Rainfall and Deforestation Dilemma for Cereal Production in the Sudano-Sahel of Cameroon

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Abstract

Time series data reveals that the Sahel of Cameroon has experienced several years of deficits in cereal production. The debate attributes the observed trends to low rainfall. Uncertainties in the debate on the role of rainfall as a principal causal factor are evident and need verification. Both field and desk studies have been used; this involved the administration of 200 questionnaires and focused group discussions. The desk studies included detailed literature review and analysis of Normalized Difference Vegetation Index (NDVI) satellite images of vegetation and rainfall from the Global Precipitation Climatology Project (GPCP). The results show that cereal production has declined while rainfall has increased by 30-40% in the last decade in the study area. With an increase in rainfall, the observed decline in cereal production cannot be explained by climate only. Land use changes such as deforestation patterns are significant in explaining the trends in cereal output as seen in population perceptions.

Keywords: Sudano-Sahel, Cameroon, Cereal, Rainfall, Deforestation

1. Introduction

Climate is dynamic and changes continuously with long term cold and warm episodes. Human activities in terms of land use patterns have been linked to extreme changes in climate. Such climate variability has had lots of effects on water and agricultural resources (Molua & Lambi, 2006). In Africa, non-linear heat effects have been recorded for maize as evidenced by historical data. This means that each degree spent above 30^0 C reduces final yields by 1% (Lobell *et al*., 2011).

The Sahel is a semi-arid shrub and grassland that is a transition zone between the arid Sahara in the North and the wetter tropical zone in the south. It further stretches from the Atlantic ocean in the west to the horn of Africa in the east (around Somalia). The climate of the Sahel is marked by seasonality expressed in a long dry season and short wet season and it has a population of over 60 million people (Hermann *et al*., 2005; Integrated Regional Information Network (IRIN), 2010).The dry spells experienced in the Sahel in the late 20th century affected production and have been attributed to human factors such as increased atmospheric aerosols and increased green house gases (GHGs), (National Oceanic and Atmospheric Administration (NOAA) & Geophysical Fluid Dynamics Laboratory (GFDL), 2007). Projections up to the 21st century illustrate that the Sahel will be drier in the future due to GHGs. If these suggestions of long term projections of temperature rise and rainfall reductions are realised, the Sahel will experience more droughts in the 21st century than in the 20th century (Intergovernmental Panel on Climate Change (IPCC), 2007). It is argued that climate change will cause a 25 % reduction in rainfall in the Sahel by 2100 (NOAA & GFDL, 2007).

As emphasized earlier, climate change can be seen as a potential big threat to the survival of humankind. This is evident as projections of climate change are however subject to uncertainties as a result of several interacting factors including, limitations of knowledge on climate change and the ongoing and ever changing debates. It has been noted that future GHG emissions cannot be known with exact precision but an understanding of socio-economic and atmospheric processes can be used to produce a range of plausible values (IPCC, 2001a, b; IPCC, 2007). The United Nations Environmental Program (UNEP), (2005) also suggest temperature changes for Africa of between 0.2^0 C to 0.5^0 C per decade. It is also mentioned that the interior regions of the continent stand at higher risks from adverse changes in rainfall and temperature (IPCC, 2001b; IPCC, 2007).

Global agricultural productivity decline has been blamed on changes in rainfall for a very long time than on changes in land use patterns over the long run (Olsson, 2008). As such, the year to year variability in agricultural output has been linked to climate change (IPCC, 2001b, IPCC, 2007). Climate has thus been seen as a key driver of food security and this is without doubt because the role of rainfall in crop yields is clearly understood (Gregory *et al.*, 2005; Verdin *et al.*, 2005).

Today, based on observed rainfall and greening trends observed in most of the Sahel, the discourse is changing rapidly and scientists now have differing views on whether the Sahel will get wetter or drier (IRIN, 2010). The changing view on the role of climate change in the entire resource limitation debate establishes climate as a key element of uncertainty in the Sahel at the moment (Olsson, 2008). Cereal shortages are a reality in the Sudano-Sahelian region of Cameroon. In 1998; the World Food Program (WFP) gave some 9500 tons of food to subvert shortages in the Sudano-Sahelian part of Cameroon. This situation repeated in 2005 following drops in agricultural output (Molua & Lambi, 2006).

Based on the current uncertainty surrounding the role of Sahelian rainfall in causing persistent food shortages in the Sahel in general and in the Sudano-Sahelian region of Cameroon in particular, this study aims to synthesize the problem by finding out if there has been cereal deficits in the region and investigating the relative influence of general Cameroonian Sahelian rainfall and deforestation on Cereal output and other possible factors that impact cereal yields in the study area.

2. The study area

The study area extends from Touroua, Garoua, and Maroua through Kousseri to the Lake Chad basin and will be referred to in this paper as the Sudano-Sahel of Cameroon. It has a short rainy season (July to October) and a long dry season. Annual rainfall ranges from about 900 mm in the Maroua area to 500 mm around Kousseri and 400 mm around Lake Chad (Molua, 2006; Maroua, 2011). Maroua which is the capital of the extreme North Region and part of the Sahel of Cameroon has a population of 2553389 inhabitants as of the 2005 population census. The total surface area involved here is 34263 km^2 with a population density of 74.52 inhabitants per km^2 (Civil cabinet of the presidency of the Republic, 2011). The Sahel in general has an area of 363000 Km^2, this implies that the portion of Cameroon under study is about 10% the size of the entire Sahel (IRIN, 2010). In general, there is great similarity between the different parts of the Sahel in terms of the trends of observed parameters such as rainfall, temperature, agricultural systems, cultures and problems faced by the inhabitants inter alia though slight spatial variations might exist in scale and magnitude (Hermann *et al*., 2005; Olsson *et al*., 2005).

3. Methodology

Three principal methods of data collection and analysis were used. Firstly, 200 questionnaires were administered to 200 grain farmers in Touroua, Garoua, Maroua and Kousseri in January 2009. 50 questionnaires were administered to each region, focus group discussions were also held with over 200 farmers and authorities of the ministry of agriculture. Kousseri has a population of about 89123 inhabitants and has a total surface area of about 14km^2 (Civil cabinet of the presidency of the Republic, 2011; Google maps, 2011). These areas are of strategic importance because they are essentially inhabited by grain farmers who have a better perception of the problems confronting agriculture in this zone. The objective here was to explore the perceptions of the inhabitants on the contributions of rainfall and land use change (deforestation) to agricultural yields. The main population sampling was through the random sampling method (Williman, 2006; Bryman, 2004).

Furthermore, time series data on cereal production trends in the study area between 1975 and 2005 were obtained from the Garoua Cereal office. In addition, other secondary data sources consulted included literature that has covered most of the recent climate polemics with respect to agriculture in the Sahel in general and the Sudano-Sahelian region of Cameroon in Particular. Most of these sources presented information on the correlation between the Normalized Difference vegetation Index (NDVI) and rainfall in the Sahel as well as trends of monthly rainfall in the Sahel (figure 4, 5 and 6) (Hermann *et al*., 2008; Olsson and Mryka, 2008). The NDVI is a ratio of the near infrared and red spectral reflections and it is calculated as (NIR-VIS/NIR+VIS). Where VIS and NIR stand for the spectral reflectance measurements acquired in the visible red and near infrared regions of the electromagnetic spectrum respectively. NDVI has served as a proxy for mapping rainfall variations because a very strong correlation has been found between NDVI and rainfall (Tucker and Nicholson, 1999; Hermann *et al*., 2008).

The questionnaires were analyzed on a simple yes or no basis as well as on a causal factor basis to find out farmers opinions about grain yields and potential causes of their perceived trends. The Statistical Package for the Social Sciences (SPSS) version 19 was used to obtain the frequencies in the analysis. The opinions of the authorities in the ministry of agriculture and the cereal office were also obtained from interviews and focus group discussions that took place in January 2009. The NDVI data was analysed by downscaling from the observations of general Sahelian NDVI and rainfall to observations of the specific situation in the Sudano-Sahel of Cameroon. This zone is represented by the region in and around the rectangle on figure 6. To smoothen out short term fluctuations in the cereal yield data and provide indications of overall trends in the data, the 3 period moving averages were applied to the data using the SPSS software package. The advantages of the three period moving averages go beyond smoothening and reduction of variations in the data to facilitating the analysis of large time series data (Valleman, 1981; Hseih, 1991). Also, averages for each five year period were calculated for the cereal output data to easy representation on the bar graphs. The data was further analyzed by subtracting the actual production from the projected production. In this way, the deficits for the different years were obtained. The equation derived by this study and used to carry out the calculations is as follows:

$$D_{iy} = PP_{iy} - AP_{iy}$$

Where D_{iy} is the deficit for the ith year

PP_{iy} is the projected production for the ith year

AP_{iy} is the actual production for the ith year

To ascertain the rainfall trends in the Sahel, gridded rainfall satellite images of the Sahel combined with NDVI was used as proxy to establish the correlation between greenness and rainfall. The rainfall estimates data was culled and modified from the Global Precipitation Climatology Project (GPCP); Herrmann *et al*., 2005; Olsson and Mryka, (2008); Eklundh & Olsson, (2003).

4. Results

Cereal output trends and Population Perceptions of causes of observed trends.

A cereal production decline was observed for the period analysed. As seen on table 1, there were 20 years during which deficits in production were observed because the projected production needs were not attained. Each year from 1993 to 2005, showed a production deficit based on the actual production data versus the projected production data (see table 1 and figure 2). However, data has been compressed through a calculation of the averages and presented on figure 3. For these averages, the period of deficit begins from the 1990-1994 average with a deficit of 70000 tons, 1995-1999 average with a deficit of 150000 tons, and the 2000-2005 average with a deficit of 190000 tons.

Based on the analysis of the questionnaires and focus group discussions, this study has found out that from the 200 respondents, 124 are farmers, 52 are cattle readers, 10 are teachers and 14 are rice vendors (see table 4). The implication of this is that the results are fairly reliable because they represent responses from key stakeholders who are most involved in the cultivation of different types of cereals. Furthermore, 72 of these respondents attribute cereal declines to climate change while 121 think anthropogenic factors are responsible. A detailed analysis of the anthropogenic factors shows that 5 respondents have the perception that vertical slope cultivation is responsible for cereal declines, 7 respondents have the perception that cattle rearing is responsible for cereal decline, 25 respondents have the perception that population growth is responsible for cereal decline, 66 respondents have the perception that deforestation is responsible for cereal decline and 18 respondents have the perception that lack of capital and technology are responsible for cereal decline while 7 respondents have no idea. 172 of the respondents think cereal output is declining, 20 think it is increasing while 8 think it is stationary. This heralds the notion that cereal decline in the study area is a big problem. From the focused group discussions most of the respondents believe that the key problem with their yields has to do with their current farming systems, cattle rearing, population growth capital technology and deforestation. These views are also tightly consistent with the views of the authorities in the ministry of agriculture who hold that declining cereal yields are due to deforestation and unsustainable farming methods such as cultivation on slopes in the Mandara Mountain region rather than rainfall which is reported rising (see Tables 2 and 3). However, among the anthropogenic factors, the most important causes of cereal decline according to respondents are deforestation, population growth and capital technology.

In the same way, overall trends in monthly rainfall for the Sahel from 1982-2003 based on the estimates of the GPCP express percentage increase in rainfall. This is confirmed when we observe that there has been a positive change in rainfall in the Sahel in general (see figure 4). If we downscale this to the Sahel of Cameroon (represented by the region within and around the double rectangles on figure 5), we observe that a percentage increase in rainfall of about 20-40 % has been recorded for the study area.

To further support the argument that rainfall in the Sahel of Cameroon is rising, linear correlations of the monthly Normalized Difference Vegetation Index (NDVI) with three monthly cumulative rainfall based on GPCP estimates have been used. If we downscale the observations we observe that for the region which stands for the Sahel of Cameroon, a correlation coefficient of about 0.85 is obtained. This means there is a very strong positive correlation between vegetation or greenness and rainfall (see figure 6).

5. Discussions

Sahelian Greening and Rainfall versus Land use Patterns

One would expect a conclusion that declining cereal output is strongly linked to declining rainfall in the Sahel. However, a new component in the debate seems to have opened. The Sahel has experienced relative greening during the period 1982 -2003 caused mainly by increase in rainfall (Olsson & Mryka, 2008; Eklundh & Olsson, 2003; Hulme, 2001). Nicholson, (2005) remarks by supporting the increased rainfall hypothesis when he argues that most of the central and southern parts of the Sahel experienced increase rainfall. If this is true, then we will have to subscribe to other factors in an attempt to explain the current declines in cereal production in the Sahel of Cameroon. This view point looks tenable since the Sahel is a zone of sharp seasonal contrast with fluctuations in rainfall at inter-annual and decadal scales. This makes the Sahel to be considered further as a region of climatic variability. As such, the current increases in Sahelian rainfall do not come with lots of doubt (Hulme, 2001).

This hypothesis has been proven by other independent studies. The Sahel experienced declining rainfall in the 1950s-1980s. However, from 1985, trends of an increase in rainfall in most parts of the Sahel have been recorded (Olsson & Mryka, 2008; Wang *et al*., 2000). The effect of declining rainfall in the Sahel of Cameroon in particular and Africa in general is that the Sahel is a hunger threatened region. Projections show that by 2020, food shortages would have reduced in most developing countries but the Sahel will still be facing problems with food shortages due to inappropriate land uses such as deforestation,over cultivation, cattle stock rearing and rapid population growth (IFAD, 2001; Olsson & Mryka, 2008). Infact, population growth in itself has recently been analysed as a major cause of deforestation in Cameroon (Epule *et al*., 2011). Even if cereal outputs will rise in Sub-Saharan Africa, it's however quite possible that due to an increased population the growth in production will be worthless and the amount of malnourished children will keep on a pessimistic turn towards 2020 (IFAD, 2001). On a global scale, it is also argued that global maize and wheat production had declined between 1980 and 2008. The latter decline is said to be influenced more by temperature than changes in precipitation. This again underscores that fact that the influence of precipitation on the decline in grain yields is not as significant as other factors, at least for now (Lobell *et al*., 2011).

The question now is, are there any other studies that support the correlations between the observed rainfall and greening? Increase greenness correlates perfectly at a coarse scale with increase in rainfall in the Sahel. Studies have argued that the areas of increase greenness are same as those of increase rainfall, though these same areas have experienced declines in cereal yields, a view supported by the following authors (Herrmann *et al*., 2005; Olsson et al., 2005; Zeng *et al.*, 1999; Anyamba & Tucker, 2005).

Based on the trends described above, one would expect that if there is an increase in rainfall in the Sahel in general and the Sudano-Sahelian zone of Cameroon in particular there should be an increase in food production. Paradoxically, this has not been the case, as seen in the cereal yields for the Sahel of Cameroon. In the past, the areas of droughts played a strong role in declining food stocks in the region (Caldwell, 1977). In the Sahel, only Burkina Faso and Mali experienced increase production of millet (kg/capita) of 55% and 35% respectively since 1980 (Olsson & Mryka, 2008). Lobell *et al*., (2011) argue that climate remains only one likely factor that can shape the past and future of food production and it is of great importance to assess other factors affecting food production. As such, the observed declines in the Sahel could be explained in line with the factors that the respondents presented above that include deforestation, population growth and capital technology inter alia. In fact, it has been discussed that agricultural production has declined in Africa due mainly to land use and cover change (Ewert *et al*., 2005; Zhao *et al.,* 2006). Land cover changes through deforestation have repercussions on food yields and this can be linked to over grazing and population pressure on dry lands (Lambin *et al*., 2000). Stephenne *et al*., (2001) also support the above statement when they argue that land cover changes through anthropogenic deforestation, cattle rearing and population growth are responsible for grain declines in the Sahel. Bala *et al*., (2000) and Epule *et al*., (2011) argue further that population growth is at the centre of rapid land use change or deforestation which affects agricultural output. LeBlanc *et al*., (1997) go further by analysing that land use change through deforestation brings about water scarcity, the effects of which are often reflected in low grain output. Therefore, deforestation for example increases water scarcity. Cereal output drops because the increase in rainfall is not entirely available for agriculture due to unsustainable systems of land usage that cause water scarcity. It can be said that, when trees are destroyed through deforestation, cattle rearing and a nexus of unsustainable methods of cultivation, the water cycle is hampered and our global, regional, national and catchment area scale agricultural systems will lack sufficient water for survival (Lobell *et al*., 2011; Epule *et al*., 2011; Zhao *et al.,* 2006).

6. Conclusions

Observed trends of declining cereal yields in the Sudano-Sahelian region of Cameroon cannot be explained by the observed trends of increasing greening and rainfall in most of the Sahel and that of Cameroon in particular. Potential explanations of the declines in cereal yields could be land use systems as seen in most of the literature and data from this work. Olsson *et al*., (2005) argue that the fact that millet yields and increase in vegetation are found to be unrelated supports this conclusion. The observations here set in a potential for better land use management since rainfall is already increasing. It would therefore be of great importance for researchers to uncover the influence of land use systems on food production in particular and environmental degradation in general in the Sahel of Cameroon and other parts of Africa. Most studies have this far not been able to establish the link between current climate trends and food production in the Sahel of Cameroon, a major aim of this study. It would also be of great interest to uncover the repercussions of different land uses on the environment and the triggers behind the deforestation at scales less than or greater than national to be able to set a better platform for mitigation.

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Table 1. Trends in Cereal Output and Quantity of Cereal needed from 1975 to 2005 for the Sudano-Sahel of Cameroon.

Years	**Total Production (Tons) Actual production**	**Quantity Needed (Tons) Projected production**	**Deficit or Surplus (Tons)** $D_{iy} = PP_{iy} - AP_{iy}$
1975/76	253 683	229 161	+ 24 522
1976/77	267 458	235 190	+ 32 268
1977/78	230 092	241 365	- 11 273
1978/79	289 485	247 722	+ 41 763
1979/80	251 292	254 243	- 2951
1980/81	262 841	260 928	+ 1913
1981/82	207 341	267 793	- 60 452
1982/83	381 153	274 840	+ 106 313
1983/84	223 298	282 066	- 58 768
1984/85	127 041	289 474	- 162 433
1985/86	364 532	297 112	+ 67 420
1986/87	450 395	304 799	+ 145 596
1987/88	424 406	312 814	- 111 592
1988/89	292 803	321 043	- 28 240
1989/90	359 528	329 486	+ 30 042
1990/91	245 992	338 158	- 92 166
1991/92	402 234	347 044	+ 55 190
1992/93	432 517	356 176	+ 67 341
1993/94	180 200	365 538	- 185 338
1994/95	180 000	367 500	- 187 500
1995/96	241 500	445 477	- 203 977
1996/97	355 000	468 000	-113 000
1997/98	384 000	491 256	- 107 256
1998/99	300 857	491 332	- 190 475
1999/00	329 372	495 345	- 165973
2000/01	325 321	496 221	- 170 900
2001/02	323 022	498 010	- 174 988
2002/03	320 213	498 376	- 178163
2003/04	318 987	498 518	- 179531
2004/05	315 025	499 259	- 184234

Table shows variations in cereal output from 1975 to 2005. Total production represents the actual quantity of cereals produced for a given year while projected production is the anticipated production target set by the government. The production deficits or surplus are the differences between actual production and anticipated production. Of the 30 years for which data was available, deficits are recorded for 20 years as indicated by the minus signs from 1993 to 2005. Calculations are based on the raw data without a calculation of means as is the case of figure 3. The original data did give the deficits that are seen above. The Cereal Office keeps all records of grain production and grain forecasts in the region. Source: Modified from Cereal Office Garoua and Ministry of Agriculture and Rural Development, (2009)

Table 2. Perceptions of climate change as the main causes of cereal decline

Yes	**No**	**Others/No Idea**
72	121	7

Table shows populations perception of rainfall as main cause of cereal decline. Of the 200 respondents 121 report that rainfall variations are not responsible while 72 think decline in rainfall is responsible and 7 respondents have no idea. Figure 3 shows the subdivisions.

Table 3. Population perceptions of the causes of cereal decline

Causes of cereal decline	Number of Respondents
Rainfall(Climate Change)	72
Vertical slope farming	5
Cattle rearing	7
Population growth	25
Deforestation	66
Capital, technology	18
No idea	7

The table further shows the detailed results of population perceptions of the causes of cereal decline.72 respondents attribute it to rainfall decline while 7 have no idea. The remaining 121 respondents think rainfall is not the cause and attribute the trends to other factors as follows: vertical slope farming 5, cattle rearing 7, population growth 25, deforestation 66 and capital technology 18.

Table 4. Distribution of professions in the study area

Professions	Number of Respondents
Farmer	124
Vegetable Vendor	0
Rice Vendor	14
Hunter	0
Teacher	10
Cattle rearer	52
Others, Specify here,	0

Table shows that a majority of the 200 respondents consulted are farmers. This shows that the perceptions are generally reliable because these farmers are partly responsible for the cultivation of all the cereal in the region.

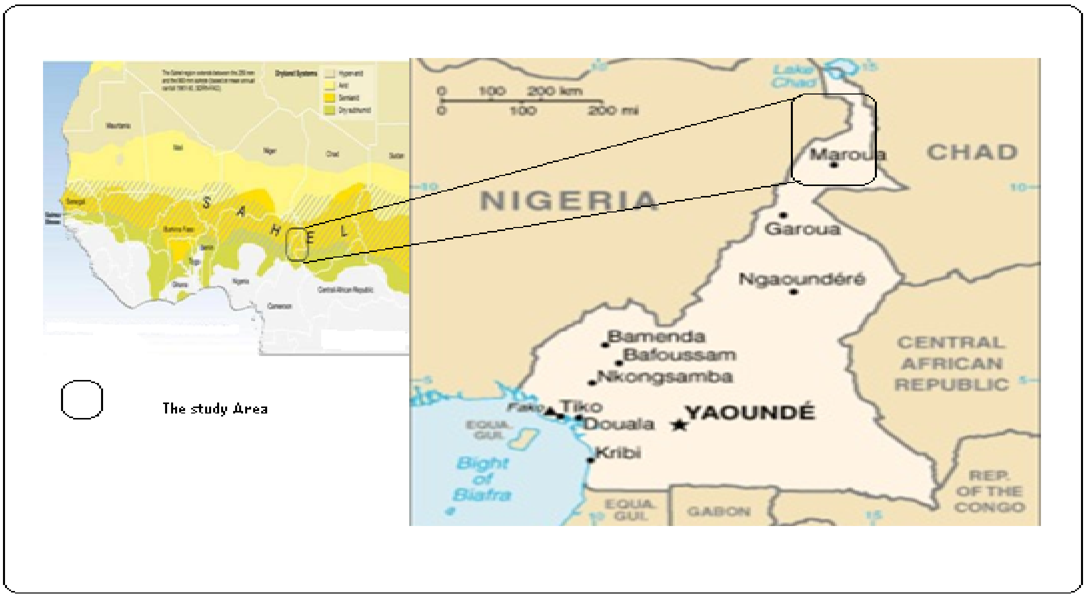

Figure 1. Map showing the study area in Cameroon and in the Sahel of Africa

Figure locates the study area which is the Sudano-Sahelian zone of Cameroon. The specific region of interest is represented by the region within and around the rectangle on the map. Source: Modified from IRIN, (2010) & Cameroon Today (www.cameroon-today.com).

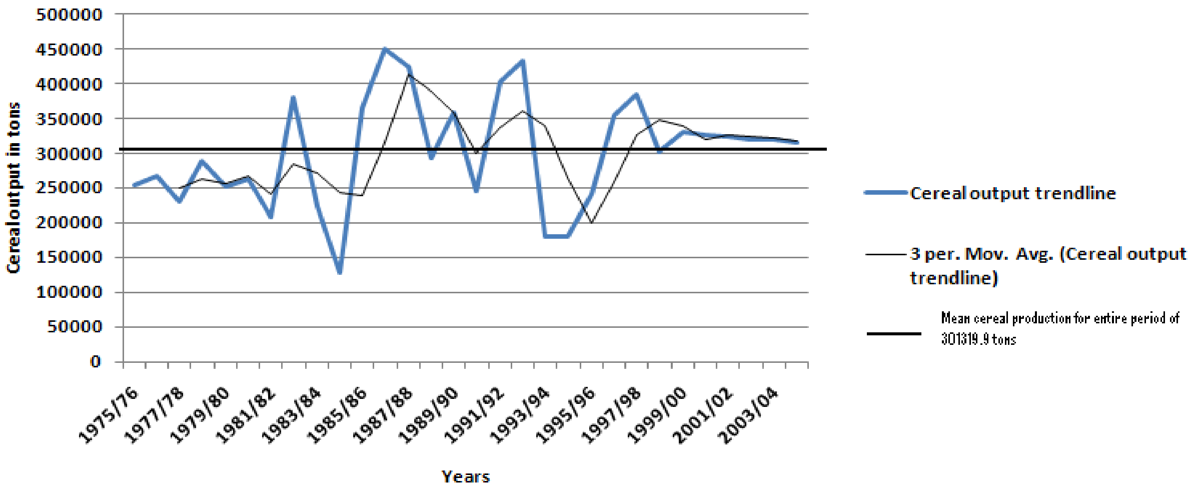

Figure 2. Trends in Cereal production, average production and 3 period moving averages

The horizontal line represents the mean cereal production for the entire periods from 1975-2005, this stands at 301319.9 tons. The thick winding line represents the observed cereal output while the thin winding line is the simulated 3 years moving average for the cereal output. These curves are based on the trends of the actual production over time and not the deficits. In general, even when the curve is smoothened there are several periods below the mean.

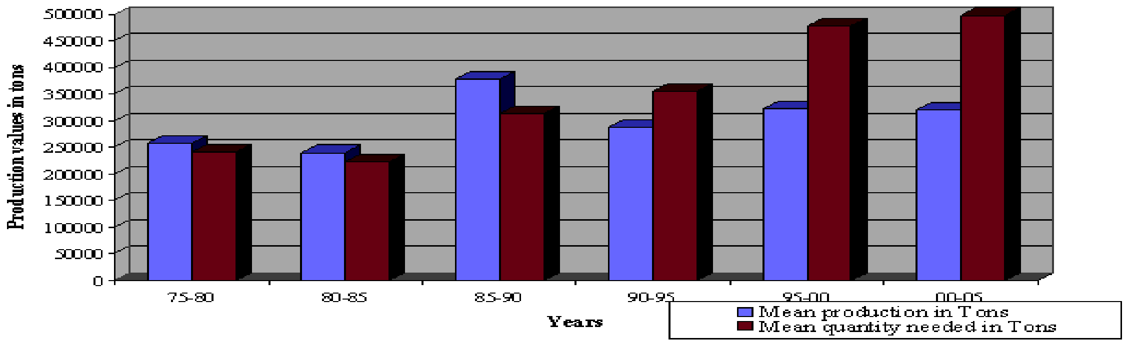

Figure 3. Mean trends of Quantity of cereal Produced and Quantity needed in the Sudano-Sahel of Cameroon

Figure shows the mean trends in the relationship between cereal produced and the quantity needed in the Sudano-Sahelian zone of Cameroon. Each pair of bars represents the means for 5 years. The observations are from 1975 to 2005. Based on these averages, persistent deficits are obtained from 1990 to 2005 meaning quantity of cereals needed is less than cereal produced.

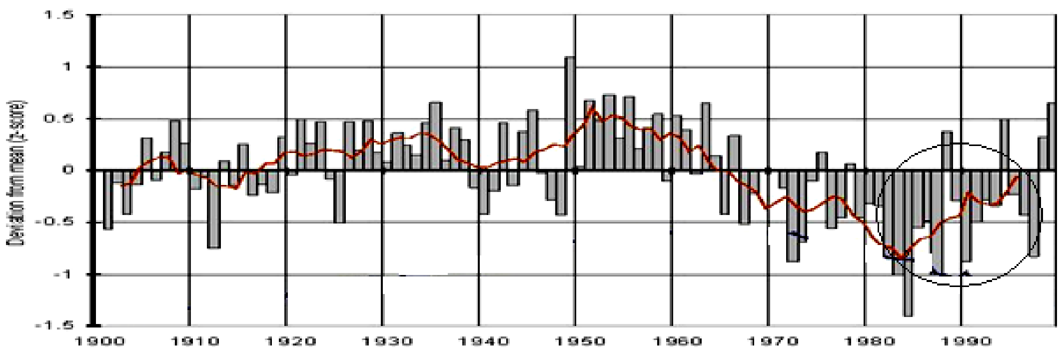

Figure 4. Sahelian Rainfall and the number of Stations providing the Data

Figure shows trends in rainfall over time. The curve that radiates around the bars is generally below the mean from the period 1965 upwards. However, the rising curve from the mid 1990s (see circle on figure) is an indication of rising rainfall as supported by figures 5 and 6.Source: Modified from Olsson & Mryka, (2008).

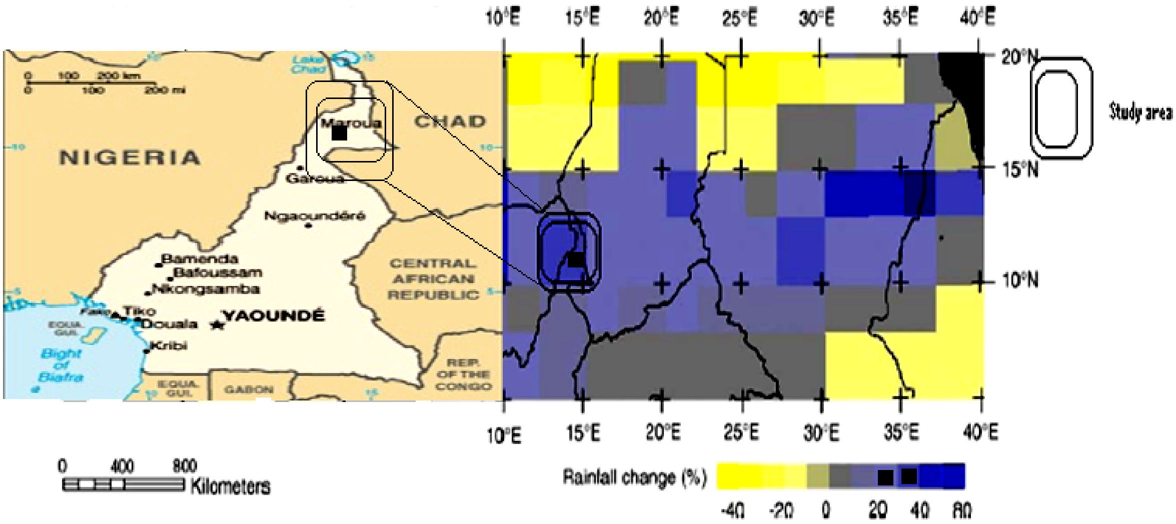

Figure 5. Overall trends in monthly rainfall throughout the period 1982–2003 based on GPCP estimates. Shows the part of the Sahel of Cameroon that has experienced an increase in rainfall. This is represented by the area within and around the double rectangles. A look at the scale below on rainfall % change (black squares) shows that this region has experienced a percentage increase in rainfall of between 20-40%. Source: Modified and downscaled from Herrmann *et al*., (2005) and Cameroon Today (www.cameroon-today.com).

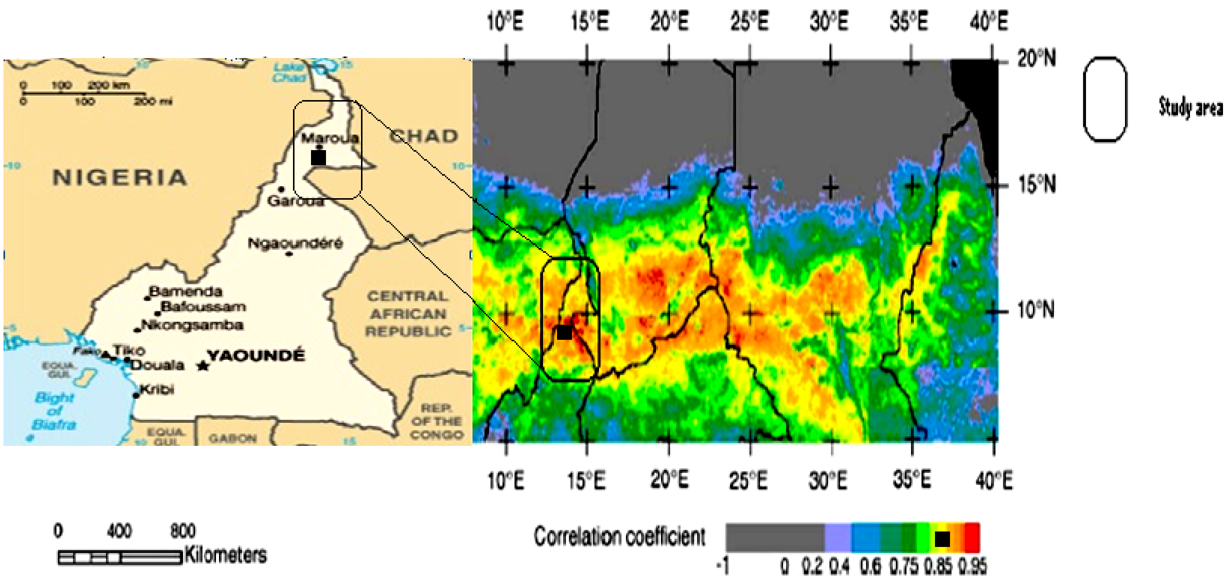

Figure 6. Linear correlations of monthly NDVI with 3-monthly cumulative rainfall based on GPCP estimates for the period 1982–2003

Note that both variables are highly correlated in the Sahel region of Cameroon. This shows the linear correlation between greening and rainfall. As rainfall increases so too does greening increase in the Sahel. In the case of Cameroon, a linear correlation of 0.85 (see black squares) is recorded for the region within and around the rectangle. This shows that the increase trends of greening observed are highly linearly correlated with rising rainfall. The data is based on the Normalised Difference Vegetation Index and rainfall data from the Global Precipitation climatology project. Source: Modified and downscaled from Herrmann *et al*., (2005) and Cameroon Today (www.cameroon-today.com).