WCRP REPORT
World Climate Research Programme

WMO IOC ICSU International Council for Science

Climate Observations and Regional Modeling in Support of Climate Risk Management and Sustainable Development

Report of Workshop I: Exploring changes in temperature and precipitation extreme indices for the GHA region

(19-23 April 2010, Nairobi, Kenya)

July 2010

WCRP Informal Report Nr. 07/2010

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Climate Observations and Regional Modeling in Support of Climate Risk Management and Sustainable Development[1]

REPORT OF WORKSHOP 1: EXPLORING CHANGES IN TEMPERATURE AND PRECIPITATION EXTREME INDICES FOR THE GHA REGION

(19-23 April 2010, Nairobi, Kenya)

1. Background

Reliable and detailed regional climate information, including current and future assessments of climate variability and change, is essential in the design of effective strategies for managing risks and adapting to climate variability and change. Such information critically depends on the availability of good quality climate observations with sufficient spatial coverage over an extended period of time, on the adequacy of climate predictions from numerical models to depict current and future regional climate, and on a thorough understanding and appreciation of the uncertainties and constraints associated with the use of both data and regional and global models.

1.1 Project Description

To assist the developing and least developed countries of the Greater Horn of Africa (GHA) region to undertake and appropriately use climate projections in climate risk management and adaptation planning, the World Climate Research Programme (WCRP), the Global Climate Observing System (GCOS), the World Meteorological Organization (WMO) and the World Bank, along with the Nairobi-based IGAD (Inter-Governmental Authority on Development) Climate Prediction and Applications Center (ICPAC) are collaborating to develop and implement a programme of three linked workshops to demonstrate the key elements of an effective climate risk management strategy for the GHA region. The overall objectives of the workshop programme are to

- Help ensure that attention is given by countries in the GHA region to observation and data needs,
- Demonstrate the use and value of regional models and provide advice on model limitations,
- Improve capabilities across the GHA for using data records and model projections for adaptation planning, in particular for the agriculture/food security and water resources sectors,
- Involve decision makers with the climate experts to facilitate the inclusion of climate information into national, regional, and local planning processes, as well as within economic sectors (i.e., ”Begin mainstreaming now”, and.
- Develop an initial set of “best practices” for the overall scientific process of ‘downscaling’ global climate predictions to provide reliable data on the future climatic conditions over the regional, national and local areas.

[1] supported under World Bank/GFDRR Project (Grant No. TF092496)

The ten ICPAC countries of the Greater Horn of Africa (i.e. Burundi, Djibouti, Ethiopia, Eritrea, Kenya, Rwanda, Somalia, Sudan, Tanzania, and Uganda) are participating in the project (Figure 1).

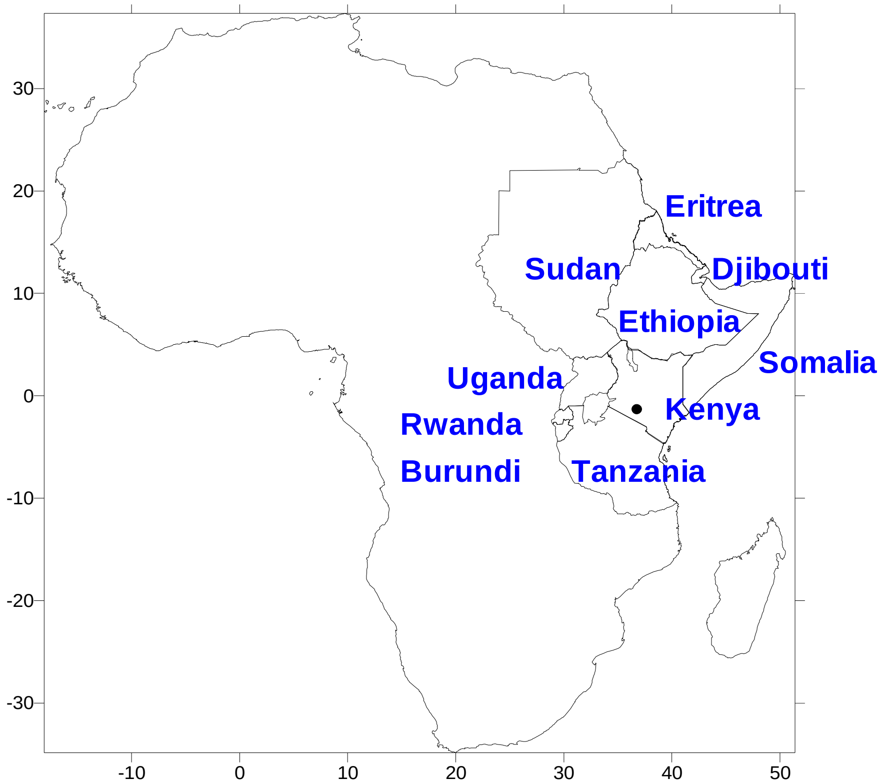

Figure 1: Participating ICPAC countries of the Greater Horn of Africa

The overall programme consists of three interrelated workshops that focus on (i) developing a process to produce quality controlled national data sets and regional climate indices based on national meteorological station data for temperature and rainfall; (ii) utilizing this data and other analyses (e.g., using satellite observations) to compare with regional model predictions (or projections) of future climatic conditions over regional, national, and local areas (i.e., validate the predictions of past climate in the model), and (iii) demonstrating how climate data can be utilized within regional, national, local planning processes, in particular for benefiting the agriculture/food security and water resources sectors.

Workshop 1: Climate indices & quality controlled national data sets[2].

The specific objectives of the first workshop, focusing on data needs, are to:

- Use available climate data from countries in the region, to enable detailed assessments of observed climate variability and change;

[2] This workshop benefits from the successful experiences of past workshops in other regions, coordinated by the *Expert Team on Climate Change Detection and Indices* (ETCCDI) that have significantly improved the understanding of climate change in those regions and have contributed significantly to the IPCC 4th Assessment. Detailed information about past workshops can be found at: http://cccma.seos.uvic.ca/etccdi. The ETCCDI is jointly sponsored by the World Meteorological Organization (WMO) Commission for Climatology (CCl) / World Climate Programme / World Climate Research Programme (WCRP) project on Climate Variability and Predictability (CLIVAR) / Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM), sponsored by WMO and the Intergovernmental Oceanographic Commission of the United National Educational, Scientific and Cultural Organization (UNESCO).

- Assess the adequacy of the quantity and quality of the available data for the evaluation of the skill of global and regional climate models for the GHA region;
- Demonstrate the value of the collaborative use of data and the application and use of standardized climate indices, including those representing extremes, among countries in the region;
- Increase regional research synergies by sharing insights and improve analyses between neighbouring countries; and
- Encourage countries in the region to improve their observing systems and to undertake data rescue and digitization efforts for use with regional models.

Workshop 2: Regional Modeling

The specific objectives of this workshop, focusing on regional modeling, will be to:

- Evaluate the baseline simulations of the regional climate model representing the current climate, through comparison with the observations and reanalysis-based results from the first workshop. Also use the same models to make one or more projections of future climate in the region for a time period of interest for adaptation;
- Provide hands-on training in data processing and in analyzing regional model output to enable such analyses at country level;
- By using the results obtained by these sample climate projection(s), familiarize workshop participants with the additional steps that would be needed to undertake further analysis after the workshop (e.g., to develop improved estimates of uncertainty); and
- Make the participants aware of both the benefits and limitations in using and interpreting regional model simulations in climate applications.

Workshop 3: Regional and National Needs, Applications and Providing Reliable Guidance

The objectives for the third workshop, which will address issues of interest to decision makers, are to:

- Facilitate interaction between climate experts from the first two workshops and sector representatives (in particular, those from the agriculture/food security and water resources sectors) to familiarize the sector representatives with the type and range of available products from regional climate scenario and with the degree of confidence that can be placed in these products;
- Develop guidance on best practices in the use of climate observations in analyses, assessments and products, including indices, and in interpretation and use of climate model outputs and other climate information in adaptation planning;
- Develop strategies for establishing two-way communication between climate information providers and users to facilitate scientifically appropriate interpretation and application of climate products by the users, recognizing that within a sector, the many types and levels of decision-makers may have different requirements;
- Discuss illustrative examples of adaptation measures that could be used when reliable climate projections are available, in light of the analysis conducted in the first two workshops; and
- Assist in building regional climate change into the portfolio of adaptation planners in the Greater Horn of Africa Climate Outlook Forum (GHACOF) and into a future WMO Regional Climate Centre (RCC) serving the climate requirements of the GHA by exploring sustainable mechanisms for regularly updating climate information.

2. Implementation of the First Workshop

The First Workshop of the joint project was successfully completed despite the fact that a number of international experts were not able to attend due to flight cancellations between Europe and Nairobi that resulted from the Icelandic volcanic dust clouds. An adequate number people with the appropriate expertise were on hand in Nairobi to allow for all items on the agenda (shown in Appendix A) to be covered[3].

Professor Laban Ogallo, ICPAC Director and the host for the meeting, engaged several local experts for the workshop in addition to Dr Joseph Intsiful (UK Met Office), Mr. Steve Palmer (UK Met Office), Mr. William Westermeyer and Mr. Carl Dingel (WB-GFDRR), who were already in Nairobi. During the week of the workshop, several teleconferences were held with the experts who could not make it to Nairobi to discuss the progress of the workshop and develop way forward strategies for the various training sessions.

2.1 Opening Plenary

The workshop, held at ICPAC Auditorium/Training Room, was formally opened by Mr. Francis Muraya, representing the World Bank's Global Facility for Disaster Reduction and Recovery (GFDRR). Brief remarks were made by Professor Ogallo, Director of ICPAC; Dr. Joseph Intsiful, representing the UK Met Office; Dr. William Westermeyer, representing WMO/GCOS/WCRP; Dr. Mukabana, Director of the Kenyan Meteorological Department and The Permanent Representative of Kenya with WMO; and Mr. Francis Muraya again, representing the World Bank's Global Facility for Disaster Reduction and Recovery (GFDRR).

- Prof Ogallo welcomed the participants to ICPAC and highlighted that climate change is one of he key focus at ICPAC. Several of ICPAC's activities also address issues related to coping with climate variability especially extreme events such as droughts and floods that currently threaten livelihoods and development in the region. The outputs from the first workshop will therefore contribute significantly to the regional climate risk reduction programmes.

- Dr. Mukabana, Director of the Kenyan Meteorological Department (KMD) and The Permanent Representative of Kenya with WMO welcomed the participants to Kenya and the Kenya Meteorological Department. ICPAC is hosted by Kenya and resides within KMD compound. On behalf of the other PRs from ICPAC member countries, he thanked GFDRR and the implementing partners WMO, GCOS, and WCRP for their support to the region through this project and many other past and on going initiatives.

- Mr. Francis Muraya presented the core business of GFDRR and noted the importance of integrating disaster risk reduction (DRR) strategies in development plans. He also pointed out that GFDRR and ICPAC are collaborating in other areas, and that a memorandum of understanding for south-south cooperation has been signed between GFDRR and ICPAC. He noted that climate risks are threatening most of the current developments in Africa and thus future investments in the region must mainstream climate variability and climate change information. The outputs from the project are therefore of great interest to GFDRR.

- Mr. Carl Dingel, who represented Ms. Amal Talbi, the focal point of the project at the World Bank / GFDRR, made a presentation on the specifics of the project and also discussed several examples of the World Bank's involvement in Africa including their project with the Nile Basin Initiative. The World Bank presentations by Mr. Maraya and Mr. Dingel are given in *Appendix B2.*

[3] Cancellation of the workshop was not really an option, as most of the participants were already in Nairobi or en route before the disruption in air traffic, and therefore cancellation would have incurred substantial costs.

- Mr. William Westermeyer, representing, WMO, GCOS, and WCRP, presented an overview of the project as a whole, including a brief history of the project based on previous GCOS involvements in the region, and a report on progress to date. He also noted that most of the foreign experts will not be attending due to the problems related to volcanic aerosols that affected all flights into and out of Europe.

- Mr. Steve Palmer, substituting for Dr Alan Thomas who was stranded in Geneva in transit to Nairobi, gave a presentation on the roles of historical observations in addressing climate variability and climate change challenges. He stressed the importance of longer duration, adequate spatial representation and high quality observations. He noted the value in the free exchange of data based WMO Resolution 40.

- Dr. Joseph Instiful gave the presentation on a regional approach to climate change analysis, which was to be a focus of the workshop. He noted that the hands-on work by the participants was very important and that the workshop approach organized by the Expert Team on Climate Change Detection and Indices (ETCCDI) was now a proven concept. He discussed the generation of indices and the expected outcomes of the workshop, including the background data and information that will be needed for the second workshop. He noted that user applications may require more than the standard 27 indices that are typically calculated. He stressed that the organizers of the workshop encourage the full release of all data. Finally, he noted that a peer-reviewed paper would be developed from the work that participants were doing at the workshop and would require several months of post-workshop analysis.

3. Hands-On Data Quality-control and Analysis Work

3.1 Introduction to the Climate and Data in the region

The hands-on work began on Monday afternoon. The participants were shown how to format the data they had brought with them for use with the User friendly R-based software (RClimDex[4]) for calculating regional climate indices. This exercise was facilitated by local experts using locally developed Excel Macros to *re-arranging the data into RClimDex format.*

The participants brought with them their country's best digital "long-term" daily station series of precipitation, maximum and minimum temperature for use in hands-on analyses. A map of the daily observed data from the National Meteorological and Hydrological Services (NMHSs) in the Greater Horn of Africa is shown in Appendix C, while Appendix D has a list of the 73 stations and summary of the data by country brought to the workshop. Most of these stations have observations in digital form starting from 1970 until end of 2009.

The participants then gave brief presentations on the climate of their country, the data brought to the workshop for analysis, and national needs and priorities.

3.2 Past, Present and Future Climates in the GHA

Professor Ogallo presented an over view of the past, present and main projected future climate of the region based on the available literature and also climate analyses that have been derived from ICPAC data and products. He indicated that climate extremes have led to various catastrophes in the region, such as flood risks that cause loss of life and property, conflicts due to the diminishing natural resources such as the

[4] User friendly R-based software (RClimDex) is available from http://cccma.seos.uvic.ca/ETCCDI

availability of pasture, health and water crises, loss of crops due to droughts, hydro energy risks, destruction of roads and infrastructure. Future climate change is projected to be devastating. ICPAC has been established to develop regional capacity to effectively cope with the current climate extremes as well as adapting to future regional and local climate change.

3.3 Quality Control, Homogenization, and Regionalization of Data

Through the first two days of the workshop, representatives from each country were trained in quality control and data homogeneity procedures and the use of metadata and then applied these procedures to their data. Local experts made presentations on basic principles of quality control (QC) with the purpose among others of detecting and removing errors in the data, including human, instrumental, technological, and environmental errors. The standard data QC methods were also presented, including both temporal and spatial homogenization tests. The detection of outliers and their significance as components of climate extremes were highlighted.

The presentations also included the need for regionalization of data into homogenous zones with similar climates based on the historical records. This often reduces the number of stations used in various analyses.

Dr. Joseph Intsiful made a presentation on using RClimDex for QC and how to customize data for ETCCDI workshops. This was followed by participants applying QC software to their data. A plenary session to present QC results was held before the participants were allowed to subject their data further analyses.

3.4 Regional Climate Models

Dr. Intsiful introduced the PRECIS model, developed by the UK Met Office, and demonstrated how Workshop 1 is linked to Workshop 2. He showed how the model is used in providing regional detail that is useful for predicting the impacts of climate change. He explained boundary conditions for regional climate models (RCMs), hardware requirements, resolution, run time, etc. He noted that with the computers that the participants were using, it would take about a week to complete a PRECIS run for 30 years of data. He stressed that participants must undergo training to use PRECIS and that so far some 280 people from 90 countries have been trained to use PRECIS.

He further presented how PRECIS simulated data can be validated using observed data. He also emphasized that PRECIS is an important tool in enhancing collaborative research in developing countries, using as an example the collaborative work being done between the Caribbean Community Climate Change Centre (CCCCC) and Cuba.

At the end of second day, an evaluation session was held to assess the progress of the workshop and agree on the way forward for the remaining components of the workshop. The participant from Uganda served as a representative of the entire group. At this point, countries were reminded that they would be expected to prepare a written report and to document all steps that they take in preparing the report.

3.5 Climate Indices derived from daily data

Once the country data had been formatted and quality-controlled, the participants developed a set of regional climate indices based on the temperature and precipitation data. These indices were developed using RClimDex (ETCCDMI), a user-friendly software package that is freely available to the international research community. In all, 27 indices (defined in Appendix E) were calculated based on the daily data from their countries.

Particular attention was placed on those indices that reflected climate extremes due to the fact that the vulnerability of society to climate variability and change is likely to depend more on changes in the intensity and frequency of extreme weather and climate events than on changes in the mean climate. By focusing on observation data, a better understanding of past changes in weather and climate extremes will occur and can be used to reduce uncertainty for the future projections and to develop better adaptation strategies. Sample indices that can be used to monitor extremes are denoted in Appendix E.

A summary of the findings from analyzing each country's data are included in the country reports given in Appendix F. It was agreed that these could be used to put together an important scientific paper that could contribute significantly to the next IPCC climate change assessment, as well as to current and planned national and regional climate variability / change programmes. Each national report can form an important subsection of the scientific paper, which will be coordinated by ICPAC, in partnership with the various experts and institutions.

4. Summary of Country Reports from the Workshop

This section presents a summary of the results from the country reports. Some countries had not completed all analyses by the analyses by the end of the workshop. It was agreed that all national reports be completed and sent to ICPAC within one month.

4.1 Burundi

After Quality Control, 2 synoptic stations (Bujumbura and Muyinga) out of 6 stations were retained for calculation of indices due to several erroneous values, outliers, and missing data. The period of data used for the 2 stations is 1961-2005 for daily rainfall, and 1961-1999 for daily maximum and minimum temperatures.

Calculated indices that were found to be statistically significant include: PRCPTOT, Rx1day, Rx5day, R10mm for rainfall; and Tr10, Tn20P, Tn90P, and Wsdi. PRCPTOT and R10mm indices were found to have a decreasing trend for both the stations

It was recommended that Burundi NMHS enhance capacity in data management, QC procedures, data rescue methods, and digitization. Some examples of the results from Burundi are given as **annex F.**

4.2 Djibouti

Only one station (Djibouti) with data from 1961-2009 was analyzed. There was less than 1% missing value that was corrected accordingly and QC showed that the data was generally of good quality, although daily precipitation showed some minor discrepancies in the mass curve.

Index of precipitation total in wet days >= 1mm (PRCPTOT) as well as that for heavy rain days (R10mm) showed decreasing trends. Index for warm days (Tx90P) showed increasing trend, while the index for cool days (TX10P) showed an increasing trend. Some examples of the results are given as **annex F.**

4.3 Eritrea

One station (Asmara International Airport) with data from 1961-2009 was analyzed. However, QC identified data from 1971-1973 as well as for the months of May and June of 1991 was missing; in spite of which calculation of extreme indices was performed.

PRCPTOT index showed a slight decreasing trend of precipitation total in wet days >= 1mm, which nevertheless is not significant at the P value of 0.337; while the CWD index (i.e., the maximum number of consecutive days with rainfall >= 1mm of rain) showed a decreasing trend that is significant at the P value of 0.024. The CCD index which is the maximum number of consecutive days with rainfall <= 1mm shows a significant increasing trend at P=0.008. The SU25 index which indicates the annual count when daily maximum temperature is >25^0C shows a significant increasing trend. Further analyses were recommended for this station to assess the physical reality of some of the observed results. Some examples of the results are given as **annex F.**

4.4 Ethiopia

16 stations evenly distributed throughout the country with data for the period 1971-2002 were analyzed. QC revealed that 2 stations with less than 10% of missing values had these gaps filled by the standard value, -99.9, before the analysis was done.

Total precipitation in wet days (> 1 mm: PRCPTOT index) showed variation from place to place, with decreasing trend for the southern and central parts of the country and increasing trend for the remaining parts of the country. The TXn index (monthly minimum value of daily maximum temperature) showed an increasing trend in most parts of the country with an exception for the north-western and southern parts of the country; while the monthly minimum value of daily minimum temperature (TNn) showed an increasing trend over most parts of the country as well with an exception in the north-eastern and southern part of the country.

The TNx index (monthly maximum value of daily minimum temperature) showed an increasing trend over most parts of the country, and more significantly in the north-eastern and southern parts of the country; indicating that there is a general increasing trend of warm nights for most of the stations in the country. Some examples of the results are given as **annex F**

4.5 Kenya

Data used was for 12 stations from 1961-2009 representing the different climatic zones of Kenya. MS Excel based macros were used to arrange the data in the RClimDex software format. QC showed that the data was of good quality. The missing data formed a small proportion of the temperature records, the highest being 2.5% for Makindu station.

The results were presented for only 2 stations i.e. Dagoretti and Lodwar. A significant observation for Dagoretti is that cold nights showed a decreasing trend, while the warm nights showed increasing trend, which is indicative of significant night time warming. Rainfall for Dagoretti Corner station did not show any significant trend while results for Lodwar station showed daytime temperature values had increasing trend which is faster than night time temperatures leading to an increase in the diurnal temperature range. The number of consecutive wet days shows an increasing trend whilst the number of days with precipitation due to extremely wet days (>99^{th} percentile: R99pTOT) showed a decreasing trend. Some examples of the results are given as **annex F.**

4.6 Rwanda

Data was available for the period 1971-2010 for 7 stations of daily rainfall, and 5 stations of maximum and minimum temperatures. However, for 2 of 5 stations of temperature data was only available from 1990 when the stations started operating. QC showed that 25% of the values were missing, but all the inconsistencies were resolved by filling the missing data with -99.9.

The rainfall indices showed a decrease in trend while the temperature indices showed an increasing trend. Due to some missing data, it was recommended that as much as possible, the analysis should be done with a complete data record for reliable results. This calls for enhancement of NMHSs capacity in data rescue efforts and modern techniques of filling for missing data. Some examples of the results are given as **annex F.**

4.7 Somalia

3 stations with data were analyzed for daily rainfall i.e. two stations (Hargeisa and Mogadishu) for the pre-war period 1961-1988, and only 1 station (Belet Weyne) for the post war period 1997-2010. The missing data is for period of the civil unrest i.e. 1990 to date. QC indicated no major issues

Hargeisa indicated minor decreasing trend in PRCPTOT while both Belet Weyne and Mogadishu showed decreasing trend. Recommendation was that rainfall estimation techniques (RFEs) be adopted for the missing stations and that RClimDex software be adopted for seasonal analysis as well. Some examples of the results are given as **annex F.**

4.8 Sudan

Data from 7 stations representing the different climatic zones of Sudan in the period from 1981-2009 was used. QC of the data revealed many problems in the raw data including gaps, missing records, incorrect tabulation and irrelevant data e.g. temperature was recorded as 377.0°C instead of 37.7°C. In other instances the minimum temperature was higher than the maximum.

Results for the precipitation indices were presented for Khartoum. Most of the calculated precipitation indices for Khartoum station revealed an extreme value between 1987 and 1988, but without any significant trend. There is need to improve the country's data collection and preparation. It was recommended that all the data should be quality controlled and checked for common errors for it to be reliable. Some examples of the results are given as **annex F.**

4.9 Tanzania

Daily rainfall and temperature data of 11 stations representing eleven climatologically homogeneous zones for Tanzania covering 39 years from 1971 – 2009 were used. QC revealed a few missing data values and some stations indicating maximum temperature being less than the minimum temperature.

The index for the number of days with very heavy precipitation (R20mm) showed an increasing trend with extreme cases occurring in 1989 and 2007. The index for the number of days with precipitation due to extremely wet days (R95p) also showed an increasing trend with extreme cases occurring in 1987 and 1997; when also the highest precipitation amounts in the one-day (Rx1day) and the five-day period (Rx5day) occurred. Some examples of the results are given as **annex F.**

4.10 Uganda

Data of 12 stations for the period extending from 1963-2007 was considered for analysis. QC revealed that there were a lot of missing values with large gaps to the extent that it was advised not to proceed with calculation of indices until when the missing data is availed for QC.

There were so many missing gaps in the data set that it was not possible to make any deductions on the calculated indices. Recommended to enhance capacity building in data recovery and rescue methods to improve the results of the calculated indices, and that the indices should also be calculated on seasonal basis. Some examples of the results are given as **annex F.**

5. Users input to workshops I, II and III

The workshop also included the participation of users from various sectors that are vulnerable to climate variability and change in the region. A session was devoted to user's presentations of their sector specific needs and priorities, especially with respect to the workshops I, II and III. There were common priorities for all the users, including data and information for running their sector specific models for impacts, vulnerability and adaptation assessments. The highest priority was availability of realistic regional/ local climate change scenarios for development of community based disaster risk reduction and climate change adaptation strategies. It was recommended that more users and some policy makers should be invited to workshops II and II.

6. Outputs from the First Workshop & Inputs to Second Workshop

The primary outputs from the meeting, besides this report, are country reports, given in Appendix G and summarized above, which describe the key findings from the perspective of climate applications. The other output would be a peer-reviewed paper, to be coordinated by ICPAC in partnership with the various experts and the collaborating institutions to disseminate the scientific findings from the workshop, similar to those from other regional activities[5].

Together with the indices and other data from Workshop 1, these documents form the key inputs for the second workshop, which will be held in October 2010, Nairobi, Kenya.

In summary specific results from this workshop include:

a. Climate indices from the national data of the 10 GHA countries were developed as well as quality-controlled temperature and precipitation data sets from all the national stations. Through discussions and hands-on analyses, the participants developed an appreciation of importance and value of their existing national data records and of the applications they can support.

b. User's priority and needs were identified and will be used to strengthen the outputs of workshops II and II

c. Each participant was provided with one USB storage stick that contains the climate indices and basic data for all the countries in the region and will provide a resource for additional analysis when they return to their countries.

d. Initial climate trends within the region were identified. Uncertainties in these trends will allow the countries to better identify shortcoming in their climate data and thus provide a strong rationale for rescuing any available past data and improving future observations. These analyses also demonstrated the value of the regional sharing of climate data and will also enhance regional data availability and access. Regionally these analyses will provide a much stronger basis to better define options to address enhanced data requirements.

e. The capacity of participants, NMHSs and users, was enhanced with training in data analysis and in developing valuable analysis skills. The participants now have guidelines for the future application in their countries not only for further analysis of data but also in planning processes related to climate risk management and economic development.

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5 For example, Aguilar, E., et al. (2009), Changes in temperature and precipitation extremes in western central Africa, Guinea Conakry, and Zimbabwe, 1955–2006, *J. Geophys. Res.*, 114, D02115, doi:10.1029/2008JD011010 or Klein Tank, A. M. G., et al. (2006), Changes in daily temperature and precipitation extremes in central and south Asia, *J. Geophys. Res.*, 111, D16105, doi:10.1029/2005JD006316.

f. While interim country reports were produced at the workshop, full country report with fully analyzed data sets are required before the second (modeling) workshop for:

- Comparison with reanalysis and regional models driven with reanalysis boundary conditions
- Validation of the PRECIS (and possible other regional models)
- Identification of what climate indices and analyses will be useful in economic models and planning for the agriculture/ food security and water resources sectors.

Appendix A: Workshop Agenda

DAY 1: MONDAY, 19 APRIL 2010 **Workshop Registration**	
8:30 a.m.	Collection of data for processing brought to the workshop by the participants from their country in the best digital "long-term" daily station series of precipitation, maximum temperature and minimum temperature and use in the hands-on analyses. *Local expert*
Opening Plenary	
9.00-9.10 am	Prof Laban Ogallo, Director, IGAD Climate Prediction and Applications Centre (ICPAC) welcomes the guests and Invites the following to make their statements:
9.10-9.20 am	Representative of Director of Kenya Meteorological Department
9.20-9.30 am	Dr Joseph Intsiful, UK-Met Office
9.30-9.40 am	Dr William Westermeyer, World Meteorological Organization (WMO/GCOS)
9.40-9.50 am	Mr. Francis Muraya, GFDRR and Disaster Management/World Bank address the gathering and declare the workshop officially open.
9:50-10.00 am	Self introductions of participants
10.00-10.20am	Group Photograph
10.20-10:30 a.m.	**Break**
10:30-10.50 am	A Regional Approach to Climate Change Analysis: A brief history of these type of workshops with examples from a past workshop and goals and expected outcomes of the workshop: hands-on analyses of indices of extremes, country reports and journal paper on changes in extremes in the region, etc. *Local expert*
10:50-11.10a.m.	The World Bank/GFDRR Project "Climate Observations and Regional Modeling in Support of Climate Risk Management and Sustainable Development": general introduction how this workshop fits in the overall goals, what the project will establish and bring for the participating countries *William Westermeyer, WMO/GCOS*
11:20 -11.50a.m.	Why historical climate and weather observations matter: observing system requirements for climate in Africa, general comments about the benefit of data from stations on the other side of a border, how local observations fit in the global picture, etc. *Dr Joseph Intsiful, UK-Met Office*
11:50 am – 1.00pm.	Questions and discussion
1:00 – 2.00 p.m.	**Lunch**
Session 1:	**GHA Climate: Past, Present and Future**
2.00-2.30pm	Main weather and climate related challenges in the GHA region *Local expert*

2.30-2.45pm	Observed and projected climate change in the region: an overview discussion of how the climate has changed and how it is projected to change in future (using information from the Climate Explorer) with special emphasis on why we need observational data *Dr. Joseph Intsiful*
2.45-3.00pm	Questions and discussion
3:00 – 3.30p.m	Coffee Break
Session 2: Introduction to the climate and data in the region ***Moderator: Dr. Joseph Intsiful***	
3:30 – 5.00p.m.	5-minute talks by the participants (one from each country) in alphabetical order. A typical presentation might start with a few beautiful photographs of the country to help orient us and a short description of the climate in the area. Each presentation should include a map showing the locations of the stations whose data were brought and a discussion of the period of record for the digital daily data. Climate change analyses (if available) are not expected to be presented at this time as that will be the topic of the Friday afternoon session.
5.00-5.15pm	Daily wrap up *Local expert*
5:15 p.m	Close
DAY 2: TUESDAY, 20 APRIL 2010	
Session 3: Quality control of daily data series **Moderator: Dr. Nelson Pyuzza**	
9:00 -9.30a.m.	Quality control (QC): General theory, ensuring correct station location, correct units, and assessment of outliers. The latter is particularly problematical as the indices we will be calculating focus on extremes, yet it is the extremes that are most likely to be flagged as bad data by QC software. Throwing out valid extreme values can cause errors as easily as keeping erroneous extreme values. Introduction to QC in RClimDex, the limitations and uses, types of graphing that can help one assess the validity of outliers (histograms, time series, neighboring stations' data, etc.). The RClimDex software is available from: http://cccma.seos.uvic.ca/ETCCDI. This software uses a statistical system known as "R". The R statistical software is available free of charge from http://www.r-project.org/. *Dr. Joseph Intsiful*
9:30 -9.45a.m.	Questions and discussion
9:45-10.30 a.m.	Participants start QC work on their data using the RClimDex software. *Dr. Joseph Intsiful, Local experts*

10:30 -10.50a.m.	**Tea Break**
10:50am -1.00p.m.	Participants continue work on their data
1.00-2.00p.m.	Lunch
2.30-3.00pm	Participants continue to work on their data *Local experts*
3.00-3.30pm	Coffee Break
3.30-4.30pm	Participants continue to work on their data. *Local experts*
Session 4: Homogeneity of station time series ***Moderator: Dr. Joseph Intsiful***	
4:30 -5:00p.m	Homogeneity: General theory, issues involved incl. the role of meta data, and implications for analyses of extremes. (Some general information on homogeneity can be found in the WMO Guidelines on Metadata and Homogeneity at: http://www.ncdc.noaa.gov/oa/wmo/ccl/) *Local expert*
5:00-5:15 p.m.	Daily wrap up *Local expert*
5:15pm	Close
DAY 3: WEDNESDAY, 21 APRIL 2010	
9:00 -9.15a.m.	Review of Previous Day's Activities *William Westermeyer, WMO*
9:15-9:40 a.m.	Introduction to Data Homogeneity Techniques in workshop software *Local expert*
9:40-10:00 a.m.	Questions and discussion *Local expert*
10:00-10:30 a.m.	Participants work on applying homogeneity testing to their data as well as continuing QC *Local experts*
10:30-10:50 a.m.	**Break**
10:50a.m -1:00 p.m.	Participants work with the software on their data

	Local experts
1:00-2:00p.m	**Lunch**
2:00-3:00p.m	Participants work with the software on their data *Local expert*
3:00-5:00p.m	Participants Hands on with the software on their data *Local expert*
5:00-5:15 p.m.	Daily wrap up *Local expert*
DAY 4: THURSDAY, 22 APRIL 2010	
Session 5: Indices derived from daily data ***Moderator: Dr. Nelson Pyuzza***	
9:00 - 9:10a.m	Review of Previous Day's Activities *Local expert*
9:10-9:30a.m	Introduction to Indices Includes discussion of: - Climate Indices as a proxy for data - Why the need for indices? - Problems with indices (e.g., non-reproducible by other scientist who lack access to the data) - Economic value of data - Data exchange problems - Examples of some indices and usefulness - Identification of indices of relevance for this region *Dr. Joseph Intsiful*
9:30-10:00a.m	Calculating the indices – specifics of how the indices are calculated in RClimDex *Local expert*
10:00-10:15a.m	Questions and discussion
10:15-10:30a.m	**Break**
10:30-10:50a.m	Participants start to work on calculating indices and continue to perform QC and homogeneity tests with a view towards preparing country/sub regional reports. *Local experts*
10:50a.m-12:10p.m	Hands on training on calculating indices *Dr Nelson Pyuzza, Mr Omondi Philip, Dr Joseph Intisiful*
12:10-1:00p.m	Hands on training on calculating indices *Dr Joseph Intsiful*
1:00-2:00p.m	**Lunch**
2:00-3:00p.m	Hands on training on calculating indices *Dr Joseph Intsiful, MOHC*

3:00-5:00p.m	Hands on training on calculating indices *Dr Joseph Intsiful, Dr Nelson Pyuzza*
5:00-5:15 p.m.	Daily wrap up *Dr Nelson Pyuzza*
7:30 p.m.	Joint Dinner at Carnivore
DAY 5: FRIDAY, 23 APRIL 2010	
Session 6: Report of outcomes ***Moderator: Dr. Joseph Intsiful***	
9:00 - 9:10a.m	Review of Previous Day's Activities *Dr. Nelson Pyuzza*
9:10-9:30a.m	Show of results of the indices for the whole region and showing a few examples of what country reports have looked like in past Workshops *Dr. Joseph Intisiful*
9:30-10:00a.m	Participants continue to work on indices and producing a country analysis. *Local expert*
10:00-10:15a.m	Questions and discussion
10:15-10:30a.m	**Break**
10:30-10:50a.m	Participants continue to work on indices and producing a country analysis. *Mr Omondi, Dr Joseph Intsiful, Dr Pyuzza*
10:50a.m-12:10p.m	Presentation of country reports: The reports mentioned the quality and homogeneity problems the data had and a summary of the indices results in 5 minutes each (max. 8 slides). *Dr. Nelson Pyuzza*
12:10-1:00p.m	Participants finalizing country analyses/reports.
1:00-2:00p.m	**Lunch**
2:00-2:30p.m	Regional report: combining the analysis results together. What do the data indicate? Showing a map of trends from stations in the area *Dr Joseph Intsiful*
2:30-3:00p.m	Meeting conclusions, discussion and feedback on the workshop (incl. software recommendations) *Dr. Nelson Pyuzza*
3:00-5:00p.m	How do the results of the first workshop serve the second workshop on regional climate change scenarios and the third workshop on impacts/adaptation? What is the way ahead? *Dr Joseph Intsiful*
5:00-5:15 p.m.	Closing ceremony *Laban Ogallo, ICPAC*
END OF WORKSHOP ONE	

Appendix B: List of Workshop Facilitators

1	Kenya	Dr Ivivi Mwaniki	Lecturer University of Nairobi P O Box 30197 – 00100 NAIROBI Tel: 254 20 4445751	Email: jimwaniki@uonbi.ac.ke
2	Kenya	Mr Wilson Gitau	Lecturer University of Nairobi P O Box 30197 – 00100 NAIROBI Mob: 0722 – 996507	E-mail: wi.gitau@uonbi.ace.ke
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8	Kenya	Mr George kabaka	Climatology Department University of Nairobi P O Box 30197 – 00100 NAIROBI Mob: +254-723330810 or +254-735166593	E-mail : gkabaka@uonbi.ac.ke

Appendix B2: List of Participants

#	COUNTRY	Scientists/ Users	Contacts	Remarks
1	Burundi Scientists	Mr Ruben Barakiza	Geographical Institute of Burundi (IGEBU) B oite Postal 331 BUJUMBURA	Tel. +257-40-2318/2526 Fax: +257-40-2625 E-mail: igebu@cbinf.com barakiza_r@yahoo.co.uk
2	Djibouti Scientists	Mr Abdoulrahman Youssouf Nour	Meteorologist Djibouti International Airport Mobile: +253 61 98 75 Office: +253 34 05 00/ 34 31 50 Djibouti Rep. of Djibouti	E-mail: abdou_kouka@yahoo.fr
3	Ethiopia Scientists	Mr. Girmaw Gezahegn Bogale	Senior meteorologist, NWP expert and in charge of modeling unit National Meteorology Agency(NMA) P. O. Box 1090 Ethiopia Tel 251116615793/79 Cell: 251911665062	girmaw.bogale@gmail.com email: girmaw.bogale@gmail.com or girmaw.gezahegn@yahoo.com
4	Eritrea Scientists	Mr. Isaac Fesseha	Asmara International Airport Head of Meteorology P. O. Box:- 5846 Fax:- 291-1-152657 Tel:- 291-1- 54538	isaacfesseha@yahoo.com 291-1-152657
5	Rwanda Scientist	Mr Mathieu Mbati Mugunga	Forecaster Rwanda Meteorological Department	Email: mbathieu@yahoo.fr
6	Somali Scientist	Ms Peris Muchiri	Climate Scientist SWALIM Cell: +254735339179	Email: pmuchiri@faoswalim.org pmuchiri@faoswalim.org
7	Sudan User	Prof Musa Tibin Musa Adam	Director General Animal Resources Research Corporation P O Box 610 KHARTOUM Tel: 249183460504	Email: musatibin@yahoo.com
8	Sudan Scientist	Mr Badr Eldin Mamoun	Sudan Meteorological Authority P O Box 574	Email: Badrmamoun63@yahoo.com

			KHARTOUM Mobile: +918205457 Sudan	
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Appendix C: Daily station data used for the workshop

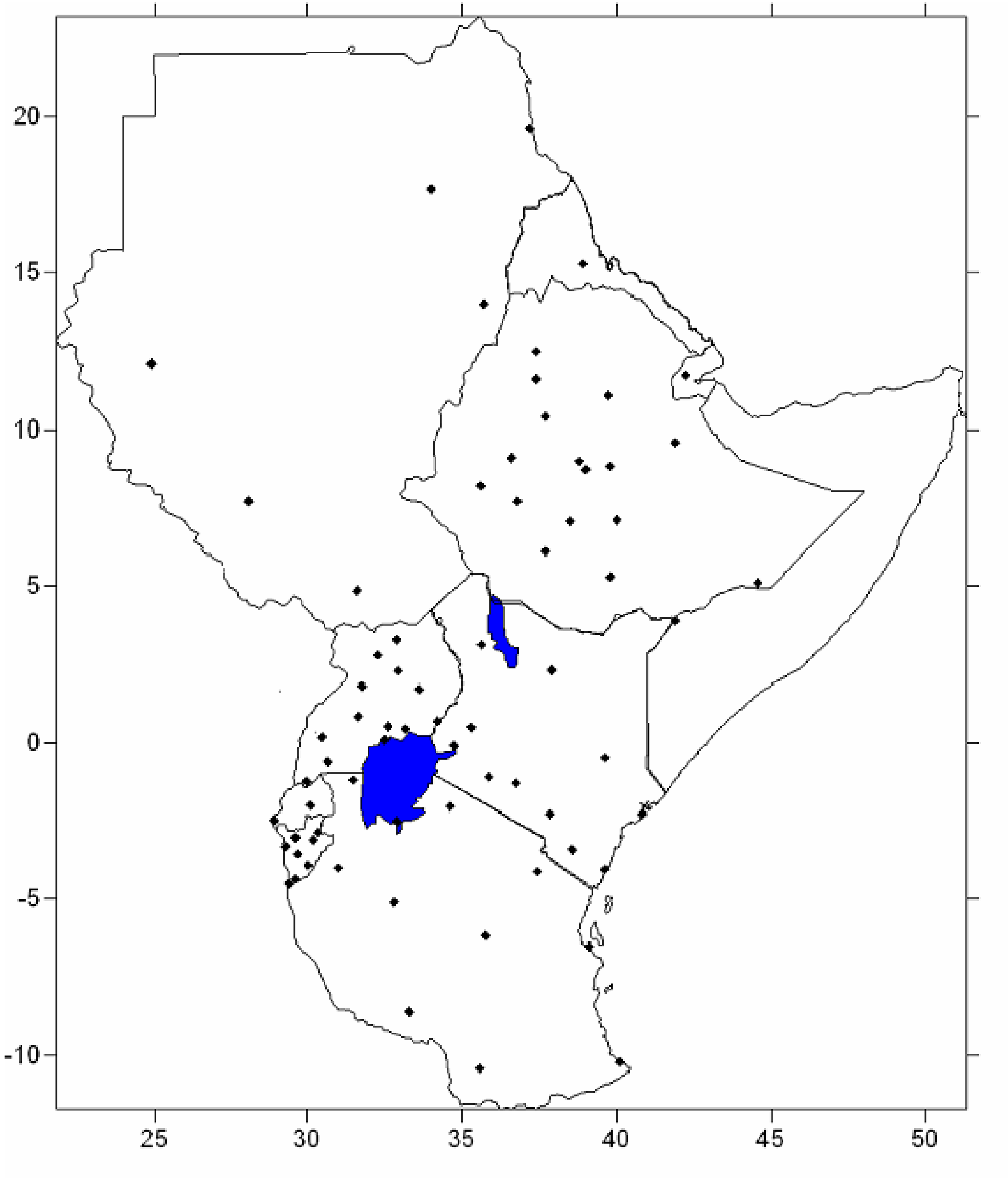


Figure 2: Location of stations with Daily Rainfall and Temperature over the Greater Horn of Africa region

Appendix D: Data available over the region

Station	Rainfall	Temperature	
Name		**Minimum**	**Maximum**

Burundi

Bujumbura	1961-2005	1950-1998	1950-1998
Muyinga	1961-2005	1961-1998	1961-1998
Musasa	1961-2005	1961-1998	1961-1998
Karuzi	1961-2005	1961-1998	1961-1998
Gisozi	1961-2005	1975-1999	1975-1999
Nyanza-Lac	1979-1990	None	None

Djibouti

Djibouti	1961-2009	1961-2009	1961-2009

Eritrea

Asmara	1961-2009	1961-2009	1961-2009

Ethiopia

Adis Ababa	1970-2009	1970-2009	1970-2009
Arba Minch	1987-2009	1987-2009	1987-2009
Awassa	1973-2009	1973-2009	1973-2009
Bahar dar	1970-2009	1970-2009	1970-2009
Combolcha	1970-2009	1970-2009	1970-2009
Debre Markos	1970-2009	1970-2009	1970-2009
Dibrezei	1970-2009	1970-2009	1970-2009
Dire Dawa	1970-2009	1970-2009	1970-2009
Gode	1970-2009	1970-2009	1970-2009
Gondar	1970-2009	1970-2009	1970-2009
Gore	1970-2009	1970-2009	1970-2009
Jimma	1970-2009	1970-2009	1970-2009
Negele	1970-2009	1970-2009	1970-2009
Metehara	1985-2009	1985-2009	1985-2009
Negelle	1970-2009	1970-2009	1970-2009
Nekemte	1971-2009	1971-2009	1971-2009
Robe	1973-2009	1973-2009	1973-2009

Kenya

Lodwar	1961-2009	1968-2009	1968-2009
Marsabit	1961-2009	1975-2009	1975-2009
Garissa	1961-2009		
Kisumu	1961-2009		
Narok	1961-2009		
Dagoretti	1961-2009	1967-2009	1967-2009
Lamu	1961-2009	1970-2009	1970-2009
Mombasa	1961-2009	1967-2009	1967-2009
Voi	1961-2009	1967-2009	1967-2009
Eldoret	1972-2009	1972-2009	1972-2009
Mandera	1961-2009	1967-2009	1967-2009
Makindu	1961-2009	1968-2009	1968-2009

Rwanda

Kigali	1964-2009	1971-2009	1971-2009
Kamembe	1971-2009*	1960-2009*	1960-2009*
Gisenyi	1975-2009*	1975-2009*	1975-2009*
Gikongoro	1967-2009*		
Ruhengeri	1977-2009*		
Byumba	1970-2009*	1960-2009*	1981-2009*
Kibungo	1979-2009*		

Sudan

Atbara	1961-2010	1961-2010	1961-2010
Portsudan	1961-2010	1961-2010	1961-2010
Gedaref	1961-2010	1961-2010	1961-2010
Nyala	1961-2010	1961-2010	1961-2010
Wau	1961-2010	1961-2010	1961-2010
Juba	1961-2010	1961-2010	1961-2010

Somalia: No data except for 3 rainfall stations with gaps during the war

Tanzania

Bukoba	1970-2009	1970-2009	1970-2009
Mwanza	1970-2008	1970-2009	1970-2009
Loliondo	1970-2009	1970-2000*	1970-2000*
Same	1970-2008	1970-2009	1970-2009
Dodoma	1970-2008	1970-2009	1970-2009
Tabora	1970-2000	1970-2000	1970-2000
Kigoma	1970-2008	1970-2009	1970-2009
Mbeya	1970-2008	1970-2009	1970-2009
Songea	1970-2008	1970-2009	1970-2009
Mtwara	1970-2008	1970-2009	1970-2009
DIA	1970-2000	1970-2000	1970-2000

Uganda

Lira	1970-2009	1970-2009	1970-2009
Soroti	1970-2009	1970-2009	1970-2009
Jinja	1970-2009	1970-2009	1970-2009
Kitgum	1970-2009	1970-2009	1970-2009
Entebbe	1970-2009	1970-2009	1970-2009
Mbarara	1970-2009	1970-2009	1970-2009
Kabale	1970-2009	1970-2009	1970-2009
Gulu	1970-2009	1970-2009	1970-2009
Tororo	1970-2009	1970-2009	1970-2009
Namulonge	1970-2009	1970-2009	1970-2009
Kituza	1970-2009	1970-2009	1970-2009
Kamenyamigo	1970-2009	1970-2009	1970-2009

* Missing Data

Summary of data brought to the workshop by country participants

Burundi – 6 stations, from 1961-2005, with one station lacking some data

Djibouti – No report*! Was presented first thing the next day; 1 station (Djibout), from 1961-2009.*

Eritrea – 1 station (Asmara), *from 1961 – 2009, with missing data from 1971 – 1973, and 1991*

Ethiopia – 16 stations from 1961 onwards (noted extreme events and droughts)

Kenya – 12 stations for different zones from 1961 (some gaps, especially in rainfall data)

Rwanda – 6 stations but some gaps

Somalia – not present, but ICPAC had some data. (Later a representative based in Kenya showed up and worked with some data): *3 rainfall stations; 1 station (Belet Weyne) from 1997 – 2010 (Post war era), 2 stations (Hergesa and Mogadishu) from 1961 – 198 (Pre war era)*

Sudan – ~~1~~6 stations, at least one for each zone, but some missing data

Tanzania - 11 stations, one per zone starting in 1971, very few missing (noted that data are needed beginning in 1961 for at least one station)

Uganda –12 stations, starting at different dates and with some gaps in data

Appendix E: ETCCDI indices

The definitions for a core set of 27 descriptive indices of extremes defined by the Joint CCl/CLIVAR/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI. User-friendly R-based software (RClimDex) is available for their calculation (See http://cccma.seos.uvic.ca/ETCCDI)

Temperature indices:

Index		Description
1. FD *	**frost days**	count of days where TN (daily minimum temperature) < 0°C
2. SU	**summer days**	count of days where TX (daily maximum temperature) > 25°C
3. ID	**icing days**	count of days where TX < 0°C
4. TR	**tropical nights**	count of days where TN > 20°C
5. GSL *	**growing season length**	annual count of days between first span of at least six days where TG (daily mean temperature) > 5°C and first span in second half of the year of at least six days where TG < 5°C.
6. TXx		monthly maximum value of daily maximum temperature
7. TNx		monthly maximum value of daily minimum temperature
8. TXn		monthly minimum value of daily maximum temperature
9. TNn		monthly minimum value of daily minimum temperature
10. TN10p	**cold nights**	count of days where TN < 10th percentile
11. TX10p	**cold day-times**	count of days where TX < 10th percentile
12. TN90p*	**warm nights**	count of days where TN > 90th percentile
13. TX90p	**warm day-times**	count of days where TX > 90th percentile
14. WSDI *	**warm spell duration index**	count of days in a span of at least six days where TX > 90th percentile
15. CSDI	**cold spell duration index**	count of days in a span of at least six days where TN > 10th percentile
16. DTR	**diurnal temperature range**	mean difference between TX and TN (°C)

Precipitation indices

17. RX1day	**maximum one-day precipitation**	highest precipitation amount in one-day period
18. RX5day *	**maximum five-day precipitation**	highest precipitation amount in five-day period
19. SDII *	**simple daily intensity index**	mean precipitation amount on a wet day
20. R10mm *	**heavy precipitation days**	count of days where RR (daily precipitation amount) ≥ 10 mm
21. R20mm	**very heavy precipitation days**	count of days where RR ≥ 20 mm
22. Rnnmm		count of days where RR ≥ user-defined threshold in mm
23. CDD *	**consecutive dry days**	maximum length of dry spell (RR < 1 mm)
24. CWD	**consecutive wet days**	maximum length of wet spell (RR ≥ 1 mm)
25. R95p TOT *		precipitation due to very wet days (> 95th percentile)
26. R99pTOT		precipitation due to extremely wet days (> 99th percentile)
27. PRCPTOT		total precipitation in wet days (> 1 mm)

* *Proposed indicators for monitoring change in climatic extremes world-wide*

Appendix F: Country Reports

Ethiopia

Dr Girmaw Gezahegn

National Meteorological Agency of Ethiopia

Climatology of Ethiopia

Rainfall in tropical countries is highly variable in time and space. Ethiopia (3^0-15^0N, 33^0-48^0E), being a tropical country, the variability of rainfall is a common phenomenon. The risks associated with this are extreme weather events including frequent drought and flood which have a great impact on socio-economic activities. Predicting these extreme events ahead of time with full accuracy remains a problem.

Ethiopia has three seasons. These are Belg (small rainy season) that spans from February to May, Kiremt (main rainy season) that spans from June to September and Bega (dry season) that spans from October to January.

The Belg rainy usually occurs in bimodal regimes of the country. Namely, the northeastern, eastern, central, southern and southwestern parts of the country are enjoying rain during this season. However, the northern and northwestern parts of the country start getting rainfall towards the end of the season. The Belg rainfall is highly variable in time and space. Moreover, the maximum temperature reaches its peak during this season.

Kiremt (main rainy season) begins in June and continues to September though its onset and cessation of the season varies over space. Segele et al., (2005) figured out, the mean onset of the main rainy season is June 21. It covers much of the country except the southern and the southeastern lowlands remain cloudy during this season. The maximum temperature goes down during this season in association with cloudy coverage. The enhancement of weather system leads to flash flood and over bank flow of rivers during this season. This rainy season contributes 65-95% of the total annual rainfall (Segele et al. 2005).

Bega is a dry season for much of the country, however, the southern and he southeastern lowlands receive their second rainy season. The minimum temperature goes down during this season in various parts of the. Especially, over highland areas the minimum temperature sometimes goes down to -8.0.

Impact of extreme events

Ethiopia is plagued by extreme events such as drought, flood and frost. Drought is a normal, recurring feature of climate. It occurs virtually in all climatic regions with high as well as low rainfall areas. It is a temporary aberration, in contrast to aridity, which is a permanent feature of the climate and is restricted to low rainfall areas. Drought is the consequence of a natural reduction in the amount of precipitation received over an extended period of time, usually a season or more in length, although other climatic factors (such as high temperatures, high winds, and low relative humidity) are often associated with it in many regions of the world and can significantly aggravate the severity of the event. Drought is also related to the timing (i.e., principal season of occurrence, delays in the start of the rainy season, occurrence of rains in relation to principal crop growth stages) and the effectiveness of the rains (i.e., rainfall intensity, number of rainfall events). Thus, each drought year is unique in its climatic characteristics and impacts.

Flood is another phenomenon which is associated with extreme events. Climate change aggravates the intensity and frequency of flood occurrence. For instance, the 2006 flood season killed thousands people and caused a lot of damage in properties. The flooding occurred in two different parts of the country. One was occurred in the eastern parts of the country. Accentually what happened heavy rainfall prevailed in

the highland and caused a flash flood in the lowland parts of the country due to channeling to river which usually dry in most of the time. The second was occurred in the southern parts of the country due to continuous and heavy rainfall, the river Omo flowed over bank.
Frost is another climatic phenomenon that affects the country during the dry season when the crops are at flowering stage. This has a significant impact on agriculture such as crops and pasture.

Justification of main streaming of climate variability and change

The earth surface temperature is increasing due the emission of green house gases. Especially, the emission of CO2 is increasing at an alarm rate since the industrial revolution, mainly from fossil fuels and coal. The concentration of CO_2 was less than 220 parts per million and by now it is more than 340 parts per million.
As the earth's surface temperature is warming, everything will be affected by it. For instance, the length of the growing period of crops either it will be shortened or lengthened. Hence, to take the mitigation or adaption option, climate variability or change has to study well. In line with this, in this study I am going to examine the climate variability and change over Ethiopia for the period of 1971-2002.

Project objective of workshops

The overall objectives of this workshop programme are to demonstrate the use and value of climate observations and regional models for decision making, to provide advice on model performance and limitations, and to improve capabilities across the region for using climate data records and model projections.
The first workshop (Workshop I) will focus on data needs. Specific goals are to:
1) Use available climate data from countries in the region to enable detailed assessments of observed climate variability and change.
2) Assess the adequacy of the quantity and quality of the available data for the evaluation of the skill of global and regional climate models for the GHA region.
3) Demonstrate the value of the collaborative use of data and standardized climate indices, including those representing extremes, among countries in the region.
4) Increase regional research synergies by sharing insights and improve analyses between neighbouring countries.
5) Encourage countries in the region to improve their observing systems and to undertake data rescue (DARE) and data digitization efforts.

Data and methodology

Data and methods used

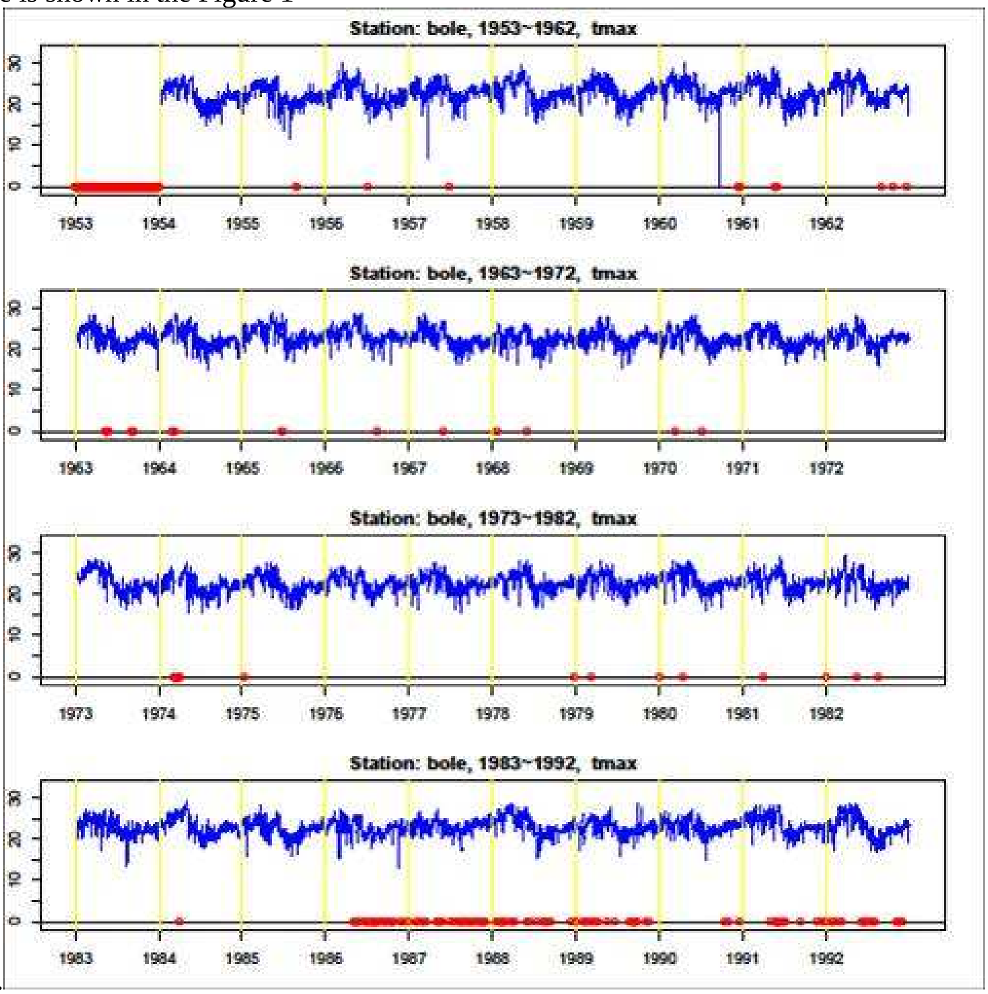
The data for this study is obtained from National Meteorological Agency of Ethiopia. It is a daily data of 16 stations of rainfall, minimum temperature and maximum temperature. The stations are fairly distributed throughout the country for the period 1971-2002. The detail of the data set is given in the table 1.

Table 1: list of stations

country	Station name	WMO ID	period	latitude	longitude	elevation
1	Addis Ababa Bole	63450	1971- 2002	9.03	38.37	2354
2	Diredawa	63471	1971-2002	9.6	41.85	1260
3	Debremarkos	63334	1971-2002	10.33	37.67	2515

4	Combolcha	63333	1971-2002	11.12	39.73	1903
5	Gore	63402	1971-2002	8.15	35.53	2002
6	Jimma	63403	1971-2002	7.67	36.83	1667
7	Mekele	63330	1971-2002	13.5	39.48	2070
8	Debrezeit	63451	1971-2002	8.73	38.95	1900
9	Gondar	63331	1971-2002	12.55	37.42	1967
10	Neghelle	63533	1971-2002	5.33	39.57	1544
11	Nekemte	63340	1971-2002	9.08	36.46	2080
12	Gode	63478	1971-2002	5.9	43.58	295
13	Awassa	63460	1972-2002	7.08	38.48	1750
14	Robe	63474	1984-2002	7.13	40.00	2400
15	Metehara	-	1984-2002	8.87	39.9	930
16	Arbaminch	63500	1987-2002	6.08	37.63	1290

Among 16 stations, 2 of them had a missing data more than 10% for three meteorological elements. The missing values were filled with -99.9. The quality of the data was checked using RClimDex and the erroneous observations were filled with -99.9. An example of the plot of maximum temperature for Addis Ababa Bole is shown in the Figure 1



1.

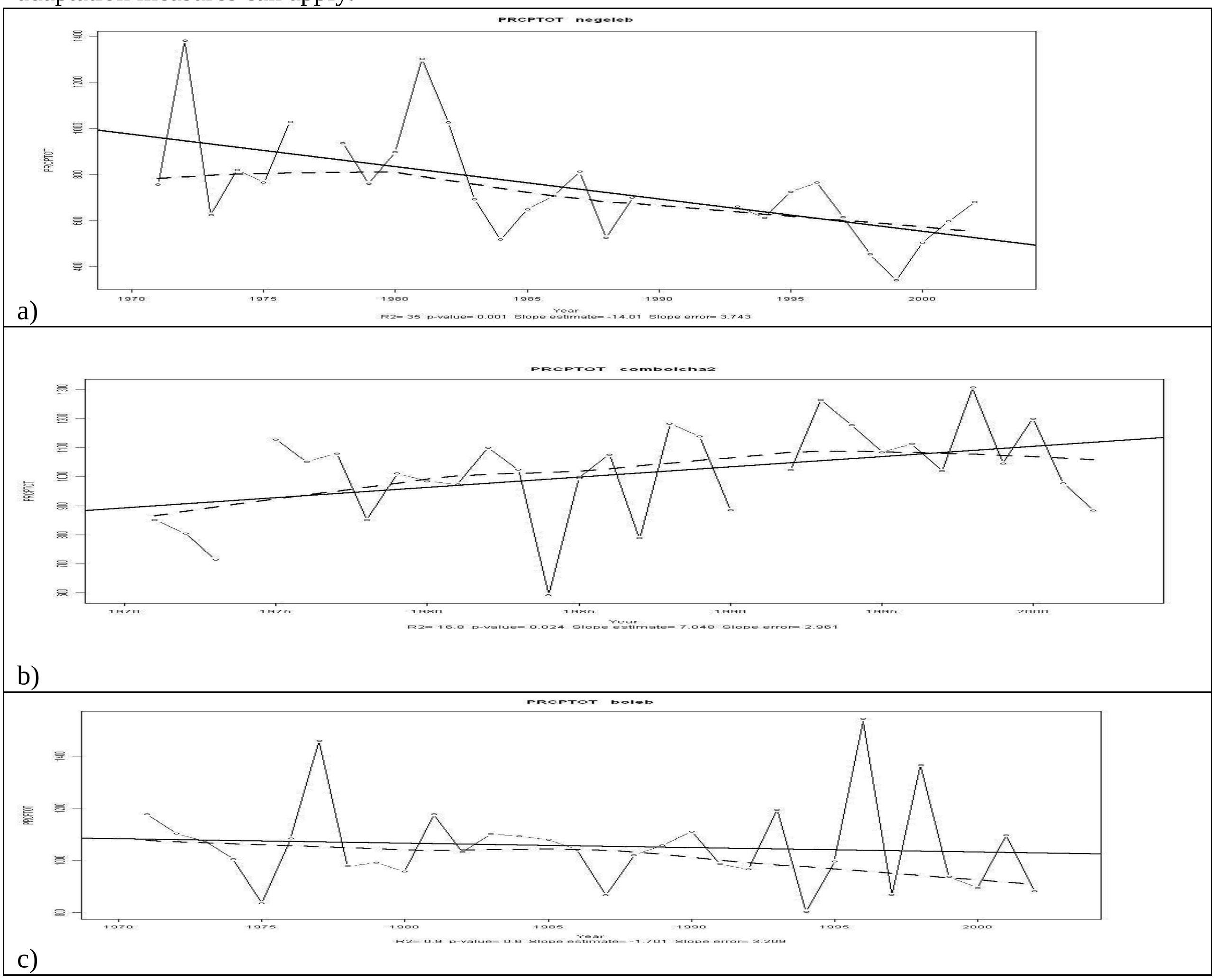
Figure 1 : time series of maximum temperature for Addis Ababa Bole

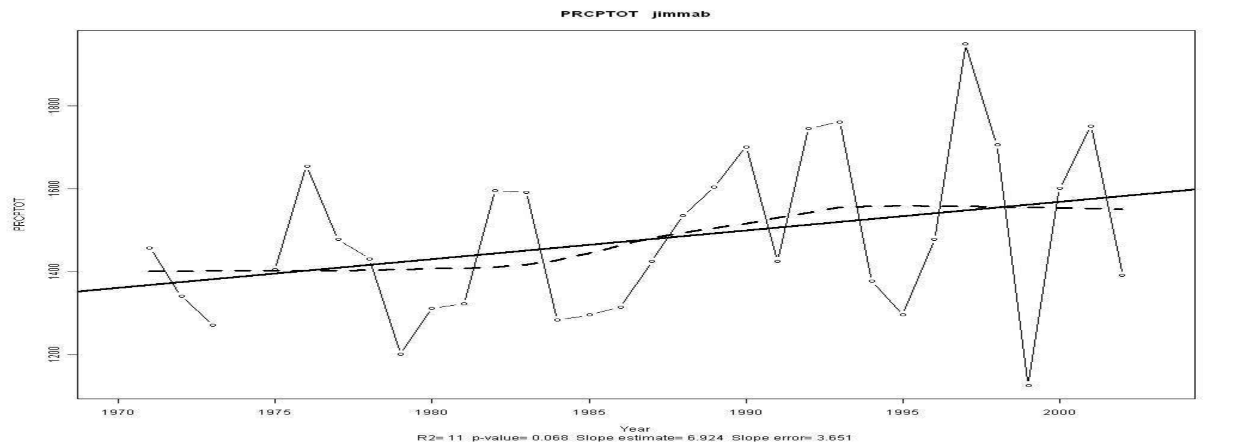
The quality of the data was tested using RClimDex and which performs data quality control and calculates indices.

Results and discussion

The Rainfall indices

Rainfall in Ethiopia is highly variable in time and space. Its annual variability leads to recurrent drought and Flood. Indices were computed for 16 stations for the period 1971-2002. Figure 1a and 1c indicated that the rainfall trend in these stations have a decreasing trend in mean annual rainfall. On the other hand, Figure 1b and 1d are showing that the total annual rainfall has a decreasing trend. From the figure we can deduce that the variability of total annual rainfall varies from place to place. The southern and the central parts of the countries have a decreasing trend in mean rainfall while stations located in the remaining parts of the country have an increasing trend in the mean annual rainfall. Hence, users have to look carefully on areas which have a decreasing trend in the mean rainfall pattern so that mitigation and adaptation measures can apply.





d)

Figure 2: Rainfall trend for the period of 1971-2002 a) Station Neghelle b) Station Combolcha c) Station Addis Ababa Bole d) Station Jimma

Eritrea

Mr Isaac Fesseha

Meteorological Services of Asmara International Airport, Eritrea

Introduction

Eritrea is located on the Northern part of the Horn of Africa, extending from about 12.2 ^{o} to 18.1 ^{o} latitudes in the Northern hemisphere. Though it is found within the Tropics, it is classified as Arid and semi-arid climate. The climate of Eritrea is modified by the influence of its topography and Geographical location. More than 80% of its population depends on Rain-fed Agricultural activities, Animal herding and Fishing therefore, Food security is the main concern of the country.

In light of the above facts, Eritrea's topography and climatic zone can be classified into, High Grounds, Escarpments and the lowlands.

It has also three rainy Seasons known as Short rainy season which extends from March, to May, Long rainy season that covers June to September, and winter rainy season that starts from October to December/January.

Climatology

Though Eritrea is fond within the tropics, it is sandwiched by the Saharan and Arabian deserts. As a result it is classified as semiarid climate. The topography modifies its climate and has three rainy seasons.
a) March to May of spring rain which is known as short rainy season;
b) June to September of summer rain known as long rainy season;
c) October to December as winter rain which is for some areas of the country.

From the long term Climatological records the country seriously affected by Droughts; Wild-fires; Heat-waves; Floods; Land-slide and (Erosion); Dust/sand-Storms; Strong wind speed etc.;

Impacts of extreme climatic events

Drought

1969, 1989, 1990, 1991, 2008 are some of the few years that the country were seriously affected by drought and where there was lose in life and damage in property particularly in Plants and Animals.

Flood and strong precipitation

July and August 2001 were the two months where heavy rain of 143mm within 3:30 duration had observed. Drainage systems were blocked; Dams were destroyed and Buildings were damaged.

Maximum temperature

Massawa and Assab reported 48.4 C^{o} in July 2004 and 49.2 C^{o} in August 1997 respectively, during these days records indicates that many people were collapsing and becoming unconscious

Minimum temperature

Asmara reported -6.5 C^{o} in January 1989 where flowers and vegetables were seriously destroyed within one night.

Strong wind speed

Reports from Assab Airport indicate in October 2006 there was strong wind 25 -27 meter per second. As a result Antennas for Radio Communication installed by AIAM were uprooted.

Land slide

This is a common phenomenon particularly in the roads constructed over the escarpments;

- Asmara to Massawa Road;
- Asmara to Mandefera-Mereb road;
- Asmara to Adikaih -Senaffe road;
- Asmara to Keren-Tessenai road;

Therefore, Land Transportation regularly interrupts due to Landslides.

Visibility

In the Western and Eastern low lands of Eritrea, Haze, Sand & sand storms reduces visibility even to less than 50 meters. In the High-grounds and Escarpments of Eritrea, Fog reduces visibility some times to less than 50 met. As a result Cars and Flight accident happens.

Justification for mainstreaming climate variability

As most of the country is high lands and escarpments it is vulnerable to erosion. In light of that tracing is widely and regularly performed by the National Services. Using plastic bags are completely forbidden and they are changed by cotton bags. Planting trees is regularly done by National Services.

Existing conditions and challenges

At this moment Eritrea is waiting for the Proclamation to establish National Meteorological Agency, however, it is performing its activities with very limited Human Power, using manual equipments, very few Stations and old archiving system.

Challenges

1. Shortage of trained Man-Power;
2. Existing Equipments are old and manual;
3. Public weather forecast is broadcasted by non Professionals;
4. Shortage of high capacity computers;
5. The data archiving system is too old;
6. Public awareness is low and needs to be sensitized;

Requirements

In order to solve the challenges that are facing the country the following solutions are required:

1. Capacity building in developing different Forecasting models in general, in Dynamic modeling in particular;
2. Training in higher WMO classes starting from WMO class II to specializing courses;
3. The Manual observing systems & equipments to be automated;
4. Big capacity Computers that helps to extract images from global Centers;
5. Latest Software and equipments to archiving historical data;
6. Pilot projects to elevate the awareness of Policy makers, end users up to village level;
7. To develop & maintain Communication and Net working systems;

8. Public Weather studio in order to disseminate the weather and Climate by the
1. Meteorological experts themselves;

Objective

The overall Goals and objectives of the workshop program are:

- To demonstrate the use and value of climate observations and regional models for decision making.
- To provide an advice on Model performance and limitations;
- To improve capabilities across the region for using climate data records and climate projections.

Discussions and results

During the workshop days the following headings were discussed.
1) Requirements GHA Climate: Past, Present and Future.
  -main weather and Climate related challenges in the GHA region;
  -Observed and projected climate change in the GHA region;

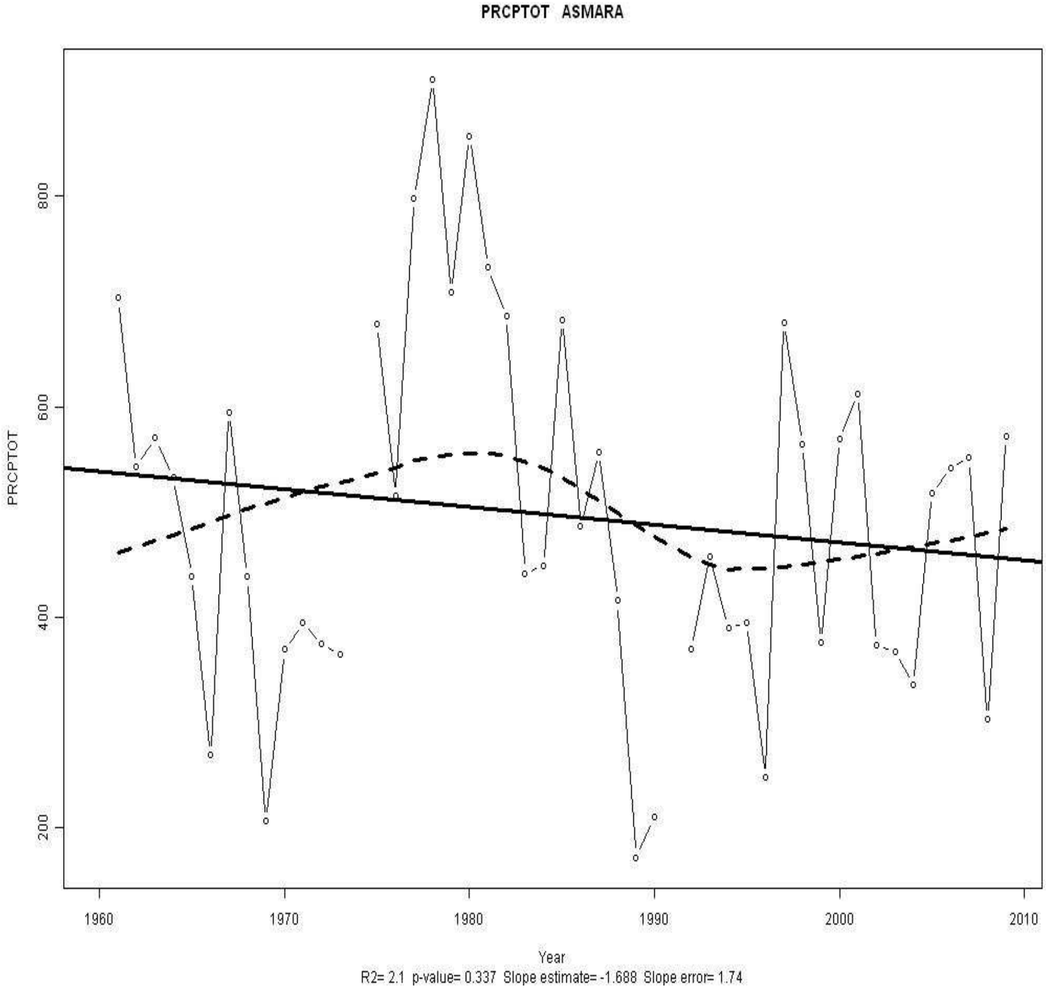
2) Introduction to the existing Climate and daily data in the region.
  -Participants climate expertise country report;
  -User community country report;

3) Quality Control of daily data Series. The general theory of Quality control;

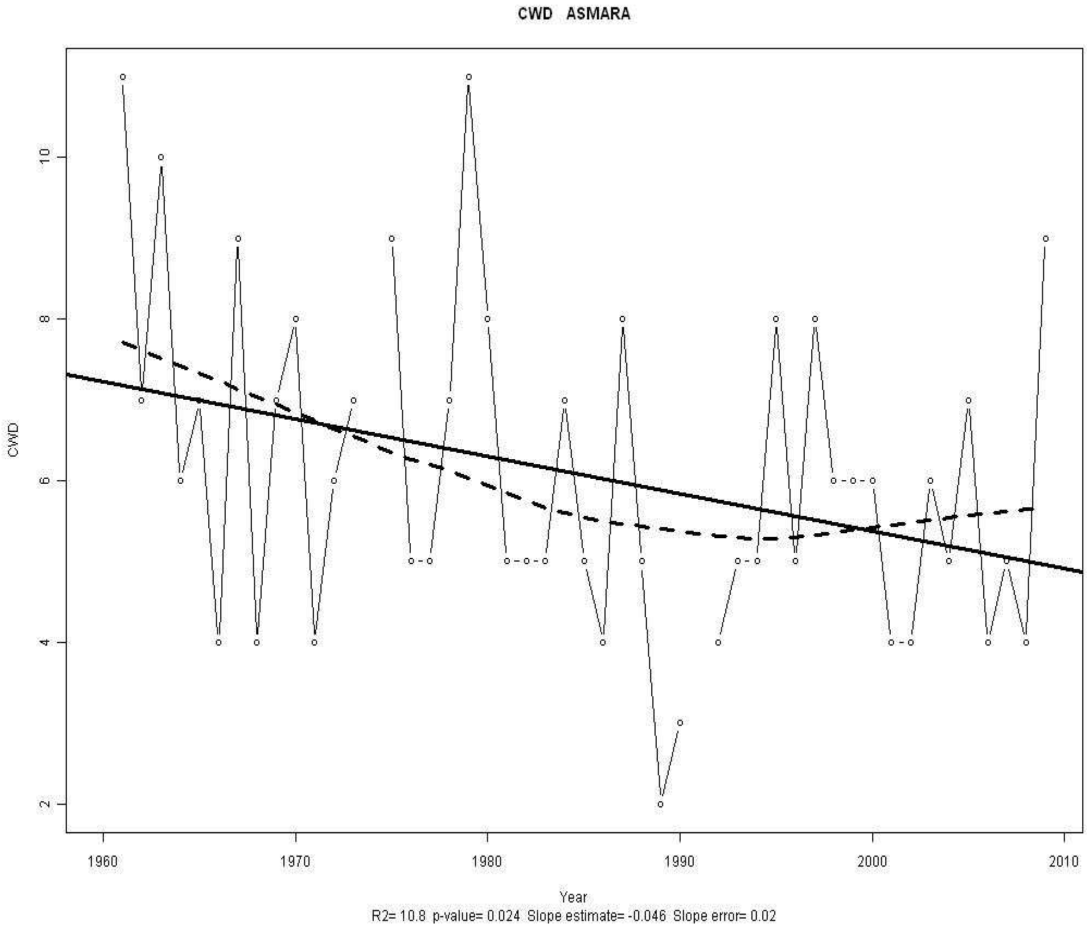
4) Homogeneity of Stations using time series. The general theory Homogeneity;

Precipitation total in wet days >= 1 MM.

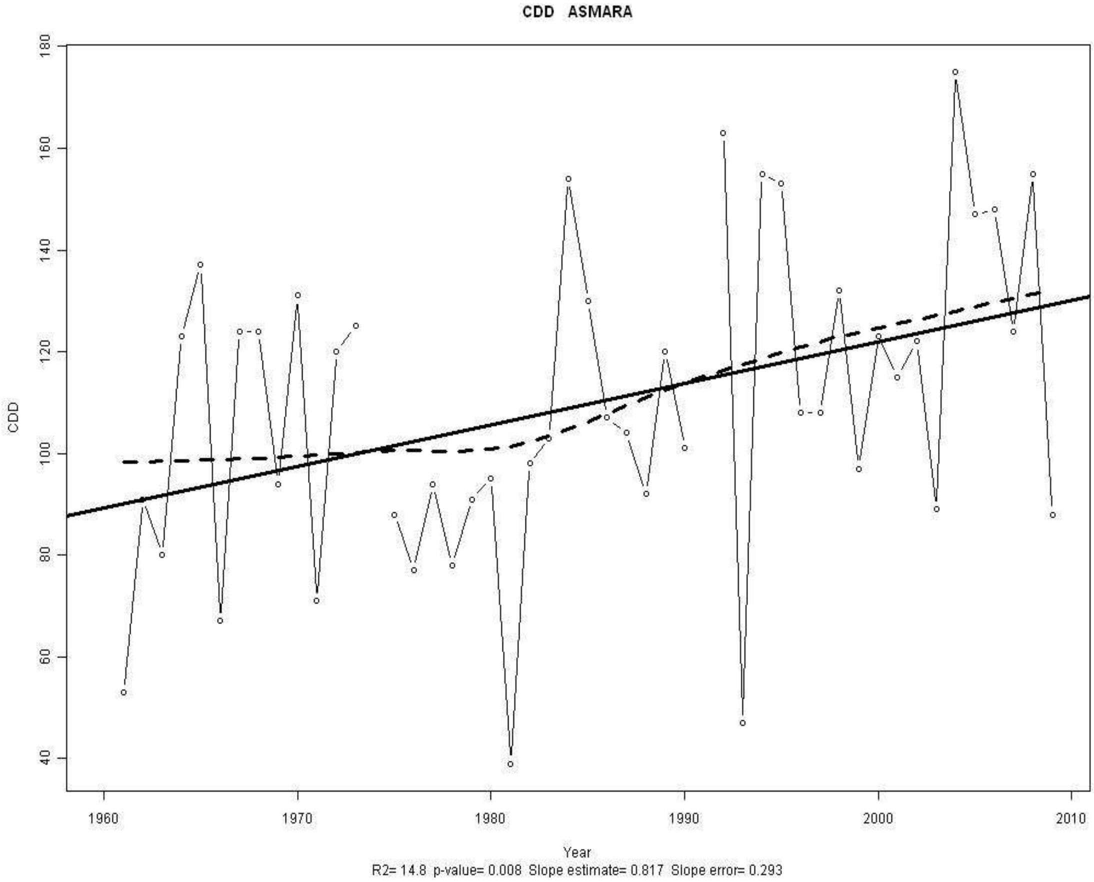
It shows slight reduction however not significant because p value =0.337.



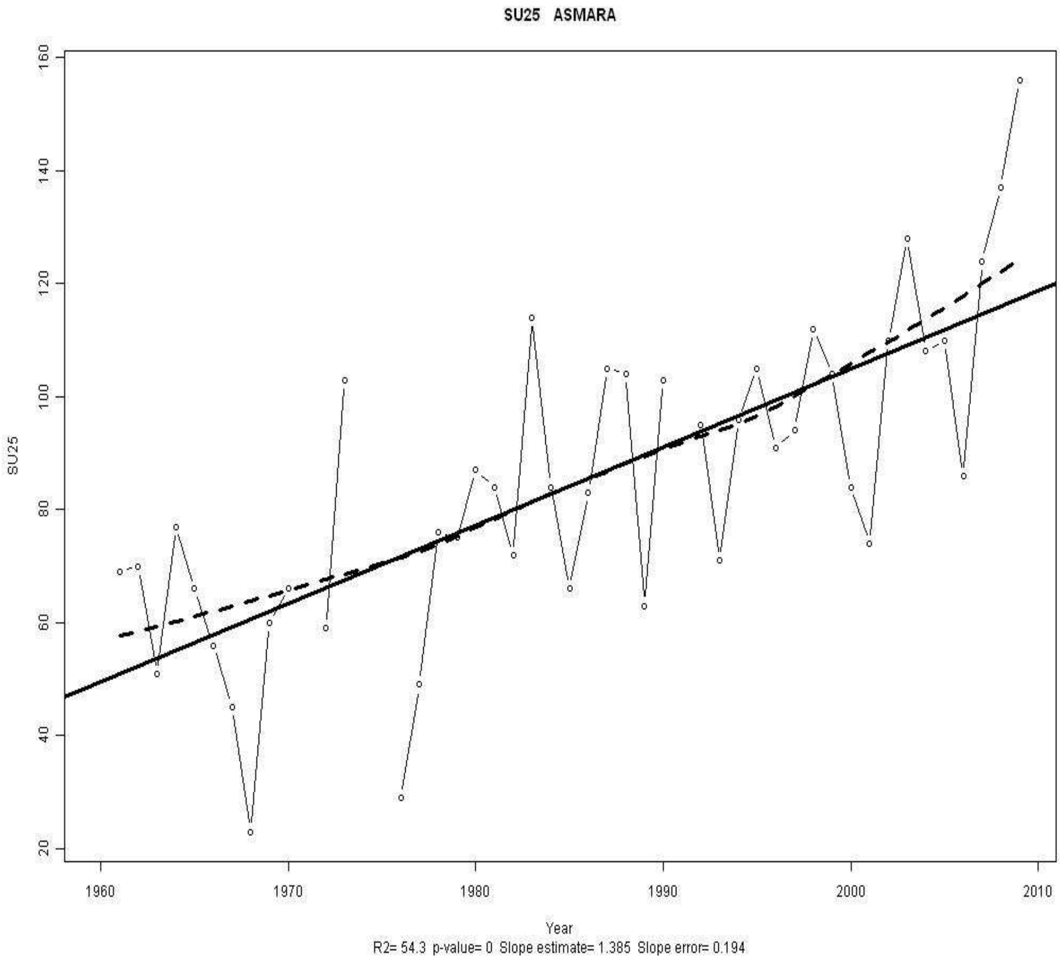
Maximum number of consecutive days with rainfall >= 1mm of rain is decreasing significantly. (P=0.024)



Maximum number of consecutive days with rainfall <= 1mm of rain is increasing significantly. (P=0.008)



Annual count when daily maximum temperature is >25Co is significantly increasing as P value is 0.



Conclusion and recommendations

Such workshop is very helpful for my country so I recommend to my organization not to miss such workshop and to ICPAC to send an experts from the region who can give training other scientists as well.

I recommend that Prof. Ogallo to stick on his promise on providing high memory computers to least developed countries, such as Eritrea.

The data what we have is archived using Excel software. However, it needs latest software so that to manipulate easily.

Policy makers are not aware very much about the use of meteorological data and information, so it needs to perform workshops to sensitize them. Therefore, to distribute Pilot projects is essential;

This type of workshops is very helpful, so there is a need to be continuous and regular.

To exercise the training gained from ICPAC, strong Computers with greater than 1000GB and more than 2 processors are required;
To enhance the existing human power, equipments and number of stations;

Uganda

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Ministry Of Agriculture Animal Industry and Fisheries

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Introduction

Uganda is a developing country with a population of approximately 25 million. Over 80% of the population lives in rural areas where agriculture is the major contributor to their livelihoods (UPHC, 2002). The agricultural activities are however rain fed, making this sector to be heavily dependent on the seasonal characteristics of rainfall, that is, onset, length and cessation of the wet season, seasonal rainfall totals and intra-seasonal rainfall distribution. Slight variability in rainfall is reflected in the productivity of agricultural outputs and pronounced variability results in far-reaching physical, environmental and social economic impacts. These impacts include famine, water scarcity, energy deficiency, and shortage of many other basic needs. Such impacts often retard the economic growth and development of the country. Unfortunately rainfall is certainly among the most difficult weather elements to predict accurately. Rainfall has a greater spatial and temporal variability than most other meteorological parameters of interest; this is because in the tropics, most of tropical systems have short life span (Mutai, 2000)

Climatology of the country

Uganda has an area of 240000 Km^2 and is located between latitudes 1.5 ^{0} S to 4.5 ^{0} N and longitudes 29 ^{o}E to 35 ^{0} E see fig. 1 below. It contains complex topography that includes large lakes, rivers, Great Rift Valley and mountains, and supports varied wildlife of scientific and economic value. High mountains include Mt. Rwenzori (5100 M) and Muhavura mountains in the south-western, Elgon (4321 m) and Moroto (3084 M) to the east. While water bodies include River Nile, Lake Victoria and Lake Kyoga and several other lakes, which lie in the Western Rift Valley example L.Albert, L.George, L. Edward and L. Katwe among others.

Rainfall distribution both in space and time determines the population densities and the agricultural productivity in Uganda. However the rainfall over Uganda exhibits large spatial and temporal variability. The spatial variation has been attributed to the complex topography and existence of large inland water bodies that have been presented above. The country generally experiences two seasonal rainfall regimes (Bimodal and Unimodal). The bimodal regime is experienced nearer to the equator with the first peak/season occurring from March–May (MAM) locally known as “Long-rains” in the East Africa region. The second season termed as “Short-rains” is observed from September-December (SOND). Both wet seasons coincide with the passage of the Inter-Tropical Convergence Zone (ITCZ) that lags behind the overhead sun by about a month (Ogallo, 1993; Okoola, 1996; Mutemi, 2003). The two rainy

seasons are separated by two dry periods in December to February and June to August. However, the northern parts of the country, further away from the equator experience unimodal rainfall regime. They receive considerable rainfall during the June-August (JJA) season, extending sometimes to September with a slight relaxation around June-July. Some regions close to the equator and eastern Uganda receive three rainfall seasons exhibiting trimodal regime, with the third peak occurring from July to August due to the moisture influx from Atlantic Ocean and the moist Congo basins by the westerly winds.
These physical features modify the spatial and temporal variations of the country's climate. They influence circulation and modify climates both local and tropical. Large-scale tropical climate systems are often superimposed upon regional factors. Indeed, the proximity of the Indian Ocean to the east and Lake Victoria (second largest lake in the world, 69,481 km^2) plus the Great Rift Valley heterogeneity terrain gives rise to dramatic variations in local circulation climatic patterns than anywhere else in the world.

Impact of extreme climate events

Major disasters

- Droughts (frequent and prolonged)
- Storms (wind, rain, thunder, lightning and hailstones)
- Floods
- High temperatures
- Pests and disease epidemics
- Heavy rains
- Landslides

Impacts

Generally reports across the country indicate manifestation of increased rainfall variability, reduction in amounts (rainfall) and rising temperatures. Occurrence of landslides is evident in the highland ecosystems, while flooding is a menace in lowland ecosystems. Prolonged droughts have been reported across the country. In addition, droughts have been observed to be more frequent and severe. The disasters reported by the communities are interlinked in that they cause similar effects. The rains are decreasing in amount, and yet they fall in concentrated heavy showers and storms, leading to landslides, floods, storms and soil erosion (figures 1 – 6). Examples of common impacts on different sub sectors in the Ministry of Agriculture are outlined below

Impacts on crop subsector

- Crop failure and reduced yields due to prolonged dry spells and droughts
- Loss of property, food stocks, crops in gardens and lives due to land slides
- Declining soil fertility, due to soil erosion and leaching resulting from heavy rains
- High post and pre-harvest losses as a result of flooding and water-logging
- Reduced yields and loss of crop due increased pests and diseases BBW on bananas, cassava mosaic,
- Crop loss destruction due to storm especially banana plantations maize and sorghum
- Increase in fungal and virus and bacterial diseases, and pests
- Invasive weeds especially striga a parasite on cereals.

Impacts on livestock subsector

- Inadequate pasture and water for livestock during drought conditions
- Livestock wasting due to inadequate water and pasture, of poor quality, and long distance walking.
- Increased livestock diseases and pests due to weather extremes: fries, East Coast Fever, FMD, new castle in poultry
- Reduced milk production
- Livestock stress, low production and productivity and emerging livestock diseases and pests due to rising temperature.
- Disease outbreak; Conflict over water and grazing land; Bush fire; pasture damages;
- Increased disease incidence (worms, ECF, Helminthiasis); Submerging of pastures;
- Death of Livestock
- Drying of seasonal rivers and watering points.

Impacts on fisheries subsector

- Receding water levels due to droughts and prolonged dry spells
- Silting and pollution of ponds and water bodies due to heavy rains
- Loss of fish species. Reduction in fish catch and fish quality
- reduction in breeding grounds;
- Direct death of fish due to drought and pollution of water.
- Loss of water oxygen and fish feeds due to nitrification of water.
- capsizing of boats due to strong winds;

Fig 1: A submerged bridge in East Uganda

Fig2: Serious floods in Butaleja District in Uganda

Fig 3: Mudslide in Bududa in East Uganda **Fig 4:** A strong storm in Kyenjojo in western Uganda 2009

Fig 5: Economic loss by mudslide in Bududa, 2010 Fig **6:** Severe drought in Eastern Uganda 2006

Project description (three workshops and how they interlink)
Reliable and detailed regional climate information, including assessments of current and future climate variability and change, is essential in the design of effective adaptation strategies. The World Meteorological Organization (WMO) and the World Bank are collaborating to develop and implement a programme of three linked workshops to assist the developing and least developed countries of the Greater Horn of Africa (GHA) region to appropriately use climate information in adaptation planning. The project involves three workshops.

Workshop I will focus on data needs with specific goals to use available climate data from countries in the region to enable detailed assessments of observed climate variability and change; Assess the adequacy of the quantity and quality of the available data for the evaluation of the skill of global and regional climate models for the GHA region; Demonstrate the value of the collaborative use of data and standardized climate indices, including those representing extremes, among countries in the region; Increase regional research synergies by sharing insights and improve analyses between neighbouring countries; and encourage countries in the region to improve their observing systems and to undertake data rescue (DARE) and data digitization efforts.

The second workshop will first evaluate the simulations of the current climate (particularly precipitation) of global coupled models by comparing them with current available data, and thereby assessing the uncertainty associated with future climate predictions. Then, available regional models will be run and compared with available data to assess performance. The skill of the global models will be used to help in the assessment of the regional models. The available regional models will be used to generate future climate projections to demonstrate how they can be used to interpret at the national level. Hence participants will the workshop with an appreciation of how reliable regional models would be for projecting future climate change in the region and at the national level, and with a greater sense of ownership in the process of producing such projections. Guidelines will be developed on the best practices in evaluating the available modeling techniques for use in making climate change projections.

The third workshop will examine the output of the first two workshops in order to assess their usefulness in the development of effective adaptation strategies. In particular, effort will be made to develop a common language between climate experts and the adaptation and climate risk management communities to better understand and interpret regional climate change projections and impacts. Such common understanding will enable a better integration of the climate information needs of the adaptation and climate risk management communities in further development of scientific and technological capacities. Emphasis will be placed on developing a common understanding of what results are robust and what the significance of the uncertainties is. The workshop will produce guidelines and best practices in the use and interpretation of climate observations and model outputs for the adaptation and climate risk management communities.

Workshop One

Objectives of workshop one

The overall objectives of this workshop were

I) to demonstrate the use and value of climate observations and regional models for decision making,

II) to provide advice on model performance and limitations, and

III) to improve capabilities across the region for using climate data records and model projections.

Data

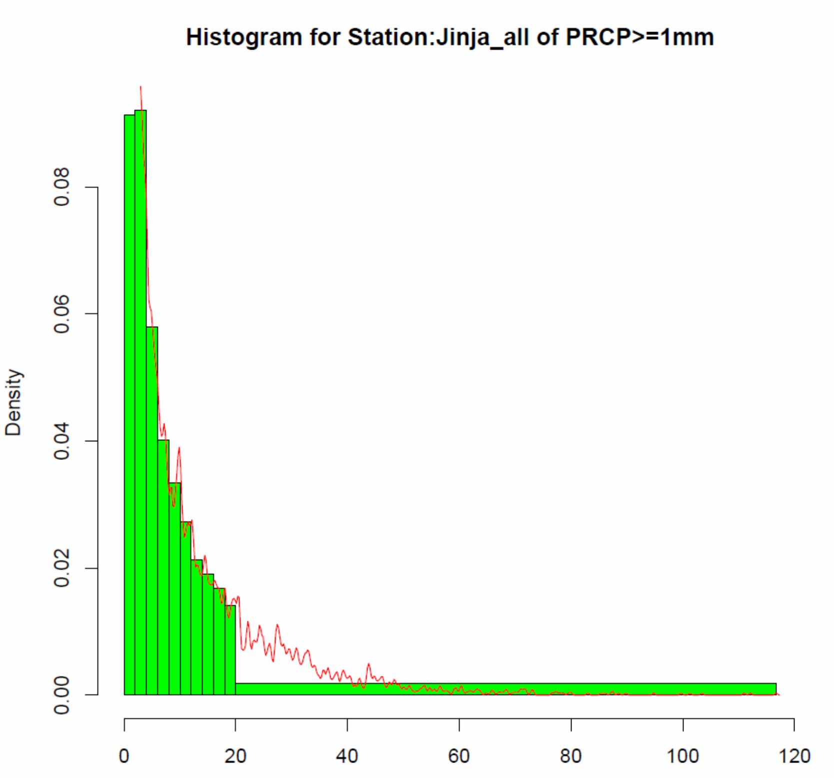
A set of daily observed temperature and precipitation for eight weather stations in Uganda were considered during the first workshop. The data used in the study were obtained from Uganda Meteorological Department and consisted of records for the period extending from 1963-2007.

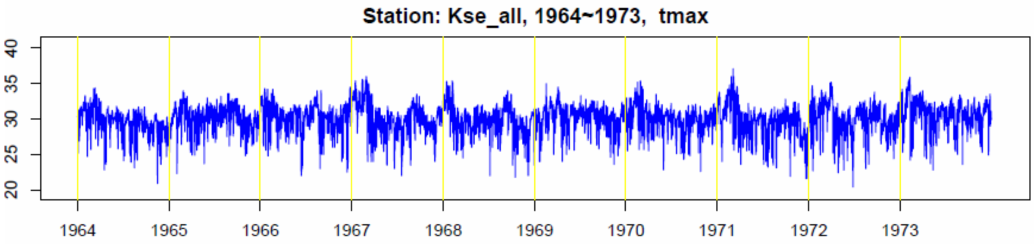
Methodology

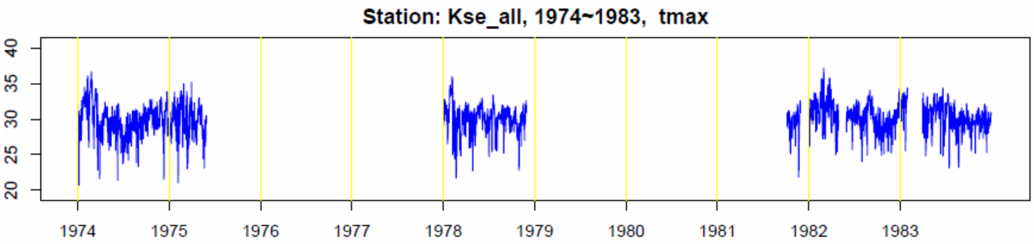
During the first workshop a set of temperature and precipitation extreme indices were analysed based on daily data. The reason for focusing on extremes was that the vulnerability of society to climate variability and change is likely to depend more on changes in the intensity and frequency of extreme weather and climate events than on changes in the mean climate. The reason for focusing on observation data is that better understanding of past change in weather and climate extremes will help to reduce uncertainty for the future projections and to develop better adaptation strategies.

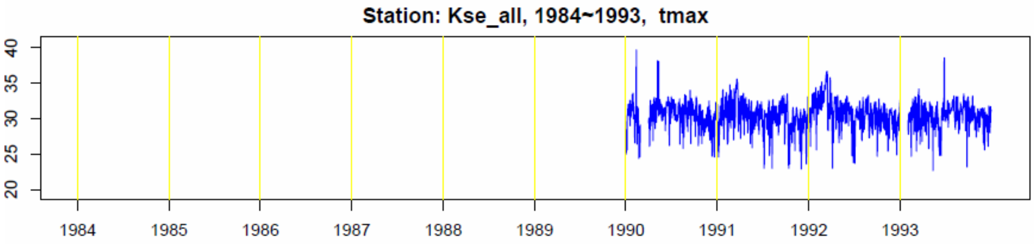
Besides studying extreme indices, training was provided on climate data management, quality control, homogeneity procedures and the use of metadata. In addition, the skill of the available reanalysis data (e.g. ERA40) were assessed by comparing with station data in an effort to establish baseline simulations to be considered in the second workshop as part of climate change scenario building.

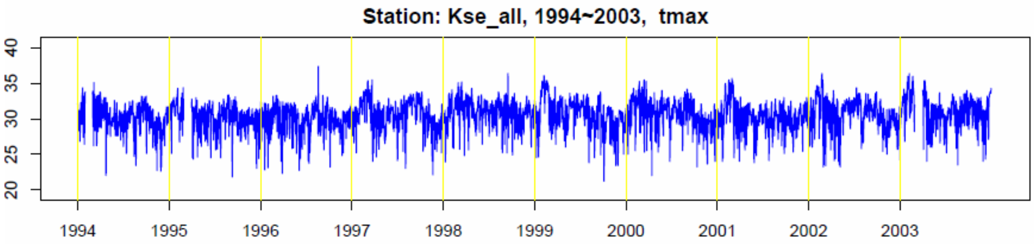
Results

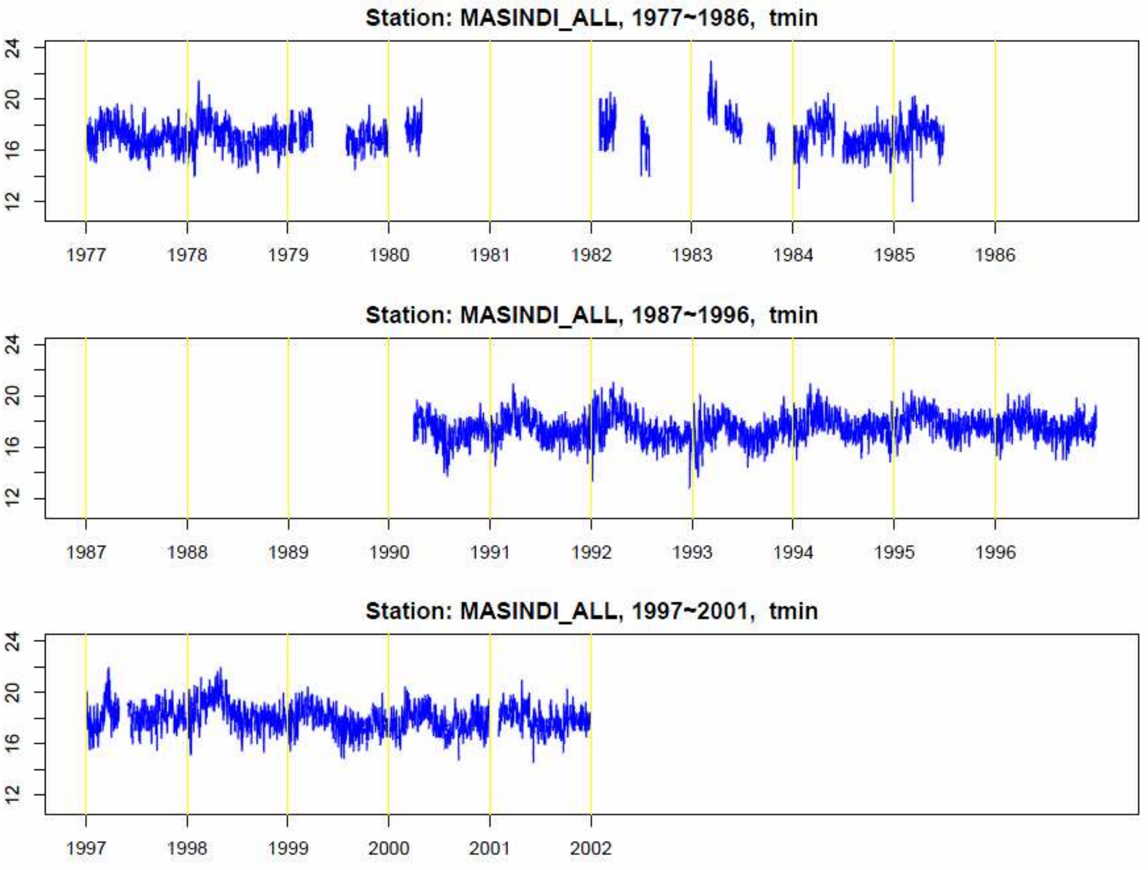



Station: Kse_all, 1964~1973, tmax
20 25 30 35 40
1964 1965 1966 1967 1968 1969 1970 1971 1972 1973

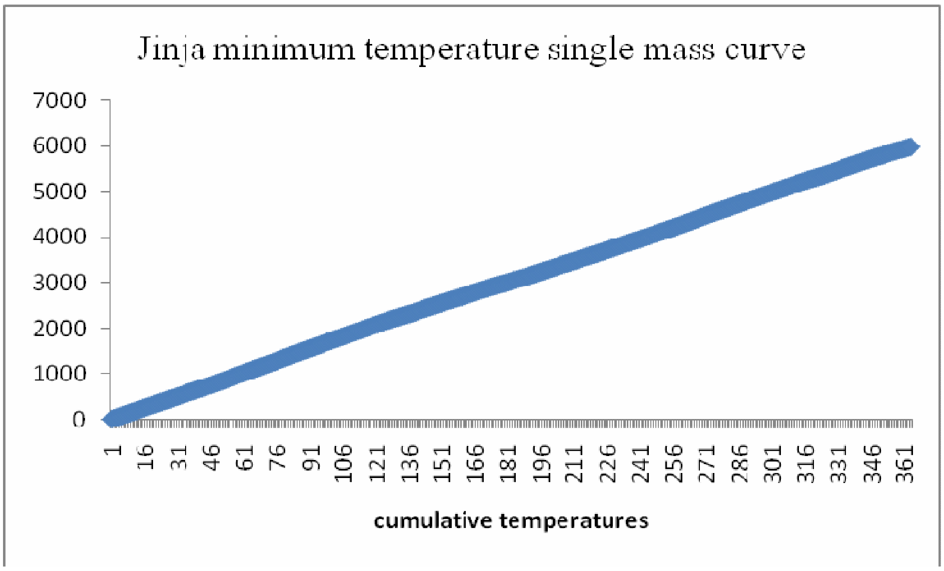

Station: Kse_all, 1974~1983, tmax
20 25 30 35 40
1974 1975 1976 1977 1978 1979 1980 1981 1982 1983


Station: Kse_all, 1984~1993, tmax
20 25 30 35 40
1984 1985 1986 1987 1988 1989 1990 1991 1992 1993

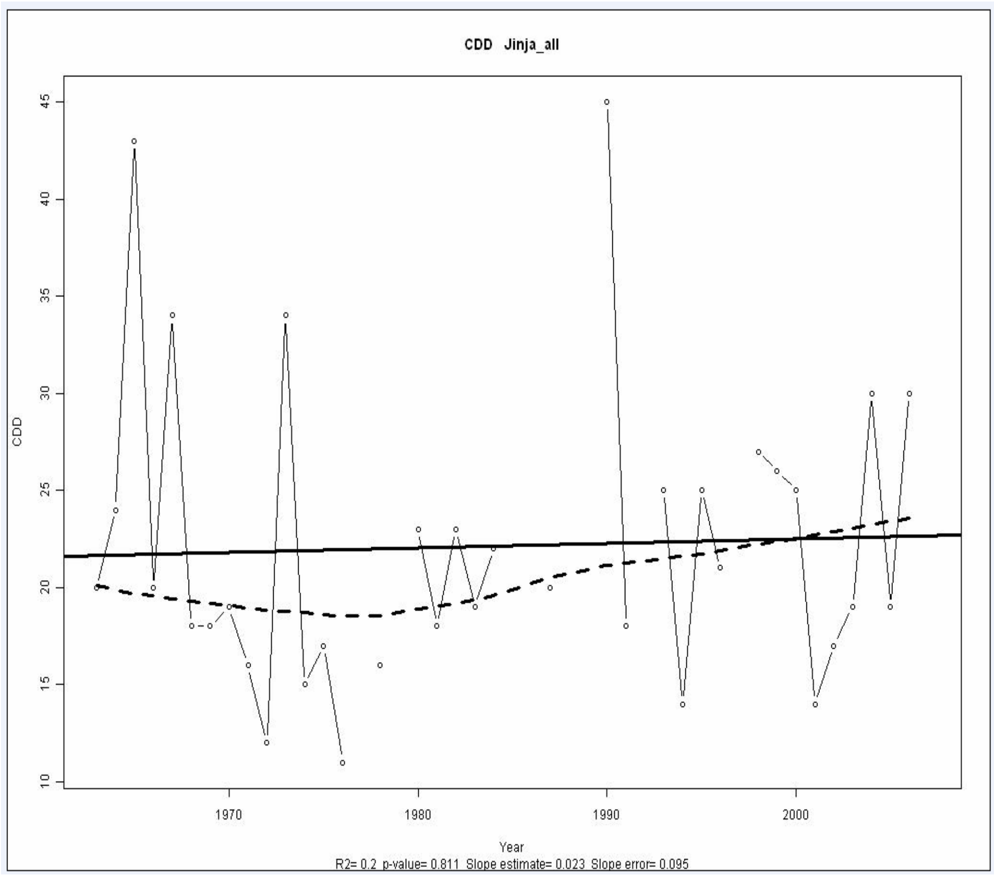

Station: Kse_all, 1994~2003, tmax
20 25 30 35 40
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003

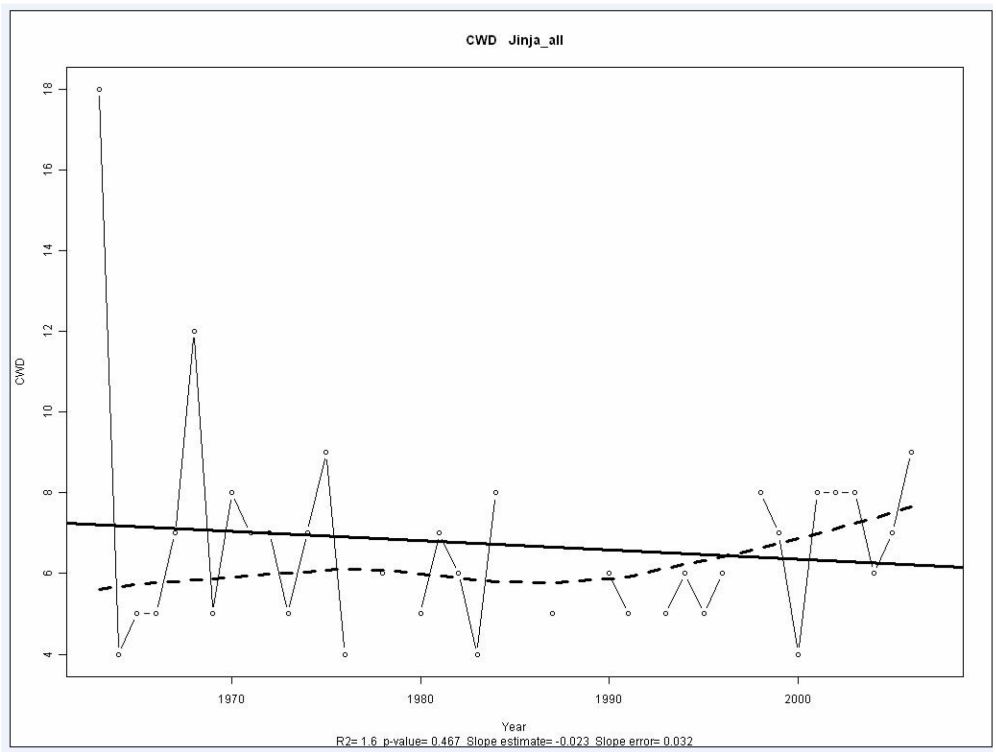


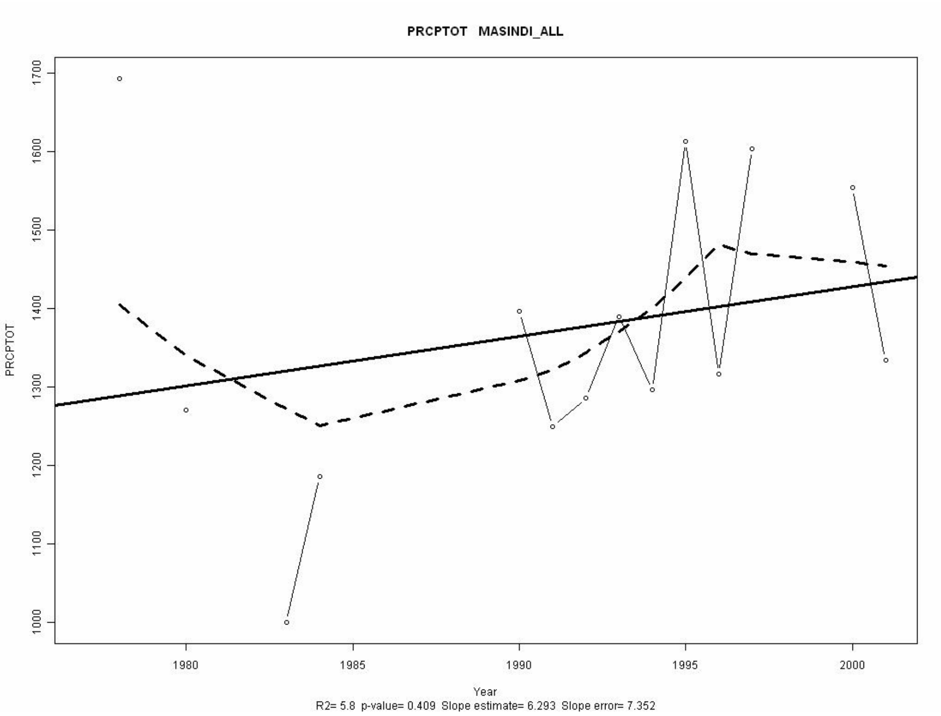
Homogeneity test was done to see data consistency using double and mass curve .



Temperature and precipitation extreme indices their magnitude, amplitude and trend over the years


CDD Jinja_all
CDD
Year
R2= 0.2 p-value= 0.811 Slope estimate= 0.023 Slope error= 0.095


CWD Jinja_all
CWD
Year
R2= 1.6 p-value= 0.467 Slope estimate= -0.023 Slope error= 0.032



It can be observed from the results above that most stations used in this study had an increasing trend in almost all indices

Recommendations

- Activate weather stations across the country.
- We recommend that indices should be calculated on seasonal basis but not annual
- Government to create budget lines for climate change and adaption activities at all levels.
- All staff in agricultural sector to undergo this training on climate change
- Work closely with research organizations on weather data.
- Create awareness seriously to local governments about climate change
- Develop guidelines and manuals to local governments in relation to climate change and adaptation
- Need to document appropriate strategies to mitigate emission of GHG (appropriate stocking rates for livestock
- Assists research to come up with appropriate technologies to address the challenges resulting from climate change
- Invest in water for production, soil and water conservation
- Support farmers in mitigation measures such as biogas production

- Establish a climate change desk office at local government level to handle all issues of climate including collection of meteorological data.
- Revise and enforce bye laws and ordinances to ensure that communities take adaptation measures seriously
- Strengthen the capacity of the Early Warning System to be able to produce and disseminate articles and newsletters on climate change and adaptation
- Strengthen the collection of weather data at local government level

Tanzania

Exploring on changes in temperature and precipitation extreme indices for Tanzania

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Caroline Kilembe (Ms)
Ministry of Agriculture and Food Security

Introduction

During the past few years, there have been numerous studies of trends in extreme temperature and precipitation indices for various regions of the globe. Overall, the findings have suggested a significant decrease in the number of days with extreme cold temperatures, an increase in the number of days with extreme warm temperatures and some detectable increase in the number of extreme wet days in many parts of the world. A recent analysis over Europe has revealed the occurrence of fewer cold nights, more warm days and an increase in the number of extreme wet days from 1946–99, although the spatial coherence of the trends was low for precipitation (Klein Tank and Können, 2003). Similar findings were observed in Africa but over a shorter period 1961–90 (Easterling et al., 2003). In China, the number of cold nights significantly decreased from 1961–2000 leading to a significant decrease in the diurnal temperature range (Qian and Lin, 2004); for precipitation, the number of rain days has decreased throughout most parts of China while the intensity has increased (Zhai et al., 2005).

Global climate models indicate that changes in climate in Tanzania are expected in a global warming scenario. Further, studies of Tanzania's climate have shown that significant changes in temperature and precipitation occurred during the twentieth century. These are likely to include changes in the intensity, duration, and frequency of droughts and floods and will have serious implications for agriculture, human health, and many other human activities. Considering these important changes in the Tanzanian climate, it is pertinent to investigate if the past warming was accompanied by detectable changes in temperature and precipitation extremes.

The objective of this work is to present the trends in various indices of daily and extreme temperatures and precipitation in Tanzania.

Many of the indices used in this study are based on the definitions and procedures recommended by ECA&D and ETCCDMI to make Tanzania results comparable with analysis conducted elsewhere in the world.

Climatology of Tanzania

Tanzania lies roughly between 2° N and 11°S and from 29°E to 41° E. Tanzania has two distinct seasonal rainfall patterns, namely bimodal and unimodal rainfall regimes. Bimodal behaviour exists over northern Tanzania and unimodal rainfall over western, central and southern Tanzania. The bimodal rainfall is characterized by two annual maxima i.e. the short rainfall season between October-December and the long rains in March-May. The March-May constitute the so called long rains locally known as '*Masika*'. The unimodal rainfall is characterized by a single annual maximum experienced between December and March

Impacts of extreme events

A climate extreme is a significant departure from the normal state of the climate, irrespective of its actual impact on life or any other aspect of the Earth's ecology. When a climate extreme has an adverse impact on human welfare, it becomes a climatic disaster.

Extreme weather events include droughts, floods and associated landslides, storms, cyclones and tornadoes, ocean and coastal surges, heat waves and cold snaps

Wet areas are likely to become wetter, with more frequent episodes of flooding, whilst dry areas may become drier, with longer periods of drought leading to an increased threat of desertification. Every region of the world experiences record-breaking climate extremes from time to time. Droughts are another devastating type of climate extreme. A more likely explanation is that increased human vulnerability to climate extremes, particularly in developing countries, is transforming extreme events into climatic disasters.

Over the last few years, devastating impacts of the 1997/98 El Niño related floods has led to loss of life and property, destruction of infrastructure and large losses to the economy in the equatorial parts of the Greater Horn of Africa sub-region and are still fresh in the minds of many. It has been observed that world-wide weather and climate extremes such as droughts, floods, cold/hot spells, tropical cyclones, etc are common.

Justification

The countries of the GHA region share pronounced climatic trends and variability and are vulnerable to extreme climatic conditions. In order to detect any climate change signals in the country which end up contributing a lot at regional level, patterns of changes of extreme rainfall and temperature events based on daily data need to be analyzed. The reason for focusing on extremes is that the vulnerability of society to climate variability and change is likely to depend more on changes in the intensity and frequency of extreme weather and climate events than on changes in the mean climate. The reason for focusing on observation data is that better understating of past change in weather and climate extremes will help to reduce uncertainty for the future projections and to develop better adaptation strategies

The project of the workshop

Reliable and detailed regional climate information, including assessments of current and future climate variability and change, is essential in the design of effective adaptation strategies.

Specific to workshop

The Specific objectives are to:

- Analyze patterns of changes of extreme rainfall and temperature events in Tanzania based on daily data

- Enable detection on any climate change signals in the country

Description of the data and methodology

Position

Tanzania is located to the south of equator from 2 to 11 degrees south and 29 to 40 degrees east (Fig. 1).

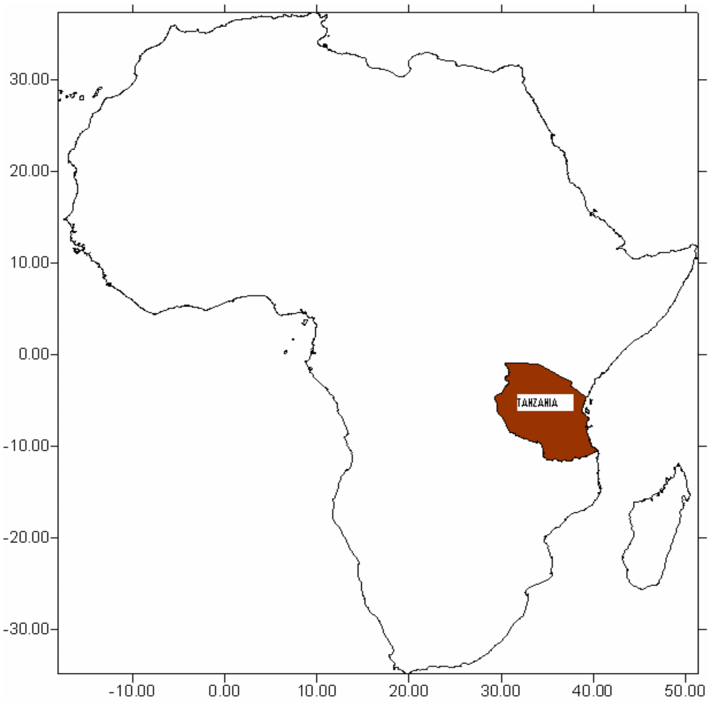


Figure 1: The position of Tanzania on the map of Africa

Source of data

Data used in this study were obtained from the Tanzania Meteorological Agency. These are the daily rainfall and temperature data of 11 stations representing eleven climatological homogeneous zones covering 39 years from 1971 – 2009 (Fig.2).

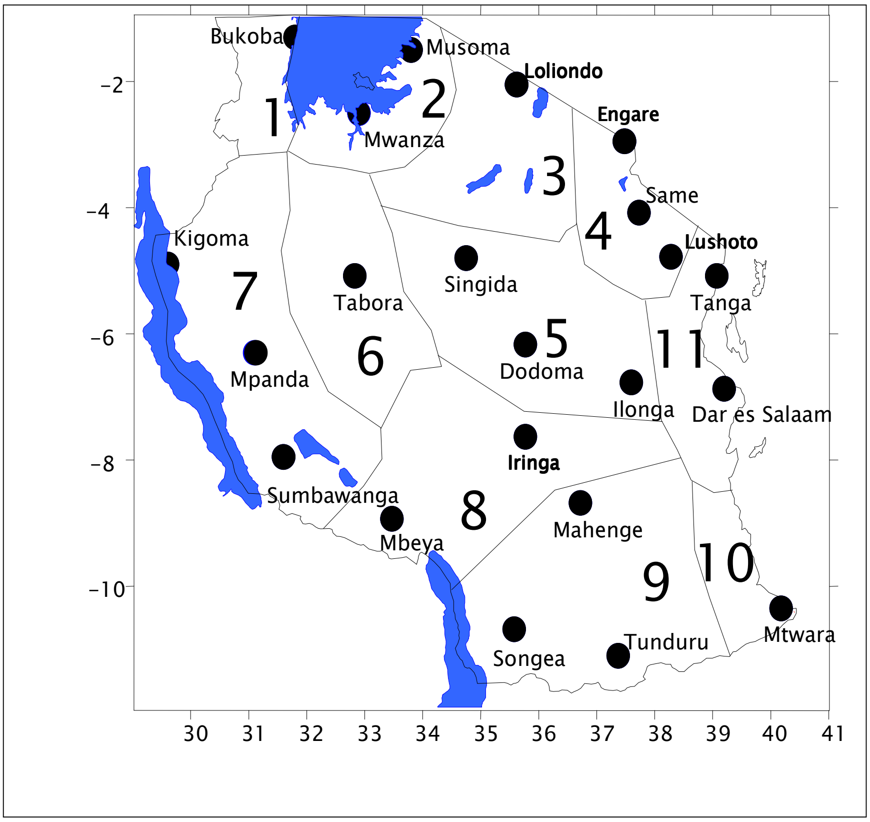


Fig. 2: Climatological homogeneous zones for Tanzania

Quality Control

Data Formatting for RClimDex:

ClimDex is a Microsoft Excel based programme that provides an easy-to-use software package for the calculation of indices of climate extremes for monitoring and detecting climate change. It was developed by Byron Gleason at the National Climate Data Centre (NCDC) of NOAA, and has been used in CC!/CLIVAR workshops on climate indices from 2001.
CRClimDwex (1.0) is designed to provide a user friendly interface to compute indices of climate extremes. It computes all 27 core indices recommended by the CC1/CLIVAR Expert Team for Climate Change Detection Monitoring and Indices (ETCCDMI) as well as some other temperature and precipitation indices with user defined thresholds.

The very first step input file is processed in the "Quality Control" step which is the input data file has several requirements:

- ASCII text file
- Columns as following sequences: Year, Months, Day, PRCP, TMAX, TMIN.
- The format as described above must be space delimited

For data records, missing data must be coded as -99.9; data records must be in calendar data order. Missing dates allowed.

Data Quality control is a prerequisite for indices calculations. The RClimDex QC performs the following procedure: 1) Replace all missing values coded as -99.9 into an internal format that R recognizes (i.e. NA, not available), and 2) Replace all unreasonable values into NA. Those values include a) daily precipitation amounts less than zero and b) daily maximum temperature less than daily minimum temperature. In addition, QC also identifies outliers in daily maximum and minimum temperature. The outliers are daily values outside a region defined by the user.

Calculation of Indices

RClimDex is capable of computing all 27 core indices in Appendix A.

Results and discussions

Dodoma station

Significant changes are observed in the number of precipitation events where the number of days with total precipitation greater or equal 20mm and the number of days with rain have significantly decreasing steadily for Dodoma Station (Fig.). These results include only days with measurable precipitation (greater than trace). It is important to mention that since the precision of minimum measurable precipitation is decreasing with over time, the trends found in the number of precipitation events could be slightly overestimated. The maximum number of consecutive dry days exhibits a mixture of increasing and decreasing trends for Dodoma station.

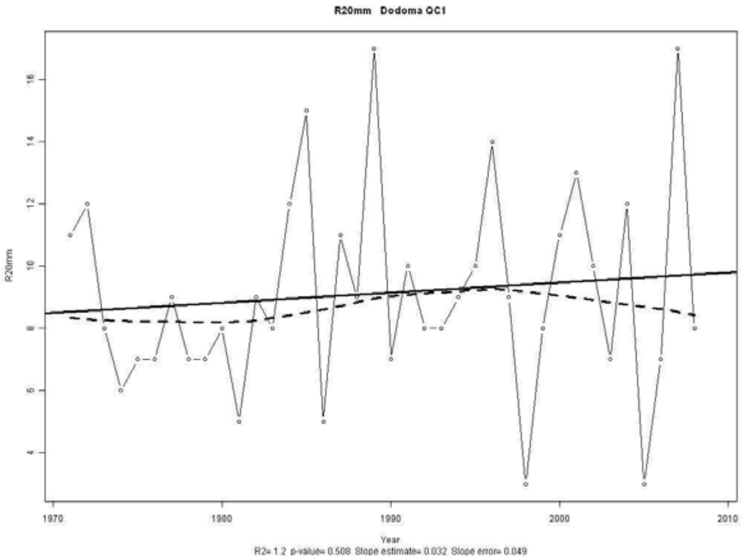


Fig: 3 Heavy precipitation days: Annual count of days when PRCP>=20mm for Dodoma

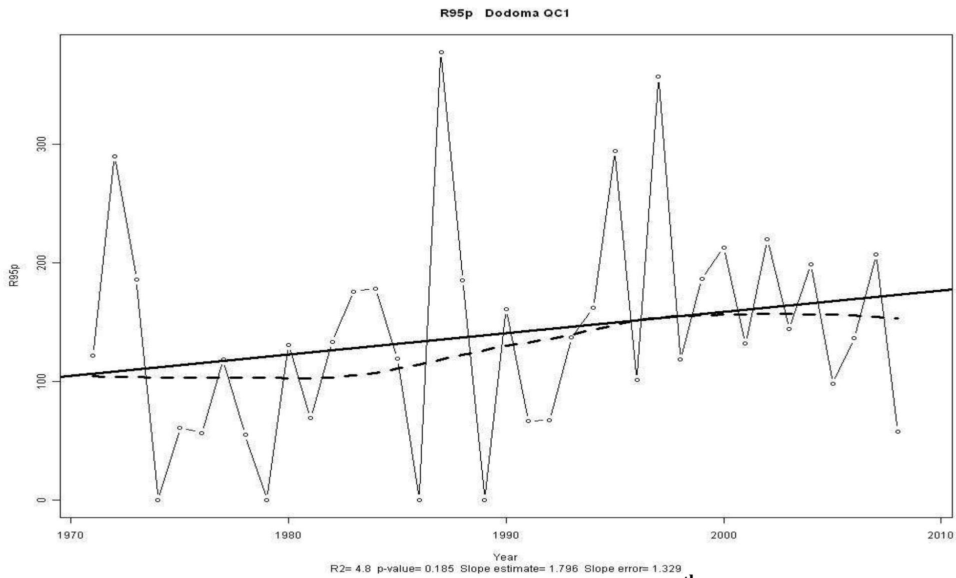


Fig: 4 Very wet days: Annual total PRCP when RR>95th percentile for Dodoma.

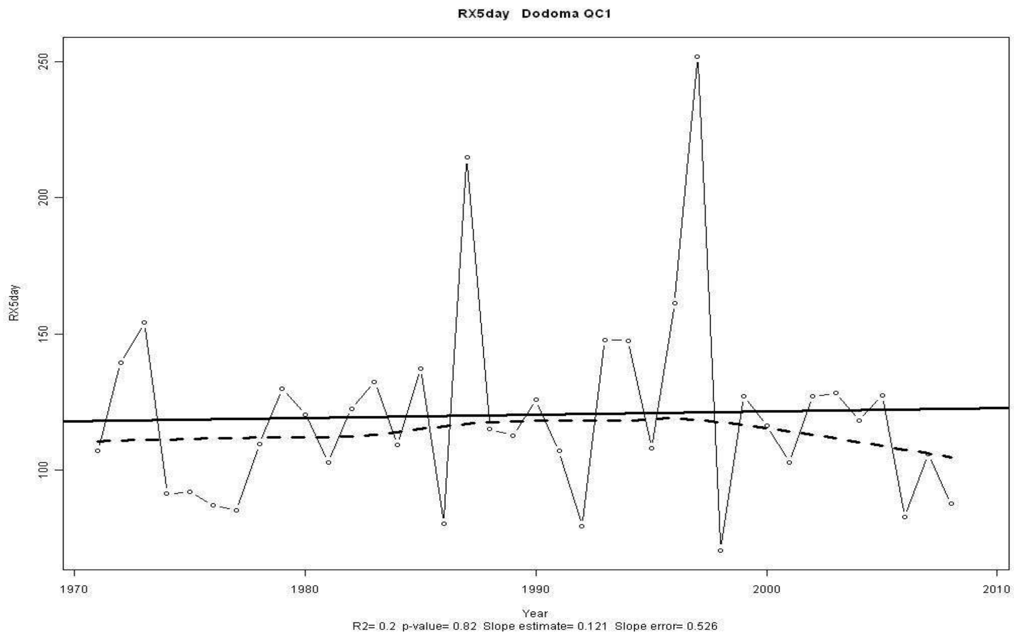


Fig: 4. Max-5-day precipitation amount: Monthly max consecutive 5-day precipitation for Dodoma

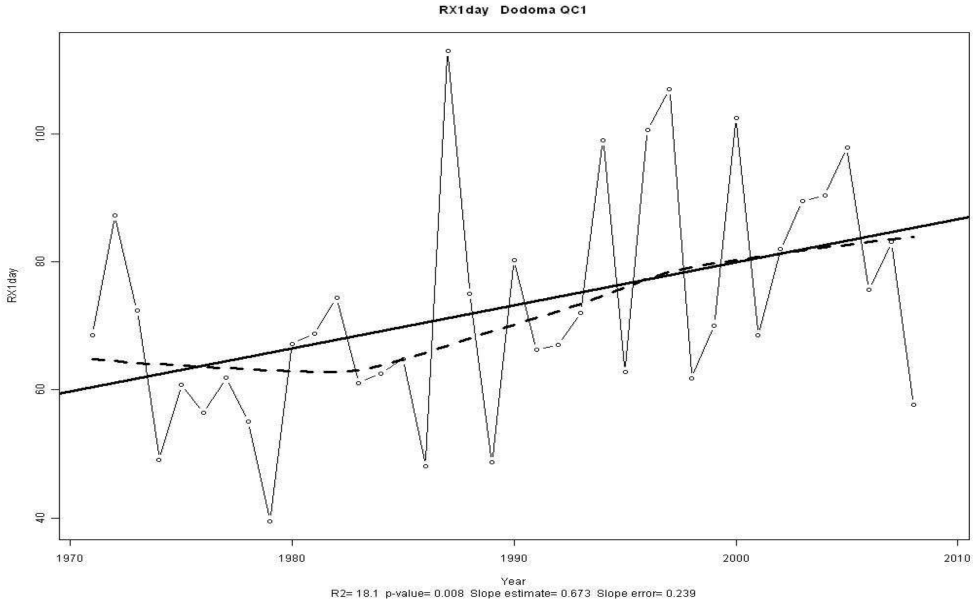


Fig: 5. Max 1-day precipitation amount: Monthly max 1-day precipitation for Dodoma

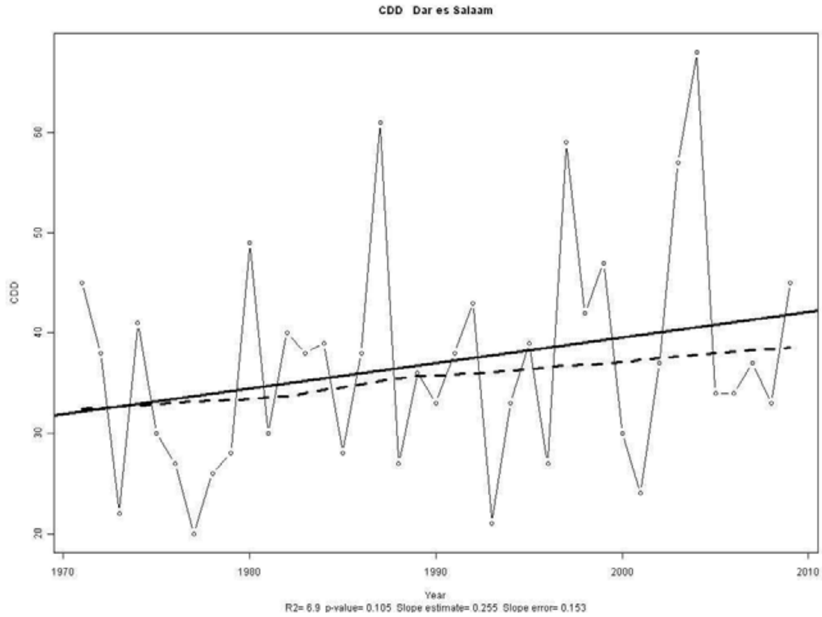


Fig: 6. Consecutive dry days: Maximum number of consecutive days with RR>=1mm for Dar

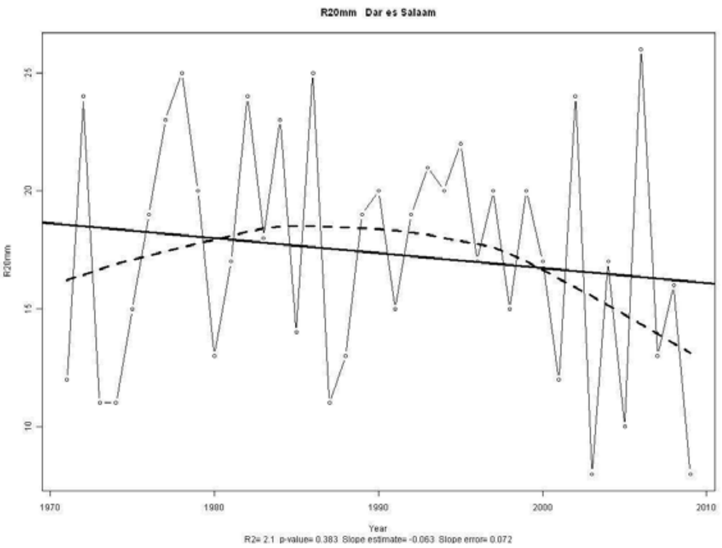


Fig. 7: Number of very heavy precipitation days: Annual count days when PRCP>=20mm for Dar

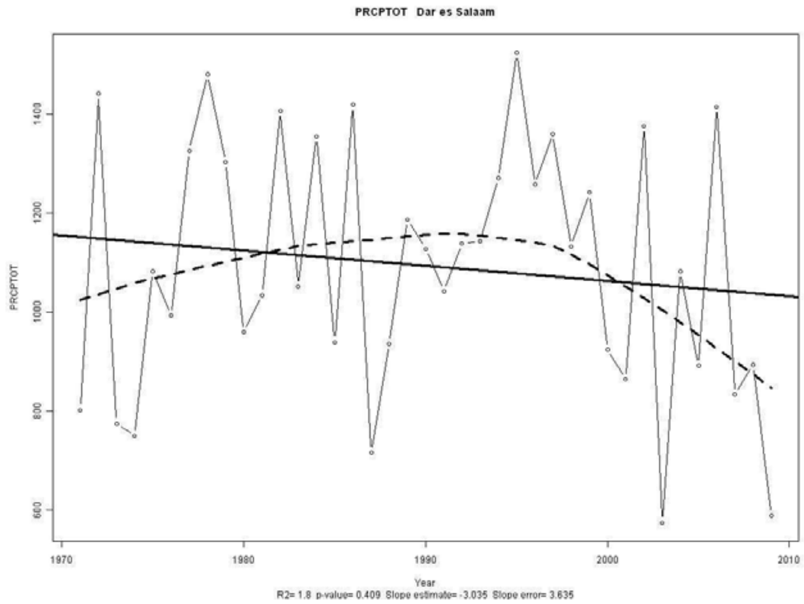


Fig. 8. Annual total wet-day precipitation: Annual total PRCP in wet days (RR>=1mm) for Dar

Conclusion

This study has examines the trends and variations in several daily and extreme temperature and precipitation indices over Tanzania from 1071-2009. It was found that the number of warm events increased significantly and the number of cold events decreased significantly during the two periods 1950–2003 and 1900–2003.

In conclusion, the results have improved our knowledge of daily and extreme temperature and precipitation trends and variability in Tanzania. However, further research is needed to obtain a better understanding of the relationship between temperature and precipitation indices and to explain how the observed changes could affect our economy, ecological systems and our everyday lives.

Rwanda

Mr Mbati Mugunga Mathieu

Rwanda Meteorological Service

Introduction

Rwanda is a land locked country located in the southern hemisphere between latitude 1^0-3^0S and longitude 28^0-31^0E.The country borders Uganda to the North, Tanzania to the East, Democratic Republic of Congo to the west and Burundi to the South.
The economy of the country depends mainly on rain-fed agriculture. Extensive farming is carried out at some areas while majority of the people carry out subsistence farming.
The country experiences two main seasons March-May for the long rains and October-December for the short rains. The rainfall in the area is influenced by the penetration of Congo Airmass into the country, the inter-tropical convergence zone (ITCZ), local circulations and teleconnections from global Sea Surface Temperatures (SSTs).

Climatology of Rwanda

Rwanda is located in the equatorial eastern Africa sub-region and therefore exhibits equatorial rainy forest climate type. The climate of Rwanda is, however, slightly different from the equatorial rainy forest type. The region has various climate types ranging from the equatorial rainy forest to savannah grasslands. Most of the central and eastern parts of the country are semi-arid. The dryness of the east has been attributed to the rain shadow area due to the western mountains.

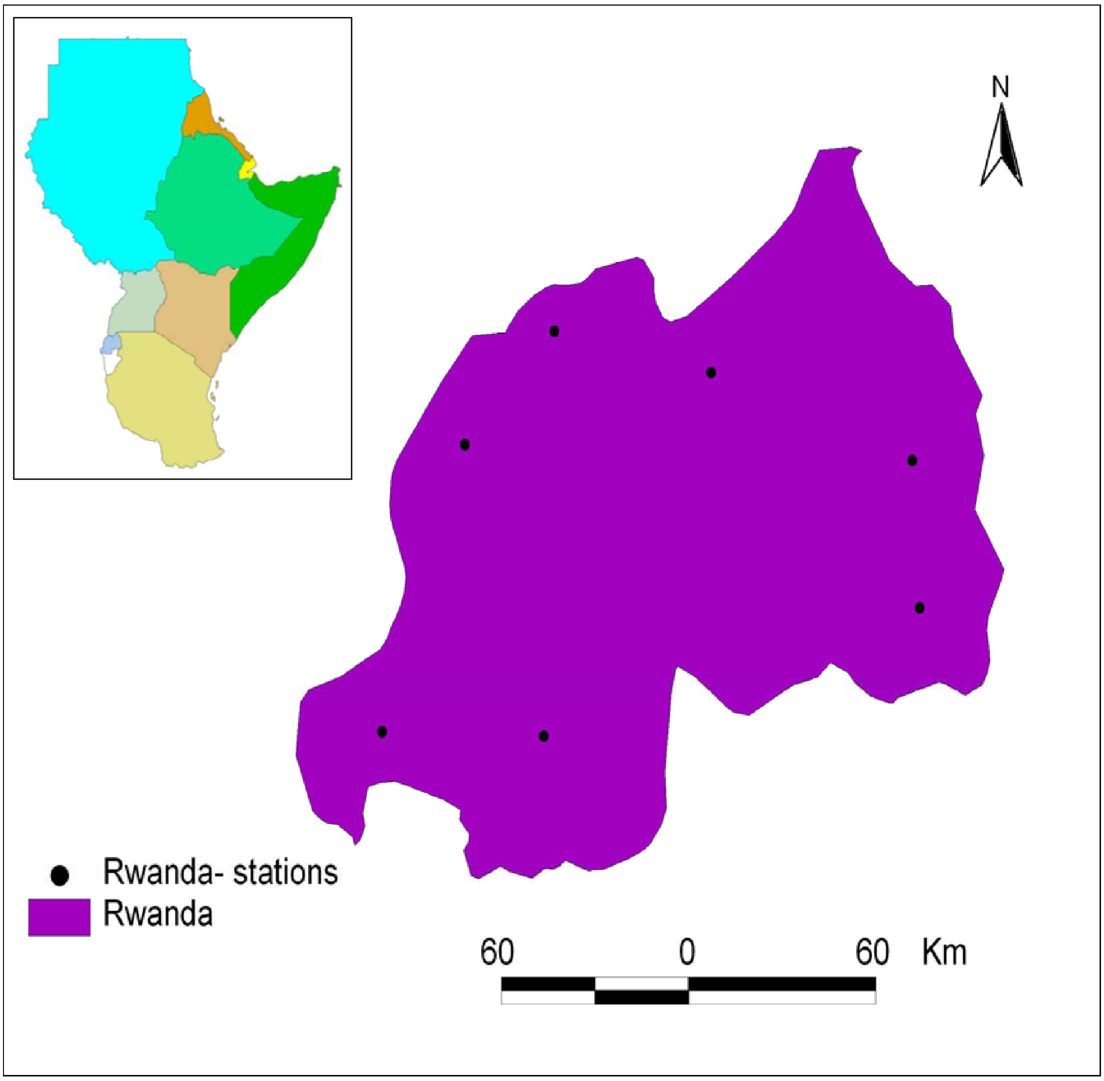
Rainfall over Rwanda exhibits large spatial and temporal variability. The spatial variability has been attributed to the complex topography and the existence of large water bodies in the region. The temporal variation of rainfall over Rwanda occurs on various time scales, which include diurnal, quasi-biweekly, intra-seasonal/monthly and inter annual. The inter annual variation has featured extreme rainfall events like floods and droughts with associated socio-economic impacts.
The main synoptic scale system controlling rainfall is the ITCZ, which displays two distinct branches mainly meridional and zonal arms. The meridional arm seems to be dominant over the country with westerly lower tropospheric winds bringing in the Congo Air mass.

The Major Extreme climatic weather events that affects Rwanda

1. Droughts.
2. Floods.
3. Land-slide and (Erosion).
4. Strong wind speed etc.
5. Wild-fires.

Justification for the main streaming

- Rwanda's economy is dependent on rain-fed agriculture.
- Seventy five percent (75%) of socio-economic activities in Rwanda are weather and climate.
- Severe weather and extreme climate events and other climatic fluctuations have been shown to have a high influence on the social and economic activities of the country and the performance of the country's economy.



Map showing the country stations map.

Specific objectives of the workshop

- Use available climate data to enable detailed assessments of observed climate variability and change.
- Assess the adequacy of the quality and quantity of the available data for the evaluation of the skill of global and regional climate models.

- Demonstrate the value of the collaborative use of data and standardized climate indices.
- Will encourage the country in the region to improve their observing systems and undertake data rescue (DARE) and data digitization efforts.
- Will help analyze patterns of changes of extreme rainfall and temperature event in the country.
- Will enable detection of any climate change signals at national level.

Data and Methodology

Data sources

a) Rainfall

The Daily rainfall data were obtained from the National Meteorological Service of Rwanda. The daily records for 1971-2010 periods were available for 07 stations across Rwanda.

Station Name	Location			Data duration			Missing
	Lat	Long	Altitude	start	End	Yrs	(%)
Kigali Airport	-1° 58’	30° 08’	1490m	1971	2010	39	2%
Kamembe Aero	-2° 28’	28° 55’	1591m	1971	2010	39	25%
Gisenyi Aero	-1° 40’	29° 15’	1554m	1975	2010	35	25%
Gikongoro Stn	-2° 29’	29° 34’	1930m	1967	2010	42	25%
Ruhengeri Aero	-1° 30’	29° 36’	1878m	1977	2010	34	25%
Byumba Stn	-1° 36’	30° 03’	2235m	1970	2010	40	25%
Kibungo Stn	-2° 10’	30° 32’	1680m	1970	2010	40	25%

b) Temperature Maximum and Minimum

The Daily Temperature Maximum Minimum data were obtained from the National Meteorological Service of Rwanda. The daily records for 1971-2010 periods were available for 05 stations across Rwanda.

Station Name	Location			Data duration			Missing
	Lat	Long	Altitude	start	End	Yrs	(%)
Kigali Airport	-1° 58’	30° 08’	1490m	1971	2010	39	2%
Kamembe Aero	-2° 28’	28° 55’	1591m	1971	2010	39	25%
Gisenyi Aero	-1° 40’	29° 15’	1554m	1975	2010	35	25%
Gikongoro Stn	-2° 29’	29° 34’	1930m	1990	2010	20	25%
Byumba Stn	-1° 36’	30° 03’	2235m	1990	2010	20	25%

Methodology

a) Quality Control

The rainfall data and temperature maximum and minimum were initially subjected to statistical quality control data using Rclimdex1.0, where the stations were selected on the basis of the length and quality of record and the need to maximize spatial coverage; we have look for the extreme use the indices. RClimdex was also used to generate climate change indices.

b) Homogeneity

Homogeneity test was carried out using the single as well as the double mass curve. All the inconsistencies were corrected immediately.

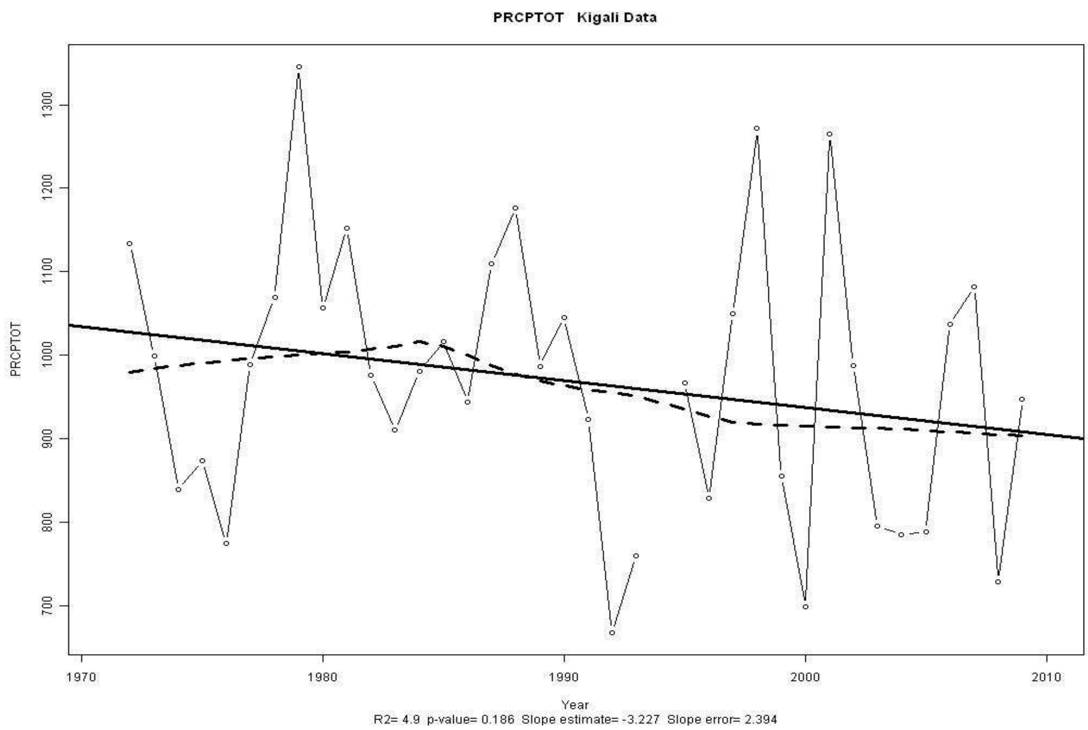
Discussion of Indices

The Indices show that all the rainfall data have extremes events, a proper analysis have been done and complete data record is required also the Calculation of different indices, Statistical computing and graphics, Statistical filling of missing data and Statistical test have been done and identifying different type of Errors.

Results and Discussion

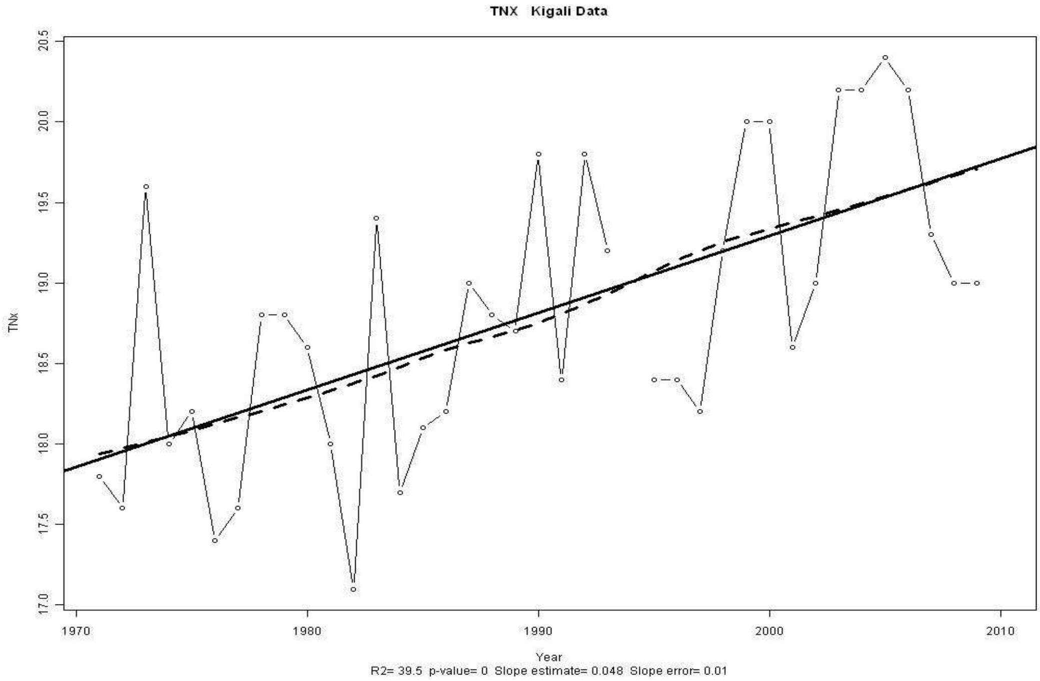
After running RClimDex 1.0 and other Statistical process different significant results was identified,

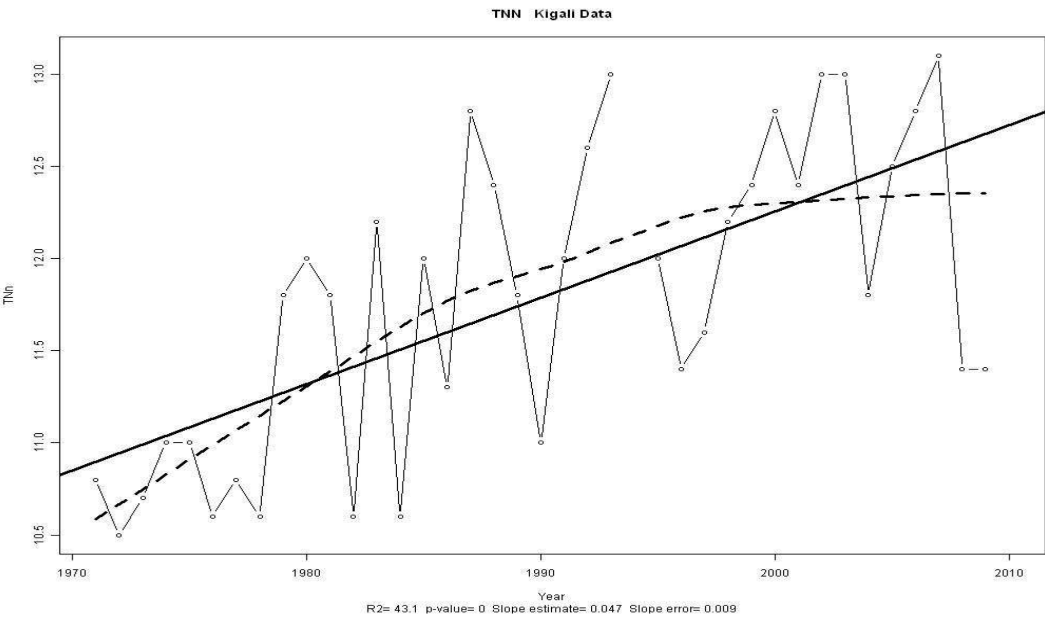
- Plots of different meteorological events was done
- Different indices were identified
- Extreme values of different parameters were indicated



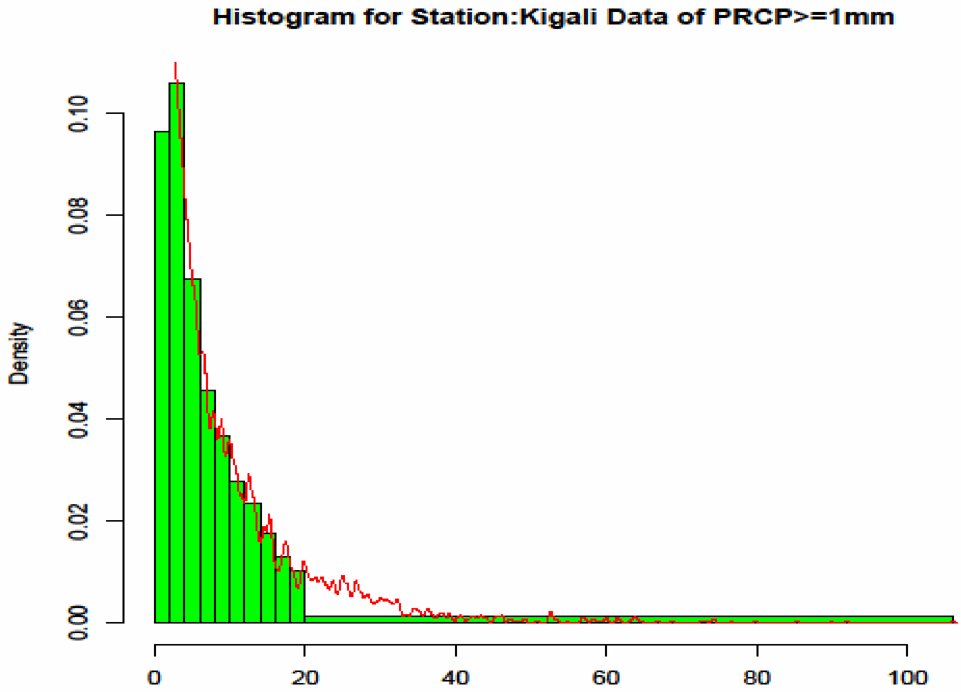
Annual Total Precipitation in wet days greater than or equal 1mm.

The trends is decreasing





Monthly maximum value of daily maximum and minimum temperature, The Trends of temperature continue increasing



Way Forward

I would like to increased regional capacity to analyze the changes and continue to expand on the workshop analysis, using the software to produce many additional country assessments also to produce both national/regional and global relevant output.

This work shop helped how to perform quality control data with quality data policy makers and end users can make proficient plan.

Meteorologists will be able to give advice and warning to all potential users of meteorology also to generate full background information needed for the workshop.

Recommendation

The data we have is archived in Excel format however, it needs latest software so that we can manipulate easily.

Policy makers are not aware about the use of meteorological data and information, so it needs to perform workshops to sensitize them.

This type of workshops is very helpful, so there is a need to be continuous and regular.

To enhance the existing human power, equipments and number of stations is required.

We recommend that indices should be calculated on seasonal basis but not annual

Kenya

S M King'uyu, M Kilavi, P Omeny, E Muigai and A K Njogu

Kenya Meteorological Department (KMD)

Introduction

Kenya is located astride the equator within latitude 5.5°N - 5°S and longitude 34 - 42° E. It borders Indian Ocean and Somali to the east, Tanzania in the south, Uganda in the west and Sudan and Ethiopia in the North. It covers an area of about 581,000 km^2 of which the lakes occupy about 2% of the total area, 18% is high potential are and the Arid and Semi Arid Lands (ASALs) constitute about 80% of the total land area. Kenya's altitude varies widely from sea level to about 5,000 m above mean seas level. on the central highlands (MENR, 2006). According to 2009 census the population is expected to be 40m.

Climate of Kenya

Kenya experiences a bimodal rainfall distribution with long rains in March – May (MAM), and short rains in October - December (OND). The major systems that influence the climate include the Inter-Tropical Convergence Zone (ITCZ), Sub Tropical High Pressure systems (STHP), El Nino Southern Oscillations (ENSO), Monsoon winds, tropical cyclones, the Indian Ocean, Lake Victoria circulation and topography . The influence of the ITCZ is modified by topography giving rise to varied climatic regimes. The country is divided into several climatic zones depending on the season MAM (12), JJAS (12), and OND (10) as shown in Figure 1.

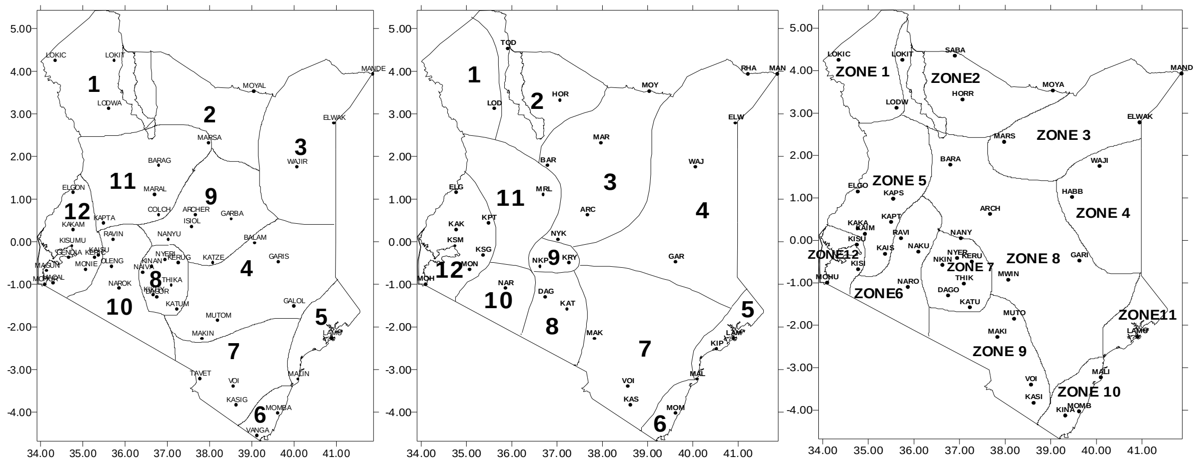


Figure 3: Kenya's rainfall-based climatological zones: MAM season (left); JJAS (middle); OND (right)

Impacts of extreme climate events

The Kenya Government acknowledges that climate influences all socio-economic sectors. The Government further appreciates that different sectors will be differently impacted by climate change and that these impacts are already being experienced in some sectors (MEMR, 2009).

Studies have indicated general warming over land stations with some cooling over coastal locations and near large water bodies (King'uyu, 1994; King'uyu *et al*, 2000; MEMR, 2009). A reduction in cold extremes has also been observed over the ASAL regions (Kilavi, 2008). There are however indications that some of the observed trends may be related to urbanisation (King'uyu, 2002). Rainfall trends, however, show mixed signals with some location indicating increasing trends in recent years, with majority not showing any significant trends. The annual rainfall shows either a neutral or slightly decreasing trends due to a general decline in the main (MAM) season. he OND rains show an increasing trend due to among others, an extension into January and February over some locations in recent years (MEMR, 2009). Bowden *et al* (2005) discerned increasing rainfall trends over the northern portions of the GHA including northern Kenya that is possibly related to an early onset and decreasing trends over the southern portion of GHA, including southern Kenya that may be related to a late start in the seasonal rainfall.

Other impacts include the depletion of glacier on Mt Kenya and Mt Kilimanjaro at the border with Tanzania (IPCC, 2007). This is a serious signal since the two mountains are sources of some of the surface and underground streams and rivers in the region. The snow-caps depletion will also adversely impact on tourism given that the two mountains are tourist attractions due to their position near the equator where no snow cover would otherwise be expected. Kenya's Ministry of Environment and Mineral Resources (MEMR) launched a National Climate Change Response Strategy (NCCRS) in December 2009 to enhance coordination of climate change activities in the country so as to ensure a climate proof socio-economic development, and provide a coordinated approach to climate change related issues. The strategy will also help the country to address threats posed by climate change and take advantage of any opportunities that may arise. Future climate change programs and projects will have to be in line with the provisions of the NCCRS (MEMR, 2009). The strategy has been adopted as the key government climate change agenda guide and will inform nationwide Climate Change programme development activities including the formulation of documents such as the National Climate Change Policy and efforts towards the attainment of Vision 2030 (MEMR, 2009).

Justification for mainstreaming climate variability and change in socio-economic development activities

Kenya's economy is dependent on rain-fed agriculture, livestock keeping, hydro-energy generation, transport, tourism, and other climate dependent sectors. Sixty percent (60%) of socio-economic activities are weather and climate dependent. Severe weather and extreme climate events and other climatic fluctuations have been shown to have a high influence on the social and economic activities of the country and the performance of the country's economy (KMD, 2009). There has also been fear that past development projects may not have taken into consideration the potential impacts on the environment and any related feedback processes. MEMR (2009) has consequently recommended that all future development programmes and projects must take climate and environmental impacts into consideration.

There is high confidence that African farmers have developed several adaptation options to cope with current climate variability, but such adaptations may not be sufficient for future changes of climate. Africa's vulnerability is aggravated by the interaction of 'multiple stresses', occurring at various levels, and the continent's low adaptive capacity (IPCC, 2007).

Objectives of the Workshop

The main objective of this workshop was to define thresholds for climate extremes for the region and develop regional climate change indices. Participants were drawn from all member countries of IGAD representing both the National Meteorological and Hydrological Services (NMHSs) and the user communities.

The specific objectives of the workshop were to:

i). Introduce the participants to relevant software like RClimdex that can be used to delineate climate change indices.
ii). Carry out data Quality Control (QC) of the data.
iii). Define thresholds for severe weather and extreme climate.
iv). Generate Climate Change Indices for the region.

This is the first of a series of three workshops, whose main objective is to help raise capacity in the use of climate information and climate projections in support of climate change adaptation. The general theme of the three workshops is the “Role of Observations in Support of Adaptation, Climate Modelling, Scenarios and Downscaling”.

Data and Methodology

The data used in the exercise were daily minimum and maximum temperature, and daily precipitation values obtained from the Kenya Meteorological Department’s Data Processing Section. Thirteen stations (Table 1 and Figure 2) representing different Kenyan climatological zones were used.

The data sets were examined for errors and rearranged using MS-Excel based micros. Quality Control was carried out using the QC facility resident in RClimdex.

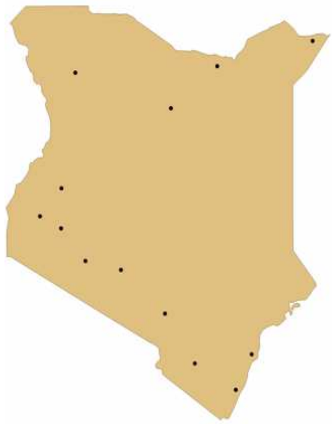


Figure 4: Network of stations used in the study

Definition and computation of indices

RClimdex was used to generate climate change indices as defined in Appendix 1. The 95% confidence level was taken as the threshold for acceptance of any index as significant.

Results and discussion

Quality Control

The stations used were found to have good quality data from the results of the mass curves and RClimdex-based quality control.

Missing data formed a small proportion of the temperature records, the highest being 2.5% for Makindu. Dagoretti-Corner had the smallest proportion of missing data at 0.9%. Some of the results are shown in Figure 3.

Climate change indices

Results showed several indices that were significant at the 95% confidence level. The cluster of significant indices, however, varied from one station to the other although some were common in several stations. These results are summarised in the following paragraphs.

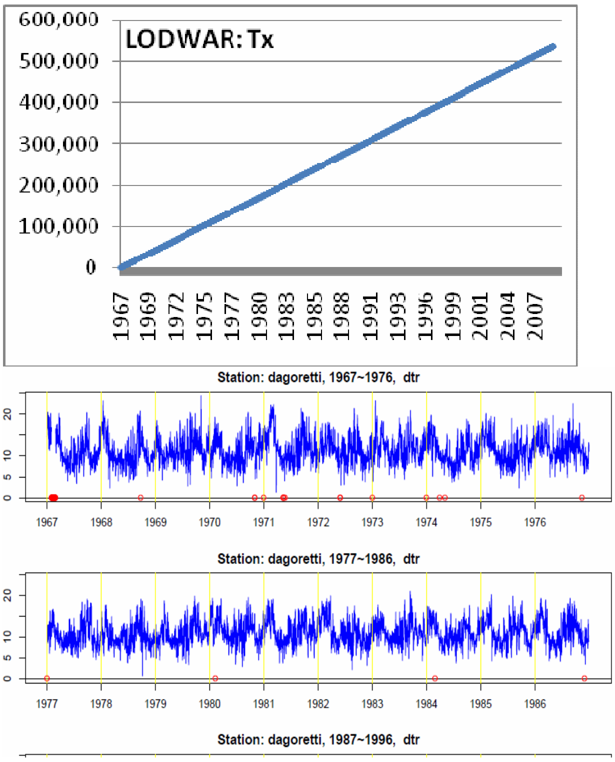


Table 1: Significant indices for Dagoretti

Indices	Slope	STD	P_Value
ID19	-0.241	0.112	0.040
FD10	-1.265	0.225	0
TNn	0.062	0.028	0.035
TN10p	-0.534	0.067	0
TN90p	0.61	0.105	0
CSDI	-0.261	0.124	0.043
DTR	-0.035	0.009	0.001
CDD	0.654	0.210	0.004

Figure 5: Maximum temperature mass curve for Lodwar (1967-2009) and RClimdex generated Daily temperature range (dtr) for Dagoretti-Corner. Both graphs generally indicate homogeneity.

The significant indices at 95% confidence levels for Dagoretti are summarised in Table 1. The indices show a decrease in the number of days with maximum temperature below 19ºC (ID19) and those with minimum temperature below 10°C (FD10), days with minimum temperature below the 10th percentile (TN10p), cold spell duration indicator (CSDI), diurnal temperature range (DTR); and an increase in monthly extreme minimum temperature (TNn), proportion of days with minimum temperature above the 90th percentile (TN90p), and consecutive dry days (CDD). A significant observation is that of night time warming as indicated by a decrease in TN10P and an increase in TN90p, leading to a decrease in the diurnal temperature range (DTR) as shown in Figure 4. Rainfall did not show any significant trend

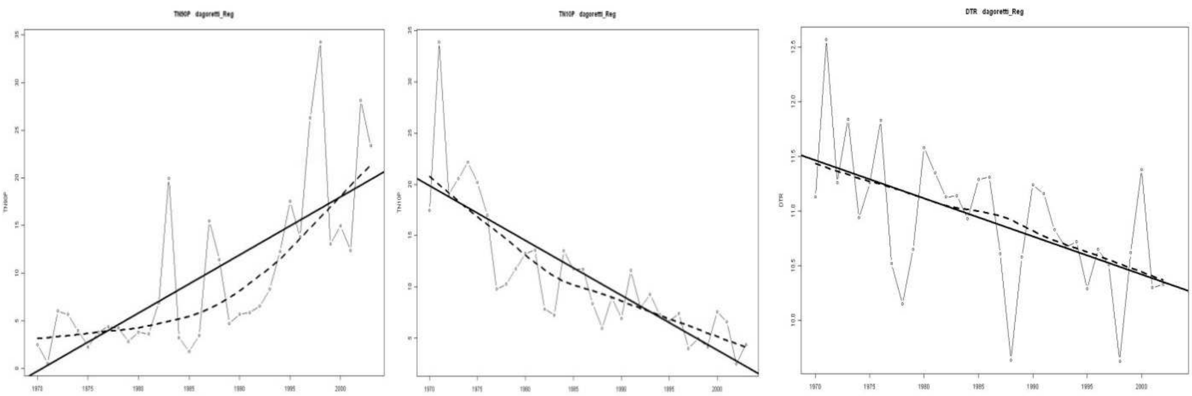


Figure 6: Dagoretti: (Left) number of days with minimum temperature below the tenth percentile (TN10p); (Middle) number of days with minimum temperature above the ninetieth percentile (tn90p); (Right) Daily temperature range (DTR).

The significant indices for Mombasa show an increase in the number of (summer) days with maximum temperature above 25ºC and also above 30ºC (SU25 and SU30); a decrease in the number of days with minimum temperature below 25ºC (ID25) and those with maximum temperature below the 10th percentile (TX10p) accompanied by an increase in the number with maximum temperature above the 90th percentile (TX90p), leading to an increase in the daily temperature range (DTR) as shown in Figure 5. Unlike the results for Nairobi, these results are indicative of significant day-time warming. Night time temperatures have also increased but the trends are not significant.

Table 2: Significant indices for Mombasa (1967-2009)

Indices	Slope	STD	P_Value
SU25	0.084	0.040	0.045
SU30	0.700	0.243	0.007
ID25	-0.061	0.028	0.038
TX10p	-0.187	0.053	0.001
TX90p	0.208	0.094	0.033
DTR	0.021	0.007	0.004

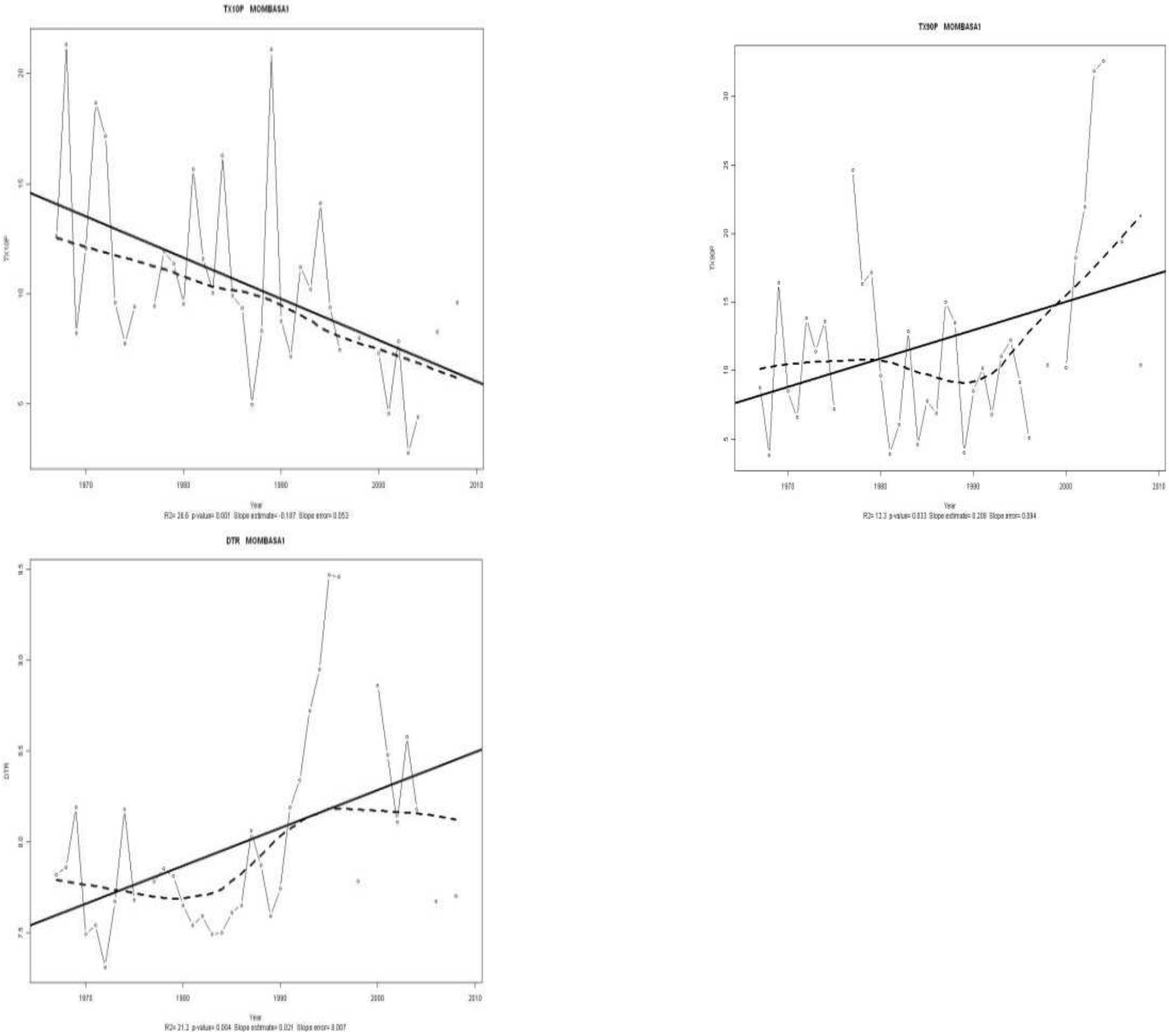


Figure 7: TX10p (left), TX90p (middle) and DTR (right) for Mombasa

The significant indices for Lodwar are summarised in Table 3. All the temperature related indices are positive except TX10p, TN10p, and CSDI (cold spell duration indicator), indicating general warming. This is also supported by positive trends in TX90p and TN90p indicative of more temperature observations being ‘promoted’ to the highest 10%. The positive trends in the number of consecutive wet days (CWD) and extremely wet days (R99p) are indicative of erratic fluctuations (extreme rainfall events) observed in recent years (Figure 6).

Table 3: Significant indices for Lodwar (1967-2009)

Indices	Slope	STD	P_Value
SU38	0.627	0.133	0.000
TR25	1.960	0.383	0.000
TXx	0.029	0.010	0.006
TNx	0.024	0.010	0.020
TX10p	-0.446	0.089	0
TX90p	0.541	0.091	0
TN10p	-0.313	0.120	0.013
TN90p	0.334	0.073	0
CSDI	-0.357	0.118	0.004
CWD	-0.035	0.015	0.026
R99p	0.678	0.275	0.019

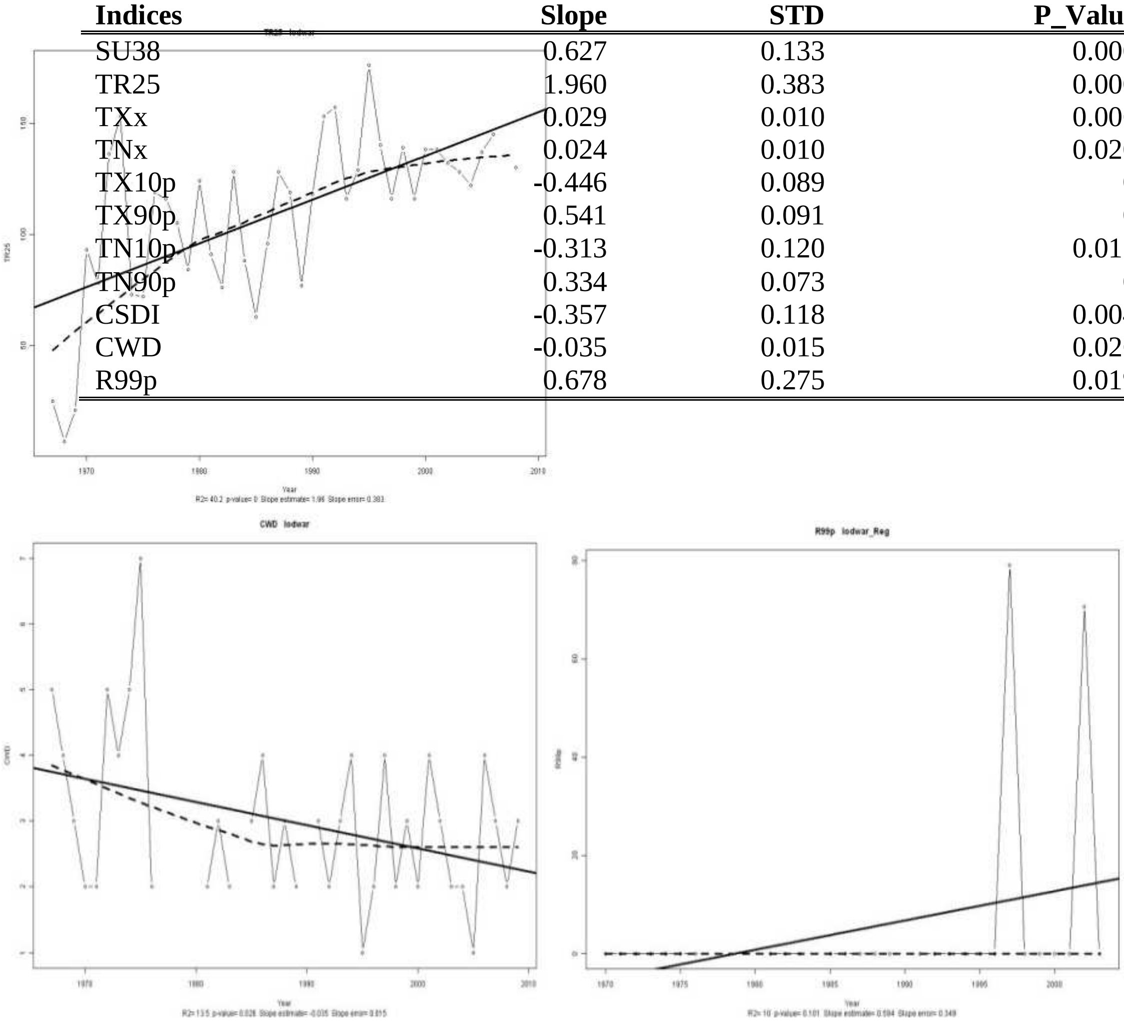


Figure 8: TR25, CWD, and R99p for Lodwar.

The significant indices for Makindu are summarized in Table 4 and Figure 7. The results show both day and night time warming as indicated by positive trends in the number of (summer) days with maximum temperature above 25ºC and also above 30ºC (SU25 and SU30), number of (tropical) nights with temperatures above 20ºC (TR20), days with maximum temperature above the 90th percentile (TX90p) accompanied by a decrease in the days with maximum temperature below the 10th percentile (TX10p), days with minimum temperature above the 90th percentile (TN90p) accompanied by a decrease in days with minimum temperature below the 10th percentile (TN10p). The warming is also confirmed by decreasing trends in the number of nights with temperature below 25ºC (ID25) and below 15ºC (FD15) and cold spell duration indicator (CSDI) accompanied by an increase in warm spell duration indicator (WSDI). The trend of the daily temperature range (DTR) was positive but not statistically significant. Rainfall did not show any significant trends.

Table 4: Significant indices for Makindu (1968-2009)

Indices	Slope	STD	P_Value
SU25	0.601	0.167	0.001
TR20	0.260	0.106	0.019
SU30	1.433	0.455	0.003
ID25	-0.482	0.135	0.001
TR20	0.260	0.106	0.019
FD15	-0.557	0.211	0.012
TX10p	-0.305	0.079	0
TX90p	0.350	0.085	0
TN10p	-0.228	0.085	0.011
TN90p	0.355	0.078	0
WSDI	0.330	0.104	0.003
CSDI	-0.094	0.046	0.047

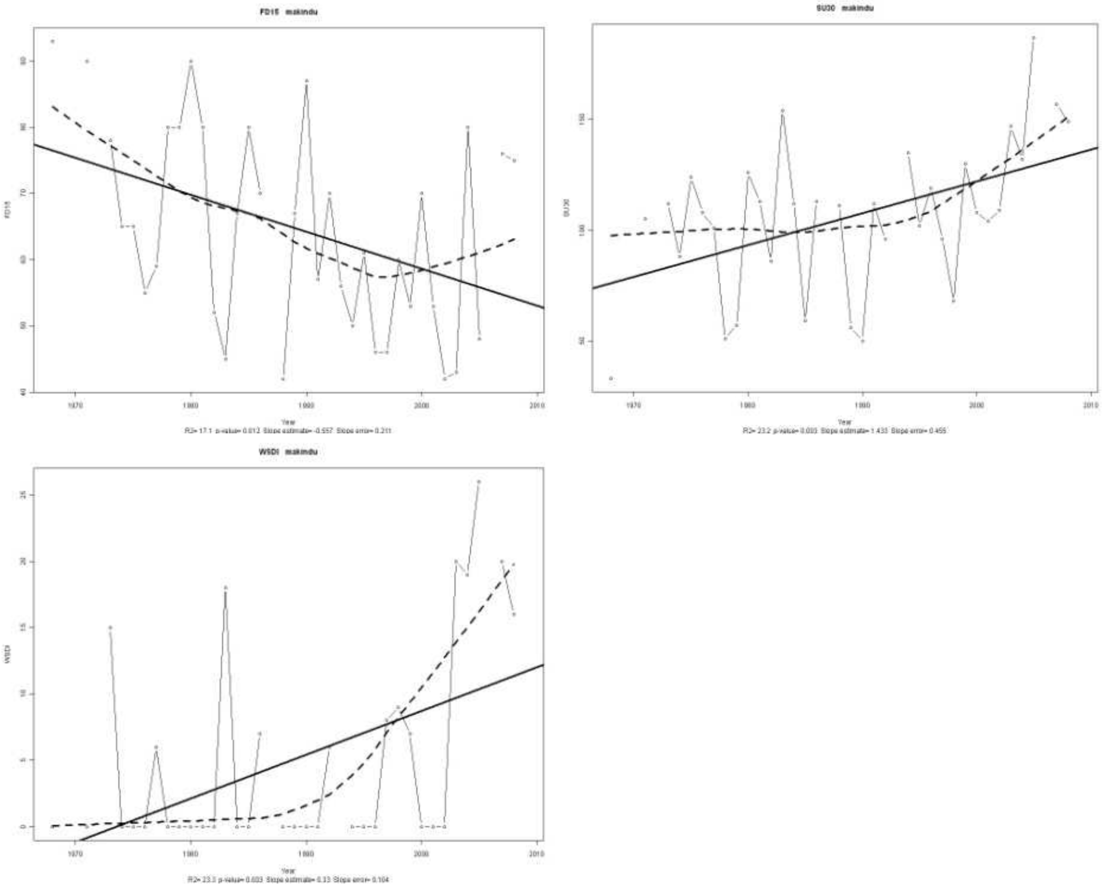


Figure 9: Days with minimum temperature below 15°C (FD15) and maximum temperature above 30°C (SU30), and warm spell duration indicator (WSDI) for Makindu

Summary and conclusions

The results of this analysis indicate a general warming over land stations in Kenya. In some stations like Dagoretti, night-time warming is more prominent than day-time warming. This may be indicative of urbanisation effects in the warming signals. The results further showed decreasing rainfall trends except for Dagoretti, but none of these trends was statistically significant. There is, however, an indication of an increase in the frequency of extreme rainfall events (floods) over some locations in recent years. These results conform with previous other studies that have indicated warming over most parts of the country. The results have also indicated that RClimdex is a good tool for delineating climate change indices for the region, however with some slight modification.

Recommendations and the way forward

The results of this analysis indicate that daily rainfall and temperature records can generate good indicators of climate change. A good proportion of the records at the KMD Climate Section is still in hard copies. There is therefore need for the Department, other stakeholders and partners to put in place concerted efforts to facilitate the digitization of these data sets. The department may need external help to acquire enough computers for this exercise. More computers will also be required to ensure that the quality control and climate change evaluation exercise started at this workshop continues after the workshop.

There is also need to 'tropicalise' the list of indices generated using RClimdex to reflect the reality in the hot tropical environment. Based on the experience from Workshop 1, future workshops need to take into consideration the dynamics of the amount of data each country group must analyse. This is because whilst the prescribed 5 workshop days may be more than adequate for groups with few data sets, it is too short a period for groups with several station data sets. This limitation adversely affected our group as there was hardly enough time to organize and analyse the close to 20 station data records initially requested for.

Lastly, we recommend that future climate change evaluation exercises should be based on seasonal values so as to ascertain the trends for each season because previous studies have shown that even in cases where the sign of the trend is the same, the magnitude may vary from one season to the other.

References

Bowden, J. H., F. H. M. Sermazzi, R. O. Anyah, and C. Schreck, 2005: Decadal temperature, rainfall and hydrological trends over the Greater Horn of Africa. 85th AMS Annual Meeting, San-Diego, California, 9-13 Jan 2005.

IPCC, 2007: Climate Change: Synthesis Report of the Fourth Assessment (AR4). IPCC 2007.

Kilavi, M.K., 2008: Analysing the temporal characteristics of extreme temperature events over ASALs and the coastal regions of Kenya as an indicator of climate change

King'uyu, S. M., 1994: Space-time characteristics of the extreme temperature values over the Tropical Eastern Africa region. MSc. Thesis, University of Nairobi, 1994.

King'uyu, S. M., 2002: Urbanisation and the climate of Nairobi. J. African Meteor. Soc. Vol. 5 No.1, 2002.

King'uyu, S. M., L. A. Ogallo and E. K. Anyamba 2000: Recent trends of surface minimum and maximum temperatures over Eastern Africa. J. Climate. Vol. 13 No. 16, 2876- 2885, 15 August 2001.

KMD, 2009: Mid-Term Report of the Pilot Project on the Evaluation of the Socio-Economic Benefits of Meteorological Information and Services in Kenya – The Agriculture Sector, KMD 2009.

MENR, 2006: Response to Climate Change and opportunities for sustainable development. UNFCCC COP 12 /COP/ MOP 2. Ministry of Environment and Natural Resources (MENR), Nairobi Kenya 2006.

MENR, 2009: Kenya Climate Change Response Strategy. Ministry of Environment and Mineral Resources (MEMR) 2009.

Appendix 1: List of ETCCDMI core Climate Indices

ID	Indicator name	Definitions	UNITS
FD0	Frost days	Annual count when TN(daily minimum)<0ºC	Days
SU25	Summer days	Annual count when TX(daily maximum)>25ºC	Days
ID0	Ice days	Annual count when TX(daily maximum)<0ºC	Days
TR20	Tropical nights	Annual count when TN(daily minimum)>20ºC	Days
GSL	Growing season Length	Annual (1st Jan to 31st Dec in NH, 1st July to 30th June in SH) count between first span of at least 6 days with TG>5ºC and first span after July 1 (January 1 in SH) of 6 days with TG<5ºC	Days
TXx	Max Tmax	Monthly maximum value of daily maximum temp	ºC
TNx	Max Tmin	Monthly maximum value of daily minimum temp	ºC
TXn	Min Tmax	Monthly minimum value of daily maximum temp	ºC
TNn	Min Tmin	Monthly minimum value of daily minimum temp	ºC
TN10p	Cool nights	Percentage of days when TN<10th percentile	Days
TX10p	Cool days	Percentage of days when TX<10th percentile	Days
TN90p	Warm nights	Percentage of days when TN>90th percentile	Days
TX90p	Warm days	Percentage of days when TX>90th percentile	Days
WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX>90th percentile	Days
CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN<10th percentile	Days
DTR	Diurnal temperature range	Monthly mean difference between TX and TN	ºC
RX1day	Max 1-day precipitation amount	Monthly maximum 1-day precipitation	Mm
Rx5day	Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation	Mm
SDII	Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as PRCP ≥ 1.0mm) in the year	Mm/day
R10	Number of heavy precipitation days	Annual count of days when PRCP ≥ 10mm	Days
R20	Number of very heavy precipitation days	Annual count of days when PRCP ≥ 20mm	Days
Rnn	Number of days above nn mm	Annual count of days when PRCP ≥ nn mm, nn is user defined threshold	Days
CDD	Consecutive dry days	Maximum number of consecutive days with RR<1mm	Days
CWD	Consecutive wet days	Maximum number of consecutive days with RR ≥ 1mm	Days

R95p	Very wet days	Annual total PRCP when RR>95th percentile	Mm
R99p	Extremely wet days	Annual total PRCP when RR>99th percentile	mm
PRCPTOT	Annual total wet-day precipitation	Annual total PRCP in wet days (RR ≥ 1mm)	mm

Source: RClimDex (1.0) User Manual By Xuebin Zhang and Feng Yang, Climate Research Branch, Environment Canada, Downsview, Ontario, Canada.

Sudan

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Ministry of Science and Technology

Introduction

The Sudan is the largest country in Africa.It is about one million square miles (2.54 km^2).
The country lies between longitudes 23 and 39°E ,4 and 22°N .It encompasses five geographical and climatic zones viz: (From the North to South) desert,semi-desert,Poor Savannah ,Wooded Savannah and Equatorial rain forest.As a result Rainfall varies from zero,100,100 – 300,300-600 and 900-1500 mm per year in the five zones ,respectively .Rain falls from December to March along the Red Sea Coast in eastern Sudan; June/July to September/October in the northern Sudan. The temperature ranges from 9 °C in winter (December –March) to 45°C in summer (April-June).The country witnesses 6-12 cycles of duststorms per month during April and May.

The extreme climate events: drought, floods, low and high temperatures have a negative impact on Agriculture, both crops and livestock. Fluctuations of rainfall, droughts and floods resulted in failure of food crops and heavy losses in livestock especially in 2008 and 2009.

It could even become worst in 2010.Dust storms clear away pasture grasses and subject livestock to stress which succumb them to diseases like theileriosis and haemorrhagic septicaemia.All these conditions have a direct effect on human livelihoods an increase vulnerability of people of the country.

Justification

Mainstreaming climate variability can avert its serious effects like damages attributed to floods; stress caused by higher or lower temperatures, famine due to droughts and damages of pastures by dust storms etc.To make these more clear on socio-economic activities, use of climate information makes us take precautions measures to avoid the consequences' of the climate variability .As a result flood plain could be avoided when there is warning about its possibilities, provide shelters for livestock in cases of possible rise or drop of temperature , store food and feeds if drought is expected and also in cases of dust storms.

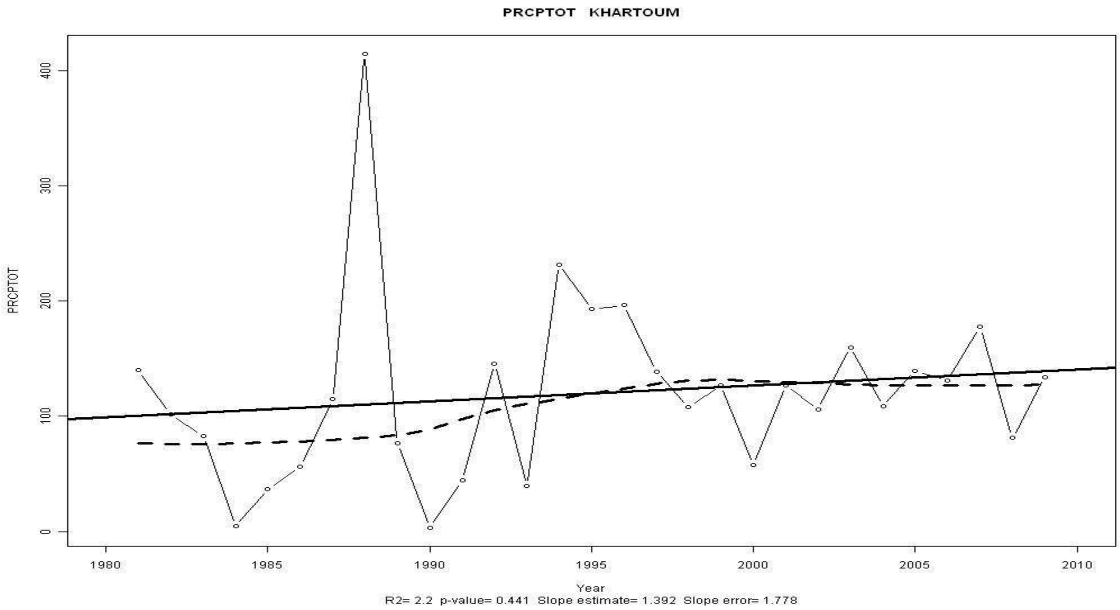
Objectives

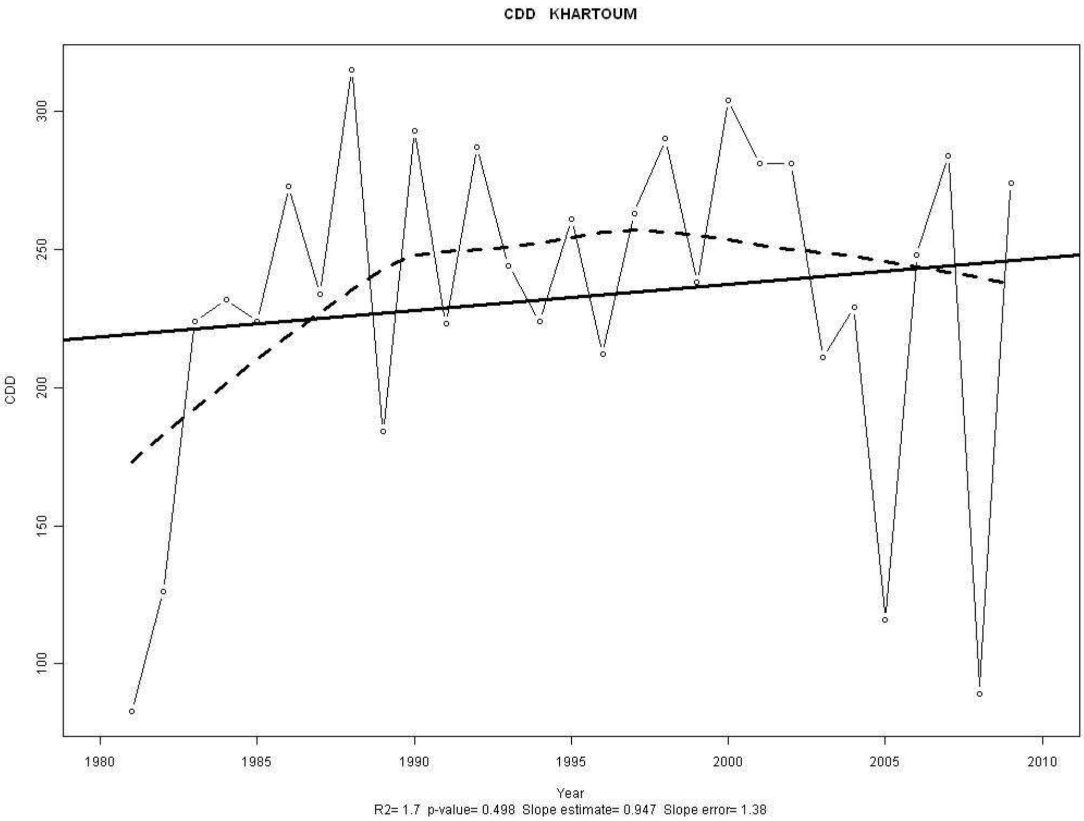
The objectives of this project were data processing and presentation, quality control and homogeneity in the region of GHA for reliable climate information so as to help in design of effective adaptation strategies for the climate changes.

Data collection

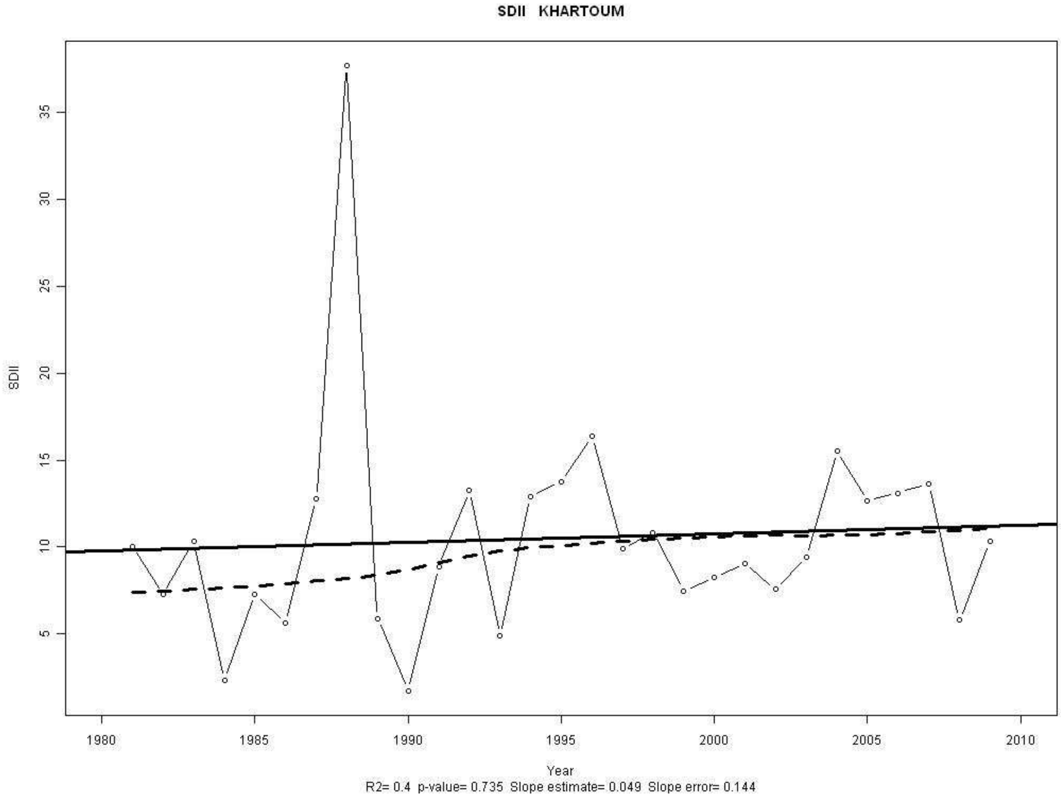
We have prepared data on the maximum and minimum temperatures and rainfall from seven stations representing the different climatic zones in the period from 1981-2009. The data were canalized quality controlled and homogenized using the RclimDex soft ware.

Results

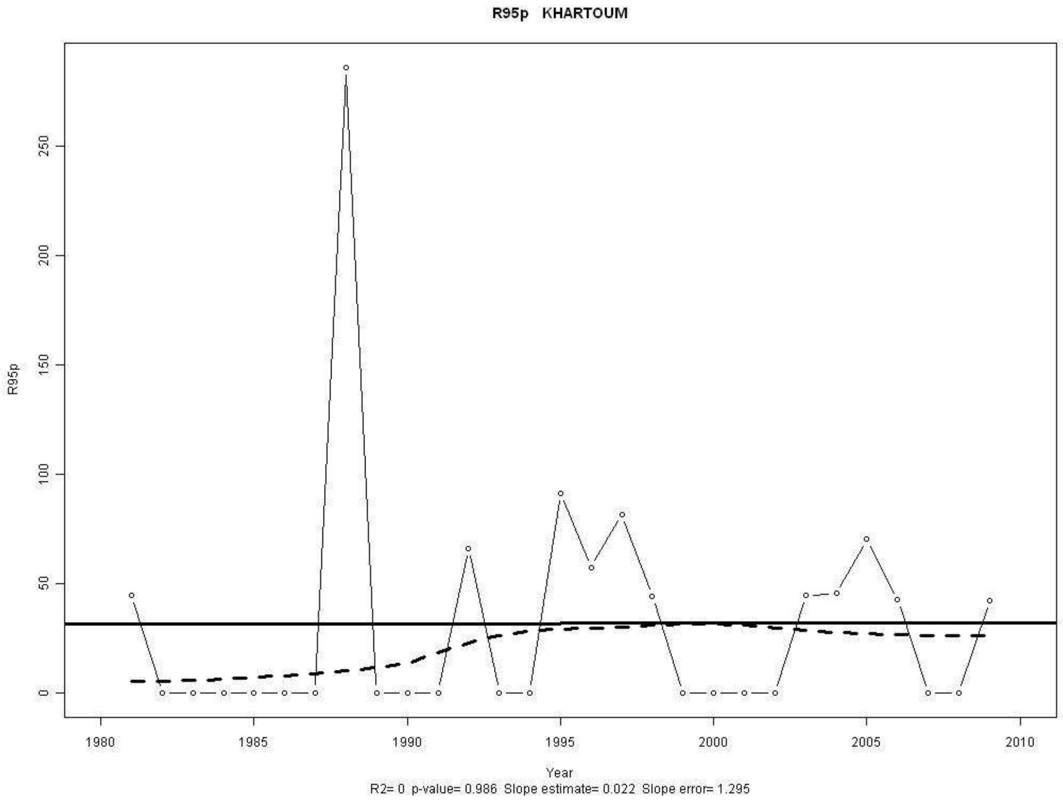

PRCPTOT KHARTOUM
PRCPTOT
0
100
200
300
400
1980
1985
1990
1995
2000
2005
2010
Year
R2= 2.2 p-value= 0.441 Slope estimate= 1.392 Slope error= 1.778

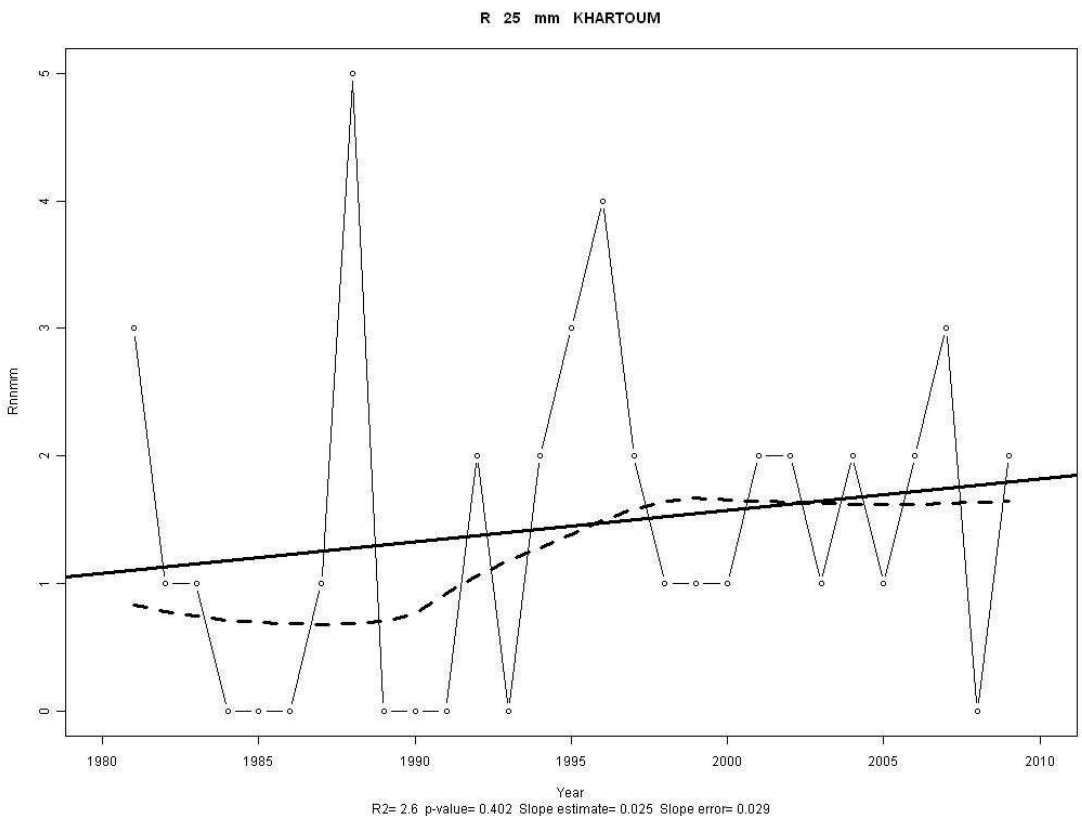


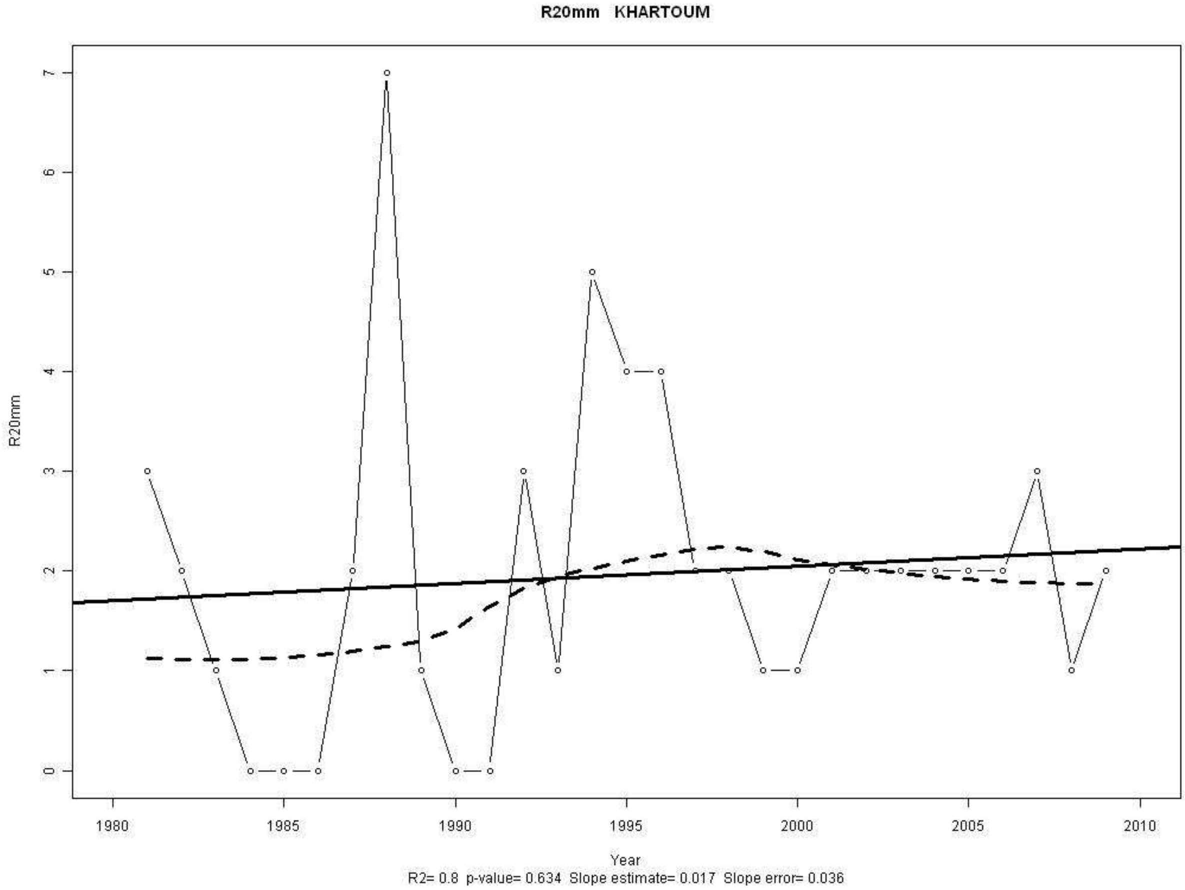
CDD is the daily precipitation amount which counts the largest number on consecutive days Where: RR <1 mm



SDII : RR_{Rwj} is the daily precipitation amount on wet days ,w(RR>1mm) in period j.


R95p KHARTOUM
R95p
0
50
100
150
200
250
1980
1985
1990
1995
2000
2005
2010
Year
R2= 0 p-value= 0.986 Slope estimate= 0.022 Slope error= 1.295


R 25 mm KHARTOUM
Rnnmm
0
1
2
3
4
5
1980
1985
1990
1995
2000
2005
2010
Year
R2= 2.6 p-value= 0.402 Slope estimate= 0.025 Slope error= 0.029



Discussion

There were so many problems in the raw data obtained from the stations including gaps ,missing records, incorrect tabulation in different months and irrelevant data e.g. temperature was recorded as 377.0 ^{o}C (instead of 37.7 ^{o}C) .In other instances the minimum temperature was higher from the maximum.

Using the present Software RclimDex, the data were quality controlled and homogenized. We were then able to produce different indices. However we need to improve the country's data collection and preparation carefully. All data should also be revised for common encountered errors so as to submit reliable information.

Somalia

Ms Muchiri Peris

Climate Scientist

Somalia Water and Land Information Management

Table of Contents

List of figures and tables

Annexes

List of Acronyms

DARE	-Data Rescue
EC	-European Commission
FAO	-Food and Agriculture Organisation
GHA	- Greater Horn of Africa
IGAD	-Inter Governmental Authority on Development
ITCZ	- Inter tropical Convergence Zone
MDGs	- Millennium Development Goals
SWALIM	- Somalia Water and Land Information Management
WMO	- World Meteorological Organization

1.0 Introduction

Somalia is situated in the Horn of Africa and covers an area of 637 660 km^2. It extends from approximately 1°40’ south of the Equator to 11° 58’° north and from 40°59’ to 51° 24’ east. The country is bordered by Djibouti to the north-west, the Gulf of Aden to the north, the Indian Ocean to the east, Kenya to the south and south-west and Ethiopia to the west. It has the longest coastline of all African countries, with nearly 3,300km. Figure 1 shows the map of Somalia. Like most developing countries, Somalia is prone to frequent climate related disasters mainly droughts and floods. The social and economic well-being of the Somali people is intrinsically linked to the status of the country’s natural resources. Many of the rules for governing the use and protection of natural resources have not been enforced since the government collapsed in the early nineties.

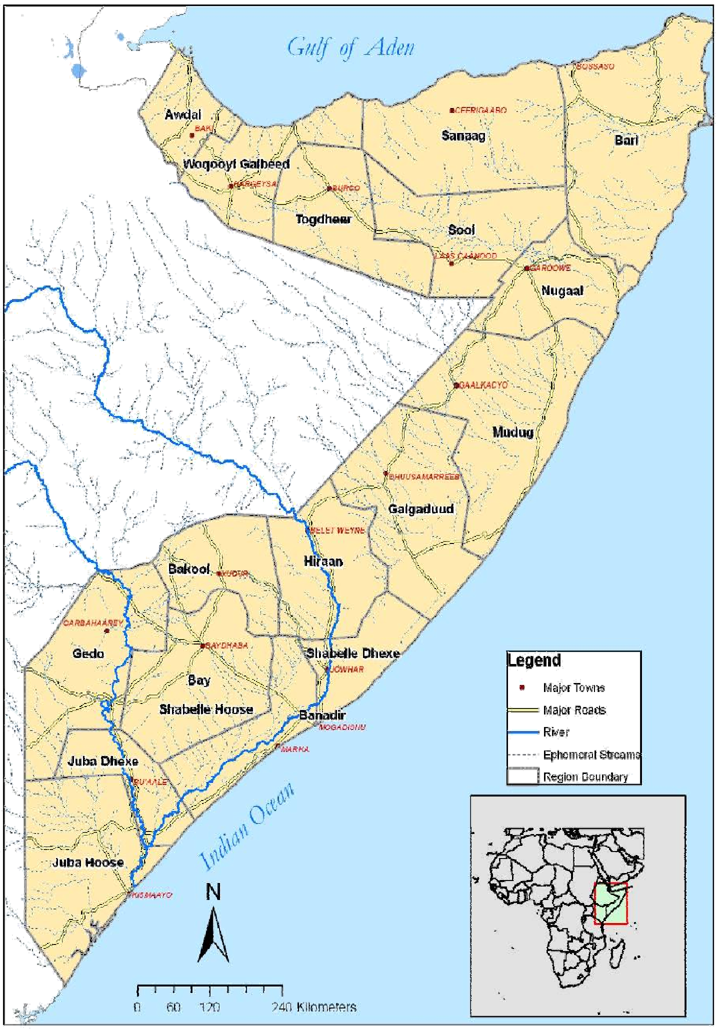


Figure 10: Map of Somalia

Economic necessity has resulted in the overuse of some the natural resources. There has been no comprehensive study of environmental change over the past decade, but various studies point to problems of rangeland degradation, deforestation, and depletion of wildlife resources, marine pollution and the depletion of marine life through excessive fishing.

Most of Somalia is desert or semi-desert. Approximately 60 percent of Somalia is savannah woodlands, which is used as rangeland and as the primary local source of fuel. Only about 13 % of the land can be cultivated, and much of that is not farmed on a regular basis. Cultivation of arable land occurs primarily in southern Somalia.

1.1 Climate of Somalia

Somalia generally has an arid to semi-arid climate. Rainfall is the defining characteristic of the climate and has a great spatial and temporal variability. The climate of Somalia is determined by the north and south movement of the inter-Tropical Convergence Zone (ITCZ). In most areas of Somalia this results in two rainfall seasons - the *Gu* as the zone passes northwards and the *Deyr* as it moves south. In both cases, rain is produced from the moist air derived from the Indian Ocean, in the southerly air stream. The north-easterly winds, emanating from Asia and Arabia, produce little significant rain. It is generally considered that rainfall is the most important meteorological element affecting life in Somalia. In particular, variation from season to season, and variations within the season are what determine the successes of agricultural activities.

The movement of the ITCZ also causes distinct changes in the wind direction throughout the year. When the ITCZ is to the south, the winds are from the northeast and when it is to the north the winds are from the southwest. This 180^0 shift to the southwest occurs gradually as the ITCZ passes over, spanning approximately between March-July, and then returning to the north-east winds by December. While there are some regional variations, this pattern is dominant across the whole country. Sea breeze can be significant and cause strong southwest winds off the north coast during June-August that are locally known as *kharif*.

Wind speeds average between 0.5 - 10 m/s, with the highest wind speeds occurring in the Northern Plateau. While the strongest winds occur between June and August, the weakest winds generally occur as the ITCZ passes over the Equator in April to May in southern Somalia.

Luuq; in Gedo region near the border with Ethiopia, has the highest mean temperature in the country, at over 30° C. Most inland areas of southern Somalia are only slightly cool with the north coast also almost having similar temperatures. Temperatures along the southern coast are lower than those of inland areas. In the north, temperatures are correlated with altitude, with a lapse rate of 6.5° C per 1000 m. Average monthly temperatures reach as high as 41° C in March mainly around Bardheere and Luuq.

Greater contrasts between daily maximum and minimum temperatures occur in inland areas compared to those at the coast. However, these contrasts are generally small in comparison to those which might be expected for the desert environments. Hutchinson and Polishchouk (1989) attribute this to the relatively high humidity across the whole country.

There are few records of evaporation and the values which have been reported in various studies to vary between about 1000-3000 mm/yr. In general, evaporation is greater than precipitation across the country but there are localized areas in southern Somalia, around Jilib and Baidoa, where for a few months of the year higher rainfall than evaporation may be experienced. This occurs at the beginning of both the Gu and Deyr seasons, thus allowing crop growth to commence. Total evaporation generally increases from south to north, with the highest annual evaporation occurring on the north coast. The time of greatest evaporation also varies across the country, being the middle of the year in the country.

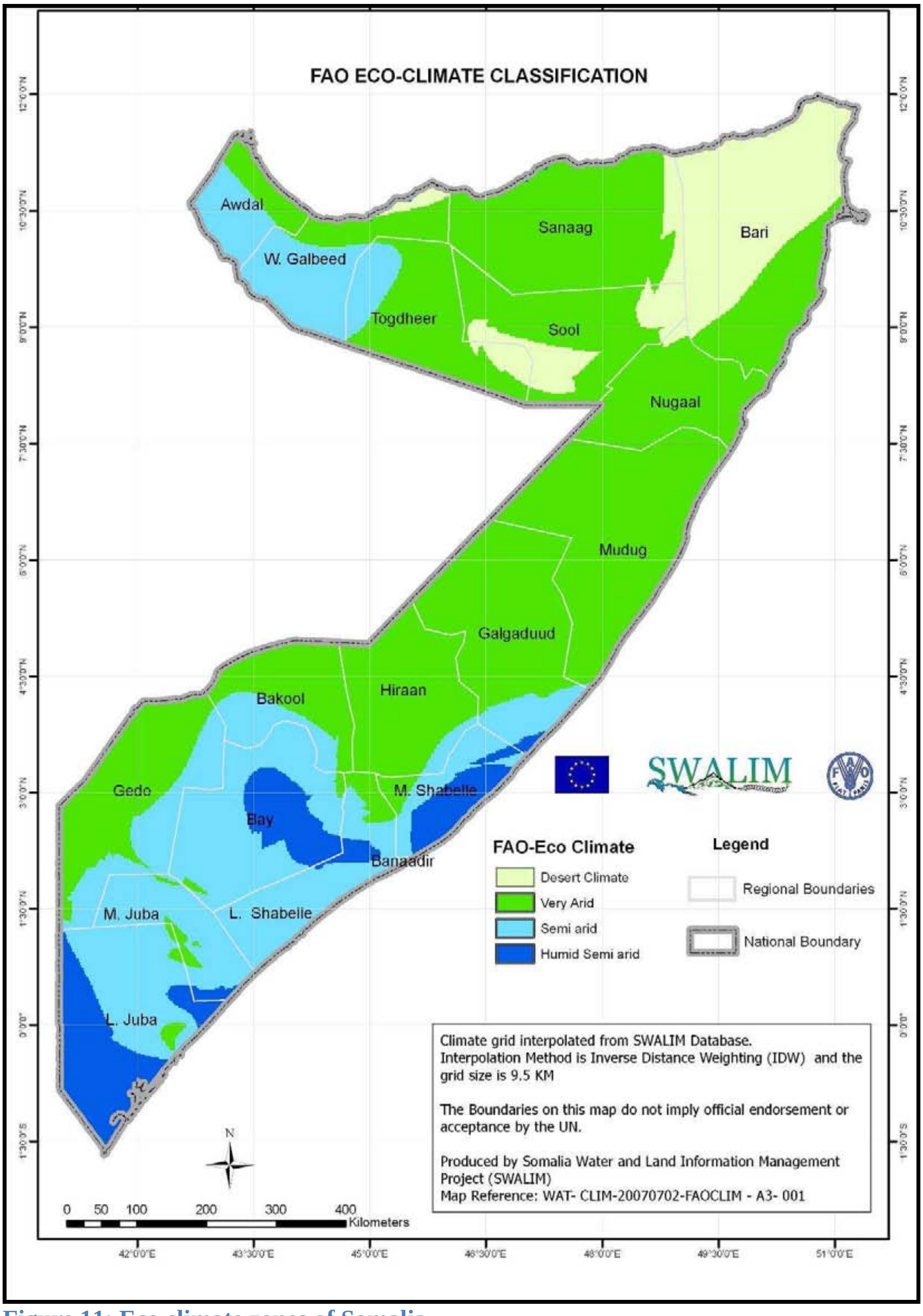


Figure 11: Eco climate zones of Somalia

1.2 Impacts of extreme climate events

Floods and droughts are the most common extreme climate events in Somalia, the two are so common that not one year passes without experiencing either or both.
Historically, along the Juba and Shabelle Rivers (the area is known as the riverine area in Somalia), floods have been the most prevalent form of natural disaster. Lately, there has been a discernable increase in the severity and frequency of the floods in the areas along the Juba and Shabelle Rivers. The most recent severe flood events were the floods of the Deyr in 1961, 1977, 1997, and 2006, and floods of the Gu in 1981, 2005 and 2010. The last three major flooding events had magnitudes larger than the one associated with the historical 50-year return period flood event.
Even if the trend toward an increase in flood frequencies is questioned, it is certain that the economic damage and casualties that result from flooding in the area have increased with time. For example, the number of fatalities in Somalia attributed to the 1997/98 El Niño floods were the sixth highest total attributed to floods globally for the decade of the 1990s (Loster, 1999).
Often, the floods leave thousands of people displaced, damaged properties and sometimes loss of lives this consequently has an negative impact to the economy of the country. Figure 3 shows some the affected villages during the 2006 flood in Southern Somalia.

Figure 12: Pictures of flooded houses in different areas in Somalia in 2006 floods

In the recent past, droughts have become very common in Somalia. Between 2000 and 2009 there were five major droughts with hundreds of thousands people affected. The droughts leave bad memories to the Somalis majority who are pastoralists. Figure 4 clearly shows the effects od drought to both human and livestock.

Figure 13: Pictures of dead camel and emaciated locals due to drought in 2004

1.3 Justification for mainstreaming climate variability and change in socioeconomic development activities

Most of all social and economic development activities are strongly related to climate variability and change. It is obvious that climate change and its impacts can have a very negative influence on people and their economies, for example on agriculture or in areas vulnerable to droughts and floods. The livelihoods of the poor, young and elderly will be most seriously undermined by extreme events (e.g. droughts, floods, epidemics) as well as more subtle changes (e.g. different disease vectors, heat stress, changes in growing season).

The global effort to fight poverty, in line with the Millennium Development Goals (MDGs), will be seriously hampered if issue on climate change and variability are not addressed. Illogically, social and economic development is the very driver of climate change. The way in which man has transformed the land over the past centuries to produce food, timber and fuel, and the use of coal, oil and natural gas to fuel our economies are directly responsible for the strong increase in green house gases concentrations in the atmosphere. The trends in exploitation of natural resources and the use of fossil fuel are not changing. Projections into the future show a further decline in the forests and natural vegetation and a further increase in greenhouse gas emissions, exacerbating climate change.

The question is how to reconcile the development aspirations of countries with the challenges posed by human-induced climate change.

The complex relationship between development and climate change necessitates a two-way approach, embracing:

- The influence of climate change and policy/strategy/action on development.
- The influence of development policies, strategies and decisions on climate change. This applies to development strategies that reduce vulnerability to climate change ('climate-safe' development or 'climate-proofing' development) as well as 'climate-friendly' or 'low-carbon' development strategies.

Both perspectives are important in order to engage effectively with the projected change in the climate. However, dealing with these aspects independently is not enough. Given the interconnectedness of development and climate change, only an integrated approach could work. Integrating (or mainstreaming) climate change is what needs to be done, for both industrialized and developing countries. Such an integrated approach moves towards what is normally called 'sustainable development'

1.4 Project objectives

Reliable and detailed regional climate information, including assessments of current and future climate variability and change, is essential in the design of effective adaptation strategies. The World Meteorological Organization (WMO) and the World Bank are collaborating to develop and implement a programme of three linked workshops to assist the developing and least developed countries of the Greater Horn of Africa (GHA) region to appropriately use climate information in adaptation planning.

The overall objectives of this workshop programme are to demonstrate the use and value of climate observations and regional models for decision making, to provide advice on model performance and limitations, and to improve capabilities across the region for using climate data records and model projections.

Workshop 1 focuses on data needs with specific goals to use available climate data from countries in the region to enable detailed assessments of observed climate variability and change; Assess the adequacy of the quantity and quality of the available data for the evaluation of the skill of global and regional climate models for the GHA region; Demonstrate the value of the collaborative use of data and standardized climate indices, including those representing extremes, among countries in the region; Increase regional research synergies by sharing insights and improve analyses between neighbouring countries; and encourage countries in the region to improve their observing systems and to undertake data rescue (DARE) and data digitization efforts.

The second workshop will first evaluate the simulations of the current climate (particularly precipitation) of global coupled models by comparing them with current available data, and thereby assessing the uncertainty associated with future climate predictions. Then, available regional models will be run and compared with available data to assess performance. The skill of the global models will be used to help in the assessment of the regional models. The available regional models will be used to generate future climate projections to demonstrate how they can be used to interpret at the national level. Hence participants will the workshop with an appreciation of how reliable regional models would be for projecting future climate change in the

region and at the national level, and with a greater sense of ownership in the process of producing such projections. Guidelines will be developed on the best practices in evaluating the available modeling techniques for use in making climate change projections.
The third workshop will examine the output of the first two workshops in order to assess their usefulness in the development of effective adaptation strategies. In particular, effort will be made to develop a common language between climate experts and the adaptation and climate risk management communities to better understand and interpret regional climate change projections and impacts. Such common understanding will enable a better integration of the climate information needs of the adaptation and climate risk management communities in further development of scientific and technological capacities. Emphasis will be placed on developing a common understanding of what results are robust and what the significance of the uncertainties is. The workshop will produce guidelines and best practices in the use and interpretation of climate observations and model outputs for the adaptation and climate risk management communities.

1.5 Specific objectives of the workshop

The first workshop (Workshop I) that was held in Nairobi in April, 2010, focussed on data needs. Specific objectives of the workshop included:

i. Use available climate data from countries in the region to enable detailed assessments of observed climate variability and change.

ii. Assess the adequacy of the quantity and quality of the available data for the evaluation of the skill of global and regional climate models for the GHA region.

iii. Demonstrate the value of the collaborative use of data and standardized climate indices, including those representing extremes, among countries in the region.

iv. Increase regional research synergies by sharing insights and improve analyses between neighbouring countries.

v. Encourage countries in the region to improve their observing systems and to undertake data rescue (DARE) and data digitization efforts.

2.0 Data and Methodology

In Somalia most of the direct data needed for climate monitoring are discontinuous, or missing or very difficult to collect on site. There is also no single institution that can claim ownership of comprehensive data resource for planning and management of natural resources in Somalia. There is a general gap in climate observations for the period 1989-2003.
As a result of SWALIM’s efforts, the pre-war manual rainfall observation network has been rehabilitated and slightly extended, and a system of automatic weather stations has been built in partnership with local authorities and international development organizations. Further, in recognition of the crucial role of good quality data in the rehabilitation and development initiatives and to efforts to mitigate natural disasters such as droughts and floods, the long term aim of the SWALIM is to compile and make available, scientifically accurate information on climate in Somalia. In this effort a climate database has been developed. There are a few stations

with significant historical rainfall datasets. For this study,three stations covering different climate zones of Somalia were analysed. The threeinclude: Mogadisho, Belet weyne and Hargeisa. Daily rainfall data for the period 1962 to 1986 was used. The location of the stations is shown on figure 5. Time series temperature data is not available for Somalia, therefore it was not possible to do any analysis based on temperature.

Under this data limitations scenario in Somalia, climate monitoring and assessment in the country remains a challenge and demands exploration of the relevance of remotely sensed information as proxies for the missing climate information or as proxies for drought assessment.

2.1 Quality control (QC)

Quality control is a very important step in any type of data analysis. This is usually done to ensure that the data being used in the analysis is of high quality and free of errors. Therefore, the products end up being useful and valid. I this study, data Quality Control is a prerequisite for indices calculations. . The quality control (QC) was carried out using R-ClimDex software. RClimDex QC performs the following procedure: 1) Replace all missing values (currently coded as -99.9) into an internal format that R recognizes (i.e. NA, not available), and 2) Replace all unreasonable values into NA. In addition, QC also identifies. The outliers are daily values outside a region defined by the user.

The datasets used here were obtained from the climate data archive for Somalia which is in custody of SWALIM. This data has been cleaned and checked for quality control as it has been used to support most of the climate related documents for Somalia. However, for this analysis, data quality control was carried to verify

2.2 Homogeneous tests

Homogeinity test was carried out using a single mass curve on MS excels. A single mass curve is a plot of the cumulative data at the station of interest for a given period. The analysis was carried out to investigate any spurious trend of the rainfall data. Daily rainfall data was used in this case.

2.3 Computation of indices

Computation of extreme climate indeces was carried out using the R-ClimDex. RClimDex is capable of computing 27 core as listed in Annex I. However, users can compute only those indices they require. In this study, indices were computed for the three station; Hargeisa, Belet Weyne and Mogadishu. In this report only rainfall related indices were considered as there was no temperature data. The indices computed include; rx1day , rx5day, sdii, r10mm, r20mm R250mm, cdd, cwd, r95p, r99p, and prcptot explanation of these indices as as indicated in Annex II.

3.0 Results and conclusions

Results of any analysis can only be as good as the input data. This is why a lot of efforts were used in this study to check the data for quality. The QC runs from the R-ClimDex produced no errors for the three rainfall stations. Therefore, a homogeneous test was carried out on the datasets. Figure 5 shows the histograms produced during the QC for Belet weyne Hargeisa and Mogadishu rainfall stations.

Figure 6 and 7 shows the homogeinity tests as carried out at Belet Weyne and Hargeisa rainfall stations. From the graphs it is clear that there are no evident spurious trends for the stations therefore the data are good for analysis.

The rainfall indices were calculated using R-ClimDex and the results are as seen on tables 1 ,2 and 3. Eleven rainfall indices were generated as mentioned in section 2.3 of this document. However, only one index was found to be useful in trend analysis.This is the prcpTOT index which indicates the total annual rainfallseries for the given period. Most of the other indices did not have a meaningful value that could be used to indicate any behavior of the rainfall data. For example, the cdd index that shows the consecutive dry days in a year. These values would only be useful if they were used for a season rather than annual series analysis.

To enhance on the trend analysis using the prcpTOT index for the three stations a 3 years moving average was generated for all the three stations as shown on figures 8, 9 and 10 for respective stations. Hargeisa did not give any indication of a trend while Belet weyne and Mogadishu rainfall stations shows a decrease of total annual rainfall over the years.

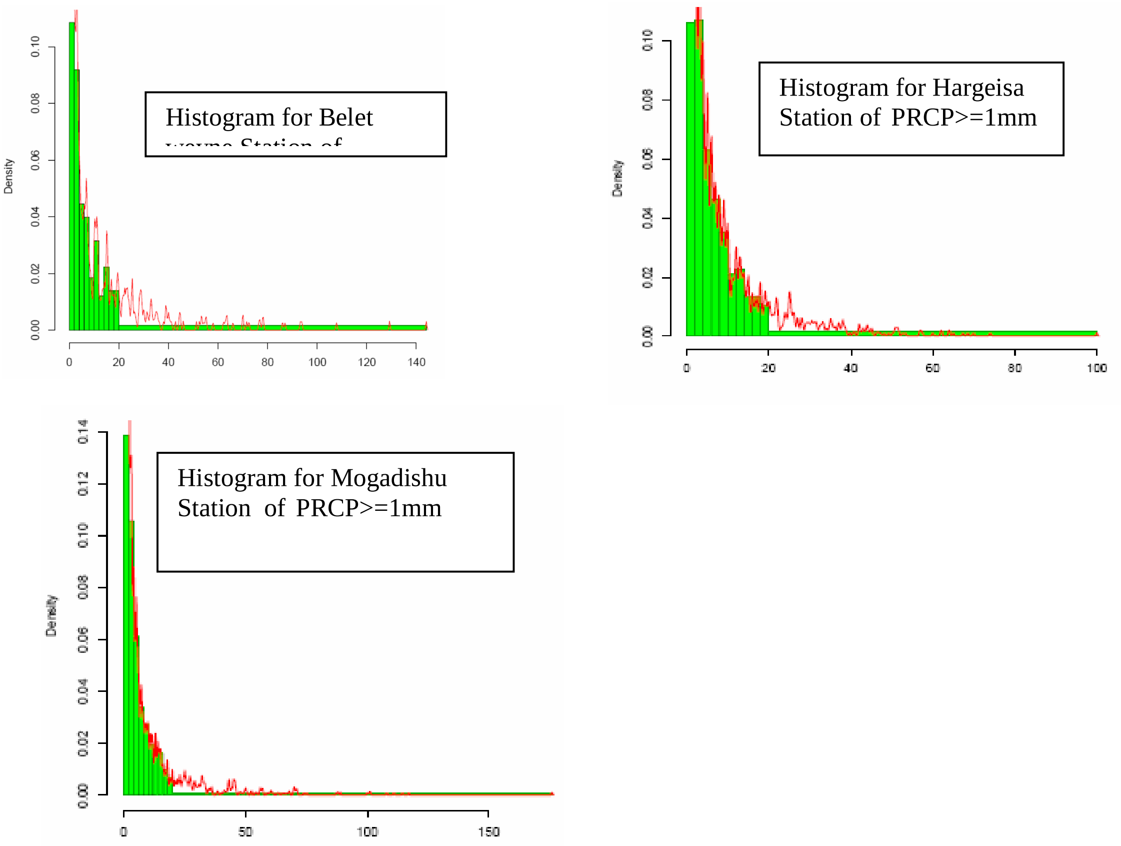


Figure 14: Histograms for the three stations during QC

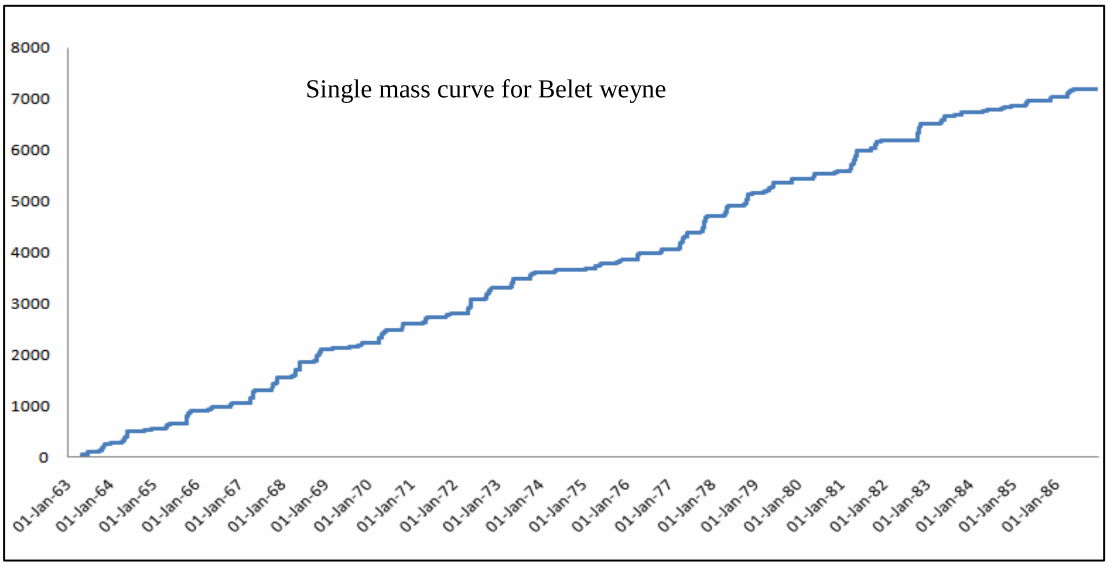


Figure 15: Single mass curve analysis at Belet weyne

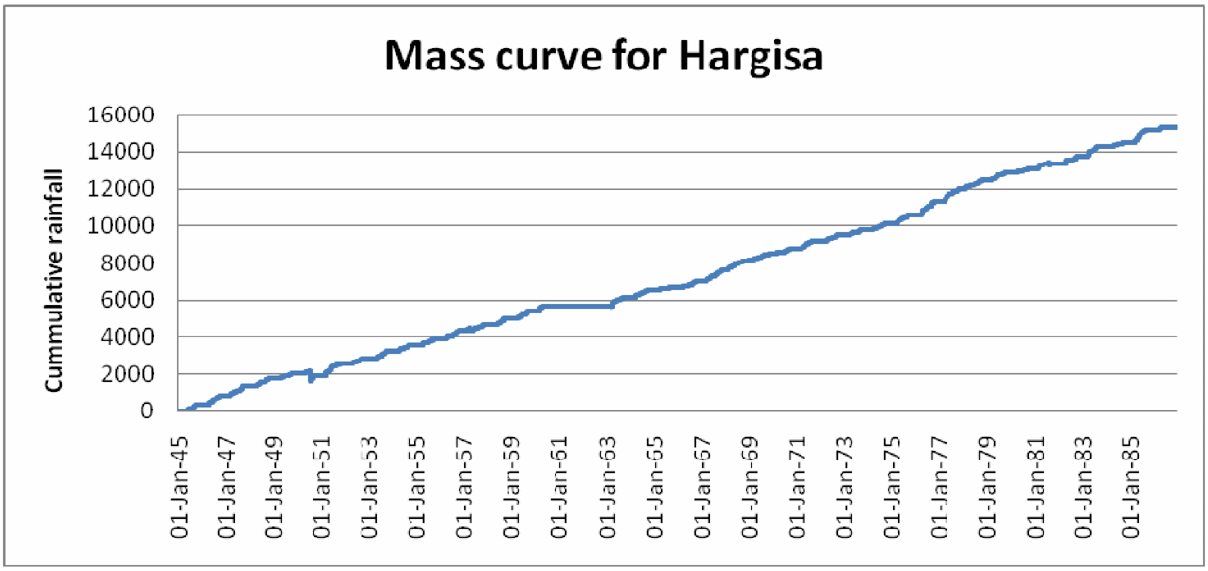


Figure 16: Single mass curve analysis at Hargeisa

Table 5: Rainfall indices for Mogadishu

Lon	Lat	Indices	SYear	EYear	Slope	STD_of_Slope	P_Value
2.03	45.35	rx1day	1963	1986	-0.62	0.654	0.351
2.03	45.35	rx5day	1963	1986	-1.749	0.865	0.052
2.03	45.35	sdii	1963	1986	-0.019	0.047	0.685
2.03	45.35	r10mm	1963	1986	-0.253	0.115	0.035
2.03	45.35	r20mm	1963	1986	-0.114	0.07	0.11
2.03	45.35	R250mm	1963	1986	0	0	NaN
2.03	45.35	cdd	1963	1986	3.23	1.919	0.102
2.03	45.35	cwd	1963	1986	-0.056	0.034	0.106
2.03	45.35	r95p	1963	1986	-1.179	1.925	0.545
2.03	45.35	r99p	1963	1986	-0.34	1.219	0.782
2.03	45.35	prcptot	1963	1986	-7.037	3.662	0.064

Table 6: Rainfall indices for Belt Weyne

Lon	Lat	Indices	SYear	EYear	Slope	STD_of_Slope	P_Value
		rx1day	1963	1986	-1.05	1.151	0.373
		rx5day	1963	1986	-0.84	1.2	0.493
		sdii	1963	1986	0.006	0.122	0.963
		r10mm	1963	1986	-0.025	0.171	0.887
		r20mm	1963	1986	0	0.105	0.999
		R150mm	1963	1986	0	0	NaN
		cdd	1963	1986	1.742	0.973	0.089
		cwd	1963	1986	-0.016	0.035	0.652
		r95p	1963	1986	-2.287	3.422	0.512
		r99p	1963	1986	-1.071	1.985	0.596
		prcptot	1963	1986	-2.461	5.881	0.68

Table 7: Rainfall indices for Hargeisa

Lon	Lat	Indices	SYear	EYear	Slope	STD_of_Slope	P_Value
		rx1day	1963	1986	0.156	0.232	0.507
		rx5day	1963	1986	0.507	0.436	0.254
		sdii	1963	1986	0.075	0.033	0.03
		r10mm	1963	1986	-0.009	0.068	0.891
		r20mm	1963	1986	0.032	0.041	0.448
		R100mm	1963	1986	0	0.002	0.86
		cdd	1963	1986	0.056	0.598	0.926
		cwd	1963	1986	0.009	0.021	0.665
		r95p	1963	1986	0.743	1.212	0.544
		r99p	1963	1986	0.433	0.531	0.42
0	0	prcptot	1963	1986	-0.349	1.956	0.859

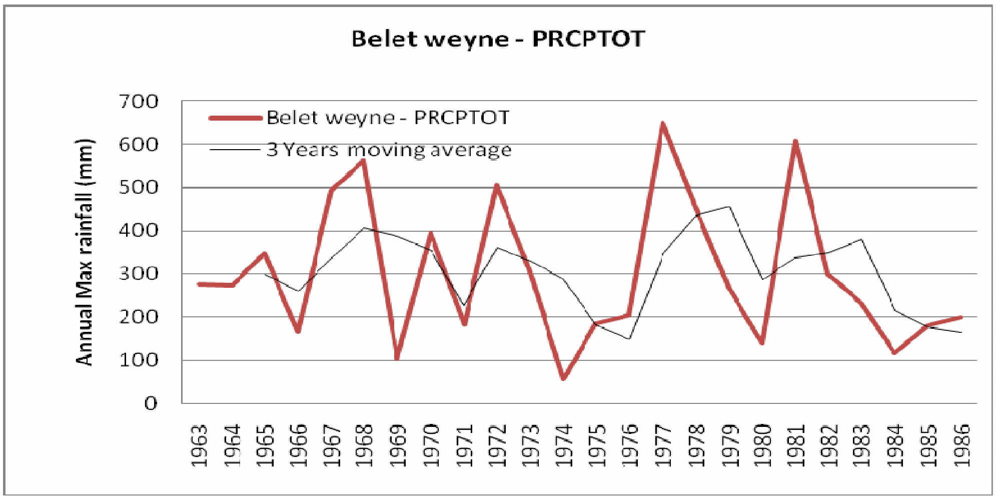


Figure 17: Belet weyne PrcpTOT Index

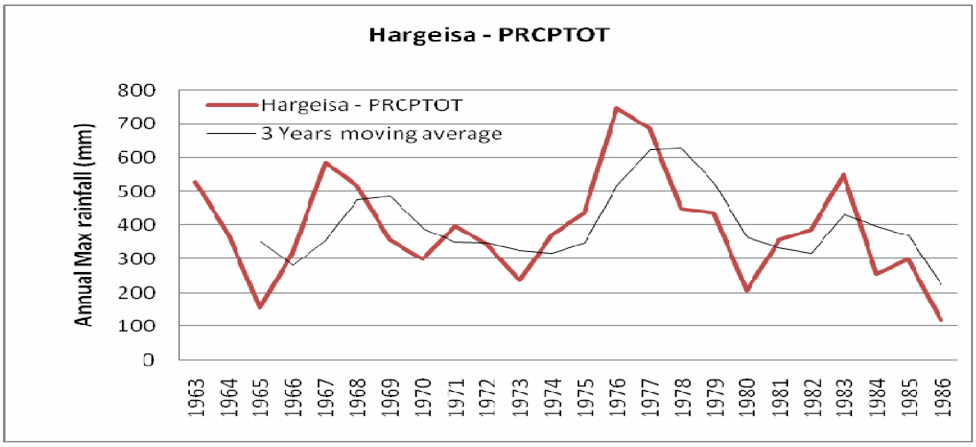


Figure 18: Hargeisa PrcpTOT Index

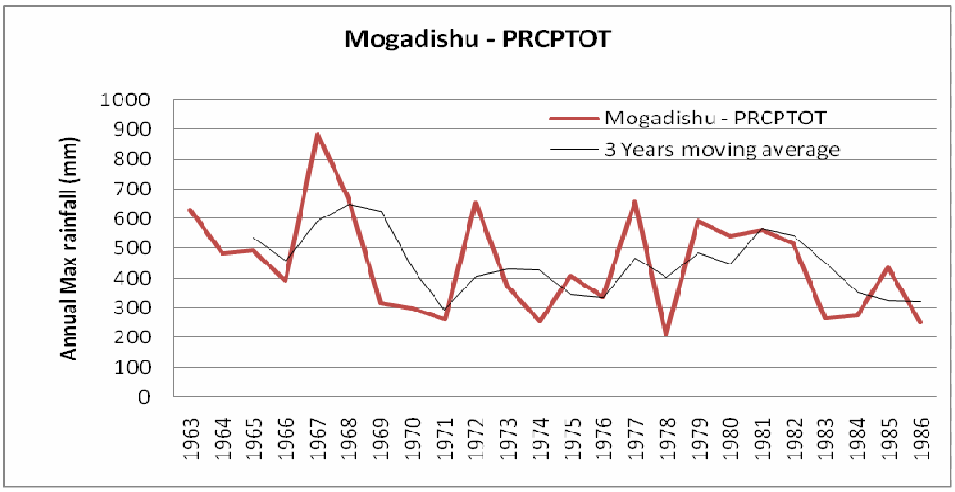


Figure 19: Mogadishu PrcpTOT Index

4.0 The way forward and recommendations

The results of this workshop and the ones to follow would be useful in recommending logical strategies for addressing the impact of climate change in agriculture and food security or any other relevant sector. The way forward is to include all the players in climate change discussions. In this workshop, users and custodians of weather data were present but these alone cannot conclude on climate change and climate vulnerability issues. Professionals like water resources persons, environmentalists etc should be involved.

Recommendations

- There is a general need for capacity building in data management for most of the national meteorological centers. During the workshop a lot of time was used in data arrangement and quality checks. This means the data in the centers is not up to date and need to be cleaned, checked and archived in a good way for any user.
- There are very few weather stations in Somalia and there is need for an extension of the monitoring network for all weather parameters. If climate is to be monitored, this should be a first step.
- The indices should be calculated on seasonal basis
- Data sharing among countries remains a nightmare; this should be encouraged through MOUs as we know that weather has no boundaries.
- Data rescue and digitization efforts should also be encouraged.
- In case where there are big gaps of missing data, remotely sensed data should be used after validation.

5.0 References

Hutchinson, P. and Polishchouk, O(1989). The Agroclimatology of Somalia. Food Early Warning Department. Ministry of Agriculture. Somali Democratic Republic. Technical Report No. 12. F.E.W.S. Project

Loster, T., (1999). Flood Trends and Global Change, Proceedings of the EuroConference on Global Change and Catastrophe Risk Management: Flood Risks in Europe, IIASA Laxenburg, Austria 6–9 June 1999.

Muchiri P.W. (2007). Climate of Somalia. Technical Report No W-01, FAO-SWALIM, Nairobi, Kenya.

Musgrave, H. (2002). Drought and Hydrological Variability in Southern Somalia. A dissertation submitted in partial fulfillment of the requirements for the degree of Master of Science in the University of London. London.

Xuebin Zhang and Feng Yang (2004). RClimDex (1.0) User Manual. Climate Research Branch Environment Canada Downsview, Ontario Canada

Annex I: List of core rainfall Indices

ID	**Indicator name**	**Definitions**	**UNITS**
RX1day	Max 1-day precipitation amount	Monthly maximum 1-day precipitation	Mm
Rx5day	Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation	Mm
SDII	Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as PRCP>=1.0mm) in the year	Mm/day
R10	Number of heavy precipitation days	Annual count of days when PRCP>=10mm	Days
R20	Number of very heavy precipitation days	Annual count of days when PRCP>=20mm	Days
Rnn	Number of days above nn mm	Annual count of days when PRCP>=nn mm, nn is user defined threshold	Days
CDD	Consecutive dry days	Maximum number of consecutive days with RR<1mm	Days
CWD	Consecutive wet days	Maximum number of consecutive days with RR>=1mm	Days
R95p	Very wet days	Annual total PRCP when RR>95th percentile	Mm
R99p	Extremely wet days	Annual total PRCP when RR>99th percentile	mm
PRCPTOT	Annual total wet-day precipitation	Annual total PRCP in wet days (RR>=1mm)	mm

Annex II: Indices definitions

RX1day

Let RR_{ij} be the daily precipitation amount on
day i in period j. Then maximum 1-day values for period j are:

$$Rx1day_j = \max(RR_{ij})$$

Rx5day

Let RR_{kj} be the precipitation amount for the 5-day interval ending k, period j. Then maximum 5-day values for period j are:

$$Rx5day_j = \max(RR_{kj})$$

SDII

Let RR_{wj} be the daily precipitation amount on wet days, $w(RR \geq 1mm)$ in period j. If W represents number of wet days in j, then:

$$SDII_j = \frac{\sum_{w=1}^{W} RR_{wj}}{W}$$

R10

Let RR_{ij} be the daily precipitation amount on day i in period j. Count the number of days where:

$$RR_{ij} \geq 10mm$$

R20

Let RR_{ij} be the daily precipitation amount on day i in period j. Count the number of days where:

$$RR_{ij} \geq 20mm$$

Rnn

Let RR_{ij} be the daily precipitation amount on day i in period j. If nn represents any reasonable daily precipitation value then, count the number of days where:

$$RR_{ij} \geq nnmm$$

CDD*

Let RR_{ij} be the daily precipitation amount on day i in period j. Count the largest number of consecutive days where:

$$RR_{ij} < 1mm$$

CWD*

Let RR_{ij} be the daily precipitation amount on day i in period j. Count the largest number of consecutive days where:

$$RR_{ij} \geq 1mm$$

R95pTOT

Let RR_{wj} be the daily precipitation amount on a wet day $w(RR \geq 1.0mm)$ in period j and let $RR_{wn}95$ be the 95th percentile of precipitation on wet days in the 1961-1990 period. If W represents the number of wet days in the period, then:

$$R95p_j = \sum_{w=1}^{W} RR_{wj} \text{ where } RR_{wj} > RR_{wn}95$$

R99p

Let RR_{wj} be the daily precipitation amount on a wet day $w(RR \geq 1.0mm)$ in period j and let $RR_{wn}99$ be the 99th percentile of precipitation on wet days in the 1961-1990 period. If W represents number of wet days in the period, then:

$$R99p_j = \sum_{w=1}^{W} RR_{wj} \text{ where } RR_{wj} > RR_{wn}99$$

PRCPTOT

Let RR_{ij} be the daily precipitation amount on day i in period j. If I represents the number of days in j, then

$$PRCPTOT_j = \sum_{i=1}^{I} RR_{ij}$$