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Managing for Uncertain Climate Risks: A case study of Sudan

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Abstract
Effective environmental governance is crucial for adaptive capacity, growing climate resilient societies and stable economies in terms of food security, health, peace and harmony. Climate change affects more people in places with arid and semi-arid conditions because it aggravates causes of poverty, food security and an already weak governance response structure. Realization of a multifaceted early warning system maybe one of the solutions required to inform impending food security threats. The main objective of the study is to investigate the existing climate monitoring and response flow channels of climate data at different levels of government and organizations present in Sudan. This is done through literature and documentary reviews and climate data analysis. Results obtained indicate that through time the amount of vegetation is reducing. Over Sudan, the northern part loses vegetation faster than the southern part. This has implication for the agricultural production. The study argues that early warning and climate communication are essential elements for effective governance of climate risks. In the end, the study concludes that there is need for policy makers to understand the impacts of climate science in their programs and likewise the climate scientists to understand the form and content required in policy processes to achieve resilient societies.
Key words: Climatic anomalies, climatic risk, early warning system.

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1. Introduction

Sudan is located in the arid and semi-arid region of the Sahara desert and has a hot climate. Due to its proximity to the desert, Sudan faces some of the largest food insecurities in the world (FAO, 2010). The past 20 years have seen decline in rainfall (Areas, 2011) and a rising number of people in dire need of food aid. In an effort to rebuild the country and secure food supply, climate risk management needs consideration in policy formulation and implementation. Often, there exists a gap between monitoring, processing and transmission of weather and climate information to potential users such as the policy makers and analysts (Tarhule and Lamb, 2003).

Many of the organizations operating in Sudan are involved in short and long-term policies in areas such as food security, water services supply, energy, peace initiatives, environmental conservation, all which require climate and weather information timely (WFP, 2011; FAO, 2010; Practical Action, 2012; FEWS NET, 2013).

This indicates that there is a growing body of climate related policy formulation and implementation in Sudan. At the same time there is no clear evidence of consistent approach or a developed framework that directs and guides these efforts despite numerous studies on Sudan Sahel climate (e.g. Conway, 2011; Areas, 2011; Tarhule et al 2009). Food security in Sudan is highly dependent on rain fed agriculture (FAO, 2010), therefore vulnerable to climate variability, leading to a serious challenges confronting agriculture in terms of how to adapt or respond whenever the rains are erratic

The main objective of this study, therefore, is to investigate the existing climate monitoring and response flow channels of climate data at different levels of government and organizations present in Sudan with a view of creating a climate early warning system (EWS).

EWS entails provision of timely and effective climate information flow that allows individuals or communities exposed to likely hazards to take action that avoids or reduces their risks. Its design prepares the communities for effective and appropriate response to ease suffering (UNEP, 2012; IPCC SREX, 2012). How key decision makers utilize EWS information is one of the most important factors for gauging its success. It is not clear if Sudan does have such information flow in place, although there exist the Famine Early Warning System Network (FEWS NET) in the Greater Horn of Africa that covers countries in the region including Sudan in terms of food security alerts (Boyd et al., 2013).Obviously, to be quite effective EWS should trigger responsive actions way before danger levels are attained in terms of the needs it seeks to alleviate.

Although climate change and variation is likely to worsen the struggle for food security (NAPA, 2007), the pastoralists and marginal agricultural communities, such as the majority of Sudanese people, are most vulnerable to the vagaries of the weather / climate (Boyd et al., 2013; WFP, 2011).

The magnitude, frequency, spatial coverage and time duration of such climate shocks are on the rise, mainly due to climate change, warming of the globe and inevitably the growing trends in the population (IPCC SREX, 2012). For example in Ethiopia, a country neighboring Sudan, climate related extreme food insecurity affected 8 million people in 1999 where urgent relief measures were required to save lives. In Sudan the long droughts that occurred in 1983, 1997, 2000 and 2011 displaced large numbers of people and had devastating effects on the agricultural sector (Tigkas et al., 2013; FAO, 2010).

Sudan is one of the developing countries that have low capacity to adapt or respond quickly to changes that might occur due to variation in climate. As a result, extreme climate variability events such as severe drought and floods sometimes result in massive deaths of herds of livestock, food insecurity, disruption of social lifestyles though migration, and at times human life loss can be quite difficult to cope with (Zakieldeen, 2009). The areas such as Khartoum, Darfur, Blue Nile and Kassala lie on the boundary of great Sahara desert. North Darfur has extremely harsh environment for growing major food crops, raising livestock and generally has poor living conditions. Already there are reports of looming food insecurity, water scarcity, drought persistence and a likelihood of conflict over declining natural resources in parts of Sudan (SFSO, 2014; UNEP, 2013).

2. Scope

Sudan is located on the African continent and lies at latitude 10º – 22º North and longitude 22º – 38º East (Fig.1). It lies within the tropical region of the northern hemisphere. It covers an area of about 1,882,000 km^2 and has a population of 33.4 million persons as at 2011 and growing at the rate of 2.5% annually (AEO, 2012).

This study centers on the states of Darfur, Kassala, Blue Nile, White Nile and Khartoum. Table (1) indicates the coordinates and the population of each state. The River Nile drains the entire country through its two main tributaries the Blue Nile and the White Nile and plays an important role in the Sudan's economic, social, cultural life and its international relations.

Regional Importance

Important social sectors will be impacted by climate change. Thus, there is need for climate resilient programs in Sudan due to these sectors suffering heavily with changing climate. NAPA (2007) maps out such areas as agriculture, water resources and health. These sectors need constant monitoring and evaluation in relation to climatic conditions.

Fig. 1. Map of Sudan, located on the African continent at latitude of 10º – 22º North and longitude of 22º – 38º East.

***Table 1**: Location and population of the selected states of Sudan used for*

Station	Latitude	Longitude	Population
Khartoum	15^0 58N	32^0 52E	1 974 647
Blue Nile	15^0 38N	32^0 31E	832 112
White Nile	13^0 27N	$32^0$20E	1,188,707
Kasala	15^0 30N	36^0 00E	1789809
Darfur	13^0 40N	24^0 00E	3 100 000

***Source;** Sudan Meteorological Agency and the Sudan Central Bureau of Statistics, 2013.*

Agriculture

Due to a projected growing population (AEO, 2012), increasing societal pressure has been exerted on the land resources, arable lands have been subdivided for settlement, and food production reduced. Climate variability compounds this vulnerability in Sudan further aggravating an already bad situation. NAPA (2007) and some studies already undertaken in Sudan (Areas, 2011) indicate that the arable lands will move southwards. Land in the pastoral communities of Sudan is a valuable asset and resource for wealth, identity and social class, and sadly a source of conflict across many families and feuding clans.

This is not unique to Sudan; it spreads in most parts of the eastern and central Africa. FEWS NET, an organization that monitors food security in the region, warns of increased desertification and high

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variability of rainfall, which may result in low agricultural production, requiring massive humanitarian relief agencies assistance to the local communities. Long drought episodes might be inevitable. Most of the insecure populations are concentrated in west Darfur and Kasala, although there is growing concern for urban areas of Sudan (UNEP, 2013).

Water resources

In the water resources sector, more evaporation due to increased temperature is expected to lead to stress on the available water ponds. Less rainfall will affect the ground recharge and hence reduce ground water storage, leading to competition on consumption by the growing population, which could result in conflict (NAPA, 2007; WFP, 2011; Practical Action, 2013). FAO statistics indicate that only 3% of water in Sudan ends up for domestic purposes while the rest directly goes to agricultural irrigation and 40% of the current population does not have access to potable water (FAO, 2010). With the envisaged water stress, irrigated agriculture will suffer. Sudan's 1st Communication under UNFCCC (2003) indicates that soil moisture would drastically reduce likely escalating the water stress. Increasing access to water supply improves health and security. Women and children do not have to struggle in the wild (Katz, 2004) to look for water. Practical Action is involved in tapping water from the ground and/or collecting from the surface of the ground. The changes in the climate will affect the quality of the water altering their sanitation programs.

Health services

Variation of the weather and climatic conditions affect health (Issa and Lamb, 2010) in many ways. Vector borne diseases such as malaria are likely to increase in wet conditions and sanitation related diseases such as cholera increases with insufficient water resources (Musa *et al*., 2012; Issa and Lamb, 2010). The NAPA (2007) indicates that communicable diseases in human and livestock in Sudan may increase significantly by the year 2025. They would bear the pressure to the social health institutions. Although most of the organizations working in Sudan such as Practical Action, UNEP and Department for International Development are substantially involved in providing health services, they need the climate information for both planning and possible preparedness for the future. They could use the data for mapping out areas of possible outbreak of environment and sanitation related diseases.

Environment services

Perhaps the environment bears the greatest shocks due to fluctuations of the climate system. In Sudan deforestation, already depleted due to arid conditions will suffer more because of projected desertification (NAPA, 2007; UNEP, 2007). The government of Sudan through the Range and Pasture General Directorate is working on development of a Pastoral Strategic Plan of Action (PSAP) that will help build resilience in climate-induced crises affecting pastoralists and agro-pastoralists by conserving and sustainable use of land and plant resources. (UNEP 2013) The program is targeted in Kasala (considered a semi-arid grassland) and North Kordofan (low rainfall Savannah land).

Poor environmental management can lead to social conflict, which may further aggravate the precarious peace and security in Sudan. According to UNEP (2007) report on environment impact assessment, Sudan's natural resources are stretched thin; competition for land, overgrazing, and desertification. The report further finds that since independence Sudan has reduced its forest cover by over 40%. While hydropower generation along the River Nile eases power supply, it is a possible source of conflict between the upper and lower communities and even the neighboring countries. Other areas such as industrial pollution, overgrazing and agro-chemicals because of large irrigation schemes are likely to harm the environment.

3. Methodology

The methodology for this study was literature review of current research papers on the subject, rainfall and vegetation climate data analysis. The data used is monthly rainfall figures for a 30 year period, 1961- 2008. Data from Global Precipitation Climatology Centre (GPCC) is also used to study spatial distribution of rainfall through time series analysis. Project reports and other publications were also sought specializing in literature on early climate warning and research, as well as by visiting the sites of networks and organizations specializing in this area. It is an accepted operation technique in applied science research to use documentary reviews (Conway, 2011) as a method of data analysis. Some the papers reviewed used different methods in their research such as questionnaires, surveys, interviews, workshops and data analysis.

4. Results and discussion

Rainfall climatologyof Sudan

Rainfall variability patterns in the Sahel region are complex in nature and rarely there is a year or season in which the whole region receives normal rainfall that is devoid of extreme climate anomalies (Lyon, 2012). The best strategy to minimize negative impacts associated with these climatic extremes in the region is timely availability of weather and climate information, prediction products, coupled with effective communication strategies for disaster preparedness policies.

Sudan experiences largely a uni-modal rain season (Figure 2), although some small areas to a lesser extent receive rains that may classify as bimodal distribution. Over most parts of Sudan the rainfall regime follows the apparent motion of the Inter-Tropical Convergence Zone (ITCZ) (SMA, 2012; Bowden and Semazzi, 2007), with an exception to the parts in extreme north where the Red Sea modifies the rain behavior greatly. . Figure (2) shows a mainly uni-modal distribution of rain. The peak comes late and is low at Port Sudan station, which could be due its location further in the North.

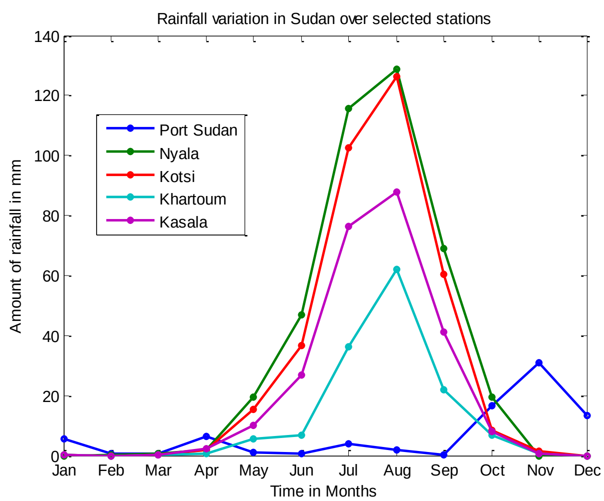

Fig. 2. Observed rainfall record in selected stations in Sudan. The data used to plot this figure was monthly rainfall values for a period of 47 years between 1961 and 2008.

A recent research (Areas, 2011), shows that spatial and temporal distribution of rainfall in Sudan has decreased since the 1970's by about 15 - 20%. Various studies advance different reasons for the observed decrease, Funk *et al*. (2005), for example, argue it could be due to warming sea surface temperatures (SSTs) over the Indian Ocean which is a phenomenon affecting the larger eastern African region. Lyon and DeWitt (2012), hold the same view as Funk *et al*. (2005), but attributes the rain decrease to abrupt changes in the SSTs over tropical Pacific Ocean.

Figure (2) shows the region's rainfall climatology for five stations. It depicts the main monsoon rain season for the sampled stations peaking between June and September, with delayed peaking for the stations in the north during November (Port Sudan). It also indicates there is a dry season in Sudan from January to March due the ITCZ being away from the region. Both the onset and cessation of the rains are abrupt, except to the north. Port Sudan largely influenced by the local systems such as Red Sea troughs, has some rains even in January (Bowden and Semazzi, 2007).

The rainfall trend which measures the uncertainty in the rainfall is observed to decrease from the northern to the southern part of Sudan (Lyon and DeWitt 2012). The decreasing trends and increased variability contribute to extreme dry events. Continuous and successive dry periods of 1978 to 1983 are good examples (NAPA, 2007). If this trend continues then it is clear that measures to mitigate against further reduction are necessary to cushion the traditional farmers and herders (Areas, 2011).

On the contrary, the observed trends of temperature in Sudan show an increasing trend, meaning that the local conditions are becoming even hotter (NAPA, 2007). Accordingly, this is likely to increase the seasons with higher temperatures in future. This will affect maximum and minimum temperatures, with both going up. The Northern Sudan is becoming hotter, drier and slowly advancing to the southern parts (Funk *et al*., 2005), which is likely to affect vegetation distribution including subsistence agricultural practices. High temperatures lead to more of evaporation that eventually wilts crops leading to crop failure, food insecurity and less moisture available in the soils.

Figure (3) shows the variations of the rains within the stations during the same period, indicating high variability in space, with stations like Kosti and Nyala receiving more rains than the others do. Figure (4) shows spatial distribution of the rain with Northern Sudan being relatively dry even during monsoon time while the southern parts receive higher rains.

This variability affects differently the local resident's livelihoods depending on locations. Other climate related phenomena that are infrequent include dust storms, thunderstorms and heat waves. One can expect that climate change is likely to increase the frequency of these events in future (IPCC SREX, 2012). These trends, if clearly picked out by the climate institutions can factor in advising behavior in all sectors during policy formulation and implementation. Although the capacity to issue these weather / climate forecasts exists in Sudan through the Sudan Meteorological Agency (SMA, 2012), it is the ability of utilization of these forecast for decision making in crucial fields such as health and agriculture that has been limited (Boyd et *al.*, 2013; NAPA, 2007).

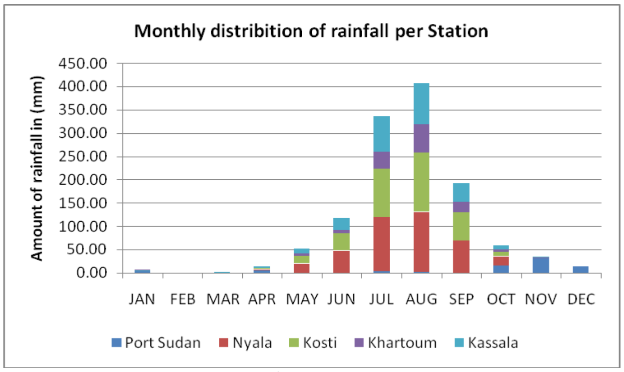

Fig. 3. Observed temporal rainfall variability within Sudan. Data used to plot this was monthly rainfall values for a period of 47 years between 1961 and 2008.

Climate institutions in Sudan

Some writers agree that the ability to predict climate further in time and accurately is important in EWS, for example Tarhule and Lamb (2003). It is therefore the existence of institutions that can provide such information that determine the availability and accuracy of the climate outlooks for the region. A number of institutions dealing with weather / climate information exist in the Sudan that could be useful in providing climate data.

The Sudan Meteorological Authority (SMA), is a government department in Sudan, which is responsible for weather and climate monitoring. It offers seasonal weather forecasting, agricultural meteorological services for farmers, hydrological services for the water and hydrological sectors including energy and power supply (SMA, 2012).

Second, there is the FEWS NET Food Security Technical Secretariat that has expertise on climate and weather science. It publishes food alerts monthly that includes a climate analysis for the period. The website at [http://www.fews.net] has most of the agro-climatic reports from FEWS NET. The scientists from this organization and the regular publications fill in the gaps for climate data. Although they operate regionally through networks with regional and global climate institutions, they offer reliable data for Sudan and other countries in the region.

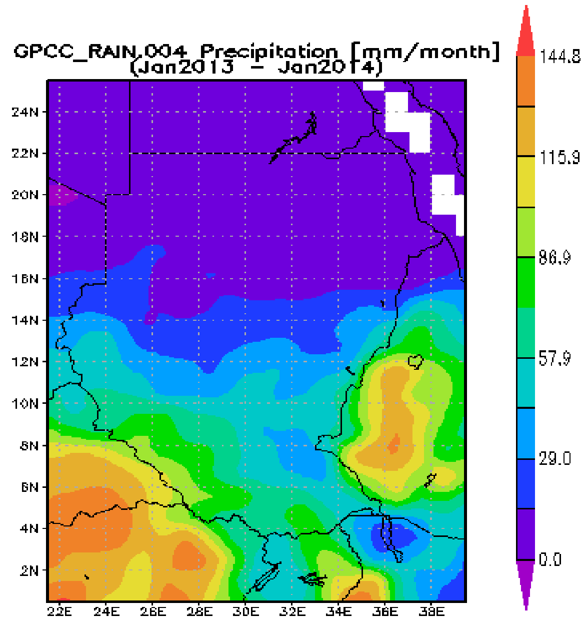

Fig. 4. Observed spatial rainfall variability within Sudan. Data used to plot this figure from GPCC (2014).

Another important source of climate data is from the Higher Council for National Environment. The Council undertakes climate risk analysis and is in charge of climate change and adaption plans. It also deals with matters on the environment including monitoring and evaluation. The ministries of water and Agriculture can provide water and soil data such as river flows, ground water and soil moisture characteristics.

Apart from the institutions inside Sudan, another climate information center that could serve Sudan include the Intergovernmental Authority on Development, Climate Prediction and Application Centre (ICPAC) located in Nairobi, Kenya, that is a regional body for eleven member countries including Sudan. ICPAC states on its website at [http://www.icpac.net/index.html] that it deals in and provides climate information, climate prediction products and early warnings in support for sustainable development in the region.

Again, with the Rainwatch program, monitoring the performance of rainfall being installed in Sudan, the development agencies in Sudan have a large resource through which they could access climate data and information to inform their policies.

Efforts for climate resilient programs in Sudan

So, what is the government of Sudan doing currently about climate resilience? It has established the SMA. Its mission is to provide information for decision makers to plan and take appropriate intervention for food security, poverty eradication and sustainable development. It is in this light that the department prepares Sudan Seasonal Monitor Issues (SAMIS), which are bulletins that give a summary of seasonal weather reviews, current and long-term weather predicted for the next seasons. The seasonal monitor also issues the state of the vegetation using the Normalized Difference Vegetation Index (NDVI). Figure (5) shows some NDI index maps for Sudan over the same dekad in 2011, 2012 and 2013.

Stations in figure (5) are colored according to total volume of the vegetation covering the soil. It turns out that through time the amount of vegetation is reducing. We note the green color gets lighter as we move from 2011(a) to 2013(c). Over Sudan, the northern part loses vegetation faster than the southern part. This has implication for the agricultural production. NDVI is a satellite-derived parameter that responds uniquely to vegetation every ten days. This is important as parts of Sudan are richly pastoral communities and the spread of vegetation defines migration patterns. This information is intended for end users that include other government departments, farmers, and various NGOs (SMA, 2012). However, there seems to be a gap between these bulletins and the intended users as most of the organizations working in Sudan mention no usage of climate information in their planning in their literature and official documents.

It is important to note that the NDVI is a measure of plant greenness, and there are limitations in applying the index to assessing fluctuations in agricultural production. There can be discrepancies between the level of green "flush" monitored by the NDVI and plant growth that can lead to confusing signals. Care is required when interpreting the signals.

United Nations Development Program (UNDP) has worked with the government of Sudan to prepare a NAPA for the country. In the NAPA, it is recognized that the country faces limited water, soil, forests, environment and grassland resources, which increases vulnerability of the people to climate change (NAPA, 2007). This admission is significant as it shows willingness to tackle the problem. Sudan's clear objective in the NAPA is to enhance suitable development practices and procedures that improve its adaptive capacity to future climate scenarios. This is achievable through integrating climate change concerns in national policies. Specifically it is to develop a permanent climate coordination unit, information center, reduce greenhouse gas emissions and upscale the existing programs (NAPA, 2007).

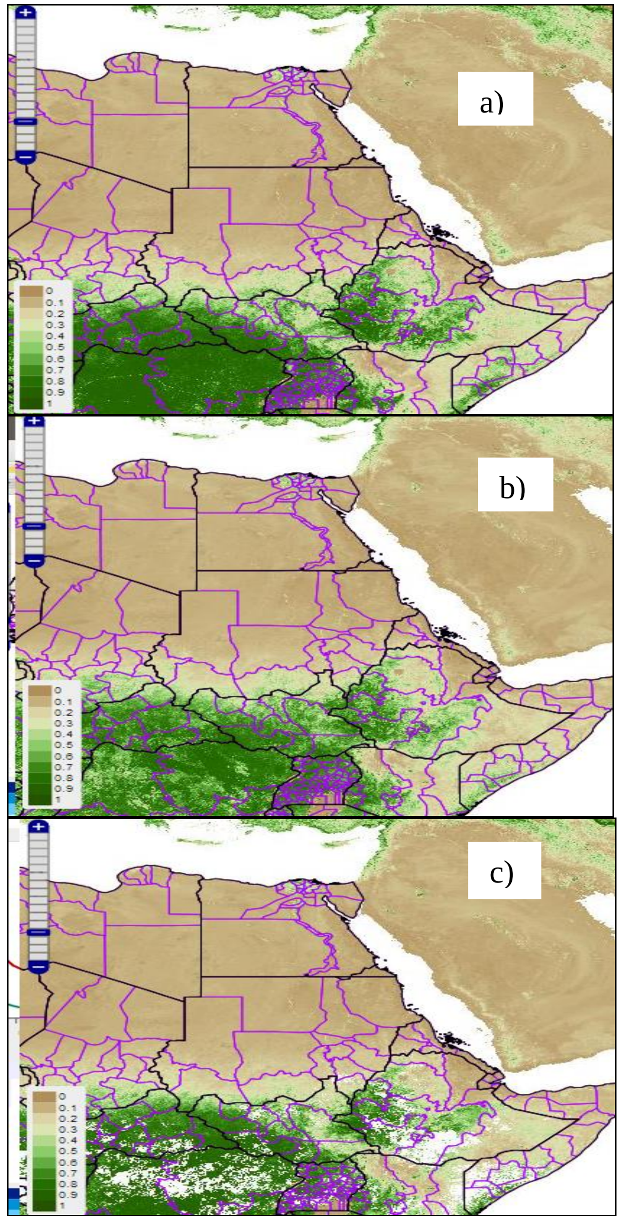

Fig. 5. Images of NDVI index over Sahel region. Figure plotted with data from Geological Survey Earth Resource Centre accessed via FEWS NET website (2013).

Sudan has identified key ministries like agriculture, health and water to oversee the implementation of the NAPA, which is funded by the UNDP with Sudan contributing only 20%. (NAPA, 2007). Sudan has also developed a policy paper 'assessment of impacts and adaptation to climate change (2006)', which seeks to reduce vulnerability by building adaptive capacity. However, though some progress has been made on the NAPA, most of the institutions set are yet to take off and the anticipated collaboration between different agencies is still low.

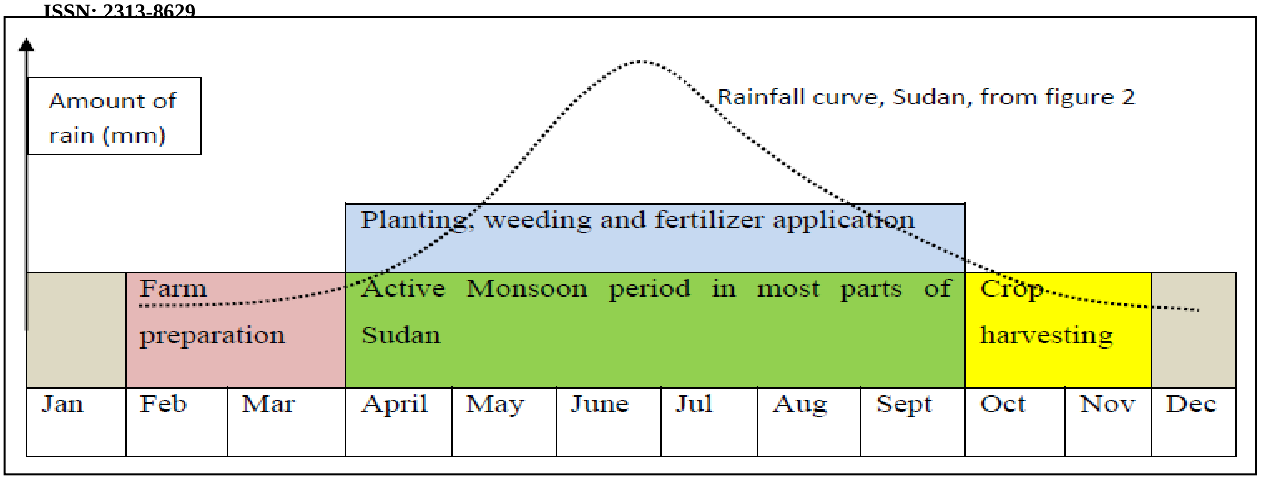

Figure 6: Dependency of rain fed food production of monsoon performance

UNEP is another key institution that is very active in Sudan on early warning and climate resilient issues. It supports the implementation of the NAPA through funding and technical advice through workshops. This is also done through capacity building and technical support on climate change negotiation processes including developing the program of Reducing Emissions from Deforestation and Forest Degradation (REDD). UNEP has also indicated that it will continue to provide required support for eight of the key goals towards achieving the realization of the NAPA (Sudan First Communication, UNFCCC, 2003).

On the international scene, Sudan is a member and participates actively in global initiatives aimed at creating climate resilient societies. Such bodies include United Nations Framework for Convention on Climate Change (UNFCCC), Framework Convention on Biological Diversity (UNCBD), the Kyoto Protocol and Framework to Combat Desertification, (UNCD) (NAPA, 2007). It turns out with the presence of numerous international organizations, a sustained collaborative effort with government departments can result in an efficient EWS.

Monsoons and rain-fed farming

A deductive relationship can be formulated based on the historical performance and seasonal variability of the monsoons (Figure 2, 3 and 4) and food production. Figure (6) shows an example of such a relationship, which can be used. For instance, if the monsoons perform ‘badly’ in the first half of the season then one can reasonably ‘assume’ that the season is ‘likely’ to underperform resulting in reduction in expected harvest. With monitoring the performance of the monsoon curve, by SMA, communities can anticipate the fluctuations in food supply on their local markets and act appropriately at any time in the season. This technique has been successfully tried by Rainwatch in Niger and is explained by Boyd *et al.* (2013). However, the assumption that poor performance on the early part of monsoons automatically leads to an overall poor rain season needs to be tested in Sudan.

5. Conclusions

This study has shown that in order to minimize disastrous climate risks monitoring and evaluation is key with a view to informing EWS. The link between climate institutions, policy decision takers both in government and in NGOs with the local communities strengthens access to climate information. This leads to increased understanding and confidence in applying the knowledge to alleviate climate related risk.

For climate information to be beneficial to these systems, it is extremely important that it is integrated in governance policies to inform priority areas for disaster prevention and mitigation. Building credible climate data inventories, identifying and continuously monitoring both the risk indicators and the vulnerable local residents are a prerequisite for success. Private sector involvement is important to Sudan’s adaptation strategy to climate oscillations. They need to be involved in knowledge sharing and move a step further to the real utilization of the gained knowledge thus reducing information barriers.

Specialized adaptation plan of actions such as Sudan’s NAPA should formulate development approaches in climate impact assessments needs for each region in Sudan focusing on their uniqueness and hence different plans. Increasing the coverage of meteorological stations in Sudan to WMO recommended levels and coverage for the entire country would increase the quality of the climate data acquired.

This study suggests that the SMA develops and continuously reviews climate monitoring structures within different states in Sudan and should incorporate other stakeholders like agricultural officers and local administrators who can advise local communities as the rainfall performance evolves. The monitoring should include other important environmental factors such as soil moisture, water balance cycle, floods, drought indices, vegetation, land cover and use among others.

Future work

The opportunities for further investigation and existing gaps in knowledge have been highlighted at appropriate stages throughout this study. Considering the analysis, future work in terms of this study could look at risk assessments of local communities in different regions of Sudan. Indeed, it is critical for such information to compliment the efficiency of an EWS in order to locate areas that require huge or fast emergence services in case the EWS is activated. The success of Sudan's climate resilient program will generate greater socio-economic impact to the citizens if it is replicated across all the 17 states in Sudan. Possible future work exists to expand the program to other communities and regions within Sudan.

6. References

Africa Economic Outlook (AEO). 2012. Sudan; [http://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Sudan%20Full%20PDF%20Country%20Note.pdf].

Areas, H. I. F., (2011), A Climate Trend Analysis of Sudan, U.S. Geological Survey Fact Sheet 2011–3072.

Bowden, J. H. and Semazzi, F. H. 2007. Empirical analysis of intra-seasonal climate variability over the Greater Horn of Africa, J. Climate, 20(23), 5715–5731.

Boyd, E., Cornforth, R. J., Lamb, P. J., Tarhule, A., Lélé, M. I. and Brouder, A. 2013. Building resilience to face recurring environmental crisis in African Sahel, Nature Climate Change, *3*(7), 631-637.

Central Bureau of Statistics. 2013. Government Bodies and Federal Ministries of Republic of Sudan. [http://www.nationsonline.org/oneworld/sudan-government.htm].

Conway, D. 2011. Adapting climate research for development in Africa Wiley Interdisciplinary Reviews: Climate Change. 2(3), 428-450.

Famine Early Warning System Network, (FEWS NET). 2014. Sudan Food Security Outlooks. [http://www.fews.net/].

Food and Agricultural Organization (FAO). 2010. Plan of action for North Sudan, emergency response and rehabilitation for food and agriculture, August 2010.

Funk C., Seney G., Asfaw A., Verdin J., Rowlnad J., Eilerts G., Korecha D., and Choularton R. 2005. Recent Drought tendencies in Ethiopia and equatorial Subtropical Africa, FEWS NET Special Report .

IGAD Climate Prediction and Application Centre (IPAC) [http://www.icpac.net/index.html]

IPCC, 2012: Summary for Policymakers, In: Managing the risks of extreme events and disasters to advance climate change adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (Eds)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, and New York, NY, USA, p. 1-19.

Issa M., and Lamb, P. J. 2010.Variability of the Intertropical front and rainfall over the West African Sudan-Sahel zone. J. Climate. 23(14), 3984–4004

Katz, C. 2004. Growing up global: economic restructuring and children's everyday live, University of Minnesota Press.

Lyon, B. and DeWitt, D. G. 2012. A recent and abrupt decline in the East African long rains. Geophysical Res. Lett. 39(2). L02702.

Musa, M. I., Shohaimi, S., Hashim, N. R., and Krishnarajah, I. 2012. A climate distribution model of malaria transmission in Sudan. Geospatial Health. 7(1), 27-36.

National Adaptation Plan Action (NAPA). 2007. Republic of Sudan, Ministry of Environment and Physical Development, Higher Council for Environment and Natural Resources, Khartoum, Available at [http://www.preventionweb.net/files/25787_sudan.pdf].

Practical Action, Focus on Sudan, a country of huge potential, [http://practicalaction.org/docs]

Sudan's First Communication under the United Nation's Framework Convention on Climate Change. 2003. Republic of Sudan, Ministry of Environment and Physical Development, Higher council for Environment and Natural Resources.

Sudan Meteorological Agency (SMA). 2012. Sudan Seasonal Monitor, Issue 5.

Sudan Meteorological Agency (SMA) [http://www.ersad.gov.sd/mission.php]

Tarhule, A., and Lamb, P. J. 2003. Climate research and seasonal forecasting for West Africans: Perceptions, dissemination, and use? Bulletin of the American Meteorological Society, 84(12), 1741-1759.

Tarhule, A., Saley-Bana, Z. and Lamb, P. J. 2009, Rainwatch: A prototype GIS for rainfall monitoring in West Africa. Bulletin of the American Meteorological Society, 90(11), 1607-1614.

Tigkas, D., Vangelis, H. and Tsakiris, G. 2013. The RDI as a composite climatic index, European water, 41, 17-22.

United Nation Environment Programme (UNEP). 2012. Early warning systems: A state of the art analysis and future directions, Division of Early Warning and Assessment (DEWA), United Nations Environment Programme (UNEP), Nairobi.

United Nation Environmental Program, (UNEP). 2013 Governance for peace over natural resources, a review of transitions in environmental governance across Africa as a resource for peace building and environmental management in Sudan.

United Nations Environment Programme (UNEP). 2007. Sudan Post-Conflict Environmental Assessment Report.

World Food Program (WFP). 2011. WFP Policy on Disaster Risk Reduction and Management, Building Food Security and Resilience

World Food Program (WFP); Sudan [http://www.wfp.org/countries/sudan]

World Food Program (WFP). 2011. WFP Policy on Disaster Risk Reduction and Management, Building Food Security and Resilience. [http://documents.wfp.org/]

Zakieldeen, S. A. 2009. Adaptation to climate change: a vulnerability assessment for Sudan. International Institute for Environment and Development.

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