Extreme Weather Events, Farm Income, and Poverty in Niger

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Abstract

Niger is one of the poorest countries in the world. The most recent UNDP[1] report classifies Niger as the last country in terms of human development index. Although more than 80 percent of the economically active population is involved in farming, the agriculture sector generates only around 40 percent of the gross domestic product. Since farm production is heavily dependent on rainfall, frequent extreme weather events may have a severe impact on agricultural output and household income. In this light, this study examines the potential impact of extreme weather events such as prolonged drought and flooding and other selected climate variables on yield of the three major crops in this country: millet, sorghum, and dry bean. Using data from a nationally representative survey conducted in 2014, the estimation results show that drought has a significant negative effect on sorghum and dry bean yield. However, flood have no impact on any of the three crop yields. An increase in temperature affects negatively all three crops yield threatening therefore farm income, and household food security. These results are likely to be further amplified by rising global warming and climate change.

Keywords: extreme weather events, farm production, poverty

[1] United Nations Development Programme

Introduction

Climate change is becoming an important worldwide issue especially in many parts of Africa. Several studies have reported its negative impact on agriculture production affecting therefore the economic growth. Since economy of most sub-Saharan countries is highly dependent on agriculture, climate change affects significantly the economy of these countries and restrains governments' efforts to reduce poverty. A study carried out in 27 Sub-Saharan countries including Niger, revealed that temperature above 24.9°C reduces economic performance and that a percentage increase in temperature significantly reduces this performance by approximately 0.13 percent in Sub-Saharan Africa (Alagidede, P., G. Adu, et al. 2014).

In this context, Niger is one of these countries which economy is mostly based on agriculture. According to World Bank (2014), the agriculture share of the Gross Domestic Product (GDP) in this country is around 40% and agriculture employment represents more than 80% of total employment. The three major crops grown in Niger are respectively millet, dry bean, and sorghum. Recent data from Niger National Statistics Services (INS-NIGER[2], 2016) show that these three crops represent more than 90% of total area cultivated and total production (Tables 4&5). World Bank (2013) also stated that these three crops are the most cultivated and represent between 85% and 90% of total area cultivated over the last fifteen years. All of these crops are grown not only for subsistence but also as cash crops. Among the three crops, dry bean is the most cultivated for market. Therefore, these three crops contribute significantly to farmers' income.

Niger is also one of the countries that experience a high level of climate change effects (World Bank, 2013). Crop production is frequently subject to severe drought, rain irregularity, flood, crop pests and diseases, etc. World Risk Report (2011) revealed that the country is highly vulnerable. Also, World Bank (2013) has reported that drought is the principal risk in Niger and that the country has experienced seven droughts between 1980 and 2010. According to the same report (World Bank, 2013), the combined effects of drought and flood led to a loss in total crop production by 10.4% from the trend production with an indicative loss value of $55,600 US in 2009 (Table 6). It has also been reported that flood impact on agriculture is increasing in this country even if its impact is lower compared with drought. Such risks lead rural households to be vulnerable to poverty.

[2] Institut National de la Statistique du Niger

In fact, Niger is ranked last in development based on the Human Development Index (UNDP[3], 2015). The most recent national census (INS-NIGER, 2014) revealed that about 48% of the population is poor. This national rate is much higher in rural areas where almost 9 rural residents mostly farmers over 10 are considered poor. Thus, poverty in Niger is more severe in farming zones than in urban areas. Furthermore, climate fluctuations not only lead to losses in farm income but also to food access instability and hence food insecurity, since a large part of farm output is for household subsistence. The national census also found that 12.3% of rural population was suffering from high level of chronic food insecurity with a per capita caloric consumption less than 1800 kcal per person per day.

The scope of this research is therefore to cover the expected relationship between climate and crops yield and its link to farmer income and poverty in rural Niger. The study focus on the three major crops mentioned above which have a high potential of contribution to farmer income. Are climate factors such as drought and flood significant to explain crops yield? How dependent are millet, sorghum, and dry bean production on temperature and rainfall in Niger? Also, how sensitive is crop yield to attacks of locusts? Are these factors consistent in explaining farmers' poverty in rural Niger? Thus, the objective of this paper is to analyze the impact of climate change on yields of millet, sorghum and dry bean in Niger, as a path to explain rural poverty in this country.

The paper is organized as follows. The next section will discuss the empirical approach used in this research by summarizing empirical methodologies and by explaining data and the estimation model. The last section presents the results and concludes with policy implications from the findings.

Empirical Approach

Growing literature has been studying the impact of climate change on agriculture. Most studies focused on the responsiveness of crop yield and crop acreage to climate change. As noted by Reilly et al. (1996), climate is well known to impact agriculture productivity. Factors such as seed, fertilizer, pesticides, labor, capital, soil quality and weather events affect crop yield (Robertson, Jeffrey et al. 2013).

This study examines how crops yield is influenced by average weather conditions (temperature, rainfall) and extreme weather events (droughts, flood). In addition, the study

[3] United Nations Development program

evaluates the impact of locusts attack on crop yield. The focus is on three major crops - millet, sorghum, dry bean.

We expect yield of each of the three selected crops to fluctuate as the climate conditions change (Lobell and Asner 2003; Deschenes and Greenstone 2007). Unfavorable climate conditions may result in a low crop yield. More specifically, a long period of drought will therefore be associated with a low crop yield and, ceteris paribus, in a low farm income, assuming market prices are favorable. This is often the case of low income rural households in developing countries who cannot afford to use irrigation (Osei and Jafri, 2016).

On the other hand, a regular precipitation with a sufficient amount of rainfall during the planting and the growing season may favor a good harvest and may be associated with a high crop yield. However, episodes of floods, either during the growing season or at the harvest period may cause important losses of output that may decrease crop yield. That is, a negative impact on the yield of the considered crops is expected from extreme weather events such as prolonged droughts and episodes of flood.

Using data from a survey conducted in fiveprovinces in China,Huang et al. (2015) found that flood and drought affect significantly rice yield. Powell and Reinhard (2016) found similar results while analyzing the impact of extreme weather events on winter wheat in Netherlands, and concluded that high temperature and precipitation events were found to significantly decrease yields.

The results of this study will be a path to explain the vulnerability of the household to poverty considering all these factors since agriculture is the main economic activity of farmers in the area of study. As noted by Mendelsohn, Basist et al. (2003), farm income has a large share of total rural income in developing countries and is therefore a possible link to examine how climate is associated with poverty. Farm income can represent from 30% to 80% of total income depending on the country and the years as noted by Bryceson (2002) and Ellis (2000) cited by Mendelsohn, Basist et al. (2003).

Estimation strategy

According to Dell et al. (2014), the relationship between climate and economic outcomes may be expressed as the following unknown functional relationship:

(1) $$\mathbf{Y = f(C, X)}$$

where the outcome (**Y**) is a function of vectors of climatic variables (**C**), and other variables (**X**). The authors noted that **C** may include temperature, precipitation, and extreme weather events. The study also stated that **X** may include any characteristics that are correlated with **C** and that may also affect the outcomes of interest, possibly by conditioning the climate response.

According to Robertson et al. (2013), quantifying the impact of weather on yield is to estimate the reduced form statistical relationship between yield and weather variables, either linear or quadratic functions. However, the author stated that the linear function may not be relevant because yield response to temperature and rainfall may not be constant with respect to all possible weather outcomes.

In this light, considering the case of corn in the United States, Schlenker, Hanemann, and Fisher (2006) found that "*an increase of temperature within the range between 8°Celsius and 32° Celsius is found to be beneficial to corn yield, but increasing the temperature further beyond 34° Celsius leads to yield losses*". This is the concept of Growing degree-day (GDD) which states that there is an optimum temperature threshold above which yield starts decreasing, depending on the crop. Other studies reached the same conclusion and found that the relationship between agricultural outcome and climate is expected to be a non-linear relationship (Osei and Jafri, 2016).Because of this non linear relationship between climate and yield, climate variables are squared (Mendelsohn et al., 1994).

Robertson et al. (2013) found that temperature variables can be expressed as a single variable in the case of GDD, a vector of monthly average temperatures, or cumulative hours of exposure to temperature intervals. Similarly, the authors stated that rainfall can be expressed as either a single variable representing cumulative growing season rainfall (in mm), or a vector of monthly cumulative rainfall variables. In this study, we use daily temperature data to calculate GDD with a base temperature set at 10°C (50°F). According to USDA[4], a base temperature of 10°C can be used for warm-season crops such as corn, sorghum, and millet. Also, it is assumed that below 10°C and above 35°C, dry bean germination is poor (Dickson and Boettger, 1984; Swiader et al., 1992).

Moreover, according to Dell et al. (2014), the outcome variable and explanatory variables are measured either in levels or logs. In the case of log functional form, coefficient estimates explain the percentage change in yield resulting from a one unit change in the explanatory variable (Robertson et al. 2013).

[4]https://www.pecad.fas.usda.gov/cropexplorer/description.aspx?legendid=312

Based on the issues discussed above, the paper uses the following model to evaluate the impact of climate variables on the yield of each of the three major crops in Niger (Huang et al. 2015):

(2) $$\boldsymbol{ln\ (Y) = \beta_0 + \beta_1 W + \beta_2 S + \beta_3 T + \beta_4 R + \varepsilon}$$

In this equation, ***Y*** represents the crop yield for the agricultural season. The explanatory variables of the model are defined as follows:

W is a vector of extreme weather events variables such as drought and flood. The variables are defined as whether the farmer has been subject to the problem or not.

S is the perception of the farmer on whether his farm has been subject to attacks of locusts during the agricultural season.

T is a vector of temperature variables such as variability in monthly temperature, GDD during the growing season, and its squared terms.

R is a vector of monthly cumulative rainfall variables during the growing season and its squared term.

Data

The study uses data from the World Bank Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) program. Specifically, the data are from the Second National Survey on Living Conditions and Agriculture carried out in Niger in 2014, with a total of 3,614 households and 26,579 individuals surveyed. It is a nationwide survey which covers all the regions and which includes household information as well as agriculture data. The study uses 1206 observations for millet, 933 for dry bean and 751 for sorghum

Climate variables data are daily data collected from the National Oceanic and Atmospheric Administration (NOAA) from January to December 2014 for each of the weather stations (regions of study). Temperature is expressed in degree Fahrenheit whereas precipitation is calculated in total hours of precipitation.

Millet Yield Estimation

Tables 1 presents the results of the estimation of millet yield on two groups of explanatory variables: disaster variables which are perceptions of farmers on whether they have been subject to the disaster during the growing season (May to September) and climate variables which make use of actual daily climate data reported during the same period. Most explanatory variables have the expected signs and are statically significant.

The estimated coefficients for drought and flood variables are negative but not statistically significant. Although, these variables have the expected sign, they are not determinants of millet yield. However the negative sign of drought variable is consistent with the coefficient sign of GGD variable. The negative and statistically significant coefficient of GDD shows that a unit increase in degree days during the growing season decreases millet yield by 8.39%. Thus, a marginal increase in temperature has a negative impact on millet yield. Boubacar (2010) found a similar result while analyzing the impact of drought on crop yield in Sahel. In addition, the coefficient of the squared term of GDD is positive and significant. This means that there is a non-linear relationship between millet yield and temperature (degree days). These results are similar to those of Schlenker and Roberts (2006) who found nonlinear effects of temperature on corn yields.

Table 1. Estimations of Millet Yield

	Millet Yield (Log)		
Variables	Coefficient	t-value	P-value
Disasters			
Drought	-0.2043289	-0.82	0.413
Flood	-0.154404	-0.58	0.565
Locuts attacks	0.162514	0.65	0.519
Climate variables			
Deviation in August temperature	**1.913288*****	5.98	0.000
August precipitation	**0.0173863*****	3.22	0.001
Growing season Degree Days (GDD)	**-0.083992*****	-3.52	0.000
GDD^2	**6.77E-06*****	3.35	0.001
Growing season rainfall	**0.0413549***	2.52	0.012
Growing season rainfall squared	**-0.0001094*****	-3.17	0.002
Constant	**253.5288*****	3.71	0.000
Adjusted R^2	0.0452		
Observations	1206		

* and *** denote significance at the 10% and 1% levels, respectively.

The estimated coefficients of both growing season rainfall variable and its squared term are statistically significant and have respectively a positive and a negative sign. A report of one additional hour of precipitation during the growing season will increase millet yield by

4.13%. These results mean that growing season rainfall increases yield of millet but at a decreasing rate. Thus, there is an inverted U-shaped relationship between millet yield and rainfall.

We also estimate millet yield on August climate records. According to Mahaman et al. (2011), August is usually the rainiest month in Niger and is determinant in the production of cereals. The estimated coefficient of August precipitation in Table 1 confirms that this variable is statistically significant and has positive impact on millet yield. The results shows that one hour of precipitation in August will increase millet yield by 1.7%. A higher August precipitation will therefore result in a high yield. Deviation in August temperature also revealed a beneficial effect on millet yield.

Sorghum Yield Estimation

The results of the estimation of sorghum yield (Table 2) are similar to that of millet yield estimation. However, unlike the result of millet yield, the estimated coefficient of drought variable is statistically significant at 10% and its coefficient has the expected negative sign on sorghum yield. Drought is therefore a determinant of sorghum yield. This observed difference in the significant impact of drought on yield between millet and sorghum may be explained by the fact that millet is more drought-tolerant than sorghum, according to the Consultative Group on International Agricultural Research (CGIAR)[5]. Crops attacked by locusts, which is one of the most frequent shocks faced by farmers in Niger, is non-significant in explaining sorghum yield. However, it has the expected negative sign.

As in the case of millet yield, results confirm a non linear relationship between sorghum yield and growing degree days and also between sorghum yield and growing season rainfall. The coefficient of GDD is statistically significant with a negative sign, explaining therefore the negative impact of temperature on sorghum yield. A marginal increase in degree days during the growing season leads to a decrease in sorghum yield by 36%. On the other hand, the positive and significant coefficient of growing season rainfall variable means that a marginal increase in rainfall during the growing season increases sorghum yield by 20%.

Moreover, results confirm that August is a significant month in cereal production in Niger. Similar to millet yield, both August precipitation and deviation in August temperature are significant determinants of sorghum yield.

[5] http://www.cgiar.org/www-archive/www.cgiar.org/pdf/drought_tolerant_crops_for_drylands.pdf

Table 2. Estimations of Sorghum Yield

	Sorghum Yield (Log)		
Variables	Coefficient	t-value	P-value
Disasters			
Drought	**-0.6230776 ***	-1.71	0.088
Flood	0.1530499	0.44	0.66
Locuts attacks	-0.2471099	-0.73	0.463
Climate variables			
Deviation in August temperature	**2.335062 *****	5.03	0.000
August precipitation	**0.0960734 *****	5.31	0.000
Growing season Degree Days (GDD)	**-0.3627898 *****	-3.9	0.000
GDD^2	**0.00003 *****	3.81	0.000
Growing season rainfall	**0.2011694 *****	3.24	0.001
Growing season rainfall squared	**-0.0005145 *****	-3.82	0.000
Constant	**1063.945 *****	3.99	0.000
Adjusted R^2	0.0725		
Observations	751		

* and *** are significance at the 10% and 1% levels, respectively.

Dry Bean Yield Estimation

Table 3 reveals that almost all of the explanatory variables have the expected signs. We found a statistically significant coefficient of drought variable at 5%. Its negative sign implies that drought impacts negatively dry bean yield in Niger. On the other hand, we found that dry bean yield is not sensitive to either flood or locusts attacks.

Table 3. Estimations of Dry Bean Yield

	Dry Bean Yield (Log)		
Variables	Coefficient	t-value	P-value
Disasters			
Drought	**-0.7508837** **	-2.49	0.013
Flood	0.2202958	0.64	0.523
Locuts attacks	0.2867204	0.94	0.348
Climate variables			
Deviation in August temperature	**1.811892** ***	4.72	0.000
August precipitation	**0.0132223** *	1.86	0.063
Growing season Degree Days (GDD)	**-0.0588541** *	-1.93	0.054
GDD^2	**4.60E-06** *	1.78	0.075
Growing season rainfall	0.0262872	1.29	0.197
Growing season rainfall squared	**-0.0000814** *	-1.87	0.062
Constant	**182.0802** *	2.08	0.038
Adjusted R^2	0.0439		
Observations	933		

*, ** and *** are significance at the 10%, 5% and 1% levels, respectively.

Although the estimate results of dry bean yield equation are quite similar to the results of the previous estimations (millet, sorghum) we noticed that the growing season rainfall is not significant in this case even though its squared term is significant at 10%. However, both growing season rainfall and its squared term show a positive impact of rainfall on yield and a non linear relationship between rainfall and dry bean yield.

Also, the results show that dry bean yield elasticity with respect to GDD (temperature) is -0.058. This statistically negative coefficient of GDD reveals a negative impact of temperature on dry bean yield. However the relationship appears to be non-linear because of the statistically positive coefficient of its squared term. This result is consistent with the previous results.

Lastly, as found previously, the significance of both deviation in August temperature and August rainfall underscores the importance of the weather records of this month for a good yield. Dry bean yield responds positively to the variability in August temperature and to rainfall of this month.

Implications of the findings

The study reveals that overall climate factors are determinants in the production of millet, sorghum and dry bean in Niger. Drought has a negative impact on sorghum and dry bean yields whereas its impact on millet yield is not significant. Moreover, a high increase in temperature during the growing season impacts negatively all three crops. Likewise, there is a positive response of yields to an increase in rainfall. However, the study finds that either flood or crop attacks by locusts are not significant enough to have an impact on yields.

These results confirm the fact that agriculture is heavily dependent on weather in this country where only a few farmers can afford to use irrigation. The findings emphasize the importance of developing irrigation and water management systems to help farmers to cope with the negative impact of climate change. Ensuring water availability to crop growth will be particularly important in August, which is critical for all three crops analyzed. Furthermore, this study suggests research towards more drought-resistant crop varieties in Niger.

The results of this study can also help in evaluating the impact of climate factors on farm income. Millet, sorghum, and dry beans are widely cultivated crops in Niger (table 4&5). Since small farmers are less equipped to cope with the climate change, an effort to reduce the negative impact of climate change is likely to help reduce extreme poverty.

Agricultural policies and government actions should focus on achieving this goal. It will enhance both food security and farm income of rural households.

Conclusion

Most studies show a negative impact of climate change on farm productivity especially in rainfed farming agriculture like Sub-Saharan Africa where farmers have fewer adaptation means. In this paper, we focus the analysis on millet, sorghum and dry bean yields and its implications for farmer livelihoods in Niger. We use nationwide agricultural survey data to estimate crop yield response to weather variables.

The paper investigates how sensitive is crop yield to extreme weather events (drought, flood) and shocks (locust attacks). The results show that drought has a significantly negative impact on sorghum and dry bean yields but not on millet yield. The study also discusses the relationship between crop yield and growing season temperature (degree days) and rainfall. The findings reveal a non-linear relationship in both cases. However, an increase in temperature affects yield negatively whereas an increase in rainfall has the opposite effect. Moreover, the results highlight the importance of August weather records for the three crops. In order to improve farm income and therefore reduce rural poverty in Niger, the study suggests to formulate more effective agricultural policy that takes into account the potential of farmers to adapt to climate change.

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Appendix

Table 4. Area Cultivated and Total Output for Crops in Niger from 2010 to 2014

Crops	Area cultivated (hectare)					Production (tone)				
	2010	2011	2012	2013	2014	2010	2011	2012	2013	2014
All crops	16,253,972	14,668,571	15,016,746	15,931,257	15,927,192	7,193,738	5,326,152	6,864,099	6,060,926	6,408,328
Cereals	10,619,124	9,959,647	10,232,508	10,716,171	10,590,461	5,192,994	3,554,795	5,257,627	4,052,463	4,267,283
Millet	*7,253,200*	*7,052,175*	*7,095,105*	*7,082,959*	*6,994,312*	*3,843,832*	*2,760,917*	*3,862,155*	*2,815,937*	*2,921,982*
Sorghum	*3,322,142*	*2,878,823*	*3,111,086*	*3,564,858*	*3,565,861*	*1,304,832*	*770,322*	*1,375,697*	*1,222,393*	*1,320,250*
Rice	*20,055*	*8,729*	*5,342*	*50,845*	*9,936*	*29,963*	*12,230*	*5,429*	*4,706*	*13,427*
Corn	*12,398*	*8,308*	*9,646*	*7,209*	*10,052*	*9,381*	*6,366*	*8,413*	*4,873*	*7,071*
Fonio	*11,329*	*11,612*	*11,329*	*10,300*	*10,300*	*5,467*	*4,960*	*5,933*	*4,553*	*4,553*
Groundnut	*795,768*	*690,853*	*741,310*	*777,205*	*778,929*	*406,246*	*395,657*	*291,763*	*342,743*	*403,365*
Legume	5,634,848	4,696,307	4,771,237	5,199,217	5,323,491	1,800,895	1,590,926	1,362,192	1,666,442	1,846,896
Dry bean	*5,570,969*	*4,644,771*	*4,700,833*	*5,130,916*	*5,253,969*	*1,773,423*	*1,568,828*	*1,329,514*	*1,633,656*	*1,789,804*
Voandzou	*63,879*	*51,536*	*70,404*	*68,301*	*68,302*	*27,472*	*22,098*	*32,678*	*32,786*	*32,784*
Onion					1,220					24,308
Roots and tubes		12,617	13,001	15,869	13,240	199,849	180,431	244,280	342,022	294,149
Cassava		*7,299*	*6,679*	*7,816*	*6,651*	*113,006*	*97,812*	*107,269*	*156,100*	*133,099*
Sweet potatoes		*3,708*	*3,894*	*4,621*	*3,700*	*51,179*	*56,203*	*78,021*	*97,784*	*81,291*
Potatoes		*1,610*	*2,428*	*3,432*	*2,889*	*35,664*	*26,416*	*58,990*	*88,139*	*79,760*

Source: INS-NIGER, 2016

Table 5. Share of Total Crops for Millet, Sorghum, and Dry Bean in Niger from 2010 to 2014

Crops	Total acreage cultivated (% of all crops)					Total output(% of all crops)				
	2010	2011	2012	2013	2014	2010	2011	2012	2013	2014
Millet	45%	48%	47%	44%	44%	53%	52%	56%	46%	46%
Sorghum	20%	20%	21%	22%	22%	18%	14%	20%	20%	21%
Dry bean	34%	32%	31%	32%	33%	25%	29%	19%	27%	28%
Total	99%	99%	99%	99%	99%	96%	96%	96%	94%	94%

Source: Author's calculation based on INS-NIGER (2016) data from Table 4.

Table 6. Adverse Events for Crop Production and its Costs in Niger

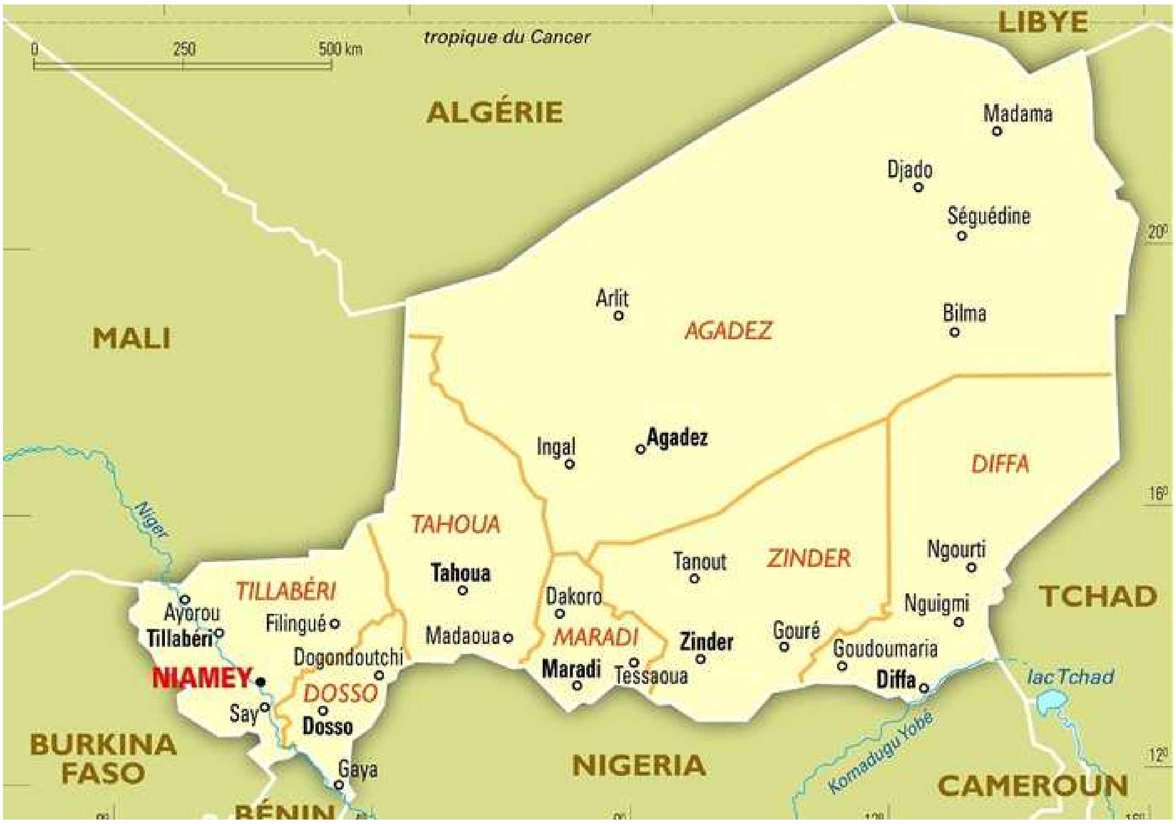
Year	Percent deviation of production from trend	Indicative loss value (2010)			Context
		FCFA (m)	$US (m)	Percent Ag GDP	
1995	-23.2%	-41,382	-122.1	-24.1%	Drought, localized locust attacks, political uncertainty
1996	-13.6%	-12,504	-35.0	-6.2%	Political uncertainty
1997	-23.1%	-49,892	-135.8	-23.7%	Drought
2000	-9.1%	-4,159	-10.8	-1.4%	Drought
2004	-17.2%	-50,920	-125.3	-11.6%	Drought, locusts
2005	-7.0%	-1,827	-4.2	-0.3%	Low rainfall
2009	-10.4%	-27,244	-55.6	-3.1%	Drought, floods

Source: World Bank (2013)

Table 7. Summary statistics of variables

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Log of Millet Yield	1206	6.005202	1.874292	-1.063028	16.1181
Log of Sorghum Yield	751	4.69754	2.086199	-2.306972	15.45312
Log of Dry Bean Yield	933	4.273309	2.033028	-2.449323	13.75667
Drought	1655	0.043505	0.204052	0	1
Flood	1655	0.044713	0.206736	0	1
Locuts attacks	1655	0.046526	0.210684	0	1
Deviation in August temperature	1655	3.51223	0.258452	2.745342	3.854725
August precipitation	1655	132.4932	35.22701	37.38	188.4
Growing season Degree Days (GDD)	1655	5681.225	248.0384	5261.3	6671.9
GDD^2	1655	3.23E+07	2820370	2.77E+07	4.45E+07
Growing season rainfall	1655	314.2846	66.48783	62.34	388.44
Growing season rainfall squared	1655	103192.8	36847.34	3886.276	150885.6

Map of Niger and its Regions



Source: http://www.presidence.ne/division-administrative