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Diagnostic Investigation of the Potential Effect of Soil Moisture Condition in Detecting Climatic Hazards During the Crops Sowing in Cameroon

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Abstract:
The beginning of the sowing period in Cameroon has always been difficult to define and determine by scientists. Most of the authors analyze the state of the beginning of the sowing period in Cameroon using rainfall and temperature data. Soil moisture, which is an essential climate variable, has not been much used, even though it can be a good climate variable to monitor the seasonal agricultural drought. The present study intends to investigate the spatial and temporal patterns of agricultural drought based on soil moisture data during the beginning of the growing season (march and July). The choice of the two months was made since they are respectably defined by the Ministry of Agriculture and the agricultural research center as the periods of the beginning of sowing in Cameroon. Rainfall and soil moisture data were collected from different sources. The analysis of the data was made using descriptive and inferential statistics as well as remote sensing. The findings show that from 1950 to 2010, while the March soil moisture was decreasing, the July soil moisture was increasing. The year 1990 has been detected as the year with an exceptional soil moisture deficiency in Cameroon. Also, it has been found that the regions from Adamaoua to the south have a high variation in March soil moisture. While the Far North and the North Region have less variation in soil moisture. It can lead us to observe that in March in the area from Adamaoua to the south of Cameroon, the beginning of the growing season is more variable and unstable than in July in the north and far north regions.

INTRODUCTION

African agriculture is more vulnerable to climate change and climatic hazards because of low adaptative capacity and forecasting (Hope, 2009). This leads to food insecurity in some parts of African countries affecting livelihood of farmers mainly in rural areas. In the past, it was possible to predict seasons based on the farmer's empirical knowledge, but nowadays the beginnings and ends of the rainy seasons became less predictable due to the irregular distribution within months (Diop et al., 1996; Houndenou et al., 1998). The growing period is the time to choose when to produce crops. It is delimited by the number of days during which a specific plant or crop needs to move from germination to maturity. It can be once or twice annually. In Cameroon, the rainfall season is the appropriate period for crop production.

Most of the farmers planned their activities according to the behavior of the rainfall (raining agriculture). Samba et al. (1999) show that useful rain to start sowing is registered within two consecutive days with an amount of 20mm. These consecutive days will not be followed by a sequence of 7 days without rain for 20 days. This quantity of water is needed for the beginning of the vegetative cycle of crops. Research has been done considering mainly rainfall to explain and analyze the sowing period. Furthermore, several studies analyzed the impact of climatic hazards on agriculture in Cameroon based on the relationship between rainfall, temperature, and crop yield (Abossolo et al., 2017; Amougou et al., 2015; Feumba, 2016). However, soil moisture was less considered in climate change impact analysis in Cameroon. Recently, the World Meteorological Organization (WMO) recommended researchers the use of soil moisture when analyzing climate change impacts on agriculture because changes in soil moisture can accordingly have substantial impacts on agricultural productivity. Magha et al. (2021) assess the soil moisture characteristics of Gleysols in the Bamenda (Cameroon) wetlands and the link between soil moisture content and selected soil characteristics affecting crop production. Carsky et al. (2000) and Sugihara et al. (2016) mentioned that soil moisture limits production more than nutrient supply. Therefore, there is a need to develop innovative strategies that increase resilience of farmers in the changing conditions (Olajire et al., 2022).

It is in view of these works and the insufficiency of works on soil moisture in the analysis of climate change that the present study was oriented on the diagnostic investigation of the potential effect of soil moisture conditions in detecting climatic hazards during crop sowing in Cameroon. We assumed that soil moisture data could be an effective method of detecting climatic hazards during the early planting period in Cameroon. Soil moisture is a major determinant of the type and condition of vegetation (agriculture), so there is a need to define it as a new research axis in the agricultural research structures of Cameroon.

RESEARCH METHODS

Study Area

The study area is in the center of Africa. The country is bordered to the north by Chad, to the south by Equatorial Guinea, Gabon, and Congo, to the east by the Central African Republic, and to the west by Nigeria. Geographically, it is located between 2.0.0N and 13.00N and 9.00E and 16.00E.

The agricultural calendar, or cropping period, is the interval of time farmers use to plan their agricultural activity based on rainfall behavior. The beginning of the rainy season is considered by farmers to be the beginning of cropping season. The end of rain is considered harvest time. In Cameroon, we have two rainfall regimes (monomodal and bimodal). In the mono-modal zones, agricultural production activity is developed once a year. while in the bimodal zone it develops twice (two production cycles). The present changes in climate are such that it is possible in some monomodal areas (western highland areas) to have two crop cycles of production. Considering the dependency of agriculture on rainfall, more than half of farmers derive their resources from rain-fed agriculture, which gives the climate a central place in the agricultural production process. For example, the table below shows the calendar of maize production in Cameroon.

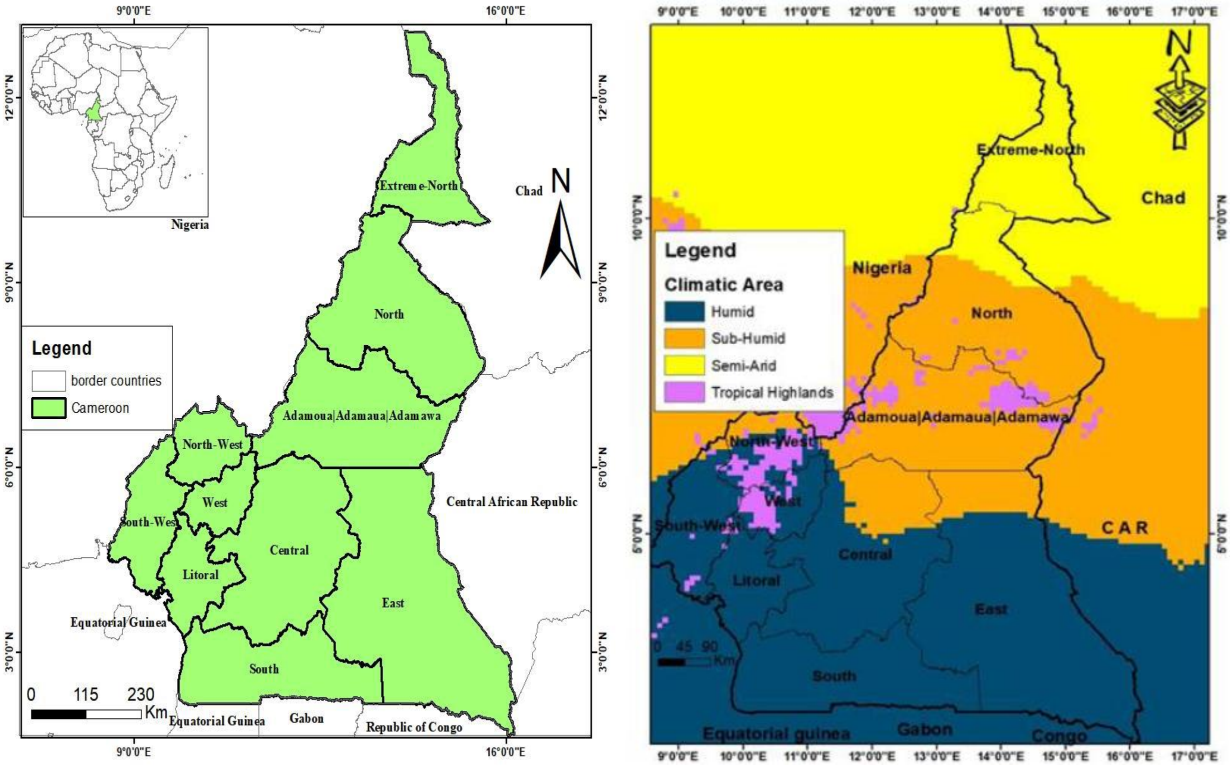

Figure 1: Cameroon in Africa and its climatic area

Table 1: Annual Length of cropping period in Cameroon

Région	Date of sowing for the first season	Date of sowing for the second season
Adamawa	May-June	-
Center	15 March-15 April	15-25 August
East	15 March-15 April	15-25 August
Far-North	July	-
Littoral	15 March-15 April	15-25 August
Nord	15June-15july	-
Northwest	Mi -April	15july- 05 August
west	Mi April	15july- 05 August
South	15 March-15 April	15-25 August
Southwest	15 March-15 April	15-25 August

Source: MINADER-Cameroon

The table presents the regions of Adamawa, Centre, East, Littoral, South, and Southwest as the regions with a cropping season starting in March. The field work and literature show that the west and northwest also begin their growing seasons in March. Even though the table shows that it begins in April. It runs from the 15th of March to the 15th of April. Those regions are in the south of the country. According to the fact that March is considered the beginning of their sowing period, it has been chosen in the present study to analyze its moisture content to find out if the month of March is suitable to start agricultural activities. The North and Far North have July as the month of the beginning of the growing season. It is the reason for the choice of the month of July in moisture analysis.

Data Collection

The lack of in situ soil moisture data over Cameroon led us to consider the satellite soil moisture product from both passive and active microwave satellites. The GLDAS monthly (March and July) soil moisture data was used. The data had a resolution of 0.25 x 0.25 degrees from 1950 to 2010. Monthly soil moisture data from GLDAS was in NetCDF format. Only July and March data were downloaded.

Data Analysis

Examining the sowing period through soil moisture can help detect some climatic constraints impacting crops. The case of July and March sowing periods has been analyzed at one dimension of 0 to 10 cm soil moisture during the years 1951, 1960, 170, 1980, 1990, 2000, and 2010. Two types of approaches were chosen to analyze the variation in soil moisture: temporal and spatial variation. The analysis of temporal soil moisture change was done through Excel 2016 software. From the NetCDF, the mean value data was extracted. The time series analysis was done to show the temporal variation in July and March soil moisture. A slope was used to determine the trends in soil moisture data. A regression analysis and level of significance for the changes in soil moisture were done.

The temporal analysis was done through GIS, which has become widely used for satellite observation and climate model data. ArcGIS is one of the dominant software packages in GIS that is appropriate for NetCDF data. This format is not a traditionally used GIS format, although it is getting popular. In this study, after downloading the different data mentioned above, we use 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, verify the extent of the layer, and export the final map and statistic data. The descriptive statistics (mean, median, standard deviation, maximum, and minimum) were done for the soil moisture of each year and for regions where sowing starts in July and March (table 1).

RESULTS

Depending on agroecological zones, Cameroon has a diverse sowing period and sowing behaviors. Each agroecological zone has a specific seasonal characteristic. July is considered as a sowing period for the North and Far North regions. While May is considered by the rest of the regions of the country (Table 1) as the period of sowing.

Temporal Variation in Soil Moisture

The time series shown in Figure 5 presents the evolution of soil moisture between 0 and 10 cm. The slope of the figure shows a decrease in soil moisture (-0.02 mm). Figure 5 depicts a significant decrease in soil moisture during the year 1990. There was a decrease in March mean soil moisture from 1980 to 1990 and an increase from 1990 to 2010. This decrease in humidity can indicate an exceptional climatic situation that Cameroon would have endured in terms of dryness.

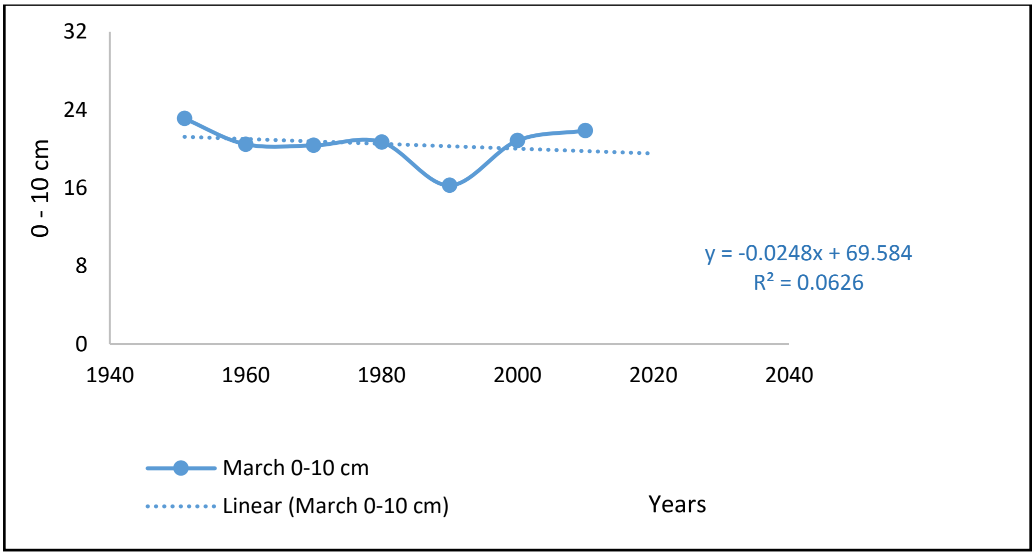

Figure 5: Monthly mean of March soil moisture at the depth of 0-10 and 100-200.

The same situation is observed in the mean soil moisture of July. The years 1970 and 1990 saw a decrease in soil moisture content. While the year 2000 saw an increase in soil moisture. A general increase in soil moisture is observed on figure 5 through the slop (0.004 mm).

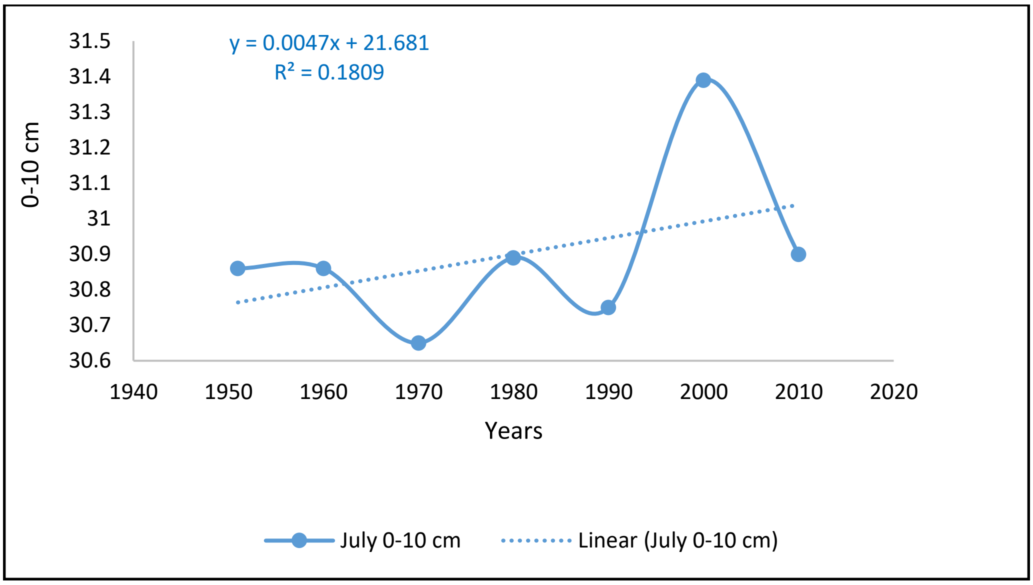

Figure 6: Monthly mean of July soil moisture at the depth of 0-10 and 100-200.

A t-test: two-sample assumption of unequal variances has been executed to see the level of variation in soil moisture at the same depth in July and March. The results have shown that the variable has a different or unequal variance. The p-value of the two-tail test is 0.0000130.05. Meaning that there is a statistically significant difference in the variation of the mean in July and March at the depth of 0–10 cm.

Table 2: t-Test: Two-Sample Assuming Unequal Variances

Months and the soil moisture depth	March	July
	0-10cm	*0-10 cm*
Mean	20.52143	30.9
Variance	4.479581	0.054733333
Observations	7	7
Hypothesized Mean Difference	0	
df	6	
t Stat	-12.8953	
P(T<=t) one-tail	0.000007	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.000013	
t Critical two-tail	2.446912	

This statistical test concludes that July and March have a significant change or variation in soil moisture. It can be too risky to sow between July and March.

Spatial Variation in Soil Moisture

The spatial analysis of the variation in soil moisture gives the value of each region. The mapping considers the moisture level from 0 to 10 cm and from 1951 to 2010. July (J) is concerned by two regions, such as the Far North and the North Region. While March (M) is concerned by the rest of the regions in Cameroon. For the year 1951, the July soil moisture mean was 30.57 mm for the two regions. The maximum is 37.13 mm, and the minimum is 20.4 mm. The sample variance is 41.30, and the standard deviation is 6.42. The descriptive analysis shows that the data are close to the mean value (30.57 mm). The March soil moisture at 0 to 10 cm shows a mean value of 29.01 mm. The maximum value of soil moisture is 38.87 mm, while the minimum is 19.15 mm. The sample variance is 54.41, meaning that there is a variation within the soil moisture value over the region of North and Far North Cameroon. The standard deviation is 7.37.

The year 1960 is characterized by decreasing mean soil moisture in July. Compared to the year 1951, the mean of the year 1960 is 27.95 mm. The maximum soil moisture is 35.18 mm, and the minimum is 20.73 mm. The sample value of the data is 27.05. This indicated low variation in soil moisture value over the Far North and the North region. The March soil moisture indicated a mean soil moisture value of 24.97 mm. The maximum soil moisture is 36.03 mm, and the minimum soil moisture is 13.92 mm. The sample variation is 63.39 mm. It shows an important variation in soil moisture amount over the south regions of Cameroon (from Adamaoua to the south region) (figure 1).

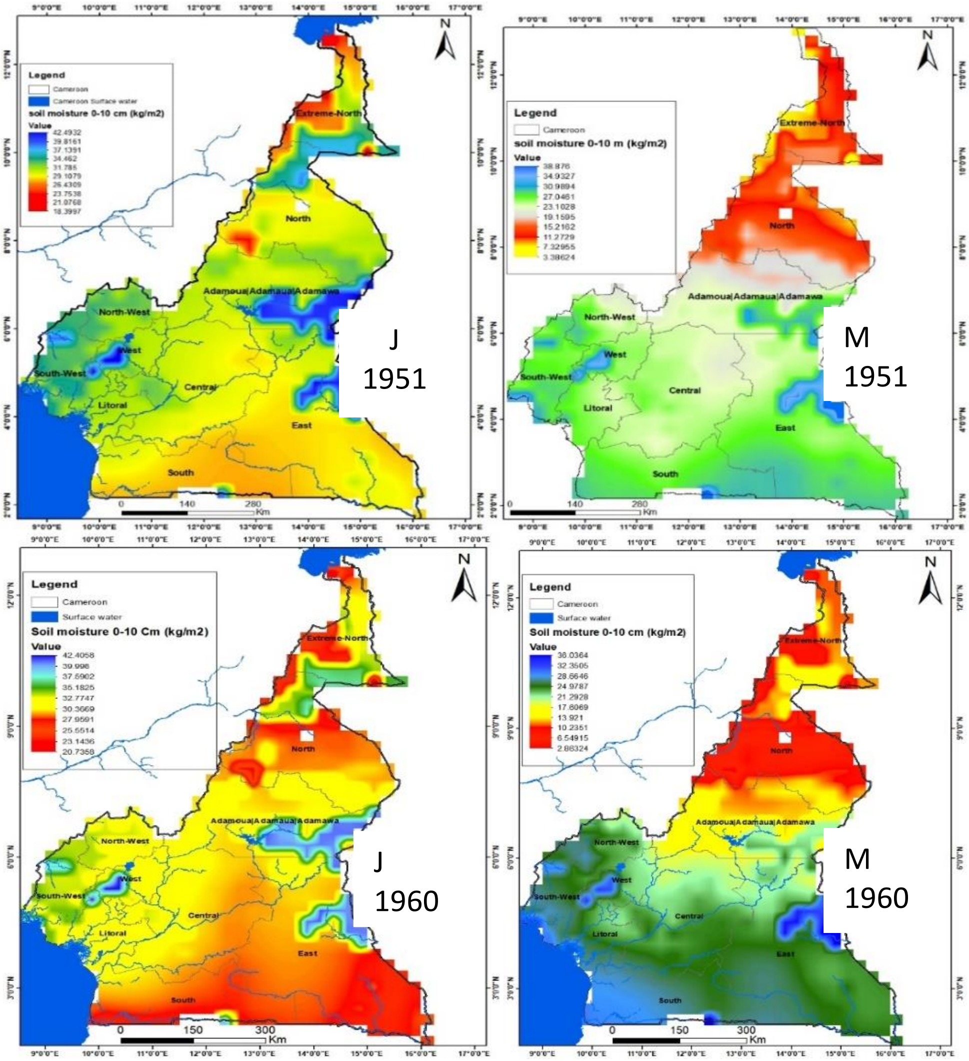

Figure 7: March and July 0-10 cm soil moisture variation from 1951 to 1960

The mean soil moisture of July 1970 for the Far North and North region was 27.97 mm. The maximum is 35.02 mm, and the minimum is 19.09 mm. The sample variance is 43.84. It indicates a low variation in soil moisture from the mean value. From Adamaoua to the south region, the March mean value of soil moisture is 24.82 mm. The maximum is 38.22 mm, and the minimum is 11. The sample variance is 133.02. In addition, the March 1980 mean soil moisture was 23.86 mm. It is lower than the mean soil moisture of 1970 (24.82). The maximum march soil moisture is 36.68 mm, while the minimum march soil moisture is 11.05 mm. The sample variance is 121.66. It shows an important variation in March soil moisture in the South regions of Cameroon. The July soil moisture mean value of 1980 was 27.12 mm. Compared to the July mean soil moisture of 1970 (27.97 mm), there is not an important change. There was a stable condition in July mean soil moisture from 1970 to 1980. The maximum soil moisture for July 1980 was 36.38 mm. The minimum soil moisture is 17.87 mm. The sample variance is 63.44 and it indicates a variation in July soil moisture in North and Far North regions of Cameroon.

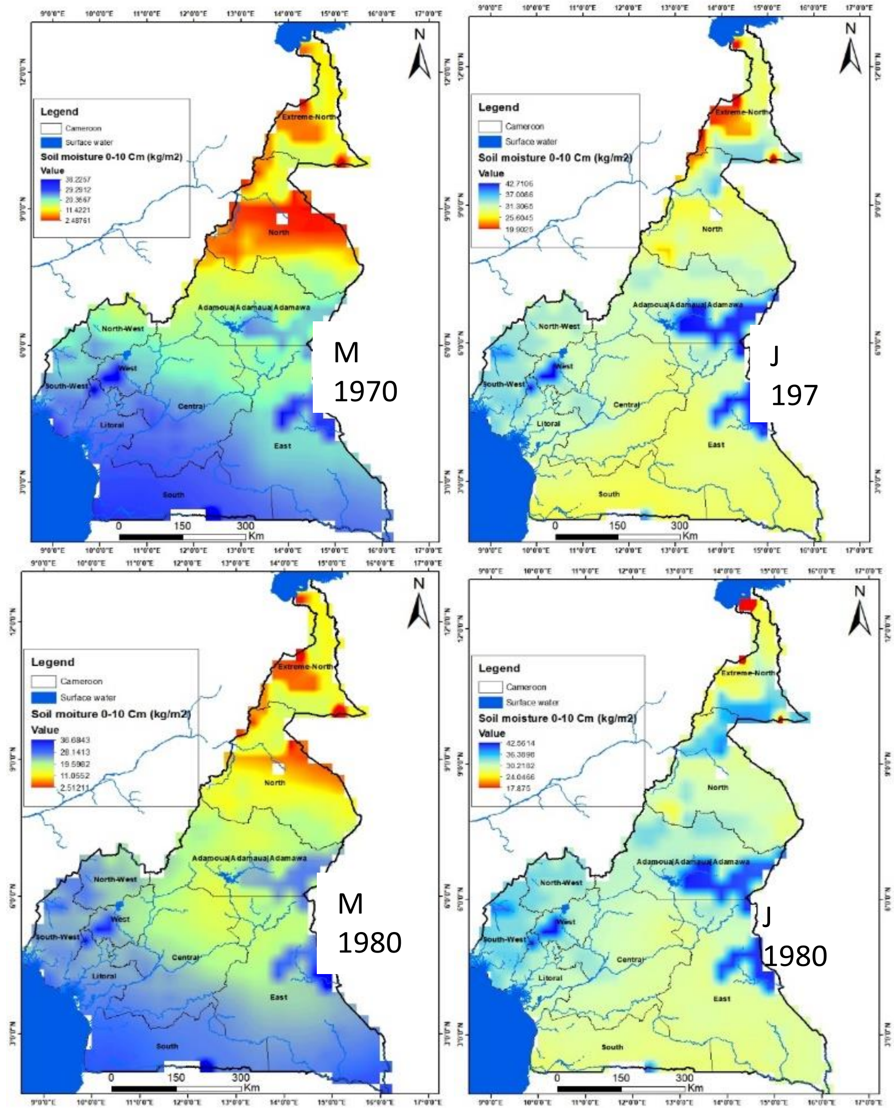

Figure 8: March and July 0-10 cm soil moisture variation between 1970 and 1980

The year 1990 is characterized by an increase in July mean soil moisture variation. The July mean value is 28.26 mm. The maximum is 36.88 mm, and the minimum is 19.66 mm. The sample variance is 54.92. In July of the year 2000, the mean value of soil moisture was increasing. Moving from 28.26 mm in 1990 to 29.13 mm in 2000. The maximum is 35.07 mm, and the minimum is 21.95 mm. The March soil moisture mean in 1990 was 19.29 mm, while it was 23.86mm in 1980. It is an important decrease in soil moisture in the south regions of Cameroon. The maximum soil moisture is 36.32 mm, and the minimum soil moisture is 2.27 mm. The sample variance is 181.17 and it is very high. It indicates an important variation in soil moisture of March. In 2000, there was an important increase in mean soil moisture in March. The mean soil moisture is 24.77mm. The maximum soil moisture is 36.85 mm, and the minimum soil moisture is 14.09mm. The sample variance (99.08) reveals an important variation in soil moisture.

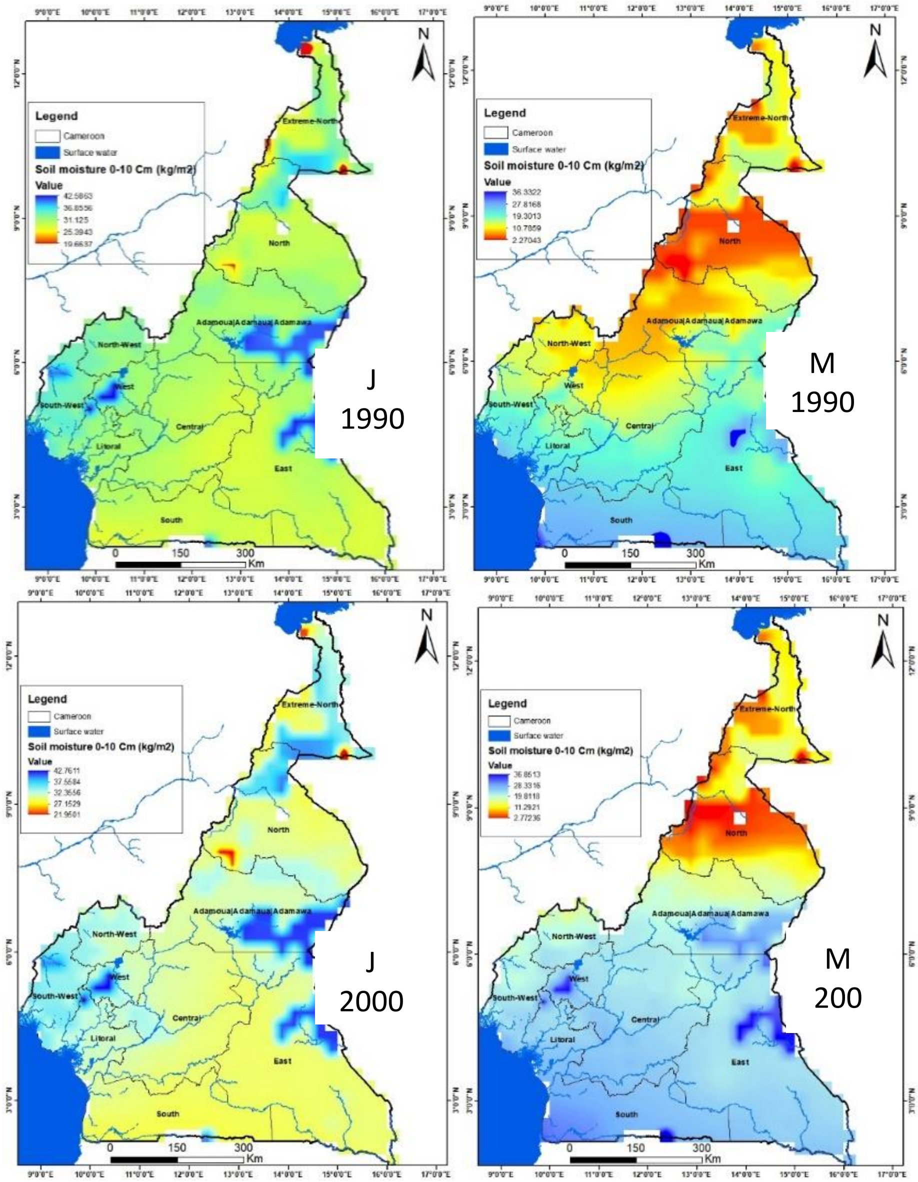

Figure 9: March and July soil moisture variation in 1990 and 2000

The mean soil moisture of March is still increasing in the south regions (from 24.77 mm in 2000 to 25.03 mm in 2010), the mean soil moisture in the north and far north regions is decreasing (from 29.13 mm in 2000 to 27.88mm in 2010). The maximum July soil moisture in 2010 was 35.06 mm, and the minimum was 21.7mm. The sample variance is 45.37 indicated the low variation in soil moisture. For March 2010, the maximum soil moisture is 35.72 and the minimum soil moisture is 17.05. The sample variance is 71.23 showing a variation in soil moisture.

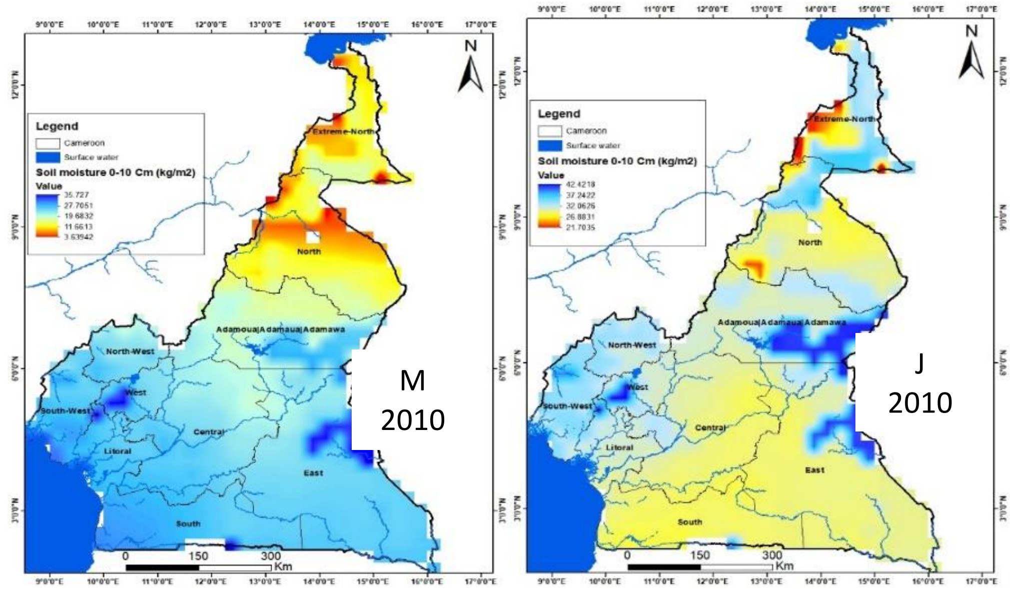

Figure 10: March and July 0-10 cm soil moisture in 2010

DISCUSSION

The present study found that 1990 was characterized by a decrease in soil moisture over Cameroon. This can be explained by a global decrease in precipitation over the country from 1970 to 1990 (Olivry et al., 1993) because of a strong positive correlation between soil moisture and precipitation (Sehler et al., 2019). Since rainfall is the source of soil moisture (Zhang et al., 2010), decreasing precipitation can lead to a deficiency in soil moisture. Tsalefac (1994) also reported that the dry years of 1982–1983 were strongly felt in the agricultural sector, not only in the Western Highlands but also in the entire country (Cameroon). The FAO/OSRO assessment of the effects of drought on food availability and the agricultural situation in 1983 indicates a 10 to 15% decline in national cereal production. It means that the decrease in soil moisture is also the result of drought impacts, which affected crop production. So, the decrease in soil moisture during March and July of the year 1990 can explain two situations, such as the dryness during those months and the decrease in rainfall. These climatic hazards have consequences for crop phenology, especially the germination phase, which coincides with the months of July and March according to the cultivation calendar. The second result of this study is that the spatial variation in soil moisture is mostly intense in the south regions and less stable in the north and far north regions. Sehler et al. (2019) explain this result with two factors, such as climatic regime and land cover. It is well known that land cover has a significant effect on soil moisture (Hillel, 1998; Rodriguez-Iturbe, 2000; Eagleson, 2002).

CONCLUSION

Overseas, this research was intended to use soil moisture for a diagnostic investigation to detect climatic hazards during the cropping period. The result indicated that, based on soil moisture, the years 1970 and 1990 have been identified as periods with an important decrease in soil moisture. March and July of the years 1970 and 1990, which are linked to sowing periods, face agricultural drought. The result shows that the mean value of soil moisture is more variable in the south regions than in the north and far north regions. This variation makes it difficult to determine the best period of sowing and can impact crop phenology. Based on this study, the Ministry of Agriculture and Rural Development in Cameroon and the Institute of Agricultural Research for Development will pay great attention to soil moisture because it is an essential tool to measure agricultural draught. The soil moisture sensor should be added to the measurement instrument for climate parameters. The association between vegetation index and soil holding capacity can be the best way to monitor soil moisture.

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