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Variation of climate indices and its effects on maize production from 1950 to 2012 in Cameroon

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ABSTRACT

Description of subject. In the agricultural sector in Cameroon, the changes in climate variables are the great challenge facing each year by farmers and maize producers. The innovation of this study is the integration of soil moisture as a climate essential variable in the analysis of the change in climate (as recommended by WMO). More often, less study has been done to establish a link between the variation in Cameroon climate indices and the global climate indices. Rainfall, temperature, and soil moisture data have been downloaded as well as the maize Yield and global climate indices to determine the type of relationship among the climate variables and the yield.
Objective. This study was conducted to analyze the change in climate variables from 1950 to 2012 and to examine the effects of the changes in climate indices on Maize Yield in Cameroon.
Methods. Statistical methods were performed to question the change in climate variables (rainfall, temperature, soil moisture) from 1950 to 2012. The output data format use in this research are excel files and netcdf file. The excel format has been analyzed in the statistical tools such as R, SPSS and Excel 2016.
Results. Findings from this study revealed that temperature is increasing significantly (p-*value* $0.0017<0.05$), while the precipitation is decreasing significantly (p-value $0.003<0.05$) from 1950 to 2012. Although there is an increase in total soil moisture over Cameroon, there is a significant relationship between soil moisture and precipitation. These changes are significantly related to the Tropical South Atlantic Index located at the Atlantic Ocean which is next to Cameroon.
Conclusion. Additionally, Soil moisture is increasing with yield but there is not a significant relationship among both variables. So, the growth of yield cannot be explained based on soil moisture because they are other factors that can explain the increase in maize yield.

Keywords: Global climate indices, Climate variables, Rainfall, Soil moisture, Temperature

RESUME

Variation des indices climatiques et ses effets sur la production de maïs de 1950 à 2012 au Cameroun
Description du sujet. Dans le secteur agricole au Cameroun, les changements des variables climatiques constituent le grand défi auquel font face chaque année les agriculteurs et les producteurs de maïs. L'innovation de cette étude est l'intégration de l'humidité du sol comme variable climatique essentielle dans l'analyse des changements climatiques (comme recommandé par l'OMM). Le plus souvent, peu d'études ont été faites pour établir un lien entre la variation des indices climatiques du Cameroun et les indices climatiques globaux.
Objectif. Cette étude a été menée pour analyser le changement des variables climatiques en lien avec des indices climatique globaux de 1950 à 2012 et pour examiner les effets des changements des indices climatiques sur le rendement du maïs au Cameroun.
Méthodes. Les données relatives aux précipitations, à la température et à l'humidité du sol ont été téléchargées ainsi que le rendement du maïs et les indices climatiques globaux afin de déterminer le type de relation entre les variables climatiques et le rendement. Des méthodes statistiques ont été effectuées pour questionner le changement des variables climatiques (pluviométrie, température, humidité du sol) de 1950 à 2012. Les formats de données de sortie utilisés

dans cette recherche sont les fichiers Excel et le fichier Netcdf. Le format Excel a été analysé dans les outils statistiques tels que R, SPSS et Excel 2016.
Résultats. Les résultats de cette étude ont révélé que la température augmente significativement (p-value 0.0017<0.05), tandis que les précipitations diminuent significativement (p-value 0.003<0.05) de 1950 à 2012. Bien qu'il y ait une augmentation de l'humidité totale du sol sur le Cameroun, il existe une relation significative entre l'humidité du sol et les précipitations. Ces changements sont significativement liés à l'indice Tropical South Atlantic situé au niveau de l'océan Atlantique qui est voisin du Cameroun.
Conclusion. De plus, l'humidité du sol augmente avec le rendement mais il n'y a pas de relation significative entre les deux variables. Donc, la croissance du rendement ne peut pas être expliquée sur la base de l'humidité du sol car il y a d'autres facteurs qui peuvent expliquer l'augmentation du rendement du maïs.

Mots-clés : Indices climatiques globaux, variables climatiques, précipitations, humidité du sol, température.

1. INTRODUCTION

Maize is cultivated and eaten in every part of the country in different ways according to the culture and the ethnics. Agriculture is practiced at the subsistence scale by local farmers using simple tools. This type of agriculture constitutes more than ¾ of the population in the country. The production is used to solve financial problem and food. The production of maize is the best way in Cameroon to reduce malnutrition and famine because maize is adapted to several eating habits depending on the ethnic and social groups in the regions of Cameroon. It can be eaten in many ways. For example, maize is eaten as *Sanga* (in center and littoral region), as *salad donuts, cornbread, and soup (*in all countries), *in form of* boiled or grilled and as a “ball" of flour cooked in hot water (in all country). Consumption of porridge, on the other hand, has significantly increased in households and Muslim communities, especially during the fast of Ramadan.

The porridge represents the food of entry during the daily end of fasting. In the last three decade, the behavior of the climate has change and the maize producers have been facing some problems such as drought, decreasing in rain fall, increasing in temperature and the multiplication of maize diseases. For example, the 20 centuries has been considering by some authors as a period during which ocean forcing dominated drivers of climate change and climate variability in many parts of Africa (Biasutti *et al.,* (2008).

Several studies have previously investigated and discussed the relationships between the Sea surface temperature and rainfall over the African continent (Becker *et al.*, 2010; Indeje *et al.*, 2000; Awange *et al.*, 2013). This type of research is limited in Cameroon, except Molua *et al.* (2007), (Mena, 2015) and Abessolo *et al.* (2017) who considered the El Niño episodes as the origin of most drought episode in Cameroon. Nicholson and Kim, 1997 demonstrated that Central Africa is among those global areas where ENSO events have been reflected in both precipitation and temperature anomalies. Consequently, a severe decrease of annual rainfall total has occurred in Cameroon under the influence of El Niño.

Seasonal precipitation during June-July-August (JAS) is usually below normal in the warm ENSO phase but above normal in the cold ENSO phase (Janicot,1997). On the other hand, the occurrence of Sahel droughts and the recent partial rainfall recovery in the Sahel has been linked to the Atlantic Multi-decadal Oscillation (Sutton and Hodson, 2005; Hagos and Cook, 2008; Mohino *et al.* 2011). It shows that the change in climate in Cameroon can be linked to the sea surface temperature at the Guinea Golf in the tropical Atlantic Ocean.

The country is fronting a serious problem in the quantity of maize produced each year. It is not sufficient for all population. That is why the last decade was characterized by an importation of about billions of tons of maize to solve the deficit in the national production (Agristat 17). Even though the trend of the production increases each year, it is not enough for all population. Climate change has been pointing out as one of the major factors causing damages on the crop growth and yield.

The study intends to analyze the changes in climate in Cameroon and correlate the changes with atlantics sea surface temperature indices. Moreover, the study will examine the impact of climate change on maize growth and Yield.

2. MATERIAL AND METHODS

2.1. Data collection

The precipitation and temperature data use in this research come from different sources such as the national meteorological services and the national observatory on climate change. Due to the missing data in the national database, we have download Climate Research Unit CRU4.0 high resolution data of

Cameroon. The data (rainfall and temperature) cover the period from 1950 to 2015. The southern oscillation index, dipole mode index and tropical south oscillation index data was obtained from the National Center of atmospheric Research (NCAR) and the Climate Prediction Center (CPC, https://www.cpc.ncep.noaa.gov/data/indices/)
The soil moisture data has been downloaded at the Global output data from https://wci.earth2observe.eu/portal/absence, due to the absent of insitu soil moisture measurement.

2.2. Methods of data analysis

The Earth 2 observing satellites especially the water cycle integrator portal has been used to downscale the research area for soil moisture data. The portal proposes many indices output data such as standard soil moisture index, leaf area index, root moisture, the standard precipitation and evapotranspiration index. The index mentioned above has been performing in the portal through the multiple models incorporated in the portal.

2.3. Correlation and regression of climate variables

The regression line for the evolution of climatic elements is defined according to the following equation:
Y = Ax + B with: A = cov (x, y) / X² and B = m (y) - am (x)
With A, the slope of the regression line with respect to the x-axis, or again the rate Average precipitation growth per time unit and B the vertical coordinate of the intersection between the regression line and the y-axis. The method is based on a combination of regression analysis and nonparametric statistical tests (Easterling & Peterson, 1995). The technique is a two-phase regression, in which the time series tested is the predictant and time is the predictor. It was presented by Solow (1987) and then modified by Easterling and Peterson (1995), Elsner, Jagger, & Niu (2000), and Lund (2002). In addition, the Pearson rank correlation was used to examine the relationship between climate variables, global climate indices and maize yield. It is defined according to the following equation:

$$r_{xy} = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\ \sqrt{n\sum y_i^2 - (\sum y_i)^2}}$$

The Pearson correlation coefficients do not provide information on the degree of significance of a relationship because it also depends on the number of observations. To determine if a relationship is significant, a hypothesis test have been carried out as follows: (1) H0: there is no relationship between the two characters X and Y (2) We set a risk of error for the rejection of H0 (example alpha = 0.05) (3) We calculate the absolute value of the correlation coefficient r (X, Y) in the corresponding table (Pearson) (4) We calculate the theoretical value r (alpha, N.) of this coefficient which is only exceeded in alpha% of cases (5) We test H0 true (6) We accept or reject H0.

2.4. Analysis Tools

Statistical methods were performed to question the change in climate variables (rainfall, temperature, soil moisture) from 1950 to 2012. The output data format use in this research are excel files and netcdf file. The excel format has been analyzed in the statistical tools such as R, SPSS and Excel 2016. Two main statistical approach has been used. The descriptive analysis (mean, median, standard deviation, maximum, minimum) of the main variable of our study (rainfall, temperature, soil moisture). And the interferential analysis helps to evaluate the cause and effect relationship between variables. This has been done through correlation analysis, regression analysis, time series analysis, hypothesis testing and level of significant, rejection or fail to reject the $H_{0.}$ On the other hand, the NETCDF data has been use especially for maps. After downloading the different data mention above, we use the ArcMap 10.2.1 for the analysis. In the software, we import the data, calculate the statistics of each layer, display and plot the netcdf data and then we verify the extent of layer and export the final map.

3. RESULTS

3.1. Changes in climate variables in cameroon

Change in rainfall and temperature

Cameroon presents a low variation of temperature from 1950 to 2012. The trend line shows an increase in temperature with time. The percentage of the variation of temperature with time is 14 % (R^2=0.14). Even though the temperature has a low percentage of variation with time, the linear regression analysis shows a significant change in temperature with time (*p-value (0.003) <0.05*). The annual mean temperature is 24.7 ℃. The maximum temperature is 25.4℃ and the minimum temperature is 24.1 ℃. In the studies period, about 40 % of year have a temperature lower than the mean and about 60 % of years have a temperature higher than the mean. It indicates a significant level of temperature change in from 1950 to 2012. The amount of changing in temperature is given by slope (-2.213) over time (1950-2012).

From one year to another, the rainfall changes in Cameroon. From 1950 to 2012, there is a decrease in precipitation in Cameroon. Nicholson in her study (2001) computes the decline of rainfall in the Gulf of Guinea (Cameroon) when compared to 1931-1960, as a drying of 6 % for 1970-1979 and of about 7 % for 1980-1989 (Aguilar, 2009) also showed a clear representation of climate change in the region, with clear warming and the total precipitation decreasing due to changes in the amount of precipitation from heavy events or the length of the maximum number of consecutive wet days. The regression line analysis shows with *the p-value (0.0017) <0.05* a significant decrease of rainfall with time (from 1950 to 2012). This result is supported by the national plan of adaptation to climate change in Cameroon, publish in 2015, which shows that the climatic changes observed in Cameroon the last 50 years is characterized by a regression of precipitation since 1960, -2.2 % per decade. Doukpolo (2014) also supports that rainfall patterns will also be affected and may drop by more than 20-30 % from the 1961-1990 reference level used by the World Meteorological Organization (WMO). The long term mean precipitation from 1950 to 2012 is 1609.8 mm with a confident interval which is within 1583.4mm to 1636.3mm. The maximum rainfall 1816.7 mm is observed in the year 1969 and the minimum 1309.4 mm in the years 1983. In general, 15 % of rainfall (R^2= 0.15) varied from 1950 to 2012. The amount of variation over time of rainfall has been examine by using slope equation which present an amount of 0.0057 each year. The result shows finally that there is a significant increase in temperature and a decrease in rainfall in Cameroon (figure 1).

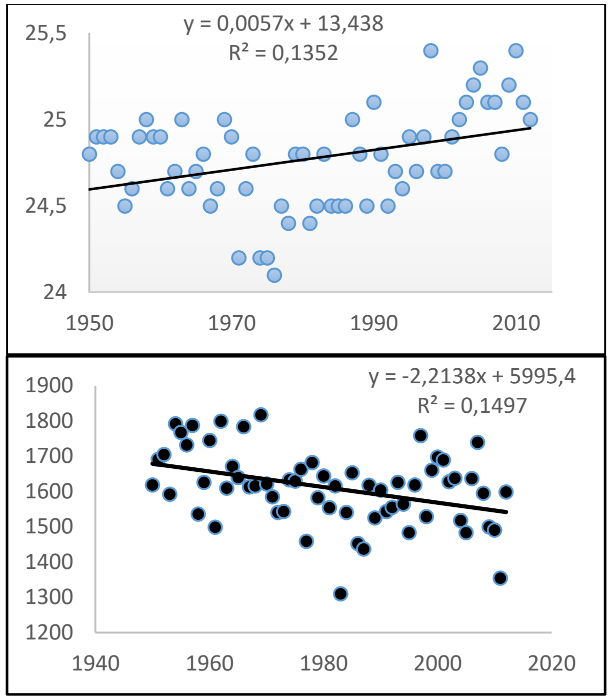


Figure 1. Regression line of climate variable in Cameroon (a) Temperature (b) rainfall

Change in soil moisture

Climate, soil and its characteristics are the major geophysical factors of maize production in Cameroon. Evaporation plays a key role in the reduction of soil moisture. High temperature is the source of water deficit throughout the process of evaporation. Drought causes a serious damage to the soil and plant growth by reducing the moisture content. The Standard soil moisture index shows a deficit in soil moisture in the far North and North region. The same situation is observed in the south and central region of Cameroon.

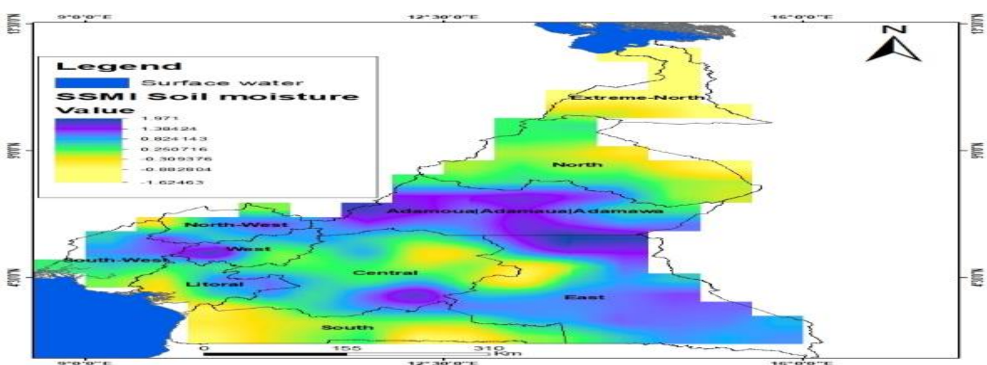


Figure 2. Spatial distribution of SSMI (standard soil moisture index) in Cameroon (1983-2012)

Figure indicates that the standard soil moisture index is present in each region of Cameroon. The values vary from positive number to the negative number. The positive number shows the increase, and the negative shows the decrease in soil moisture.

Gradually, all country is facing the deficit of soil moisture. The spatial representation of SSMI, gives the state of soil moisture in each region of Cameroon.

It is important to mention that drought which is the main factor of the deficit in soil moisture, is the result and the consequence of climate change. Its multiplication reduces the soil moisture. A simple regression line of soil moisture index from 1983 to 2012, shows an increasing from negative values to the positive value (fig3). The annual percentage of the variation in soil moisture index is low (10 %). There is no significant variation in soil moisture from 1983 to 2012 (0.36<0.05 alpha).

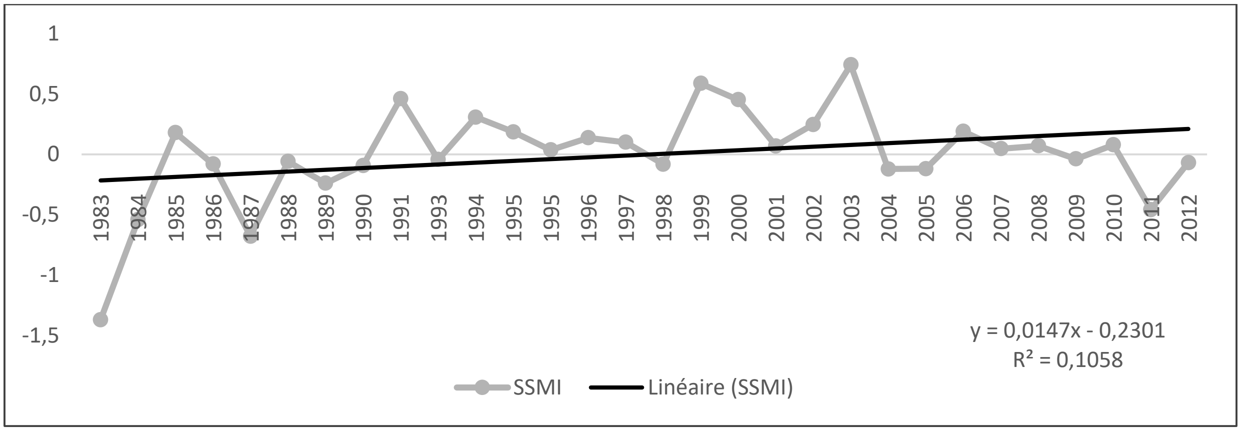


Figure 3 Variation of soil moisture index from 1983 to 2012

Figure 3 shows that there is a stability in soil moisture over Cameroon due to the feedback between rainfall and evaporation. This can be considered as a better condition for the population and farmer to increase their production. The proximity of Cameroon to the ocean (Atlantic Ocean) can explain the decrease in rainfall and the increase in temperature?

3.2. Relationship between atlantics sea surface temperature indices and climate variables of Cameroon

The study of the relationship through correlation analysis between the global climate indices (SOI, DMI and TSAI) and the climate variable of Cameroon especially rainfall and temperature soil moisture) will shows two main information: the type of correlation and the significance. Samo and Fink (2014) carry out same study by analyzing the statistical relationship between remote climate indices and West Africa monsoon variability.

Firstly, the SOI and temperature has a low negative relationship (R=-0.18*)* while the SOI and rainfall has a low positive relationship (R= 0.12*)*. A regression analysis, show a level of significant F of 0.25 which is greater than the alpha value (0.05) in this case. The R^2 =0.04 means that 0.4 % of rainfall and temperature varied with the. Since our p-value is greater than alpha, we fall to reject the non-relationship between SOI, rainfall and temperature of Cameroon. This shows that there is not a significant relationship (figure 4).

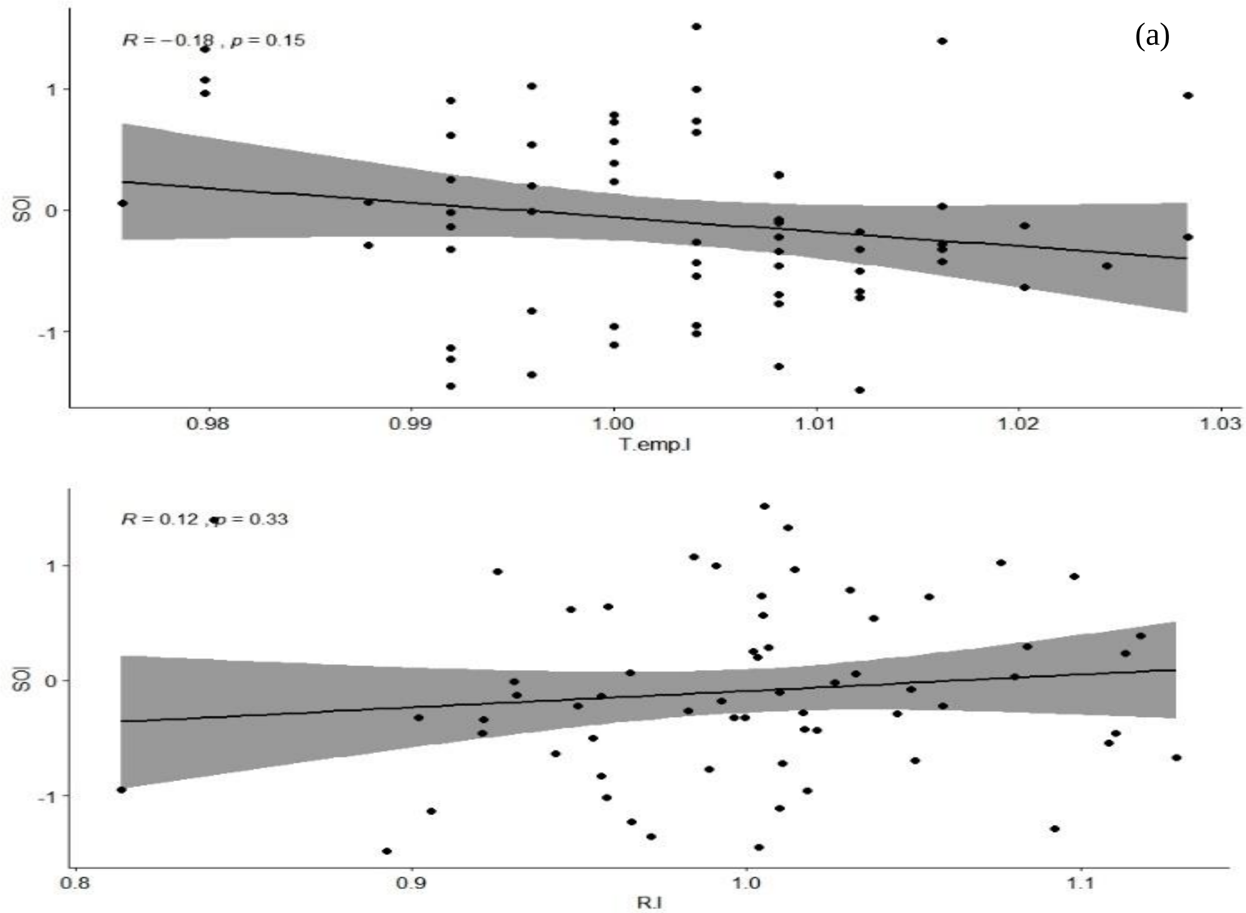
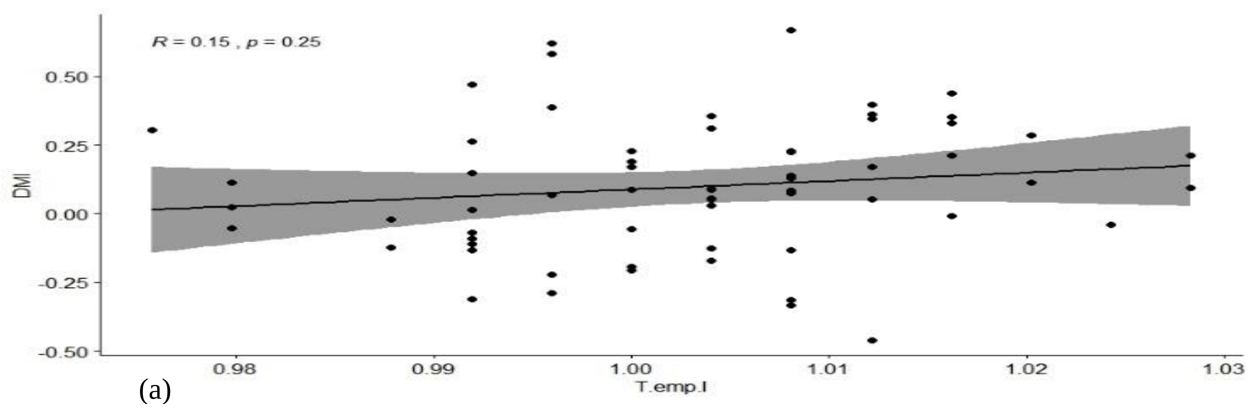


Figure 4 Correlation between Southern Oscillation Index (SOI), temperature index and precipitation from 1950 to 2012; (a) Southern Oscillation Index (SOI) and temperature index (Temp.I) (b) Southern Oscillation Index and Rainfall Index (R.I). (b)

Secondly, the Dipole Mode Index and temperature index has a low positive correlation and a negative correlation with rainfall index (figure 5). The coefficient of correlation for DMI and temperature R=0.15 and for the precipitation R= -0.19. An overall statistical analysis (regression) indicates a level of significant F of 0.21, which is greater than the alpha value (0.05) uses in this case. Since our p-value is greater than alpha, we fall to reject the non-relationship between DMI, rainfall and temperature of Cameroon. This bring us to conclude that there is not a significant relationship.



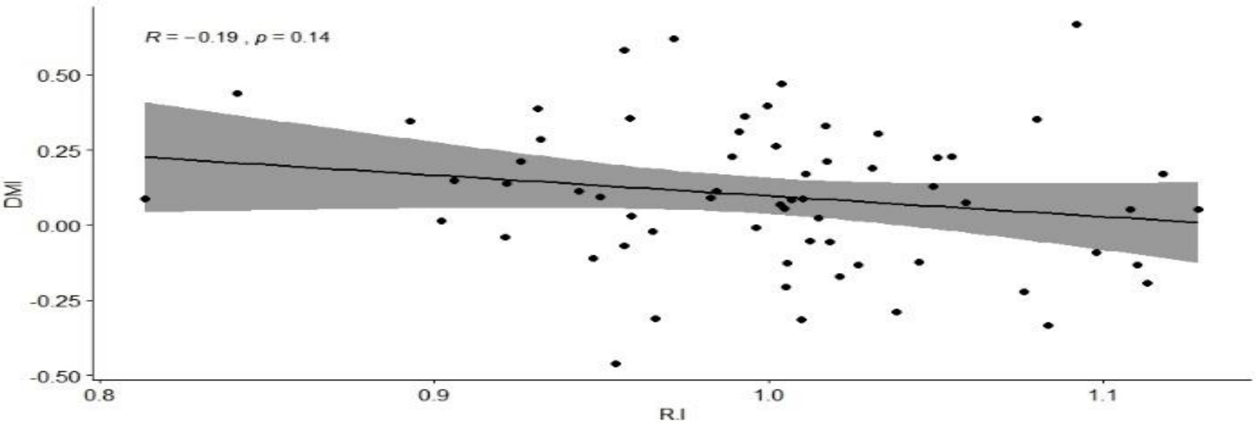
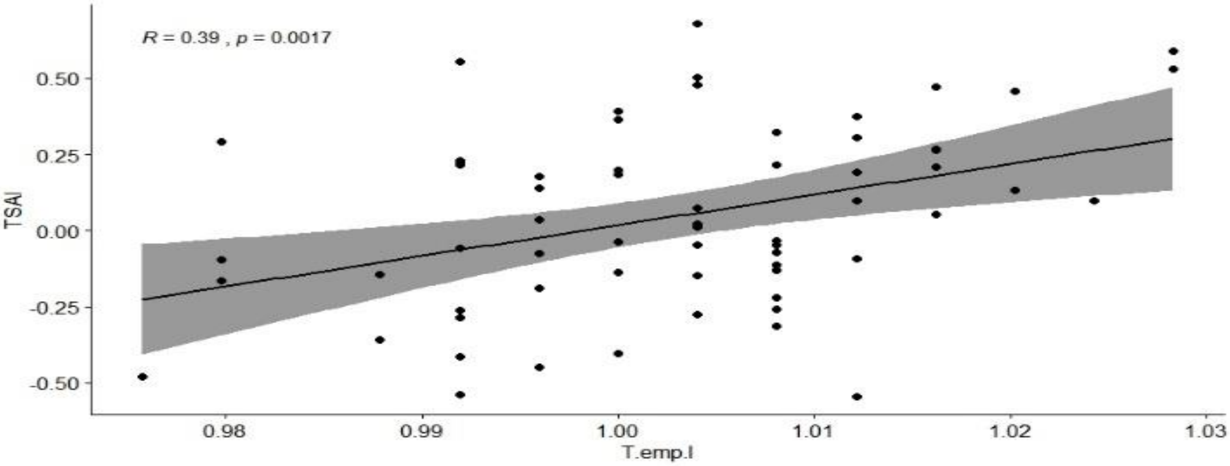


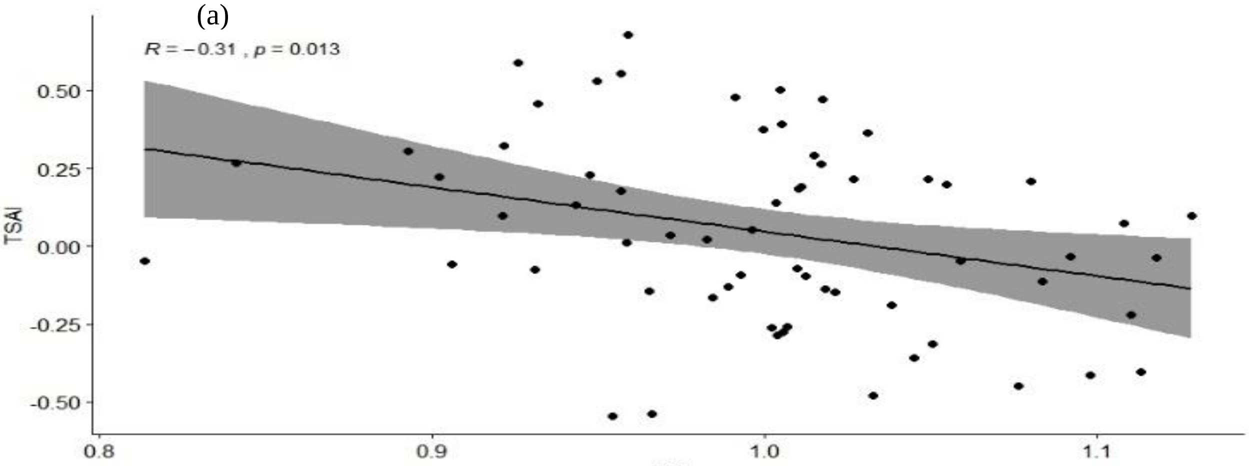
Figure 5. Correlation between Dipole Mode Index (DMI), Temperature index and Rainfall index from 1950 to 2012; (a) Southern Oscillation Index (SOI) and temperature index (Temp.I) (b) Southern Oscillation Index and Rainfall Index (R.I)

(b)

Lastly, the Tropical South Oscillation Index and temperature has a positive relation R= 0.39 while the relationship is negative with rainfall R= -0.31(figure 6).



(a)



(b)

Figure 6. Correlation between TSAI, Temperature index and Rainfall Index from 1950 to 2012 (a) *Southern Oscillation Index (SOI) and temperature index (Temp.I) (b) Southern Oscillation Index and Rainfall Index (R.I)*

In this last case, the regression analysis has confirmed a significant relationship between TSAI, temperature index and rainfall index. The significant test F (0.00062) is lower than the alpha (0.05). The R^2=0.21 means that 21 % of rainfall and temperature varied with the influence of TSAI. In the contrary of the case of SOI and DMI, the individual t-test will be applied to rainfall index, temperature index and TSAI because the significance F is lower than alpha. Rainfall index and temperature index has respectively a p-value of 0.025 and 0.003 (slopes) It means that, the two variable has a significant positive and negative correlation with TSAI. (Janicot 1997) has shown that SST anomalies in the Gulf of Guinea are linked to rainfall variability during boreal summer, from July to September (JAS). Janicot also suggests that a decreasing trend of precipitation is associated with a slow heating of austral seas (the South Atlantic) and a slow cooling of boreal seas (the North Atlantic).

The rainfall and temperature played a key role in the changing of soil moisture. This has been proved in the study conducted by (Tchuenga, 2019) on the relationship between soil moisture, rainfall and temperature in Cameroon. So, the interference of global climate indices on rainfall and temperature will automatically affected the soil moisture. Moreover, Douville *et al.* (2000) in research conducted on the Influence of Soil Moisture on the Asian and African Monsoons found that African rainfall increases with increasing soil moisture. Meaning that same type of relationship between rainfall and global climate indices can be observed with soil moisture as well.

3.3. Effects of the variation in climate variables on maize production in Cameroon

The climate and the soil of Cameroon are favorable to the production of maize. As it is shown on the figure below, there is an increase in maize production from 1979 to 2012 (fig7**).** The environment in which the maize production increase is characterized by the increasing in soil moisture and temperature, and the decreasing in precipitation.

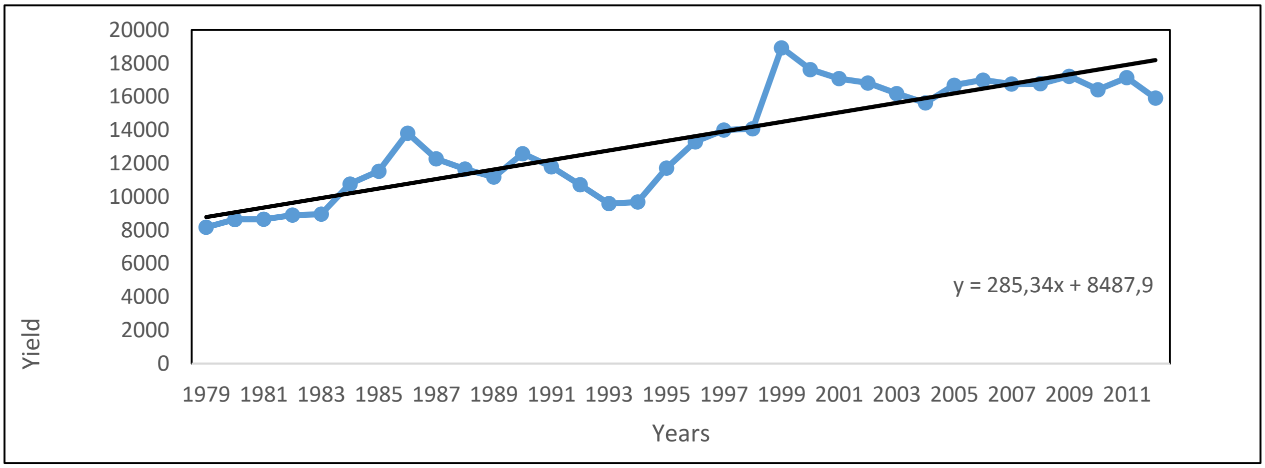


Figure 7. Cereals production and temperature in Cameroon (Source: FAOSTAT, 2016)

According to Laux *et al*. (2009), yield forms an important factor in the agricultural production and is sensitive to three forms of climate anomaly: 1) differences in the averages of factors like temperate and precipitation, 2) differences in distribution of climatic events, 3) differences in both point 1 and point 2. Due to the instability in rainfall and temperature, farmers have noted the appearance of insects and disease that attack maize at different stages of growth. It should also be noted that the climate of Cameroon is now favorable to the development of bacteria, viruses responsible of the damages observe on maize. The table 1 presents an inventory of maize pests, their effects on plant and the stages of the plant's development affected by them.

Table 1. The main maize pests and their damages on the plant

Maize pests	Climate condition	Impact on plant	The stage of growth
Lepidoptera stalk borers	High temperature	Young larvae pierce the leaves and older larvae burrow the stems and attack the ears	Maturity Before maturity
The weevils (Sitophilus oryzae and Sitophilus zeamaïs)	High temperature	They feed on the grains and dig egg-laying holes or exit holes on the stems	Stage of maturity

Source: Adapted from IRAD-USAID, 1993

The production and the yield of maize in Cameroon depends on climate behaviors, meaning that climate play a key role on the maize growth and yield. After presenting the effect on plant growth, a statistical analysis is used to determine the effects of climate change on yield. Correlation and regression were used to examine the relationship between the climate variable and the maize production or yield. Previous studies had used rainfall and temperature to study the impact of climate change on maize production (Tchuenga *et al*, 2015; Abossolo *et al*. 2017). In this study, soil moisture is used to indicate the relationship with yield and their significant. Soil moisture was chosen because of the significant relationship with rainfall due to the exchange mechanism between infiltration of precipitation and soil moisture content. The figure below illustrates that soil moisture index and yield has a positive correlation. The correlation is showing a low positive link between soil moisture and yield.

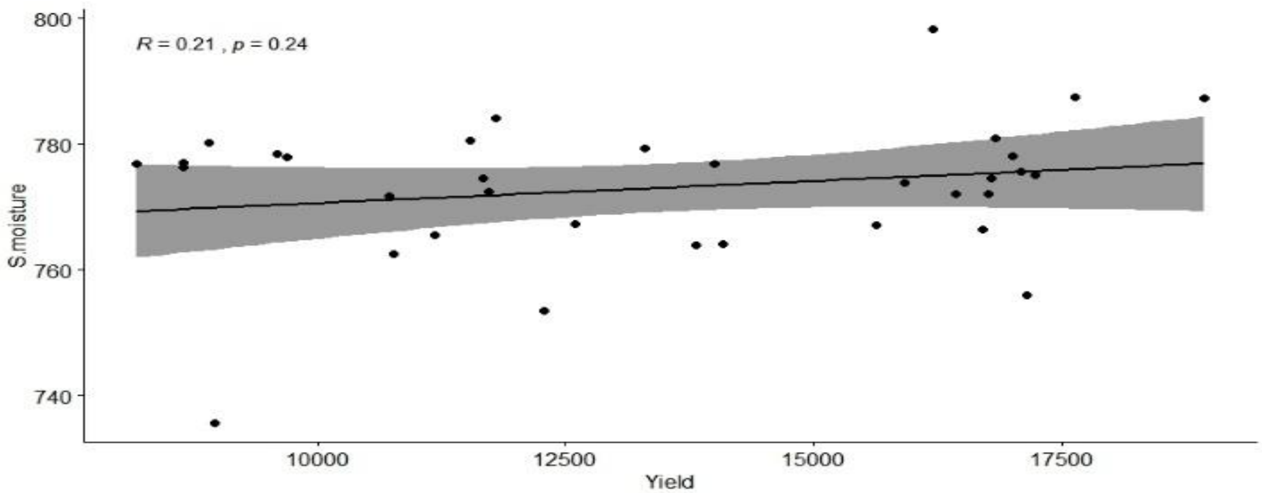


Figure 8. Relationship soil moisture and maize yield

The regression analysis demonstrated that there is no significant relationship between soil moisture and yield because the p-value 0.23>0.05 (α). So, the soil moisture is not the only factor of the increase of maize yield. Many other factors can explain it, such as the annual increase in cultivation area due to the increase of agricultural population.

4. DISCUSSION

Findings obtains from the analysis of data shows that, the temperature and soil moisture are increasing while precipitation is decreasing. The increase of temperature is about 0.005°C/year from 1950 to 2012 was supported by Ngondjeb *et al*. (2013) who conducted an interview with farmers in Cameroon regarding climate change and its effect on Cameroon's agriculture; 56 % of the respondents noticed average temperature differences and 72 % rainfall variation (Ngondjeb *et al.* 2013). Most respondents answered that temperature increased (77 %) over the last 20 years and precipitation decreased (72 % of the respondents) (Ngondjeb *et al.,* 2013). In addition, Molua and Lambi (2007) suggest that rainfall already diminished per decade more than 2 % since 1960. The UNDP (United Nations Development Programme) Cameroon climate change profile data also states that temperature is increasing 0.15 °C per decade and that the increase is highest in the North, as wassuggested in the interviews of this project (Mc Sweeney *et al*., 2010).

Even though the annual variation in soil moisture is low, the spatial representation of the standard soil moisture index brings out a gradual deficit in soil moisture in many regions of the country. It has been noticing that the main factor of soil moisture deficit is drought. It was approved by Rosenweig & Hillel (1995) who expressed their views that extreme meteorological events such as high temperatures, dry spells, frequent droughts and reducing rainfall do not only reduce water supplies but also increases the amount of water needed for plant transpiration.

The changes in climate in Cameroon, influence the productivity and plant growth. The increase in temperature has occur the multiplication of insect and diseases which destroyed plant at the different stages of growth. The high prices of chemical product to fight again those insects and disease are not always at the level of farmers. The lact of financial support increase the damages. That is why, Bele *et al*. (2011) suggests that climate change will have substantial effects on Cameroon because of three main reasons: 1) Poverty will worsen due to climate change in Cameroon where most current natural disaster are climate related, 2) the population is reliant on resources for necessary activities such as agriculture but the resources for this activity are easily affected by climate change. 90% of the agriculture in Cameroon is for example rained and therefore heavily dependent on the rainy season. 3) the poorest societies are already struggling to deal with the current climate and have few facilities or possibilities to cope with future climate change. These groups are most dependent on climate sensitive resources, such as agriculture (Bele *et al*., 2011).

Therefore, agriculture belongs to one of the most climate vulnerable parts of Cameroon's community (Bele *et al*., 2011). The correlation and the regression analysis suggest that here is a non-significant relationship between soil moisture and yield. Meaning that apart from the key role of soil moisture in plant growth, there are other factors which can explain the increase of yield. Climate variables are not the only factors explaining the annual augmentation of maize yield. Tchuenga (2015) suggest that the increase of maize yield is due to the increase of the maize cultivation area. The increase in yield don't mean that there is not an impact of climate change on maize production.

5. CONCLUSION

Overall, our founding suggests that from 1950 to 1982, the temperature is decreasing while from 1983 to 2012 the temperature is increasing. The general trend shows an increasing of temperature with the slope of -2.213. The trend of precipitation shows a decreasing from 1950 to 2012, with a slope of 0.0057. The trend line of the variable soil moisture is showing an increase from 1983 to 2012. From the geographical location of Cameroon, several global climate indices have been correlated to the change of the precipitation and temperature of Cameroon.

The findings confirm that a change in rainfall and temperature has no significant relationship with the variation of the South Oscillation Index and the Dipole Mode Index while both variables have a significant change with the variation of the Tropical South Atlantic Index. The different form of variation in climate variables over Cameroon influences maize production. The soil moisture and yield have a positive relationship which is not significant. Meaning that other factors than the climate factors can explain the increase of yield. The findings of the present study will contribute to policy formulation, and to the national and international planning strategies for sustainable development of Cameroon. Also, the study will provide to the national organization which work on climate change and student of university useful information for the understanding of climate change in Cameroon.

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