

Implications of climate change on grain yield of sorghum and millet over selected areas in Uganda

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Abstract

Climate change undoubtedly raises serious productivity and livelihood challenges in Uganda's socio-ecological systems, which are dominated by smallholder farmers practising rainfed agriculture. While sorghum and millet are some of the key food security crops in Uganda's socioecological systems, they have received suboptimal attention with respect to how they will be affected by climate change. In this study, we investigated patterns of climate change and its effect on yields of sorghum and millet in Soroti and Gulu areas of Uganda on a medium timescale of up to 2040. Downscaling and projections of future climatic conditions up to 2040 was undertaken using the PRECIS Model focussing on rainfall and temperature. Projected daily temperature and rainfall conditions were incorporated into AquaCrop and Penman Grindley Soil moisture balance model to simulate sorghum and millet yields for Soroti and Gulu, respectively. Results shows projected rainfall increase in Soroti, while for Gulu, a slight decrease is anticipated by 2040. In Soroti, sorghum yields are expected to respond positively to rainfall with yields increasing by up to 35% by 2040. The highest increments are second season (SON) in comparison to the first season (MAM) crops. Millet will experience dismal changes in yields 2.6%, which are projected to be negative, but tending towards red as the short rains (SON) increased. Surprisingly, there was a decline in the annual minimum and maximum temperature of 0.3 °C and 1.0 °C, respectively. More attention needs to be paid to stabilizing millet production including optimization of water use.

Keywords: Climate change, crop yields, Gulu, sorghum, Soroti, Uganda

Résumé

Le changement climatique pose indubitablement de sérieux défis de productivité et de subsistance dans les systèmes socio-écologiques de l'Ouganda, dominés par les petits exploitants agricoles pratiquant l'agriculture pluviale. Bien que le sorgho et le millet soient des cultures clés pour la sécurité alimentaire dans les systèmes socio-écologiques de l'Ouganda, ils ont reçu une attention sous-optimale quant à la manière dont ils seront affectés par le changement climatique. Dans cette étude, nous avons étudié les modèles de changement climatique et son effet sur les rendements du sorgho et du millet dans les régions de Soroti et de Gulu en Ouganda sur une échelle de temps moyenne allant jusqu'en 2040. La réduction d'échelle et les projections des conditions climatiques futures jusqu'en 2040 ont été réalisées en utilisant le modèle PRECIS en se concentrant sur les précipitations et la température. Les conditions de température et de précipitations projetées quotidiennement ont été intégrées dans le modèle de bilan hydrique du sol AquaCrop et Penman Grindley pour simuler les rendements du sorgho et du millet pour Soroti et Gulu, respectivement. Les résultats montrent une augmentation des précipitations projetées à Soroti, tandis qu'à Gulu, unelégère diminution est anticipée d'ici 2040. À Soroti, les rendements de sorgho devraient répondre positivement aux précipitations avec des rendements augmentant jusqu'à 35 % d'ici 2040. Les augmentations les plus importantes

sont observées pendant la deuxième saison (SON) par rapport aux cultures de la première saison (MAM). Le millet connaîtra des changements minimes dans les rendements de 2,6 %, qui devraient être négatifs, mais tendant vers le rouge avec l'augmentation des petites pluies (SON). De manière surprenante, il y a eu une baisse de la température annuelle minimale et maximale de 0,3 °C et 1,0 °C, respectivement. Il est nécessaire de prêter plus d'attention à la stabilisation de la production de millet, y compris l'optimisation de l'utilisation de l'eau.

Mots-clés : Changement climatique, rendements des cultures, Gulu, sorgho, Soroti, Ouganda

Introduction

The impact of climate change on yields of key food security crops remains a fundamental societal challenge in the food systems, particularly of Sub Saharan Africa (SSA), where crop production is highly dependent on intra-seasonal and inter-annual variation in rainfall (Schulze *et al.*, 1993). There is seeming unanimity from extensive studies that yields of crop grown under rainfed conditions are more adversely impacted by climate change severely affecting the poor farmers due to limited adaptive capacities and inefficient systems manifested by limited education, limited technology, limited supporting institutions and limited access to financial assets (Hepworth and Gouden, 2007; Kilembe, *et al.*, 2012; Sultan *et al.*, 2013). While, understanding site specific changes in climate facilitates quantification of expected impacts on key food security crop yields (Sultan *et al.*, 2013), substantial gaps on this requisite knowledge still exists on local specific expected changes and the expected effects on crop yields. In some cases, divergence in estimations by coarse models warrants detailed studies to elicit site specific variations and expected changes. Millet and Sorghum are key staple and food security crops in Uganda's food systems and are grown on a relatively larger scale in Eastern and Northern Uganda. Under stressing climatic situations including drought conditions in the past, sorghum and millet have withstood climate variability better than other crops. Nevertheless, the direction and magnitude of climate change poses different conditions and dimensions even with tolerant crops. Cognizant of the paucity of knowledge especially at spatially explicit level, we evaluated the impact of climate change on the yields of sorghum and millet in two areas at a finer scale.

Materials and Methods

The study focusses on two areas, namely, Soroti and Gulu which are located in Eastern and Northern Uganda, respectively. Gulu largely experiences a unimodal rainfall distribution structure, while Soroti is bimodal. Climate change projections were undertaken using the Providing Regional Climates for Impact Studies, PRECIS (Wilson *et al.*, 2010) downscaling at a scale of 25km² to generate daily rainfall and temperature under changed climate. Historical observed monthly rainfall for Soroti district, for the years 1990 to 1998, and PRECIS model generated monthly rainfall for Soroti district for the same period were used to determine the fitness of the PRECIS model for rainfall prediction in the area, using simple Linear Regression, Correlation analysis, and the Average Absolute Error. The mean deviation of observed values from generated values was determined by the value of the Average Absolute Error. Simulations of climate change impacts on millet yields were undertaken using the AquaCrop model as well as the Penman Grindley Soil moisture balance model. The major parameter variations in the simulations to test millet yield were temperature and rainfall across the temporal scale of interest under changed conditions. Related data were collected for Gulu in Northern Uganda.

Results

RECIS model results project a general increase in annual rainfall for Soroti district albeit with noticeable variations between and within years. The long term trend showed that the years 2019 and 2040 will have the highest positive change in rainfall total of about 15%. The predicted and projected period is expected to have a positive increase in rainfall total of up to 5%. Tailored to the seasons, a reduction is projected for first and most important season (MAM), also considered the long rains. For the second season (SON), the projections show an increase in rainfall totals. Temperature are projected to decline in Soroti. The expected average changes in annual average minimum and maximum temperatures by the year 2040 are 0.3⁰C and 1.0⁰C, respectively. This projected change is contrary to notion of general increase in temperature over the Uganda surface, which most studies report. With respect to Gulu, PRECIS downscaled and projected results do not show any significant changes in the rainfall conditions on the medium timescale (Figure 1). The projections show a slight decrease in rainfall and increment in temperature by 2033.

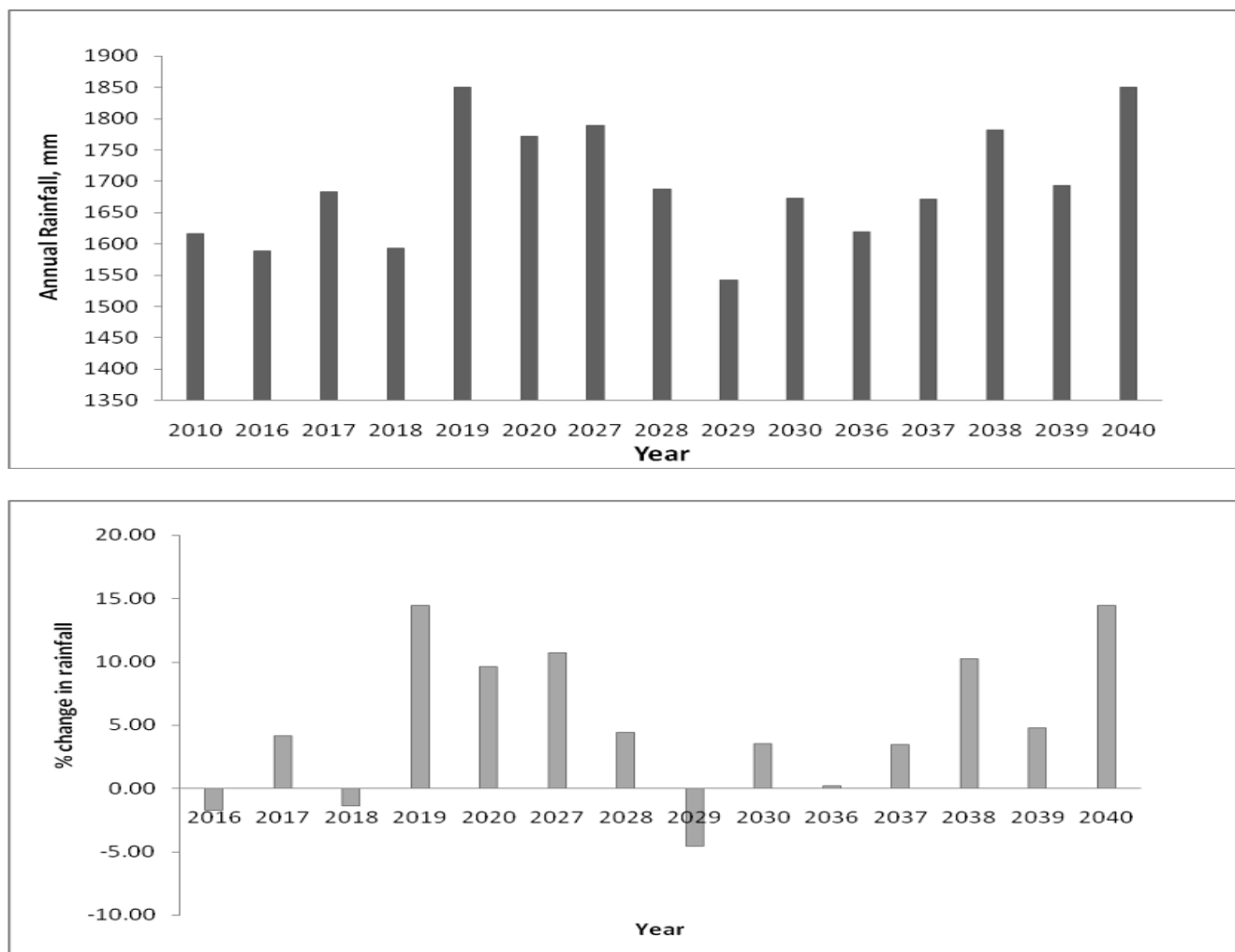


Figure 1. Projected annual total and percentage change in rainfall for Soroti in Eastern Uganda

The expected changes in sorghum yields due to climate change are given in Table 1. Sorghum grain yields (*Serena*/*Edeidei* varieties) in Soroti are expected to increase to 4.6/3.28 ton/ha and 4.11/2.79 ton/ha for during August-December and May-Aug seasons respectively by 2040. A comparison of current observed yields and the projected reveals that sorghum grain yield will increase by up to 35% by 2040. These results are however unexpected in light of several assessments that have shown potential negative effects of climate change on crop yield estimates.

Table 1. Average sorghum yields (ton/ha) and change under changing climate in Soroti

Year	Season Aug-Dec				Season May-Aug			
	<i>Serena</i>	% change	<i>Edeidei</i>	% change	<i>Serena</i>	% change	<i>Edeidei</i>	% change
2016	4.1	17.8	2.7	2.1	3.8	16.1	2.6	28.6
2017	4.5	31.1	3.2	22.3	4.2	28.2	2.8	37.2
2018	4.5	31.9	3.2	23.4	4.2	27.6	2.8	39.3
2019	4.7	35.2	3.3	27.9	2.7	-17.8	2.0	-2.2
2020	4.6	35.0	3.3	27.7	4.2	25.7	2.8	37.6
2027	4.7	37.4	3.4	29.2	4.3	31.1	2.9	42.5
2028	4.8	38.7	3.4	30.5	4.1	24.7	2.8	36.5
2029	4.7	37.4	3.4	28.5	3.8	15.9	2.8	39.0
2030	4.8	39.5	3.4	31.4	4.4	32.9	2.9	44.2
2036	4.4	28.0	2.9	10.1	4.3	29.7	2.9	41.2
2037	4.9	41.7	3.5	33.0	4.5	35.2	3.0	46.4
2038	4.7	37.8	3.4	30.0	4.2	27.5	2.8	38.9
2039	4.9	42.6	3.5	33.8	4.2	27.6	2.9	39.4
2040	4.9	41.0	3.4	30.9	4.5	35.6	3.0	45.7

The expected changes in millet yields owing to changes in climatic conditions in Gulu are given in Figure 2. Findings reveal slight changes in millet yields by 2013-2033 with the exception of 2027 where drastic increase is expected as a result of net gain of soil moisture. The changes in yields range from 1812 to 2189 kg/ha/yr. Overall, a slight decrease in millet yields of 2.6% may be experienced by 2033. This finding therefore rejects the hypothesis that under future climate change stressors, millet yields will reduce by 20% by 2033.

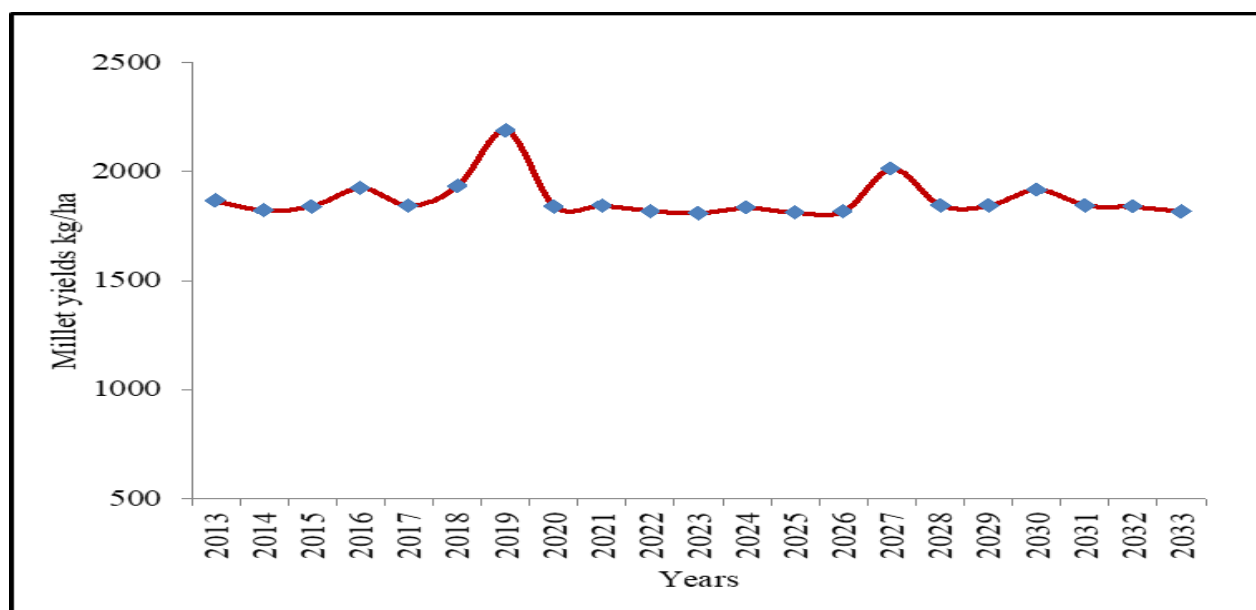


Figure 2. Simulated millet yields for Gulu in Northern Uganda by 2033

Conclusions

Contrasting future climatic conditions are projected for Soroti and Gulu regions of Uganda with increments and slight decrease in rainfall expected, respectively, albeit with the expected annual variations. These conditions will culminate into increased yields in Sorghum in Soroti region, but no substantial changes are forecast for millet in Gulu on a medium timescale. The projected conditions, particularly rainfall in Soroti show a strong seasonal gradient which also reflects in the simulated yields.

Acknowledgement

This research was funded by RUFORUM. Its publication is enabled by the Food and Agriculture Organisation of the United Nations (FAO) as part of the South-South and Triangular Cooperation on Climate Change Adaptation and Agri-Food Systems Transformation in Africa. This paper is a contribution to the 19th RUFORUM Annual General Meeting and Conference held 28th October - 2nd November 2023 in Yaoundé, Cameroon.

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