Livestock & Crop Index Insurance

Parametric/ Index-based insurance can result in different forms. The following paragraphs will only briefly introduce both micro- and macro insurance solutions based on indices focussing on the agricultural sector. While micro-insurance is directed at individuals, e.g. farmers, macro (or sovereign) insurance much rather targets for instance (sub-) national governments.

Micro insurance aims at providing insurance services to poor and low-income people who are excluded from the existing insurance markets. Although there are several definitions of micro insurance, most of them agree on the same key elements: (1) tailored to low-income clients' needs and requirements (e.g. flexible coverage periods, accommodating for irregular payments, limited or no insurance literacy, etc.), (2) low premiums and low coverage, (3) coverage of simple and targeted perils, i.e. simple product design, to allow for low premiums, additional to limited coverage, administrative processes such as distribution, enrolment and claims processes are kept simple and flexible through e.g. less restrictive eligibility requirements or allowing for alternative identification.

Although micro insurance is a wide field covering almost all areas regular insurances are covering, this annex takes a focus on agricultural (livestock and crop) insurance following the assets selected for the ECA study according to the relevant population's core livelihoods. Although there have been many pilot projects implemented including either livestock or crop insurance the effectiveness in practice has been mixed and often reliant on subsidies. Key constraints are, besides insurance and financial literacy, designing high quality products that are still affordable to the low-income target population. To keep products reasonably priced agricultural micro insurance is commonly index-based. Linking the pay-outs to indices (such as e.g. rainfall or vegetation cover) rather than compensation farmers for actually occurred losses has the great advantage of skipping costly loss-verification processes. It further limits the two common problems experienced in the insurance sector: (1) moral hazard, i.e. the risk of the insured behaving differently or careless as they are protected, and (2) adverse selection, i.e. a situation where only or predominantly participate who are more likely to suffer losses caused by information asymmetry, in this case for example predominantly low-performing farmers. As agriculture index insurance is not linked to the farmer's performance and the actual cause of the loss but much rather to an independent index those two issues are overcome. However, the employed index needs to be calibrated with great care as it has to reflect the experienced losses as accurately as possible. The risk of individual farmers experiencing a qualifying losses without a pay-out being triggered by the index or receiving a pay-out without experiencing a loss is called basis risk, i.e. when the index measurements do not 100% match insured losses[161] To ensure trust and financial sustainability the basis risk needs to be kept as low as possible, although it will never be eliminated as any index covering average conditions will not be able to capture every influencing factor at any given location within the defined area.

Well-known and successful examples of agricultural insurance include, for instance, the *R4 Rural Resilience Initiative* implemented by the World Food Programme and Oxfam America. The index based risk transfer component of the programme builds on remotely sensed precipitation data. The satellite data are being ground-truthed and validated by both, plastic rain gauges distributed to farmers (who were trained on their application) as well as automatic rain gauges installed and maintained by the Ethiopian National Meteorological Agency. Using multiple sources for climatological data allows the minimization of the aforementioned basis risk and thus the efficiency and efficacy of the product. The programme is active in several African countries including Ethiopia (Amhara and Tigray regions) and has been aligned with the national Productive Safety Net Program (PSNP) targeting the country's poorest farmers.[162]

Another recent livestock insurance programme is currently being piloted in the Somali region by the World Food Programme. The *Satellite Index Insurance for Pastoralists in Ethiopia* (SIIPE), just as the R4 programme, is an index insurance scheme utilising the *Normalized Differenced Vegetation Index* (NDVI) as the index. Its aim is to strengthen pastoralist's adaptability and resilience by insuring them against drought-related livestock risks. Participating households receive insurance receive coverage for five tropical livestock units (TLU) during the rainy seasons of March- June and October- December. The programme is closely linked to the PSNP programme and hence targets the poorest farmers. Aside from being participating in the PSNP programme and living in one of the 17 selected pilot *kebeles*, the ownership of five to eleven TLU is the final eligibility criterion. This ensures that the programme is limited to small herders. Covered livestock types are the same as the four selected for this study: camel, cow, goat, and sheep. Since the programme is still quite young, little robust lessons learned, including those regarding people's willingness-to-pay for insurance products ensuring the sustainability beyond premium subsidies, can be drawn.[163]

Contrary to the individual micro insurance a (sub-) sovereigns, e.g. the country's or the region's government, can revert to sovereign insurance. Such large scale insurance schemes too often rely on remote sensing data and similar indices such as NDVI or the Water Requirements Satisfaction Index (WRSI), although also indemnity based schemes, such as risk pools, do exist. The pay-outs are made to the policy holder and hence not directly to the suffering farmers, thus protecting public budgets by providing governments with immediate funds after a disaster strikes. In the case of the prominent example of the *African Risk Capacity* programme (ARC), a specialised agency of the African Union, a key criterion to achieve the *Certificate of Good Standing* is a detailed contingency plan outlining how the pay-

[161] This is a rather simplified statement. Depending on the specific insurance product design and individually policy there may be losses

[162] For more information see e.g. WFP (2020). *R4 Rural Resilience Initiative. Quarterly Report 2 2020*. Available at https://www.wfp.org/publications?f%5B0%5D=topics%3A2209

[163] For more information see e.g. WFP Country Office Ethiopia (2019). *SIIPE Impact Evaluation Report, August 2019.* Addis Ababa, Ethiopia.

out received is being used and how it is channelled to the target group, e.g. through cash-transfers, food aid, or even reconstruction of infrastructure. As such programmes aim at entire countries or substantial parts of them and rather aim at supporting large scale emergency aid the pay-out is typically only triggered if when a large share of the population is expected to be affected. A major advantage of such programmes is the timely and predictable pay-out in case of emergency and thus allowing the governments to take swift action to avoid further damage through knock-on effects.

Finally, as any (parametric) insurance product design is rather complex, the simplified module implemented in CLIMADA relies on only few inputs, such as the tick value, i.e. the expected pay-out, and coverage range (SPI -1.8 to -3). The tick values are estimated based on the total value, unit value and the annual expected damage (AED) of the corresponding asset groups. Further, as it is unrealistic to assume that all crops and all livestock can be insured, even independent from factors such as subsidies, it was assumed that only about 13% of the crops and 15% of all livestock will be covered by a potential insurance option. For both cases a premium of 10% of the insured value was assumed which results in a premium of 4 485 USD, rounded to 5 000 USD, per centroid (i.e. 500 livestock of each type). In the case of crops, this translates to 41 735 USD, rounded to 42 000 USD, per ha.

V.xiv Overview

Table 41: Overview of all measures applied in the Afar and Somali Region incl. location in the respective agro-ecological zone. The total cost until year 2050 (incl. construction & maintenance) and the respective impact reduction are listed.

AFAR REGION		
Measure	**Location (AEZ)**	**Total Cost in USD** (for 31 years, incl. construction & maintenance)
Wetland restoration and rehabilitation	A2, M2, SM2	834 750
Tree-crop species intercropping (Agroforestry)	A1, A2, M2, SM2	546 530
Replanting of indigenous and improved fodder trees and grass species	A1, A2, M2, SM2	628 400
Management of protected environmental areas	A2, M2, SM2	907 986
Establishment of fodder tree and grass nursery sites	A2, M2, SM2	3 007 000
Subsurface Dams in Riverbeds	A2, M2, SM2	502 871
Riverbank restoration	A1, A2, M2, SM2	1 176 622
Improvement of water storage systems	A2, M2, SM2	188 475
Improved forage storage & treatment	A2, M2, SM2	874 880
Establishment of communal seed banks	A2, M2, SM2	1 938 000
Establishment & Rehabilitation of small- & medium sized irrigation systems	A1, A2	12 724 998
Livestock Index Insurance	all	5 000 per 500 of each livestock/a
Crop Index Insurance	all	42 000 per 5x5km raster /a

TOTAL		23 330 512

SOMALI REGION		
Measure	**Location (AEZ)**	**Total Cost in USD** (for 31 years, incl. construction & maintenance)
Wetland restoration and rehabilitation	A2, A3, M2, SM2	834 750
Tree-crop species intercropping (Agroforestry)	A1, A2, A3, M2, SM2	546 530
Replanting of indigenous and improved fodder trees and grass species	A1, A2, A3, M2, SM2	628 400
Management of protected environmental areas	A2, A3, M2, SM2	907 986
Establishment of fodder tree and grass nursery sites	A2, A3, M2, SM2	3 007 000
Subsurface Dams in Riverbeds		502 871
Riverbank restoration	A1, A2, A3, M2, SM2	1 176 622
Improvement of water storage systems	A1, A2, A3, M2, SM2	188 475
Improved forage storage & treatment	A2, A3, M2, SM2	874 880
Establishment of communal seed banks	A2, A3, M2, SM2	1 938 000
Establishment & Rehabilitation of small- & medium sized irrigation systems	A1, A2	12 724 998
Livestock Index Insurance	all	5 000 per 500 of each livestock/a
Crop Index Insurance	all	42 000 per 5x5km raster/a
TOTAL		**23 330 512**

Region	Total Cost in USD (for 31 years, incl. construction & maintenance)
AFAR Region	**23 330 512**
SOMALI Region	**23 330 512**
TOTAL	**46 661 024**

Annex VI *Economic Resilience*

Although measures classified as "economic resilience" did not rank high enough during the multi criteria selection process described in Annex IV to be included in the running of CLIMADA, the study team, in agreement with key stakeholders, opted to include this brief annex on the role and importance of such measures. The low ranking of this type of measures is largely due to the low scores reached at key criteria such as *stakeholder acceptance*, *cost effectiveness*, and *institutional support* required. However, measures aiming at financial inclusion, integration into formal markets, and general capitalisation of populations are quite flexible and can include strong and targeted gender components. Further, such measures can be coupled with other, often times community based, measures and thus leverage on synergies and provide additional motivation to the population (e.g. cash-for-work programmes).[164]

To limit the extent of this annex the focus will lie on 1) microfinance solutions, e.g. (informal) loan and savings groups or microfinance institutions, and 2) other capitalisation programmes, such as cash-for-work programmes, as applied in similar contexts. The goal of this annex is to highlight the co-benefits of such initiatives with a special focus on the drought events and highlighted adaptation measures.

VI.i Microfinance

First, informal savings and loans groups or associations have the potential to provide access to basic financial services to and by the poorer population, particularly those living in rural areas. These groups are oftentimes informal and formed within a village that bear the advantage of being managed by its own members, hence following no corporate interest and by definition being close to their clients (i.e. members). The funds of the groups are contributed by the members in form of their pooled savings. Savings are usually paid in regularly, e.g. during regular group meetings, and offer credit facilities to the members. Based on the self-managed nature, transparency and repayment is ensured. Such groups can take different forms in size, level of proficiency in management, as well as investment (e.g. livestock) and gender foci (e.g. women's groups) supporting specific economic activities and the empowerment of marginalised groups. Additionally, some groups set aside a social or solidarity fund which is reserved to assist group members in emergencies such as the death or illness of a family member.[165]

[164] However, one has to be careful, once people get used to financial incentives without realising the actual benefit of e.g. rangeland clearing cutting off the incentive payments will most likely result in the same situation prior the intervention. For further information see e.g. Flintan, F., Ebro, A., Eba, B., Assefa, A., Getahun, Y., Reytar, K., Irwin, B., Yehualashet, H., Abdulahi, M., Gebreyohannes, Z. T., Awgichew, S. and Gudina, D. (2019). *Review of participatory rangeland management (PRM) process and implementation. Rangelands Research Report 2*. Nairobi, Kenya: ILRI.

[165] K.A. Theophilus, S.-M. Paul (2019). The impact of savings groups on female agency: insights from village savings and loans associations in Northern Ghana. Asian Journal of Agriculture and Rural Development, 9(2), 133-146.

The forming of such groups entail the empowerment and financial inclusion of the members. Further benefits include a stronger social safety net for individual risks faced by the group member, but even in e.g. drought events affecting all community members the savings (that potentially would not have been put aside if it wasn't for the group) provide a financial buffer. Both savings and group members' investments can promote food security as people are provided with the opportunity to take out loans for larger and potentially more profitable investments. As the forming of groups oftentimes is accompanied with financial literacy training through NGO's, the Government or development partners, members improve their understanding of economical thinking, develop higher self-confidence and may take a more business-oriented perspective on their livelihood and even re-prioritize income generating activities.[166,167]

Similar impacts can be expected from more formal micro finance institutions (MFIs). MFIs too serve the purpose to provide access to financial services to those parts of the population that so far are underserved and in most cases are not deemed to be economically worth the effort for larger commercial financial institutions. The major differences to usually smaller informal groups are the higher degree of professionalism of the leadership as well as having employed agents and a branch network serving multiple communities, potentially being spread all over the country. Based on their agent or branch network MFIs offer e.g. payment services, money transfers and (basic) risk transfer/ insurance solutions to poor and low income households and their small enterprises. Commonly accepted key elements determining the success, i.e. supporting poverty alleviation and reducing peoples' financial vulnerability, of microfinance and MFIs are on the one hand financial sustainability, but on the other hand also the element of supporting people in developing a basic level of financial literacy and management capabilities.[168]

VI.ii Cash-for-work programmes and community agreements

Additionally, cash-/food-for-work programmes, community contracts/ agreements and similar programmes that aim to set certain incentives for either behavioural change or the application of certain activities, can be counted in this category of economic resilience measures. Similar to the measures presented above, this type of programmes can be tailored to local needs targeting different locations, goals and even perspectives. For instance, the primary goal could be to provide aid to people (e.g. in the form of cash, food or vouchers), while also asking for some form of repayment, possibly labour hours. Alternatively, the core idea of the programme could be to set incentives for people to apply certain practices such as agricultural or land management practices they would not pursue otherwise. There are

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[166] Karlan, D., Savonittob, B., Thuysbaertb, B., & Udrya, C. (2017). *Impact of savings groups on the lives of the poor*. Economic Sciences, 114(12), 3079–3084.

[167] CARE International Tanzania (2006). Village savings and loans and women's empowerment: Strategic impact inquiry (SII). Dar es Salaam, Tanzania.

[168] B.A. Kinde. (2012). *Financial Sustainability of Microfinance Institutions (MFIs) in Ethiopia.* European Journal of Business and Management. 4(15).

of course other reasons one might design such programmes for, however, those two shall serve as examples here. In most cases it can be assumed that multiple goals, with thin lines defining them, are being followed when implementing such programmes.

In general, such programmes can be successful in the sense that people receive payments/food for work done, apply the measures and strategies as desired by the programme and potentially change their behaviour. Based on the increased cash and/or food for the participants as well as the supply of the product resulting from the participants' work another benefit can be drawn. However, depending on the goal, the deciding factor over the real benefit to the participants can be their remuneration, be it in cash or in kind. The controversy of reaching eligibility for support provided by aid and development agencies potentially creates opposing effects of people being frustrated as they are often not compensated adequately for their work.[169] Such effects have especially negative implications if the overarching goal is to introduce new measures, strategies or behaviours to the participants' community while using financial or other benefits merely as an incentive.

However, if implemented with great care and clear communication with the target communities such incentives can serve to overcome e.g. transaction or opportunity cost and showcase the benefit of newly introduced activities such as agricultural or land management practices or other maintenance activities as potentially relevant for some of the adaptation measures in this study. Using coupling cash incentives with a rangeland exclosure measure as a for instance, it is of great importance that participants experience the true benefit of the measure: The sustainable recovery of the enclosed rangeland portion in order to provide richer and more diverse pasture to pastoralists and their livestock in the following season rather than the incentive payments. Making sure the true goal of the programme remains in the foreground ensures the sustainability and longevity of the intervention.

All here described branches of economic resilience measures, especially community agreements that incorporate (financial) incentives, bear some risk of mal-adaptation, low cost-effectiveness, and require a high degree of support and acceptance among the target group, from institutions, and other stakeholders. However, providing access to financial services such as loans and savings, and access to risk transfer solutions allows for better integration into markets. Further, larger as well as riskier, but potentially more profitable, investments can be taken. Such investments have the potential to cross the threshold from e.g. subsistence farming into for-profit farming or establishing an alternative income source. Incentive payments on the other hand, if carefully applied with the necessary transparency in order to avoid negative perceptions, can indeed serve to introduce behaviour changes or to overcome barriers to activities that have not been considered yet due to doubts about their benefits (such as e.g. maintenance of public goods). Therefore, such programmes can be suitable tools to accompany adaptation measures, especially those involving limited maintenance work, (limited) behavioural change, or the application of new practices, in a targeted manner and even increase the respective measure's impact through increased incentives among the participants/ beneficiaries.

[169] For more information see e.g. L. Carruth, Freeman, S. (2020). Aid or exploitation?: Food-for-work, cash-for-work, and the production of "beneficiary-workers" in Ethiopia and Haiti. World Development

Authors: Florian Waldschmidt, Eike Behre, David Daou, Alvaro Rojas, Teresa Arce Mojica, Preeti Koirala, Zita Sebesvari, Sönke Kreft and Maxime Souvignet

Design: Aileen Orate (UNU-EHS)

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