CLIMATE CHANGE AND AFRICAN AGRICULTURE
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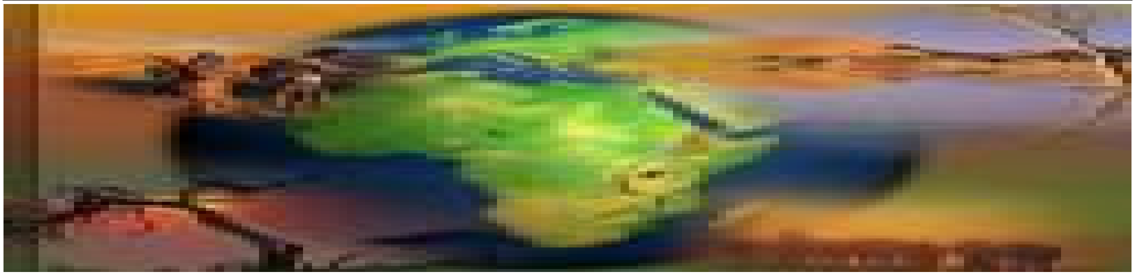


Climate change and crop water use and productivity in Niger[1]

With the predicted decline in agricultural yields as a result of global warming, the pressure on agriculture is expected to increase. This is of particular concern in the developing world and especially in Africa, which has worse starting conditions and limited adaptation options. Reduced yields will increase the demand for converting land to agricultural use, extracting water for irrigation, introducing more new and exotic plant and animal species and intensifying the use of chemical inputs. This pressure will increase environmental damage such as pollution, erosion, and seriously accelerate biodiversity loss.

Further warming is expected to affect crop productivity adversely, and this will have serious consequences because agriculture is especially prominent in the economies of African countries and particularly of Niger, and the farming systems tend to be less capital and technology intensive.

This study used the CROPWAT model to predict the soil moisture deficit (SMD) with climate change scenarios and assess the crop water requirements (CWR) and variations in yield of the main rainfed crops in Niger. Two districts, Aguié and Gaya, were selected to conduct the SMD analysis in relation to climate change under various climate and soil characteristics and cropping patterns.

Case study areas and crops studied

Niger is a landlocked country in the Sahel more than 700km from the sea, with a surface area of 1,267,000km^2 and a population of about 10 million. The climate is typically Sahelian, with two seasons: a long dry season of eight months and a short rainy season of four months which usually starts in May or June. The rainfall is low, variable and undependable. The cropping area is limited to the region that has a length of growing period (LGP) of 75 to 150 days, which is classified as semi-arid.

The semi-arid part of Niger is a region that faces very serious challenges for developing crop production. Cultivating crops and keeping livestock are the most important activities in the rural areas,

[1] This Policy Note is prepared by R Hassan based on Moussa & Amadou (2006), Using the CROPWAT model to analyse the effects of climate change on rainfed crops in Niger, *CEEPA Discussion Paper No. 32, CEEPA, University of Pretoria.*

practiced by 90% of the total population. But harsh environmental conditions – high temperature, low rainfall and low soil fertility – restrict the range of crops grown. In general, technology based agriculture has not come to Niger on a significant scale. Most of the agricultural growth that has occurred has been through extensive farming, but there has been little improvement in yields. Low rainfall as a result of climate change, land depletion, the very low level of external input and low investment in irrigated agriculture constitute the major constraints on crop production in this region of Niger.

The model and data

The program used for simulating crop yield response to water (CROPWAT) is a decision support system developed by the Land and Water Development Division of the FAO. Its main functions are to calculate reference evapo-transpiration, crop water requirements and crop irrigation requirements in order to develop irrigation schedules under various management conditions and scheme water supply and to evaluate rainfed production, drought effects and efficiency of irrigation practices. It uses procedures for predicting yields when all the climate, soil and crop parameters are known. This approach allows estimation of actual evapotranspiration (ETa or actual crop water use), after having estimated the stress factor Ks from the ratio of actual to potential yield.

Table 1: Characteristics of selected districts, Aguié and Gaya

	Aguié	Gaya
Geographical area	Sahelian zone	Sudan savanna zone
Type of system	Short season SAT, rainfed mixed agro-pastoral	Intermediate season SAT, rainfed mixed cropping
Length of season	60–100 days	100–125 days
Soil (Hcr %)	Sandy (9)	Loamy (22)
Rainfall (mm)	< 600	600–800
Based system	Semi-intensive millet-based system	Sorghum/Millet-based system
Main crops	Millet, sorghum, cowpea, groundnut	Sorghum, millet, cowpea, groundnut
Intensity of crop	Low–medium	Low
Cash crops	Reasonable	Limited/Reasonable
Role of trees	Fertility management	Fruit, firewood
Role of livestock	Manure, transport, animal traction	Corralling, transport
Major constraints	Rainfall, high temperature, soil fertility	Soil fertility
	Livestock shortage in farming systems, priority for crop production with no specific pasture area	Reduction of fallow, pest and disease management
Sub Systems	Millet-cowpea-sorghum-groundnut low input	Sorghum-millet-cowpea-groundnut

The input data for the model are monthly climatic parameters including maximum and minimum temperature, humidity, sunshine and wind speed. CROPWAT calculates reference evaporation ETo and maximum crop evapotranspiration ETm from crop coefficient Kc. The water stress coefficient Ks further diminishes ETm to actual evapotranspiration ETa owing to lack of water. Ks is determined via a comparison between actual yields Ya and maximum yields Ym, using a yield response factor Ky.

Three types of data were collected and used for the selected districts. Meteorological data were acquired from the national meteorological service. These included temperatures for 1961 to 1990, rainfall for the same period and evapotranspiration for the period 1978 to 1998 for Gaya and 1978 to 2002 for Aguié. Soil data were supplied by INRAN (the Agronomic Research Institute). Crop yields, LGPs, and dates of sowing and harvesting for the selected crops (millet, sorghum and cowpea) were provided by the National Service for Agricultural Statistics.

Districts with meteorological stations since 1960 (Birni N'Konni, Gaya, Mainé Soroa, Aguié, Tahoua, Tillabery and Mirriah) were selected to conduct the CWR study. Except for the Gaya district, all the districts have LGPs, T° (temperature), rainfall, ETo (evapotranspiration) and soil characteristics similar to those of Aguié.

The same dates of sowing and harvesting were used for each crop for all the districts. The growth cycle for each crop is longer in the Gaya district. The total cropped areas for each crop, and maximum/actual crop yields (millet, sorghum and cowpea) for each district were provided by the National Service for Agricultural Statistics. The Ky (yield reduction) factor from the FAO (Food and Agriculture Organization) was used for each. Among the CROPWAT model outputs, the CWR, ETc (crop evapotranspiration), and Ks (stress factor) were used for crop yield analysis.

Simulating crop water yield response

Millet is the most common rainfed subsistence crop in Niger. Millet farming suits almost all the studied districts. The highest value of ETo was observed in the Tahoua district, with 741mm (Table 1). This district is in fact located in the central northern part of the country at the limit of the Sahara Desert and characterized by a high diurnal temperature during the rainy season. Mainé Soroa, located in the eastern part of the country, shows the highest Etc owing to the high evaporation demand linked to a high temperature. There is some variation in CWR between districts, given that millet is a crop which does not need a lot of water and the most commonly cultivated variety has a short cycle in all the districts except Gaya, where varieties with a long cycle are used. The maximum yields were obtained in Gaya (815kg/ha), where the annual average rainfall is 800mm, and Aguié (757 kg/ha), where cropping systems are more intensive, with higher inputs. Tahoua and Mainé Soroa have the highest rates of ETo for the cowpea growing period (816 and 747mm respectively). The cowpea's CWR is almost the same for all the districts, except for Tahoua. The response coefficients due to water stress are low everywhere except in Tahoua and Mirriah. This is explained by a poor rainfall distribution that caused a critical drying up of the soil's usable moisture. Thus the yield reduction can be considered significant.

Table 2: CROPWAT outputs for millet, cowpeas and sorghum in study districts

District	ETo mm	Kc	ETc mm	Ky	Ya kg/ha	Ym kg/ha	Area cropping intensity, %	Ks	Eta mm	CWR mm
Millet										
B. Konni	581	1.00	380	1.20	502	543	45	0.94	356	196
Gaya	451	1.00	305	1.20	746	851	50	0.90	275	153
Mainé S.	682	1.00	440	1.20	372	524	71	0.76	334	232
Aguié	536	1.00	363	1.20	483	757	51	0.70	254	181
Tahoua	741	1.00	416	1.20	298	312	53	0.96	399	251
Tillabery	636	1.00	432	1.20	412	428	60	0.97	419	216
Mirriah	597	1.00	405	1.20	408	461	55	0.90	365	203
Cowpeas										
B. Konni	633	1.15	502	1.15	142	314	36	0.52	261	251
Gaya	497	1.15	396	1.15	171	317	30	0.60	240	198
Mainé S.	747	1.15	452	1.15	51	87	13	0.64	289	298
Aguié	581	1.15	461	1.15	134	304	23	0.51	237	231
Tahoua	816	1.15	427	1.15	122	189	32	0.69	294	325
Tillabery	697	1.15	496	1.15	207	216	28	0.96	476	278
Mirriah	650	1.15	494	1.15	189	216	29	0.89	440	258
Sorghum										
B. Konni	650	1.00	450	1,25	351	385	18	0.93	418	154
Gaya	519	1.00	362	1,25	676	800	15	0.88	317	46
Mainé S.	771	1.00	473	1,25	111	160	10	0.76	357	280
Aguié	592	1.00	408	1,25	190	309	10	0.69	282	121
Tahoua	832	1.00	486	1,25	275	276	11	1.00	486	321
Tillabery	697	1.00	492	1,25	363	409	10	0.91	448	114
Mirriah	666	1.00	456	1,25	198	248	12	0.84	383	195

Notes: ETo (reference crop evapotranspiration), ETc (evapotranspiration of the crop), Ky (yield reduction factor), Ya (actual yield of the crop), Ym (maximum yield of the crop), Ks (stress factor), CWR (crop water requirement), ETa (actual evapotranspiration).

Sorghum being a water demanding crop, only the area of Gaya that has favorable meteorological and edaphic conditions presents a optimal yield. Here, the need for crop water is almost entirely satisfied (the CWR is 46mm for the whole cycle). In fact, the rainy season covers the sorghum cycle. The areas of Tillabery, Konni and to some extent Aguié have favorable valleys and alluvial plains where sorghum is farmed, but the high evaporation demand (ETo above 500mm) increases the crop's evapotranspiration and therefore its demand for water. The additional water CWRs of the sorghum for the areas mentioned above are 114mm, 154mm, 121mm respectively. This water deficit thus can be seen to affect the yield: only 363kg/ha in Tillabery, 351kg/ha in B. Konni and 190kg/ha in Aigué. The very low yield in Aguié is explained by the type of soil, which is also subject to over-cropping.

Impacts of predicted climate change trends

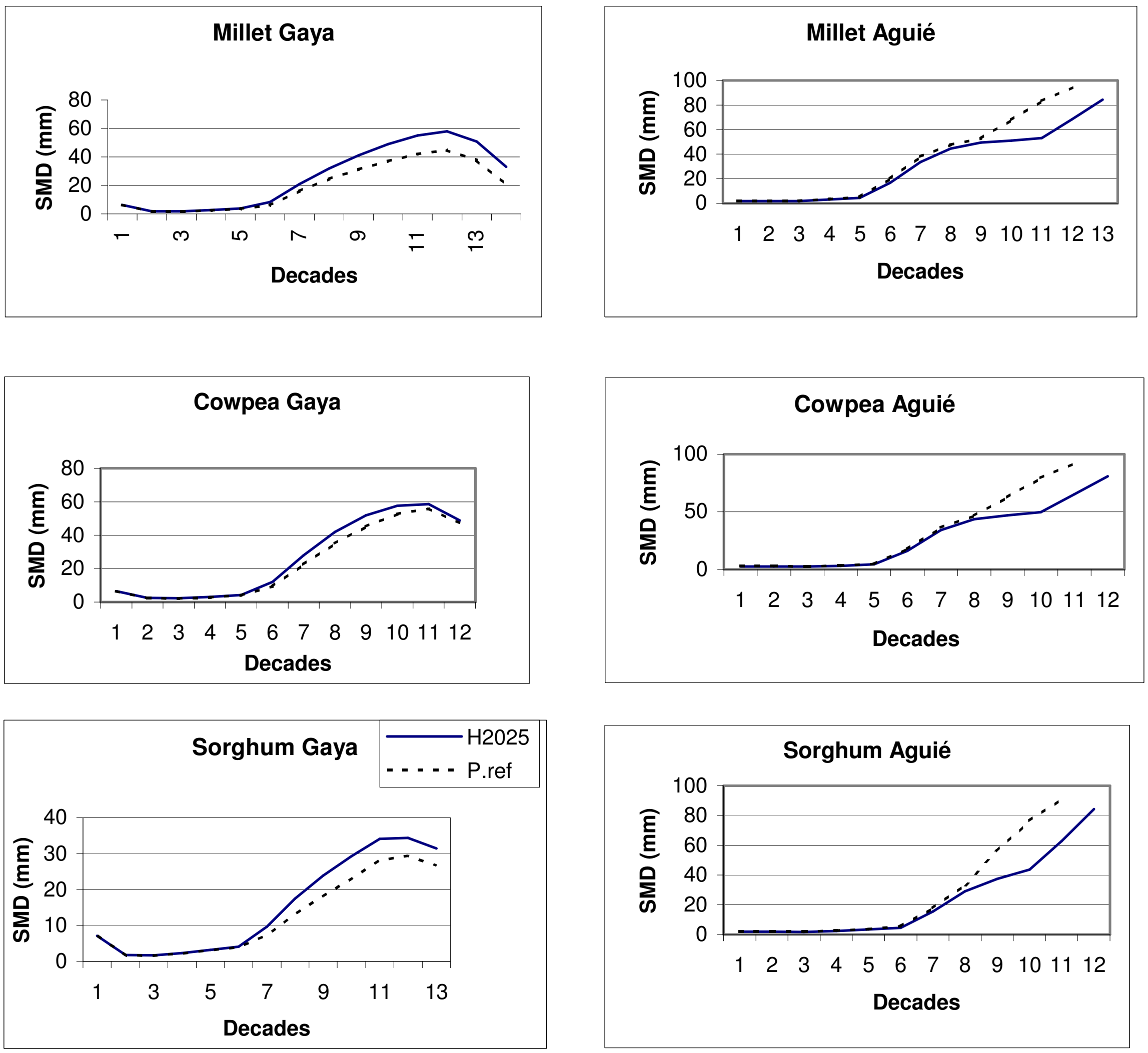
Two districts, Aguié and Gaya, were selected to assess the degree of SMD caused by climate change. Climate and soil characteristics, including other farming and cropping patterns, are summarized in Table 2. The three main crops grown in the selected districts (cowpea, sorghum and millet) were tested. The MAGICC (Model for the Assessment of Greenhouse-gas Induced Climate Change) coupled to the SCENGEN (SCEnario GENerator) software set up by the IPCC (Intergovernmental Panel on Climate Change) during the second appraisal report (Houghton et al. 2001) was used in this study to predict the impact of climate change on the soil water availability and water uptake by crops. The HadCM2 (Hadley center unified model 2 transient, UK) GCM was selected and the actual annual average temperature and rainfall figures for 1961 to 1990 were used as the basic scenario and IS92A (reference scenario) to generate temperature and rainfall figures for 2025. The choice of 2025 was justified by the availability of demographic projections for Niger at this period. The country's oldest meteorological stations in the MAGICC/SCENGEN square degrees were identified and selected in order to use the serial climate data available since 1960.

At this step of its development, the MAGICC/SCENGEN can only give temperature and rainfall for 2025 for most of the African regions. The temperature and rainfall generated by the model for Aguié (12°5'N–17°5'N and 2°5'–7°5'E) and Gaya (7°5'–12°5'N and 2°5'–7°5'E) were recorded. The evapotranspiration for 2025 was obtained by using the Penman-Monteith method (Monteith 1965) with the temperatures for the corresponding period. The other required parameters for 2025 were used as defined in the CROPWAT model. The yields of the main crops, the rainfall and the LGPs were considered.

The MAGICC/SCENGEN outputs predict that in 2025 the amount of rainfall will decrease and temperature will increase in both Aguié and Gaya. The CROPWAT outputs such as TAM Lost(mm), RAM User(mm), Total Rain(mm), Efct.Rain(mm), Etc(mm), Etc/Etm (%) were considered as crop yield parameters for the three selected crops and locations. The SMD variation for each crop and location, with and without climate change, are shown in Figure 1.

The SMD trends are the same for both the reference period and 2025 but different in Aguié and Gaya. Figure 1 shows that the SMD trend is more critical in Aguié than in Gaya for both the reference period and for 2025. For all the selected crops, the SMD will increase in 2025. The SMD is almost the same for the two scenarios during the first crop growth stage and does not exceed the evapotranspiration. It decreases drastically during the vegetative phase and maturity. The CROPWAT analysis also shows that there is a significant decrease in crop yield for all crops and locations. This decrease is more significant in Aguié, which will have less rainfall in 2025. In Gaya the decrease in the millet yield is not significant as there will be enough rainfall to maintain soil moisture during the crops' maturity.

Figure 1: Variation of soil moisture deficit (SMD) according to crop and location for reference period (1960–1990) and 2025



These results seem to match the climate change scenario as predicted in the literature, but further discussion is needed to bring them in line with the project's objectives and needs.

Conclusions and policy implications

The major crops covered in this report are cultivated in mixed cropping systems in all the districts studied. This mixture of crops allows us to forecast the risks related to the amount and timing of the rainfall during the cropping season, as all these selected crops are cultivated exclusively during the rainy season. There is no possibility of irrigation, even if the rainfall deficit is critical, as farmers cannot afford the required input. In all the districts the fertile areas in the field are allocated to cash crops such as okra, tobacco, sesame, galingale (an aromatic ginger-like root used for medicine) and maize. These cropping systems are common and known at national level as a confirmed strategy for adapting to climate variability and change.

According to the above, the CROPWAT model is applicable in Niger's agricultural conditions even if irrigation is not common, with less than 60,000ha being used for irrigated agriculture.

The study results show a significant difference between the scenario with climate change (2025) and without climate change for Aguié in terms of soil water availability and soil moisture deficit but this difference is not significant for Gaya where the decrease in rainfall with this scenario (2025) will maintain adequate soil water availability for producing subsistence crops. There is little chance of irrigation for subsistence crops in Niger in the future, other than Gaya,.

These findings may have important implications for Niger's agricultural policy. Based on these intermediate conclusions, the following recommendations can be made:

1. Strategies for adapting to climate variability and change should be formulated and adopted at community, district and national level.

2. Cropping systems should be improved by changing to irrigation for crops that are not adapted to Sahelian conditions.

3. Small-scale farmers should be helped to combine into large units (cooperatives) to increase the irrigation efficiency.

4. Water resource management should be recognized as the main constraint on crop productivity in the country and steps taken to improve it.

References

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The agricultural sector in sub-Saharan Africa is predicted to be especially vulnerable to climate change because this region already endures high heat and low precipitation, provides the livelihoods of large segments of the population, and relies on relatively basic technologies, which limit its capacity to adapt. This series of Policy Notes reports on the methods and results of the first continent-wide study of this kind assessing how the economic well-being of African farming communities is currently affected by climate, predicts how future climate change effects may unfold under various possible global warming scenarios, and evaluates the roles adaptation to climate change could play. The study is based on collaborative research efforts conducted in 11 countries: Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Niger, Senegal, South Africa, Zambia and Zimbabwe. The sampled districts used as the unit of analysis cover all key agro-climatic zones and farming systems in Africa. This is the first analysis of climate impacts and adaptation in Africa on such a scale and the first in the world to combine cross-country, spatially referenced survey and climatic data for conducting an analysis that uses economic impact assessment methods, river-basin hydrological modeling and crop growth simulation techniques.

All the reports produced under this GEF/WB/CEEPA funded project, *Regional Climate, Water and Agriculture: Impacts on and Adaptation of Agro-ecological Systems in Africa*, are found on CEEPA e-Library at its website link (www.ceepa.co.za/discussionp2006.html) and can also be accessed directly through the project link (www.ceepa.co.za/Climange_Change/project.html)

Centre for Environmental Economics and Policy in Africa (CEEPA)*, University of Pretoria, Room 2-7, Agricultural Annex, 0002 PRETORIA, South Africa. Tel: +27 (0)12 420 4105, Fax: +27 (0)12 420 4958, Web address: www.ceepa.co.za*

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