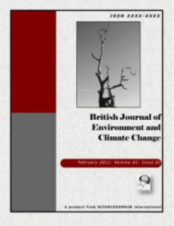

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The Environmental Quadrupole: Forest Area, Rainfall, CO_2 Emissions and Arable Production Interactions in Cameroon

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ABSTRACT

Aims: This paper evaluates the interactions between forest area, CO_2 emissions, rainfall and arable production at a national scale in Cameroon.
Methodology: The data used for this analysis was essentially time series data for all the variables spanning the period 1961-2000. It uses regression analysis to determine the most important of these variables that affects CO_2 emissions and uses correlation analysis and coefficient of determination to verify the nature of the interactions between the variables.
Results: The results show that as forest area reduces there is an increase in CO_2 emissions concentration in the air in Cameroon. On the other hand, as forest area and rainfall reduce arable production also reduces but forest area is seen to be more responsible for changes in arable production than rainfall.
Conclusion: The study concludes that the interactions between CO_2 and forest area, arable production and forest area seem to be the most significant while rainfall is denoted as very variable from year to year.

Keywords: Forest area; CO_2 emissions; rainfall; arable production.

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1. INTRODUCTION

The interaction between CO_2 emissions, rainfall, arable production and forest area is very vital at a global scale in general and at a national scale in Cameroon in particular (Pielke et al., 1998). In general, CO_2 emissions have recently occupied a central stage in environmental discussions because they do not only cause global warming but also affect the world's forests and food production systems (Zhang and Justice, 2001). Rainfall on its part has been known for decades to be a very important factor when it comes to the survival of trees and crops and generally, it is common knowledge that water remains a very important resource to humans (Epule et al., 2011a). Globally, forests have been known for their ability to sequester CO_2, protecting our catchment areas and thus managing the land phase of the hydrological cycle (Zhang and Justice, 2001). The absence or disappearance of forests would have astronomic effects on the environment among which will be an increase in CO_2 (Aber, 2001). The importance of arable production cannot be over emphasized. Food production systems are of great importance to humankind, yet they survive at the expense of large expanses of forests (Pielke et al., 1998).

Cameroon is host to part of the tropical rainforest of the Congo basin which is the second largest rainforest hotspot in the world (FAOSTAT, 2010). As such, the trends of forest area loss in Cameroon will greatly affect the amount of CO_2 that can be sequestered and this will have a feedback on the arable production sub-system as well as the water resources on the land phase of the hydrological cycle (Zhang and Justice, 2001). On the other hand, agriculture is said to be responsible for 96% of the deforestation in most of Africa, Asia and Latin America in general and Cameroon in particular (Epule et al., 2011b; Geist and Lambin, 2002).

Much work has already been done in the area of quantifying the causes of forest area loss in Cameroon, establishing the lost forests based on satellite images and determining the relative importance of rainfall and deforestation in affecting cereal production (Epule et al., 2011b; Lambin and Ehrlich, 1997; Mertens and Lambin, 2000; Mertens and Lambin, 1997). However, the interactions between CO_2 emissions, rainfall, arable production and forest area have not been given adequate attention. This study therefore seeks to verify how forest area dynamics influence CO_2 emissions, rainfall, arable production and how rainfall affects arable production and CO_2 emissions. This approach is vital because a holistic approach of most environmental variables can be explained better from a systemic approach rather than in isolation (Lambin and Ehrlich, 1997).

2. MATERIALS AND METHODS

2.1 Study Area

This study is a national scale study that covers data for all of Cameroon. The intention of analyzing the interactions between forest dynamics, rainfall, CO_2 emissions and arable production at a national scale is guided by the fact that such a scale permits adequate review of the situation as it takes into consideration various regional disparities that are often absent in smaller scale analysis (Lambin and Ehrlich, 1997).

Cameroon is located between latitude 2° N and 13° N of the equator and longitude 8° E and 15° E of the prime meridian (Molua, 2006; Molua and Lambi, 2006) (Figure 1). In the South of the country we have an equatorial climate and a Sahelian climate in the North. The South has more than 1500 mm of rain yearly that is fairly distributed all year round with average annual temperature of about 25°C and deep red ferralitic soils (Molua, 2006; Molua and Lambi, 2006). In the North, annual average rainfall drops to about 400 mm around Lake Chad with temperatures of about 28°C and the soils are essentially ferruginous (Molua, 2006).

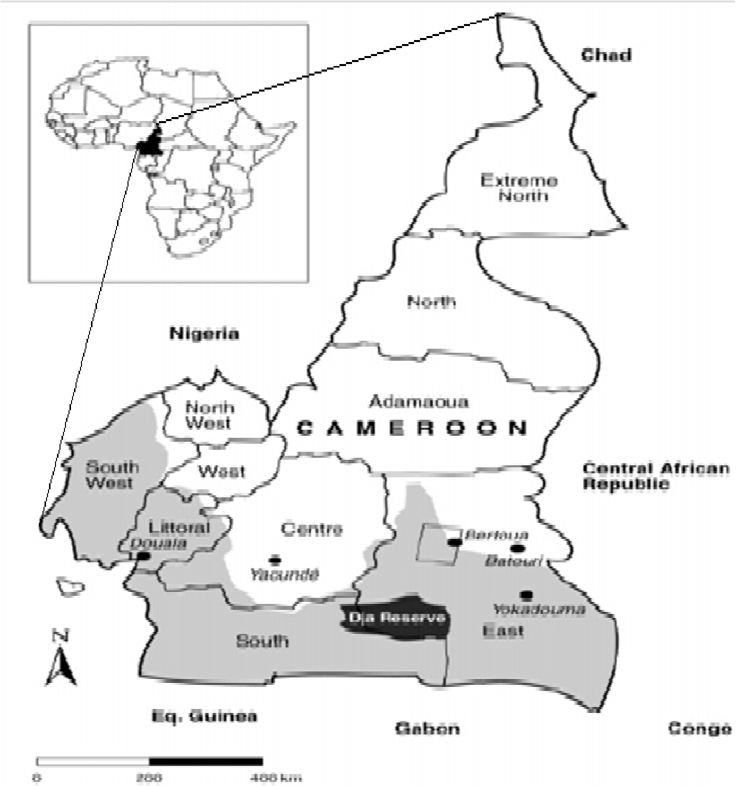

Fig .1. Map of Cameroon showing approximate spatial extent of the tropical rainforests (shaded in light grey) and the grasslands.

The regions to the north are dominated by essentially tropical grassland ranging from Sudan savanna in the Adamawa and North regions, Sahel savanna in the Extreme North and Guinea savanna in the transition zone between the south of the country and the north of the country.
Source: Modified from Mertens and Lambin, (2000).

2.2 Data Collection

To be able to explore the interactions between forest area, arable production, CO_2 emissions and rainfall in Cameroon and the importance of the variables that affect CO_2 emissions, a number of data bases were used. The data on forest area in 000 hectares, arable production per capita index in international $, and CO_2 emissions from forest area change in 000 metric tons was obtained from FAOSTAT (www.faostat.org) and validated with that from World Resource Institute (earthtrends.wri.org) (see appendix, Table 3). Rainfall data was obtained from the online climate data base co-sponsored by the school of Geography and the environment of the University of Oxford and the United Nations Development Program (www.country-profiles.geog.ox.ac.uk). All the data was time series data spanning the period 1961-2000.

To actually get the data, we opened the FAOSTAT and/or WRI data base interfaces, selected the variable of interest, the country and the years of interest for which data was needed and clicked search. With this the data is populated on an excel sheet (Table 3). For the purpose of verifying the reliability and validity of the data, ground observations were made and satellite images from the USGS and NASA were examined.

2.3 Data Analysis

The data was analyzed with the aid of the Statistical package for the social sciences (SPSS) version 19 and the Sigma Plot version 11.0. Three principal analytic tools were applied. These included multiple linear regression analysis, Pearson correlation statistical tool and the coefficient of determination (Motulsky, 1999).

The multiple linear regression approach is used to verify the most significant determinants of CO_2 emissions in Cameroon at a national scale. The equation used to fit the multiple linear models is:

$$y_i = \beta_{0+} \beta_1 x_{i1+} \beta_2 x_{i2+} \beta_3 x_{i3+} \beta_4 x_{i4+ \acute{\varepsilon} i}$$

Where: y_i is the dependent variable (CO_2 emissions), β_0 is the intercept, β_{1+} β_{2+} β_{3+} β_4 partial regression coefficients, $x_{i1}+x_{i2}+x_{i3}+x_{i4}$ independent variables (forest area, rainfall and arable production), $\acute{\varepsilon}_i$ is the error term.

To determine the interactions between the selected variables, the following pairs of correlations were computed, note that the first variable in each pair is the independent variable (x) while the second is the dependent variable (y): (forest area and CO_2 emissions, forest area and rainfall, forest area and arable production, rainfall and arable production and rainfall and CO_2 emissions). The equation used to fit these models is:

$$r=\sum(x-\mu)\ (y-\mu) / \sqrt{\sum(x-\mu)^2 \sum(y-\mu)^2}$$

Where: r is the Pearson correlation coefficient, x is the independent variable, y is the dependent variable ,µ is the mean of both variables, r ranges as follows: $-1.0 \leq r \leq 1.0$, where: -1.0 to -0.7 strong negative associations, -0.7 to -0.3 weak negative association. -0.3 to +0.3 little or no association, +0.3 to +0.7 weak positive association, +0.7 to +1.0 strong positive association.

The coefficient of determination (r^2) was also used to determine how well the regression line represents the collected data and the extent to which variations in y are explained by the linear relationship between x and y. It ranges between $0 \leq r^2 \leq 1$. This is often computed by simply squaring the Pearson correlation coefficient (r).

3. RESULTS AND DISCUSSION

The linear regression outputs show that forest area is the most significant variable that affects CO_2 emissions. As forest area declines CO_2 emissions increase (Figure 2). Arable production and rainfall are second and third respectively. This is evident in the fact that forest area has a t-value of -21.32 which is the highest, heralding a larger effect on CO_2 and a p-value of 0.001 which is the smallest of all the p-values. This p-value shows that there is only a 0.1% chance of observing a difference in the result. Generally, the smaller the p-value, the more reliable the results. Arable production has a t-value of -1.27 and a p-value of 0.086 (8.6%), this denotes an 8.6% possibility of a difference as large as observed while rainfall has a t-value of -0.61 and a p-value of 0.552 (55%), this denotes a 55% possibility of a difference as large as observed. From all indications, rainfall remains the most variable factor and its influence on CO_2 emissions is weakest (Table 1).

Table 1. Linear Regression model with three most significant determinants of CO_2 emissions including land use change

Variables	Coefficient	Standard error	t-value	Ranks of t-value	p-value
Forest Area	-0.94	0.34	-21.32	1	0.001
Arable production	-0.05	95.59	-1.27	2	0.086
Rainfall	-0.02	-0.61	-0.61	3	0.552

Independent variables = 3(forest area in 000 hectares, arable production per capita index In international \$ and rainfall in mm), dependent variables = 1 ($C0_2$ emissions including Land use change in 000 metric tons). The r is 0.983, r^2 is 0.965, adjusted r^2 is 0.962 and F statistics is 324.693.

Time series plots of the evolution of forest area and total CO_2 emissions from forest area change are consistent with the regression analysis results and depict forest area in a declining linear trend while there is a rise in total CO_2 emissions. The linear trend of forest area is evident because the model assumes a constant yearly decline in forest area of 220000 hectares inspired from FAO, 1990; FAO, 2010 (Figure 2). The World Bank, (2011) supports this trend in CO_2 in Cameroon when it argues that the CO_2 emissions per capita in metric tons have risen from 0.09 in 1990 to 0.21 in 2005 to 0.24 in 2006 and to 0.34 in 2007.

However, the current trends of increase are not as high as the 0.66 recorded in 1983. This is explained by the increase in newly established industries and wide scale reckless deforestation and a lack of compliance to regulations to curb emissions. The 1990s on the other hand saw the birth of the national environmental management plan(NEMP) that called for strict enforcement of environmental regulations in Cameroon, the reason why the emissions from the 1990s are relatively lower than the period before (Biwas and Tortajada, 2011). The conclusion that CO_2 emissions are however rising in Cameroon are consistent with many other sources (Mundex Index, 2011; WRI, 2003; Detwiler and Hall, 1988; Lugo and Brown, 1992; Dixon et al., 1994; Houghton, 1995; The World Bank, 2011).

In terms of scatter plots, an inverse relationship between forest area and total CO_2 emissions is observed (Figure 5). As forest area reduces, CO_2 increases and vice versa. This model appears to be the most reliable of all the models as already mentioned above because it has an r^2 of 0.963 which signifies that about 96% of the variations in CO_2 emissions are explained by the linear relationship between forest area and CO_2 emissions. The r of -0.981 also goes to reinforce the notion of a very strong negative or inverse association or correlation between forest area and total CO_2 (Figure 5 and Table 2).

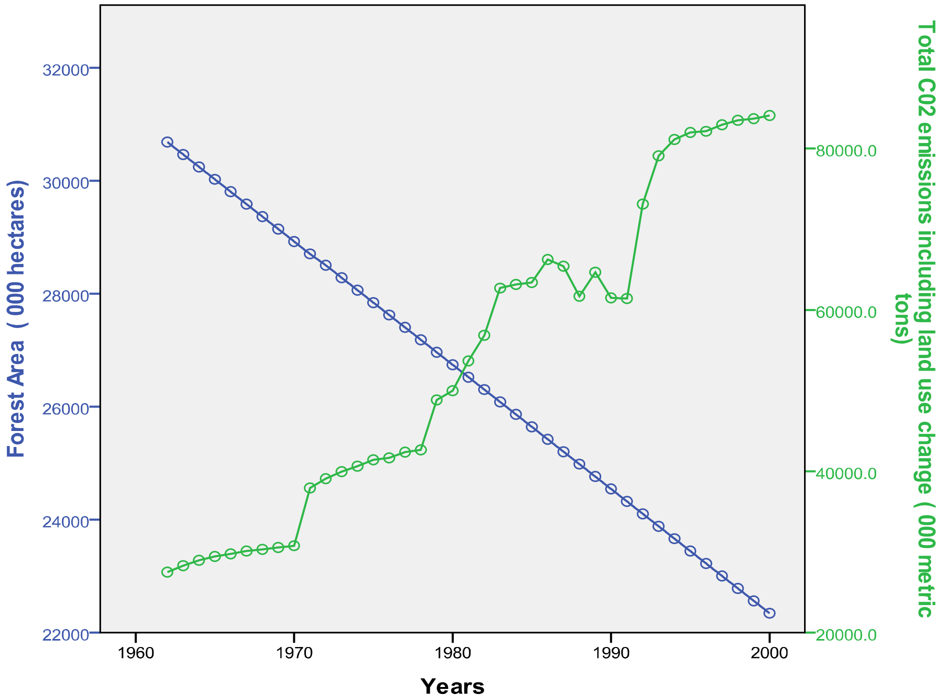

Fig. 2. Time series plot of the evolution of Forest area and total CO_2 emissions.

The observed trends in rainfall can be described as a”white noise” since rainfall is a highly random variable which barely has a fixed trend and therefore remains highly variable. However, the generalized trend is that of higher rainfall before the 1960s, very low rainfall in the late 1960s and early to mid 1980s due to droughts and rising but highly variable rainfall from the 1990s with some years of increase and others of decrease. However, with the 1990 levels of rainfall being much lower than what obtained in the later years, as is the case in the Sahel of Cameroon at moment but between 1999/2000 a declining trend is observed (Epule et al., 2012a) (Figure 3). This is closely consistent with several studies which argue that sub-Saharan African rainfall is highly variable yet increasing at the moment (Olsson and Mryka, 2008; Wang and Eltahir, 2000; Anyamba and Tucker, 2005). However, in terms of the influence of rainfall on CO_2 emissions, a very weak relationship is established (Table 1, Figure 9). This is explained by the fact that the very variable and increasing rainfall cannot be used to explain forest loss which is being impacted negatively by population growth (Olsson and Mryka, 2008; Epule et al., 2012a).

In terms of correlation between forest area and rainfall we observe a relationship with an r of 0.377 which depicts a weak correlation. The slightly positive trend is explained by the variability of rainfall and the fact that at the end of the simulation (1999/2000) we observe declining rainfall. The r^2 of 0.142 depicts that about 14% of the variations in rainfall are explained by the linear relationship between forest area and rainfall which remains very weak.

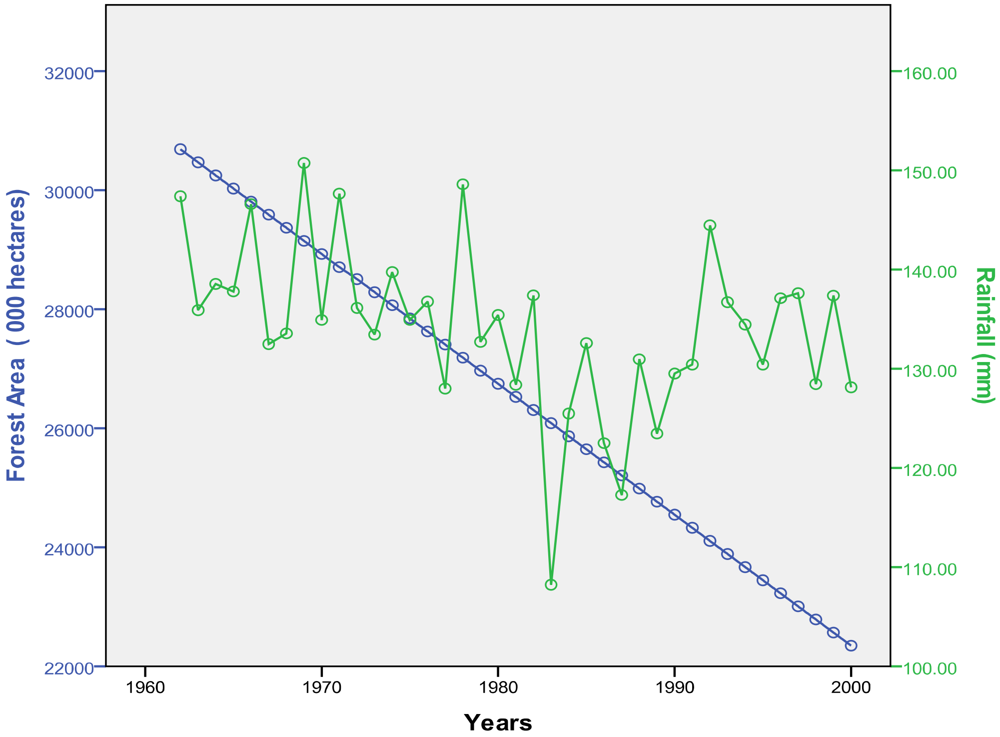

Fig. 3. Time series plot of the evolution of forest area and rainfall.

Though the relationship is weak, an important view point here is that both forest area and rainfall are moving towards the same direction. The increasing greening observed in the Sahel of Cameroon from the 1990s is for example a reflection of the increase in rainfall (Olsson and Mryka, 2008; Eklundh and Olsson, 2003; Epule et al., 2012a). This also helps us to conclude that when forest area declines it reduces the amount of water available in the ecosystem by disrupting the land phase of the hydrological cycle (Figure 6 and Table 2). On the other hand, rainfall is not a significant determinant of forest area dynamics (Epule et al., 2011b).

Arable production per capita index also observes a generalized declining trend with declining forest area with the lowest levels in the series obtained during the droughts of the 1980s when most of the moisture available from rainfall was not available for crop growth (Figure 4). According to Epule et al., (2012a) the fact that rainfall was rising in the mid 1990s and arable production still declined, means that this decline is essentially explained by the large scale deforestation in Cameroon that affected food supplies. This argument is supported by Molua and Lambi, (2006) and Olsson and Mryka, (2008).

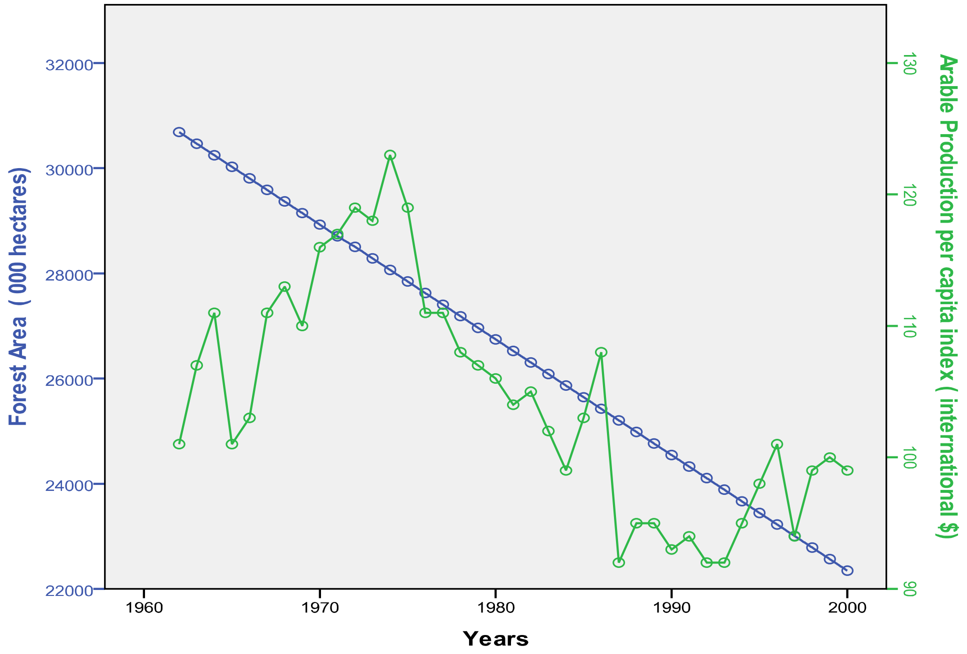

Fig. 4. Time series plot of the evolution of forest area and arable production per capita index.

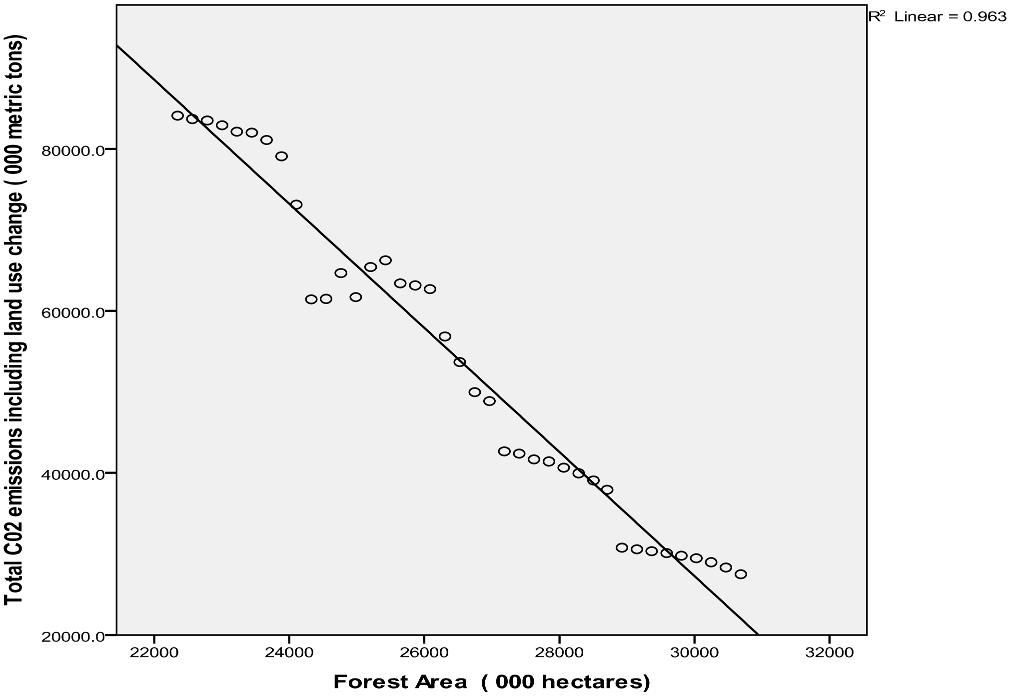

Fig. 5. Scatter plot of the inverse relationship between forest area and total CO_2.

Table 2. Pearson correlation and coefficient of determination results of the model

Independent variables	Dependent variable	Pearson's R	R^2
Forest Area	CO_2 emissions	-0.981	0.963
Forest Area	Rainfall	0.377	0.142
Forest Area	Arable production	0.668	0.446
Rainfall	Arable production	0.268	0.072
Rainfall	CO_2 emission	-0.389	0.151

Forest area is expressed in 000 hectares, $C0_2$ emissions is expressed in 000 metric tons, Rainfall is expressed in mm and Arable production per capita index in international \$. There are 40 years of time series data significant at 0.01 level (2-tailed).

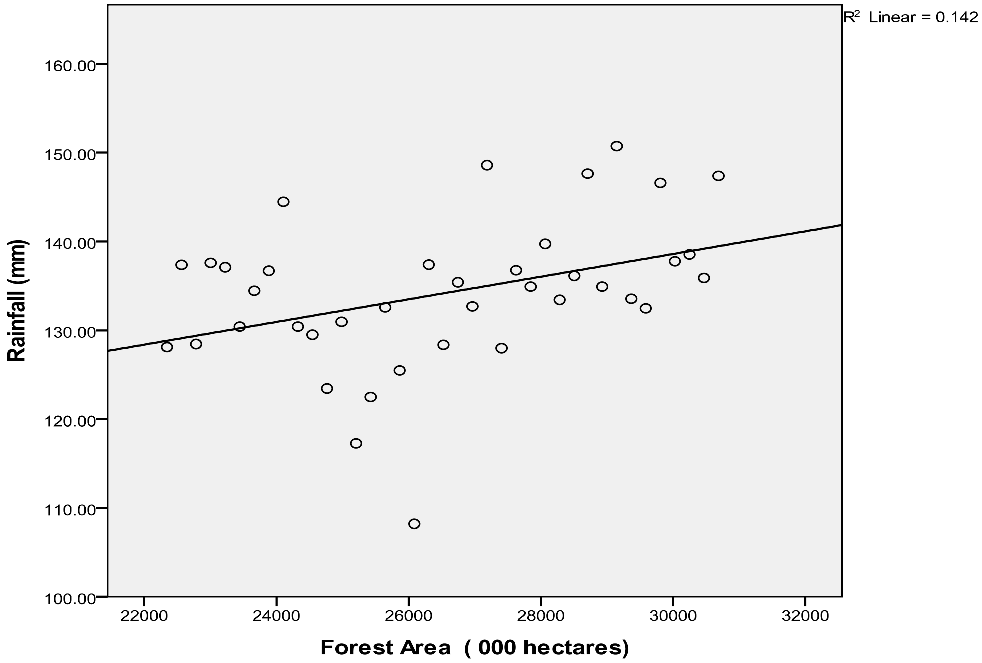

Fig. 6. Scatter plot of the correlation between Forest area and rainfall.

The correlation between rainfall and arable production per capita index depicts a relationship in which as rainfall decreases so does arable production per capita index and vice versa. The r of 0.268 depicts a weak association or correlation between rainfall and arable production per capita index. The r^2 of 0.072 means that about 7.2% of the variations in arable production can be explained only by the linear relationship between rainfall and arable production (Figure 7 and Table 2). This goes to confirm the fact that rainfall cannot be used to explain the declining trends observed in food production in the area. This is so because at the moment rainfall is rising in the region and at the same time food production is still in a deficit because the effects of declining forest area affect arable output more, this goes to explain why such a weak correlation exist (Epule et al., 2012a; Anyamba and Tucker, 2005).

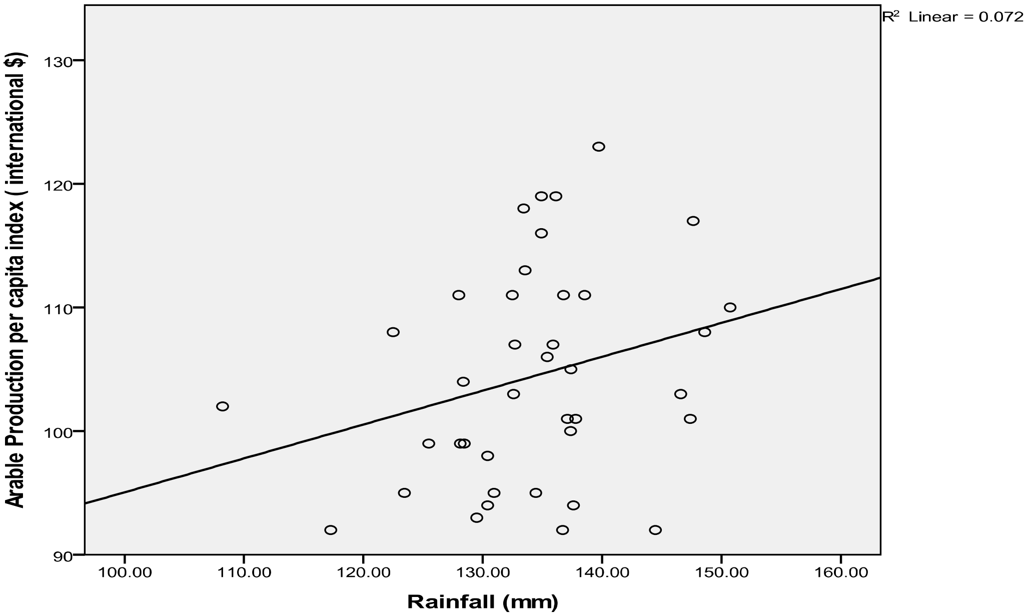

Fig. 7. Scatter plot of the correlation between rainfall and arable production per capita index.

Scatter plots of the correlation between forest area and arable production per capita index depicts a relationship in which as forest area reduces so does arable production per capita index and vice versa. The r of 0.668 depicts a fairly moderate positive association or correlation between forest area and arable production per capita index. The r^2 of 0.446 depicts about 44% of the variations in arable production can be explained by the linear relationship between forest area and arable production. The level of predictability of this model is ranked at slightly below average but better than in figure 7, this means that changes in forest area account for changes in arable production better than rainfall does account for changes in arable production (Figure 8 and Table 2). Forest area decline affects arable production per capita by reducing the amount of water available in the land phase of the hydrological cycle. Epule et al., (2012a) argue that forest area is a more dynamic factor that affects arable production in the region than rainfall. These views are supported by, (Hulme, 2001; Olsson and Mryka, 2008; Eklundh and Olsson, 2003).

Finally, scatter plots of the correlation between rainfall and total CO_2 emissions depicts an inverse relationship in which as rainfall reduces, CO_2 increases and vice versa. The r of -0.389 depicts a weak negative or inverse association or correlation between rainfall and total CO_2 emissions. The r^2 of 0.151 depicts that only about 15% of the variations in CO_2 emissions can be explained by the linear relationship between rainfall and forest CO_2 emissions. The relationship between rainfall and CO_2 is usually indirect as decrease rainfall only increases CO_2 by reducing forest area. Therefore, forest area is affected more by deforestation rather than by rainfall (Figure 9 and Table 2) (Epule et al., 2011b; Wang and Eltahir, 2000).

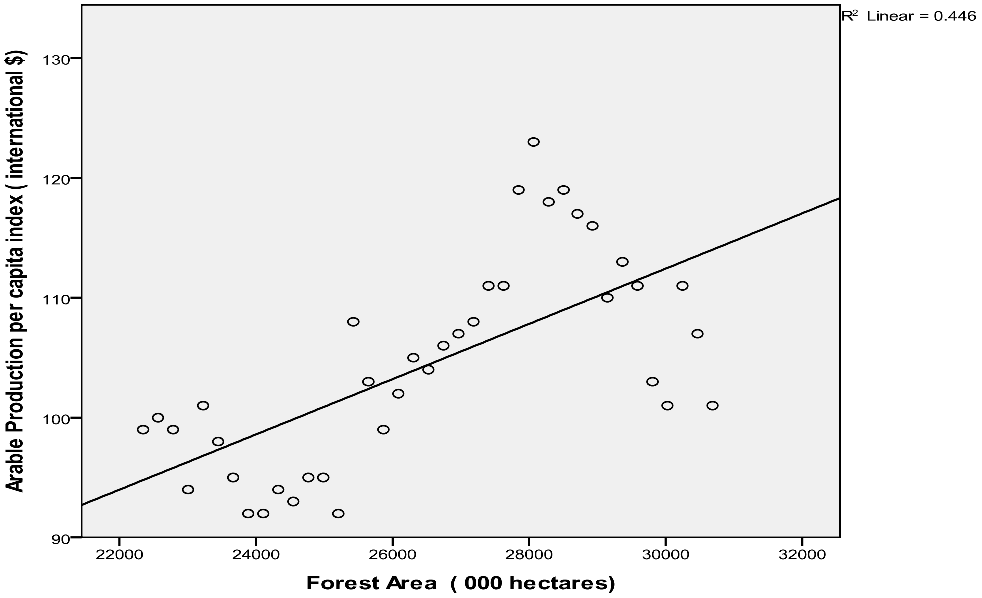

Fig. 8. Scatter plot of the correlation between Forest area and Arable production per capita index.

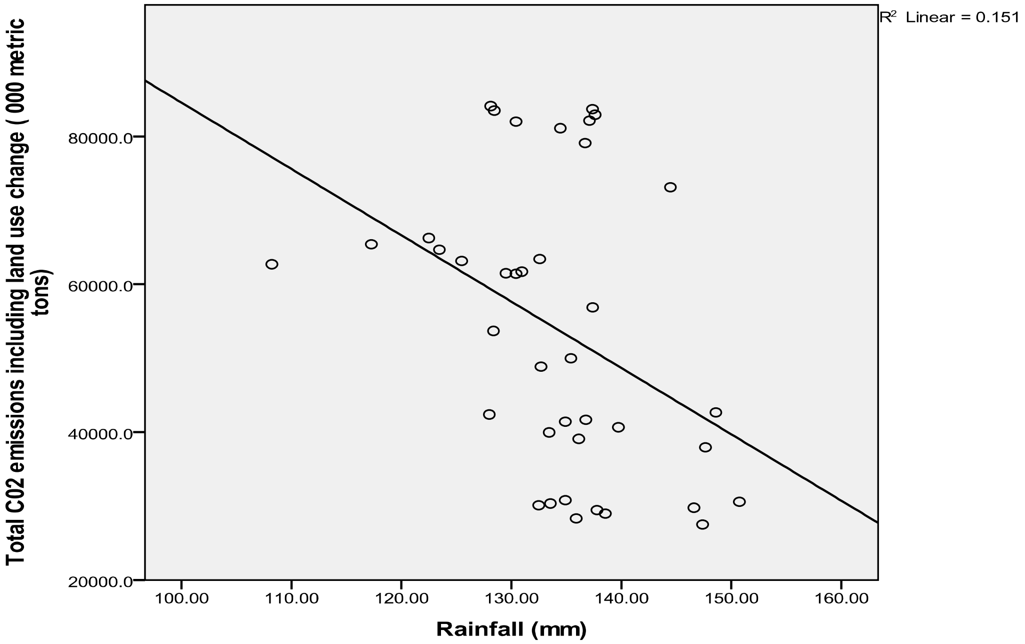

Fig. 9. Scatter plot of the correlation between rainfall and total CO_2 emissions.

4. CONCLUSION

This study concludes that there is a very intricate interaction between rainfall, CO_2 emissions, forest area and arable production. However, it is even more significant to note that according to this study the most significant variable that affects CO_2 emissions in Cameroon is forest area dynamics and the most significant variable that affects arable production is forest area. This is because as forest area reduces the CO_2 in the atmosphere increases and vice versa. Also, as forest area declines, arable production also declines. There is a weaker correlation between rainfall and arable production (when compared to that between forest area and arable production) in which as rainfall reduces arable production also reduces. From the simulations, rainfall is very variable and remains a very uncertain factor that cannot explain arable production adequately as it rises in the 1990s and between 1999/2000 it falls. However, this study proposes that the use of compost fertilizers could help improve arable production in Cameroon (Epule et al., 2012b). Other studies could be carried out at continental scales in Africa and other regions of the world to test these results. It is also recommended that more variables be brought into other analysis; these may include the effects of fertilizers, temperature and winds which are not considered in this study.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Table 3. Raw Data of the core variables under consideration

Years	Total CO2 emissions from forest area loss (000 metric tons)	Forest Area (000 hectares)	Rainfall (mm)	Arable Production per capita index (international $)
1961	26424.4	30907	139.92	97
1962	27503	30687	147.38	101
1963	28314.3	30467	135.89	107
1964	28975.6	30247	138.54	111
1965	29458.4	30027	137.78	101
1966	29771.4	29807	146.59	103
1967	30110.1	29587	132.48	111
1968	30343.4	29367	133.55	113
1969	30565.7	29147	150.73	110
1970	30780.5	28927	134.91	116
1971	37929.5	28707	147.64	117
1972	39083.9	28505	136.13	119
1973	39959	28285	133.43	118
1974	40653.2	28065	139.73	123
1975	41420.5	27845	134.91	119
1976	41674.5	27625	136.77	111
1977	42382.9	27405	127.99	111
1978	42662.6	27185	148.59	108
1979	48859.5	26965	132.7	107
1980	49981.7	26745	135.41	106
1981	53687.8	26525	128.37	104
1982	56865.6	26305	137.39	105
1983	62706.8	26085	108.21	102
1984	63152.3	25865	125.48	99
1985	63411.1	25645	132.58	103
1986	66258	25425	122.49	108
1987	65413.5	25205	117.26	92
1988	61710.8	24985	130.95	95
1989	64686.4	24765	123.45	95
1990	61490	24545	129.5	93
1991	61429.3	24325	130.41	94
1992	73131.4	24105	144.46	92

Table 3 continues……

1993	79107	23885	136.7	92
1994	81111	23665	134.45	95
1995	82007.4	23445	130.41	98
1996	82137.9	23225	137.1	101
1997	82936.3	23005	137.6	94
1998	83502.9	22785	128.45	99
1999	83696.5	22565	137.37	100
2000	84105.5	22345	128.12	99

Sources. www.faostats.org, www.wri.org, www.country-profiles.geog.ox.ac.uk

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