Research Application Summary

Enhancing the capacity of Kenya on climate risk reduction and climate change adaptation for sustainable agricultural productivity and food security

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Abstract

Most vulnerable groups in countries in Sub Saharan Africa including Kenya are the poor who have least capacity for coping with the adverse impacts of the current climate extremes, and adapting to future climate changes. Lack of suitable coping and adaptation strategies coupled with limited institutional, economic, and technological capacity to support the required actions increases the vulnerability of the country to adverse climatic impacts. This project aims at exploring ways of enhancing Kenya's capacity through training to adequately respond to the devastating climatic extremes such as droughts, floods and other weather related disasters that have impacted negatively to its socio-economic development and community livelihoods. This was addressed through four supervised projects by postgraduate meteorology and agrometeorology students of the university of Nairobi. Both field work and desk top studies involving analysis of secondary data of various project concerns were carried out. Decision on-farm experiments covering potential adaptation strategies targeting both crop (pigeon pea and sugarcane) and livestock (pasture) production systems were conducted in selected study districts of the country. Preliminary results of the project show great potential for using remote sensing data for rainfall estimation and identification of pasture availability and management by ASAL communities as well as policy makers. With regard to sugarcane-based livelihoods, climate variability as determined by rainfall variability during the grand growth stage of sugarcane was identified as exerting greater influence on sugarcane productivity. The study also showed that the use of basal phosphorus fertilizer in pigeon pea growing area of Makueni district resulted into tremendous crop yield increase.

Key words: Agriculture, climate change, climate risk reduction, food security

Résumé

La plupart des groupes vulnérables dans les pays de l'Afrique au Sud du Sahara dont le Kenya sont des pauvres qui ont moins de capacité de composer avec les effets néfastes des phénomènes climatiques extrêmes actuels, et de s'adapter aux futurs changements climatiques. Manque d'adaptation appropriée et des stratégies d'adaptation associée aux limites institutionnels, économiques, et technologiques pour soutenir les actions nécessaires et accroît la vulnérabilité du pays aux effets néfastes sur le changement climatiques. Ce projet vise à explorer les voies et moyens de renforcer la capacité du Kenya grâce à la formation afin de répondre adéquatement aux extrêmes réactions climatiques dévastatrices telles que les sécheresses, les inondations et autres catastrophes météorologiques liées qui ont eu un impact négatif à son développement socio-économique et les moyens de subsistance de la communauté. Cela a été adressé par le biais de quatre projets supervisés par la météorologie et les étudiants de troisième cycle de l'agro-météorologie de l'Université de Nairobi. Les deux études, du terrain et de bureau, ont porté sur l'analyse des données secondaires concernant différents projet ont été effectués. Les décisions des expériences sur la ferme portant sur les stratégies possibles d'adaptation visant à la fois des cultures (petit pois et canne à sucre) et de l'élevage (pâturages) des systèmes de production ont été menées dans les districts sélectionnés du pays. Les résultats préliminaires de ce projet montrent un grand potentiel pour l'utilisation de données de télédétection pour l'estimation des précipitations et l'identification de la disponibilité des pâturages et la gestion par les communautés ASAL ainsi que les décideurs politiques. En ce qui concerne les moyens de subsistance à base de canne à sucre, la variabilité du climat, tel que déterminé par la variabilité des précipitations au cours de la phase de grande croissance de canne à sucre ont été identifié comme exerçant une grande influence sur la productivité de canne à sucre. L'étude a également montré que l'utilisation d'engrais phosphatés de base dans la zone de culture du petit pois du district de Makueni a entraîné une augmentation considérable du rendement des cultures.

Mots clés: Agriculture, le changement climatique, réduction des risques climatiques, la sécurité alimentaire

Background

Climate extremes are very common in Sub-Saharan Africa which is among those sub-regions of the world facing low agricultural productivity and serious food insecurity. The agriculture and food security sectors in this region continue to be threatened with the adverse impacts of climate change. The recent Intergovernmental Panel on Climate Change (IPCC) report has shown that in general, agricultural production in Sub-

Saharan Africa is expected to be "severely compromised" as the amount of land, the growing season and yield in semi-arid and arid regions will decrease. In some countries, yields from rain-fed agriculture could fall by as much as 50 percent by 2020.

In Kenya, most of agricultural production systems are rain-dependent and hence quite vulnerable to the adverse impacts of climate variability and climate change. Inter annual climate variability that often leads to recurrences of climate extremes such as floods and droughts often have far reaching impacts on agricultural production. Climate change would therefore exacerbate the negative impacts of climate. Adapting to future climate will depend on the ability to cope with the current climate variability including the extremes, based on existing climate risk management systems. Climate change being a dynamic entity that presents new and unexpected challenges calls for new and timely efforts to deal with the changes. There is need therefore to explore beyond the limits of present knowledge in order to propel agricultural science to greater heights.

Adapting to future climate changes will thus require not only the integration of effective climate change-related risk management systems with other risk factors, but also sustainable multi-hazard disaster risk reduction strategies with effective climate risk screening system. This will contribute tremendously to the understanding of the issues affecting the majority of people who rely on natural resources for their livelihoods and hence assist them to adapt to the inevitable climate change.

Success towards realization of this noble goal will depend on the availability, access and use of scientific climate risk management knowledge by decision-makers at all levels, ranging from farmers to extension agents to international negotiators to make judicious choices (McNie, 2007). This calls for initiatives that will link up the knowledge generated with various actions geared towards sustainable socio-economic development. Key on the agenda are research undertakings that strive to provide understanding of methods and tools that can effectively deliver tangible benefits at all levels of the agricultural value chain. The major focus should be on improving the adaptive capacity and coping strategies of the highly vulnerable communities and/or households.

In an attempt to mitigate the adverse impacts of extreme climate events in Kenya, this project was formulated with the overall objective of enhancing the country's capacity through training to adequately respond to the devastating droughts, floods and other weather related disasters that have impacted negatively on its socio-economic development and livelihoods of its citizenry.

Literature Summary

The impacts of climate change are likely to be felt differently in different geographical locations (IPCC, 2007). Mid- to high latitude regions are likely to experience slight increase in crop productivity following increases of local mean temperatures of up to 1-3^{o}C according to crop types, while at low latitudes crop yields are projected to decrease following the slight mean temperature increase of 1-2^{o}C. This calls for location specific tailor-made strategies for adaptation and mitigation of the adverse impacts of climate change.

Develoing countries have been identified as the vulnerable countries to the adverse impacts of climate change probably due to their low coping and adaptive capacities (Thomas and Twyman, 2005). Approximately 300 million people out of the world's poorest 1.3 billion people are found in sub saharan Africa, where about 60% are engaged in livestock production as a means of livelihood (Thornton *et al.*, 2002). Sub Saharan Africa has been classified as the food crisis epicenter of the world where the projected climate change during the first half of the 21st century will make the situation worse (Scholes and Biggs, 2004). climate change will therefore exacerbate the burdens of the already poor and vulnerable.

Despite the risk that the pastoral communities are exposed to in the ASALs, there is emerging consensus that pastoral systems are best suited (as compared to other land use practises) for maintaining the integrity of rangelands (Reid *et al.*, 2005). However, benefits from pastoral systems can only be realized if there is sustainable management of the available natural resource. The growth cycles of natural grasslands, which are the source of forage for livestock in the ASALs, should thus be monitored so as to provide information for sustainable management strategies.Vegetation growth cycles, in terms of phenological events, have been derived from NDVI data in a number of studies (Reed *et al.*, 1994; White *et al.*, 1997; Myneni *et al.* 1998; Zhang *et al.*, 2003; Fisher and Mustard, 2007). In particular, Zhang *et al.* (2003) developed a method of identifying phenological stages by use of simple logistic functions of time fitted to NDVI data in a piecewise manner.

Currently, studies are being carried out in order to use microwave channels to estimate rainfall. Klepp *et al*. (2003) used rainfall estimates derived from the Special Sensor Microwave Imager (SSM/I) on board National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellites to study rainfall processes associated with frontal and cyclonic systems over North Atlantic. Furuzawa and Nakamura (2005) used Tropical Rainfall Measuring Mission precipitation radar (PR) and TRMM Microwave Imager, to investigate the performance of TMI rainfall estimates. The results showed that TMI underestimates rainfall with low cloud height and overestimate rainfall with high cloud height. Combination of microwave imager and precipitation radar improved rainfall estimates.

Tapiador *et al.* (2004) evaluated an operational procedure to produce half-hourly rainfall estimates at a 0.1 spatial resolution which combined rainfall estimated by a Neural Network (NN) approach utilizing passive microwave and infrared satellite measurements. Half hourly rain gauge data over Andalusia, Spain, were used for validation purposes. Results showed fused methodologies improved the performance of estimations.

Study Description

This project aims at exploring ways which could enhance the resilience of the agricultural community in Kenya to cope with current climate risks as well as adapt to future climate changes for sustainable agricultural productivity and food security. The project comprised of four sub-themes distributed across three national livelihood zones in tackling the climate change adaptation /resilience concerns for the agriculture sector in Kenya. The three livelihood zones considered were the pastoral (Garissa district), agropastoral (Makueni and Baringo districts), and high potential (Mumias district) according to the characterisation by the World Food Programme (2008).

The four sub-themes addressed in this project include assessment of the response of Pigeon Pea to Phosphorus fertilizer under the climatic regime of the semi-arid Makueni District of Kenya; Monitoring phenological stages through remote sensing data for pasture management in ASAL areas of Kenya; Investigation of the impact of climate variability on sugarcane production in the Mumias Sugar growing zone of Western Kenya; and, Validation of satellite derived rainfall estimates over Kenya using rain gauge data for improved agriculture.

For each selected ASAL area, annual NDVI values were subdivided according to wet and dry seasons, i.e., January – February (dry), March – May (wet), June – September (dry) and October – December (wet). Logistic functions were then piecewise fitted to the subdivided NDVI data by determining different function parameters for each of the subdivision, using the Levenberg-Marquardt algorithm. The determined parameter values were then applied to the half-maximum (or half-minimum) method in order to identify transition NDVI values so as to discriminate the phenological stages in terms of onset of greenness and senescence. NDVI data from the identified phenological stages were then correlated with concurrent and lagged rainfall data so as to find out the relationship between phenological stages and rainfall. Additionally, this relationship was investigated by assessing the temporal patterns of the curves of correlated rainfall and NDVI from different phenological stages. Finally, the lengths of growth stages were computed from the difference between the time when the stages started and when they ended, after which the spatial patterns of the lengths of growth stages were assessed.

Monthly rain gauge records were gridded using Kriging method to a grid scale of 0.25 º by 0.25 º to match with the TRMM satellite's rainfall estimates. The two gridded data sets were then compared by plotting scatter diagrams for a dry season (January to February), a wet season (March to May) and for the whole period of study. Simple correlation analysis was carried out to determine the relationship between the two variables. Principal component analysis was performed in both spatial and temporal modes to investigate the underlying physical processes which gave rise to the two data sets. The first principal components were presented on spatial maps for both Kriged rainfall and satellite rainfall estimates respectively. A pair of maps with similar patterns, one for each variable, was obtained for the wet season, dry season and for the whole period of study. Time series of the first and the second principal components of the Kriged rainfall and TRMM satellite's rainfall estimates were also plotted.

The accuracy of TRMM satellite rainfall estimates was also determined using the mean absolute percentage errors (MAPE), Mean errors (Bias), Mean absolute errors (MAE) and Root mean squared errors (RMSE). Canonical correlation analysis was performed to determine a linear combination of each of the two sets of variables such that the correlation between two functions was maximized. CCA which is equivalent to multiple regressions was also used to develop models for estimation of areal rainfall using satellite derived rainfall estimates.

Research Application

Interannual phenological stages appeared to follow a clear growth–senescence temporal cyclic pattern. Two growth periods were identified in all the districts, consistent with known cycles of different grass and browse species in the areas. Peak growth was seen to occur during the short rains in Kajiado district while during the long rains in Baringo district. Growth in the two seasons was almost the same in Garissa district. Phenological stages were significantly correlated to different lags of rainfall, with response to a longer lag observed during the March to June growth period. Patterns of lagged rainfall were also found to be similar to those of NDVI at the different stages. The length of both growth periods showed spatially coherent patterns that signified the distribution of different pasture species. Consequently, the logistic functions developed were able to model grassland phenological stages in the study ASALs.

Spatial maps of the loadings of the first Principal Component, drawn in order to compare the two variables had similar patterns. PCA was also done in temporal mode and time series of the first Principal components of the two data sets were plotted and the resulting graphs had similar trend. On the other hand, results from scatter plots showed that the two variables were compactly arranged with few outliers. Results from simple and canonical correlations showed large correlation coefficients. The results obtained from error analysis indicated that the temporal mode method generated larger errors than the spatial mode method, while wet regions had larger errors than dry regions. Also dry season had smaller errors than the wet season.

Finally spatial and temporal Canonical Correlation (CCA) models were developed using the significant Principal components (PCA) to estimate rainfall in areas with sparse rain gauge network over Kenya. The study found that no one mode was similar to the other. July was found to have largest CCA loadings while January had the least.

Recommendation

The information generated from this study can be used by policy makers in coming up with strategies for aiding pastoral communities to delineate and preserve pasture. This is especially because setting aside pasture for dry periods is already recognized as an important coping method for these communities (IIRR, 2005). The pastoral communities themselves can also take up the information on spatial distribution of the length of growth periods to better manage pasture in the ASALs. Another desirable quality of this information would be in the formulation of a spatial plan for alleviating land degradation by allowing known areas to rest and regenerate. The results, when used together with climate information, can be easily incorporated into guidelines for pasture management.

Satellite derived rainfall estimates may be used for planning and decision making in areas with inadequate rain gauge observations that could be associated with sparse network of rainfall stations and in case of missing data records.

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