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Sensivity of Crop Yields to Temperature and Rainfall Daily Metrics in Senegal

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Abstract Senegal is a sub-Saharan country marked by rainfed agriculture, which is under the recurrent threat of climatic upheaval, mostly due to irregular rainfall and temperature. This study shows evidence of the influence of daily rainfall metrics on crop (groundnut and millet) yields. Statistical analysis has been carried out using observational datasets and over the period 1961-2018. The results show an increase in temperatures in our zone, which is in line with the decrease in groundnut yields. Also, significant correlations of 0.81 and 0.69 between the total rainfall indices and groundnut and millet have been found respectively. Rainfall intensity, length, and distribution would contribute up to 66% and 49% to the variability in groundnut and millet yields respectively. A decrease in crop yields is considerable during dry periods (18% for groundnut and 10% for millet) due to the occurrence of long dry spells and low rainfall distribution. The groundnut yield appears most affected by these indicators, while millet is more resistant in dry conditions. To face the major future challenges, it is essential to ensure that changes in these metrics are effectively taken into account in agro-climatic model simulations.

Keywords: *temperature, rainfall, metrics, yield, climate impacts, sensivity*

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1. Introduction

Climate variation and change have a strong influence on agriculture over West Africa (e.g. [1,2]). The impacts of climate on agriculture vary from one region to another. Developing countries in tropical latitudes tend to be more exposed to socio-economic conditions. According to the reference [3] report in many cases, their endemic poverty increases the risk and severity of natural disasters (e.g. [4,5,6]).

In Senegal, Reference [7] show that climatic factors contribute to a major role in the distribution of plant landscapes and soil types. In addition, the inter and intra annual variability of precipitation has an impact on the state of cultural intensity which is very low on average. The climatic upheaval (decrease in rains, considerable occurrence of extremes, increase in temperatures) will certainly have repercussions on water resources and on agricultural production (e.g. [8,9]) as well as on the varietal map (e.g. [10]).

However, most of this work has focused only on the impact of seasonal accumulations and not on seasonal mean of rainfall metrics such as the intensity of rainy days, the number of rainy days, the length of the season, the dry and wet sequences, among others. Even though the cumulative rainfall remains a good indicator of the season's deficit or surplus, it is nevertheless insufficient to explain the variability of agricultural yields (e.g [11]). The length and the distribution of rain throughout the season are key factors (e.g. [12]). Long or frequent dry spell during the growing season (in the vegetative and reproductive phases) can for instance lead a decrease of agricultural yields (e.g. [13,14]). We also know that, for example, false starts and early cessation of the rainy season impact crop growth (e.g. [15]).

The objective of this study is to provide a detailed analysis of the influence of rainfall metrics on the speculations yields such as groundnut and millet in Senegal. Similar analyzes were carried out by Reference [16,17,18] but in other geographic areas and / or with different methodologies. Reference [16] focused on Africa and Asia and did not take daily rainfall metrics into account. Reference [17] worked on the socio-economic model to be adopted in Senegal by family farms for better resilience against climate change. In the same perspective, reference [18] looked only at the impact of climate change on dry cereal crop yields by considering 35 possible climate scenarios combined with precipitation anomalies and temperature anomalies using the SARRAH agronomic model. Thus, the specificity of this study comes down to the in-depth work of rainfall metrics and temperature, a study based on the descriptive analysis of their influence on agricultural yields in Senegal. The study is organize as follow. Section 1 present the study area, section 2, the data and the methodology, section 3, the results and finally, section 4, the conclusion and discussions.

1.1. Study Area

Senegal is a country located in the far west of the African continent with an area of 197,161 km2. Then 3.8 million ha of the land are arable (20% of the country's surface) within which 3.352 million ha sown in 2018 (e.g. [19]). Its rainfall is distributed in the North by about 300 mm / year, in the Center about 600-800 mm / year and in the Southeast about 1200 mm / year (see figure on inter-annual and decennial variability). Precipitation occurs in a single rainy season which extends from June - July to October - November and is caused by the northward shift of the Intertropical Convergence Zone (ITCZ) e.g.[20]). This precipitation is characterized by high spatial and temporal variability and by periodic droughts, particularly during the 1970s and 1980s (e.g. [21]). However, since 2002, the amounts of annual rain collected in Senegal, as in West Africa (e.g. [15,22,23]), show a positive trend, without however reaching the values of the 1950s. Its population is estimated at 16,209,125 inhabitants. 60% of this population live in rural areas and 2/3 are less than 25 years old, according to reference [24]. The agriculture is mainly rainfed. According to the Reference [25], agriculture occupies about 60% of the active population. It is largely dominated by family farms and constitutes around 95% of the country's agricultural land. However, the high variability of intra- and inter-seasonal precipitation, coupled with population growth and declining soil fertility, means that local households continue to face considerable food insecurity (reduced yields, drought, deficit food stocks, among others).

The study focused mainly on the areas of the groundnut basin which concern millet and groundnut speculations. This zone is characterized by a generally flat relief with three types of soils: tropical ferruginous soils weakly leached on sand (Dior soils) on sandy-clayey sandstone or battleships on shale, hydromorphic soils on clay and halomorphic soils on clay alluvia. Leached tropical ferruginous soils are suitable for a wider range of crops because of their greater mineral richness but also because they are located in areas that are relatively better supplied with water. They are suitable for groundnut, millet, corn, rain-fed rice, sorghum, cotton, arboriculture and market gardening. Halomorphic soils on clay alluvia are chemically rich, but their excessive salinity and the difficulties of working the soil are the main constraints. The soils with the widest range of suitability are mostly alluvial hydromorphic soils which have the advantage of having a great depth, a balanced texture, a large capacity for water, a relatively good natural fertility (e.g. [26]).

The departments chosen are Bambey, Mbour, Thiès, Kaolack, Fatick and Diourbel. Their choice is defined by the actual availability of their climate data for the entire study period. Local farming systems include a mixture of compound fields and bush cultivated by rural households.

2. Data and Methods

2.1. Agronomic Data

The agronomic data for millet and groundnut cover all 42 agricultural departments of Senegal over the period from 1961 to 2018. These data are provided by the Direction de l'Analyse, de la Prévision et des Statistiques Agricoles (DAPSA) and structured in terms of area (Ha), production (Tons) and yield (Kg/Ha).

In Senegal, the small seeded varieties are intended for the oil mill and the larger seeded varieties are theoretically intended to be sold and consumed as such (in seed), they are called groundnuts . Due to the North-South climatic rainfall gradient, the northern part of the groundnut basin (GB) requires varieties with short (90 days) or very short (80 days) cycles. TRPs are produced in the South of the GB and in Upper Casamance. In varietal terms for Senegal, two new varieties appeared in the mid-1990s, the variety with a very short cycle, GC8-35 (80 days), an original creation, and the variety Fleur 11 (90 days), an introduction-adaptation from China, which has the same cycle but a higher yield than the 55-437. Varieties 55-33, 73-9-11 and SRV1-19 have been registered (e.g. Table 1).

This table shows all the varieties listed and their cycle in days.

Table 1. Presentation of the most commonly used groundnut varieties and according to their cycle

Varieties cited (in bold, those used in the study area)	
Early: 75 to 90 days, use in oil mills or "green": **55-437 : 90j** **Flower11 : 90-95 d** SRV1-19: 90d 55-33: 80d 73-9-11 :80d GC8-35: 80d 78-936: 75d	Semi-late and late: 105 to 120 days mixed use or TREE **73-33: 105-110j (mixed use *)** **GH119-20: 115d** PC7 79-79 :120j H75-0: 120d 28-206: 120d (mixed, Casamance)

In order to distinguish the contribution of the metrics, an evaluation is made in the study area essentially on the groundnut basin where varieties 55-437 and flower 11 are the most used according to the varietal map updated by research in 1996 (e.g. [10]), due to the new climatic conditions and new varieties, which take into account the shift in isohyets (e.g. Figure 1). This is an "ideal" varietal distribution based on recent regional agro-climatic data, the results of multi-local experiments and available varieties. Depending on the growing areas, the varieties present also differ according to their destination, mouth or oil mill. The varietal map was the main tool for guiding seed production when the latter was centralized at the State level (e.g. [27,28]).

In addition, millet is often grown in permutation with groundnuts in this area for the most part. They are often characterized by their vegetative cycle and productivity. The Souna 3, Thialack 2 and IBV varieties are the most used by farmers in this area. However, with the increase in rainfall since the 2000s, some crops that were previously abandoned are now being reintroduced (e.g. [17]). All the varieties are listed in the Table 2.

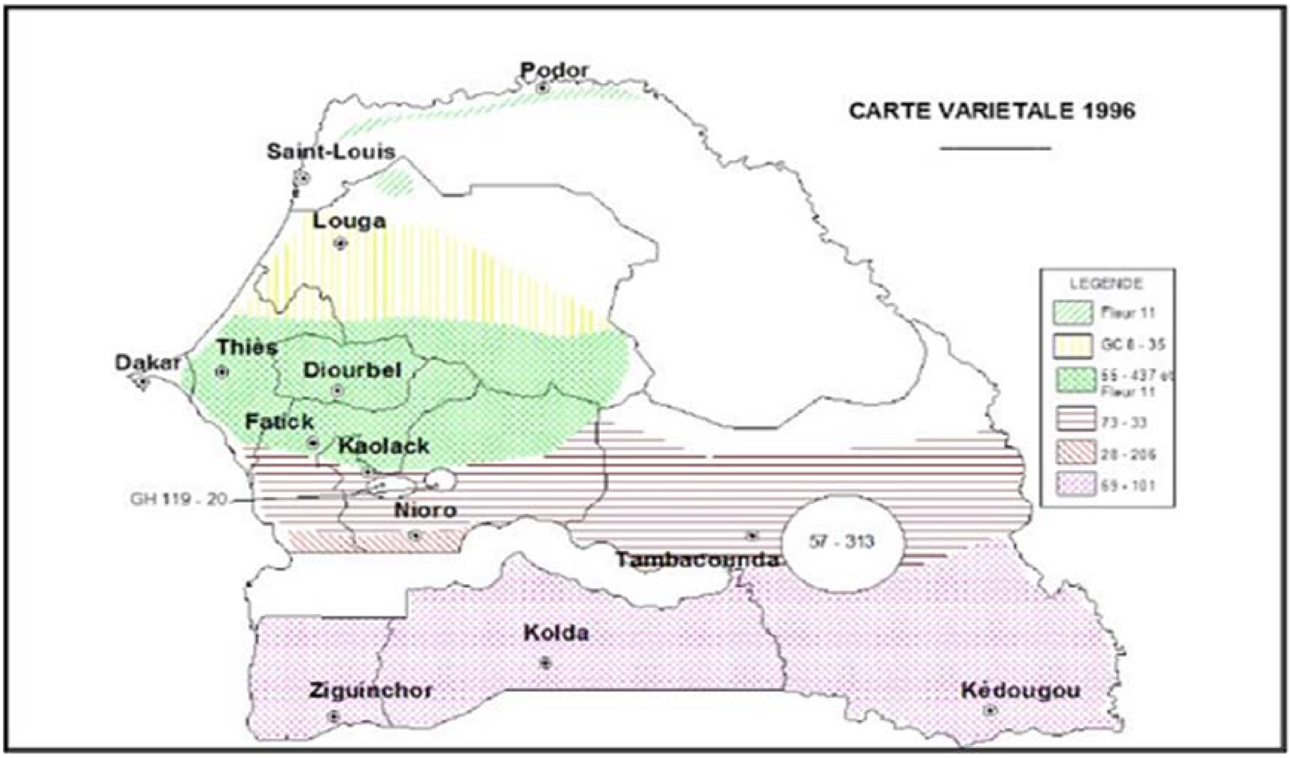

Figure 1. The 1996 variety map. This map takes into account the "southward shift of isohyets", a rainfall restriction of the order of 20% that affected the north and center of the Senegalese groundnut basin in the early 1980s (e.g. [10]).

Table 2. Presentation of the most commonly used millet varieties and according to their cycle

Varieties	Areas	Cycle (days)	Yields (T/ha)
Souna 3	Fatick - Kaolack	85 - 95	2.4 - 3.5
IBV 8001	Kaolack - Fatick	90	2.4 - 3.4
IBV 8004	Thiès - Diourbel - Louga	75 - 85	1 - 2.5
IBMV 8402	Thiès - Diourbel	75 - 95	2
ISMD 9507	Thiès - Diourbel	85	2.5
Gawane	Thiès - Diourbel	85	2.5
Thialack 2	Fatick - Kaolack	95	2 - 3

2.2. Climatic Data

In this study, we used daily rainfall data from meteorological stations in the departments of Bambey, Diourbel, Fatick, Kaolack, Mbour and Thiès over the period from 1961 to 2010. It should be noted that these six departments are all included in an area of very high agricultural production in Senegal called the Groundnut Basin. However, it is important to point out that the Groundnut Basin extends further south into other administrative departments of the country.

In addition, the temperature data collected are at monthly level and cover most of the study period from 1978 to 2008. They cover all regions of the country. In addition, the data is divided into average temperature, minimum temperature and maximum temperature. For this purpose, we will divide them more into two groups: a cold period (November, December, January, February, March) and a hot period (April, May, June, July, August, September, October). All these data come from the National Agency for Civil Aviation and Meteorology (*ANACIM*), which collects them.

2.3. Methods

Based on the data presented in the previous section, rainfall metrics over the period 1961 to 2010 are calculated following the definition of Expert Team on Climate Change Detection and Indices (ETCCDI e.g. [29]). Correlation tests are carried out to quantify the relationships that may exist between the defined metrics and millet and groundnut yields. Note that all data are calculated using the moving average method (with a 5-year window) before correlation calculations. Finally, dry and wet year composites are set up using Standard Precipitation Index (SPI) to analyze the crop yield profile during these periods. Indeed, according to reference [30], the evolution of rainfall in Senegal from 1961 to 2010 makes it possible to divide the series into two parts: a dry period from 1968 to 1998 including 31 years and two wet periods from 1961 to 1967 and from 1999 to 2011 including 20 years. This decomposition makes it possible to understand how rainfall metrics varie during these periods and also to detect the role that they play in agricultural productivity.

The analysis of rainfall is done in two phases respectively with the highlighting of the whole period from 1961 to 2010 then by a comparison between dry and wet periods during which each is evaluated at the yields of speculations such as groundnuts and millet.

During the study, temperature datasets (hot and cold periods), and rainfall metrics (number of wet days NRR, rain intensity SDII and the number of dry and wet days during the winter period, length of season, start and end dates etc.) and yields will be represented. Then, significant links between mean rainfall and precipitation indices and agricultural yields of in situ data are investigated through a test of the significance of correlations between in situ data and agricultural yields.

3. Results of the Study

3.1. Evolution of Climate Metrics in Senegal from 1961 to 2011

3.1.1. Temperature Evolution

According to reference [30], two seasons have been distinguished in Senegal, the cool season from November to March (5 months) and the warm one from April to October (7 months). Figure 2 shows the temperature evolution in Senegal for these two seasons. It is noticeable that during all seasons, the temperature rises, but trend is more important during the cold season in agreement with the results of the Intergovernmental Panel on Climate Change (IPCC e.g. [31]). Meaning that the temperature rises more quickly during cold periods. In this respect, it is important to take into account this factor which is a major contributor to climate variation. Reference [18] have shown that when warming exceeds +2°C, the negative impacts caused by temperature rise cannot be compensated by any change in precipitation. In addition, temperature increases tend to shorten the crop growth cycle (e.g. [32]). The continuous rise in temperature has a greater impact on these interannual variations in yield, as pointed out by reference [33].

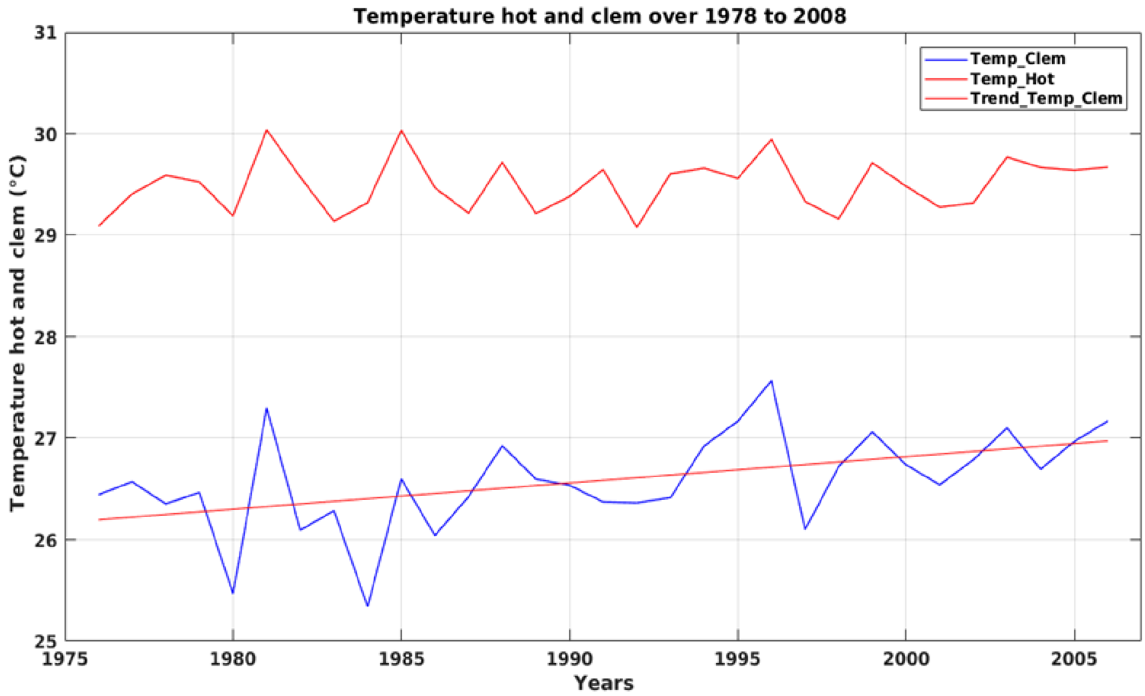

Figure 2. Comparison of average hot and cold period temperatures from 1978 to 2008

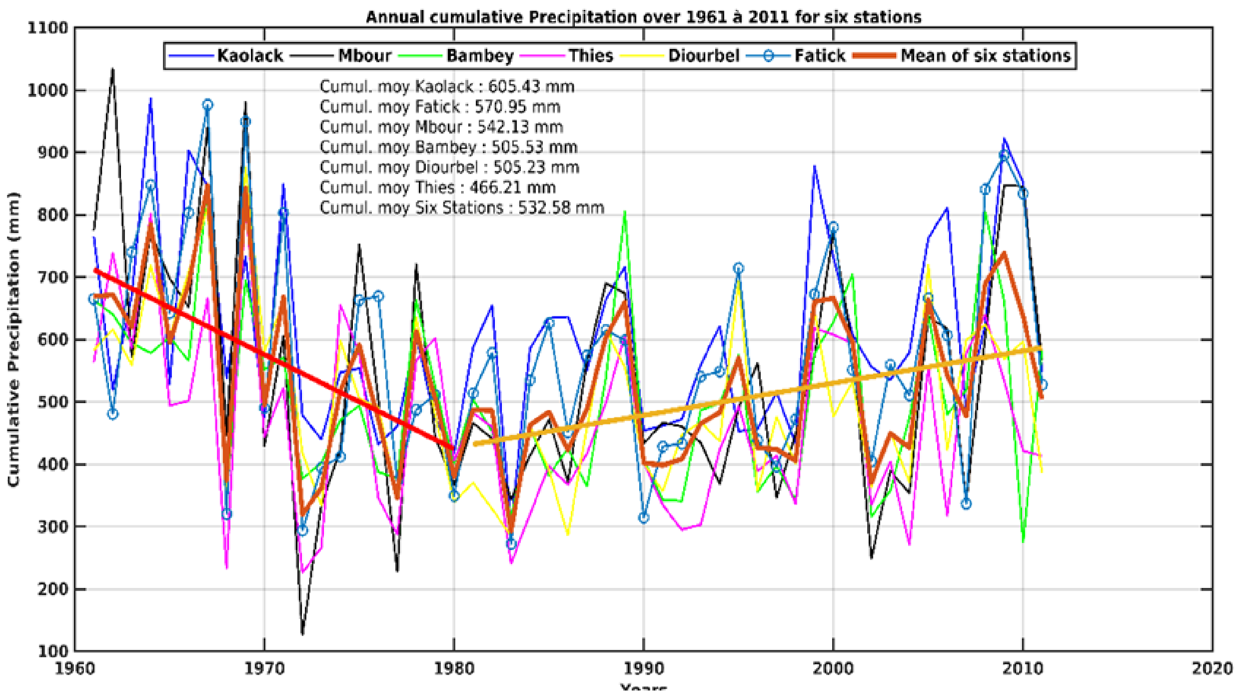

Figure 3. Graphic representation of the annual total rainfall

3.1.2. Evolution of rainfall patterns

The warm season consists mainly of the rainy season expected mostly in the period from May to October. The analysis of rainfall accumulation and metrics focused only on the rainy period for this study.

Rainfall in Senegal and particularly in the groundnut basin is marked overall by two trends: a decrease from 1960 to 1980 and an increase from 1981 to 2011 (Figure 3). However, this situation includes wet and dry years which, according to reference [30], have made it possible to distinguish between two wet periods (1961 to 1967 and 1999 to 2011) and one dry period (1968 to 1998). An exhaustive and comparative analysis is made between 1961 and 2011.

The graphical representation of the cumulative total gives a global overview with a high interannual variation in the period from 1960 to 2011. However, rainfall metrics would give more information. A total of 14 metrics that may impact on productivity are identified in the Table 3.

Table 3. Summary of the calculated rainfall indices and their respective extremes

Rain metrics	Rating	Average value (min - max)
Number of rain	NRR	20 - 52
Number of rain for 95 percentile	NR95p	1 - 4
Intensity of rain	SDII	12 - 19
Length of season	LS	48 - 128
Date of start on season	ONSET	170 - 230
Date of end of season	OFSET	275 - 300
Length of wet spell	LWS	0 - 3
Number of wet spell	NWS	13 - 27
Consecutive wet spell	CWS	0 - 9
Consecutive wet day	CWD	1-11
Length of dry spell	LDS	4 - 12
Number of dry spell	NDS	17 - 27
Consecutive dry spell	CDS	1 - 10
Consecutive dry day	CDD	11 - 31

Daily rainfall data have been used to calculate several metrics in order to attribute the most significant ones to our agricultural yields, particularly for groundnut and millet speculation (e.g. Figure 3).

3.2. Impacts of Rainfall Metrics on Agricultural Yield Variability

In order to avoid subsequent bias using the linear interpolation method (Replace missing values with the average of the surrounding valid values; the interval of neighboring points is the number of valid values above and below the missing value used to calculate the mean), the extreme values of agricultural yields were replaced by the mean between the 3 preceding and 3 following years that surround them (e.g. [34,35]). Also, in order to fill in the missing data for the 1982 to 1985 period, the five-year moving average (Rmean) is used.

From 1961 to 2011, the declining trend in groundnut yield is consistent with the trend of rising temperatures over time (e.g. Figure 2). Millet, on the other hand, is reported to be more resilient to climate variability (e.g. Figure 4). This results support the Reference [33]. Also the trend in rainfall is quite similar to that of groundnut yield. However, the variation in millet yield is not as consistent. This may be due to the resilience of millet to water stress. Nevertheless, the climate projections noted predict a decline in overall agricultural yields. According to the scenarios defined by the IPCC, these projections show productivity declines, particularly for short- and long-cycle millet, of 18% and 28% respectively by 2050 and about 50% by 2100.

In order to know the contribution of each rainfall index to the agricultural productivity of millet and groundnut, correlations are calculated between these metrics and the yields of these speculations.

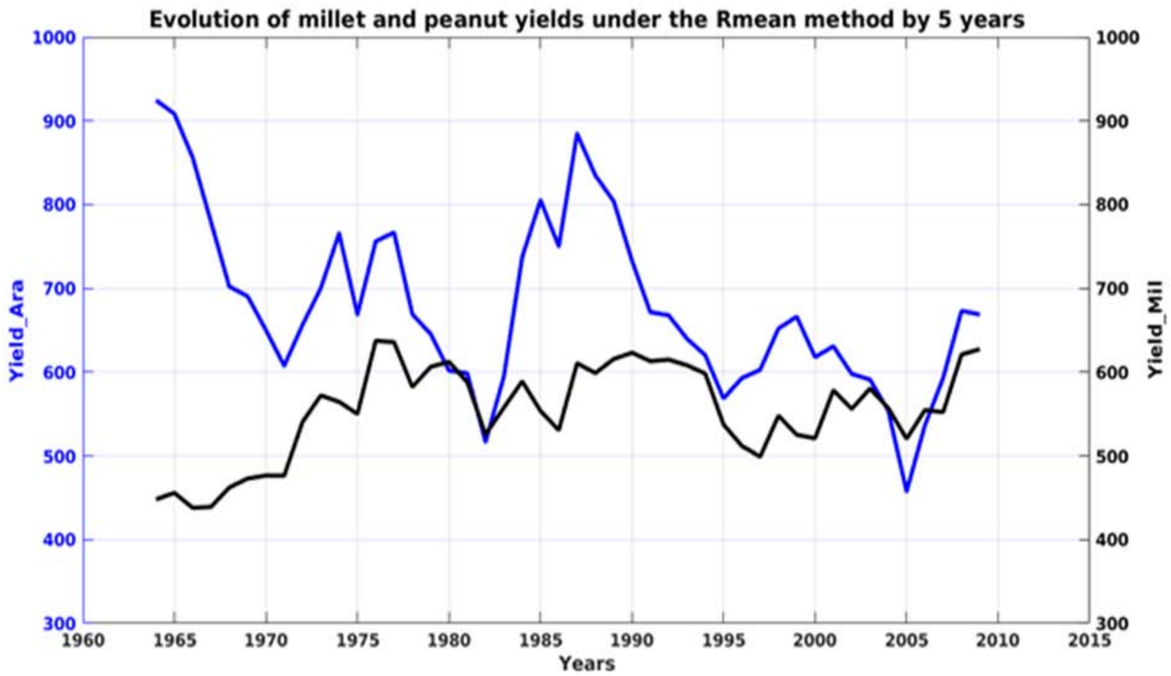

Figure 4. Graphical representation of groundnut and millet yields (top and bottom, respectively) in the raw state on the left and below the 5-year moving average between 1960 and 2011 on the right.

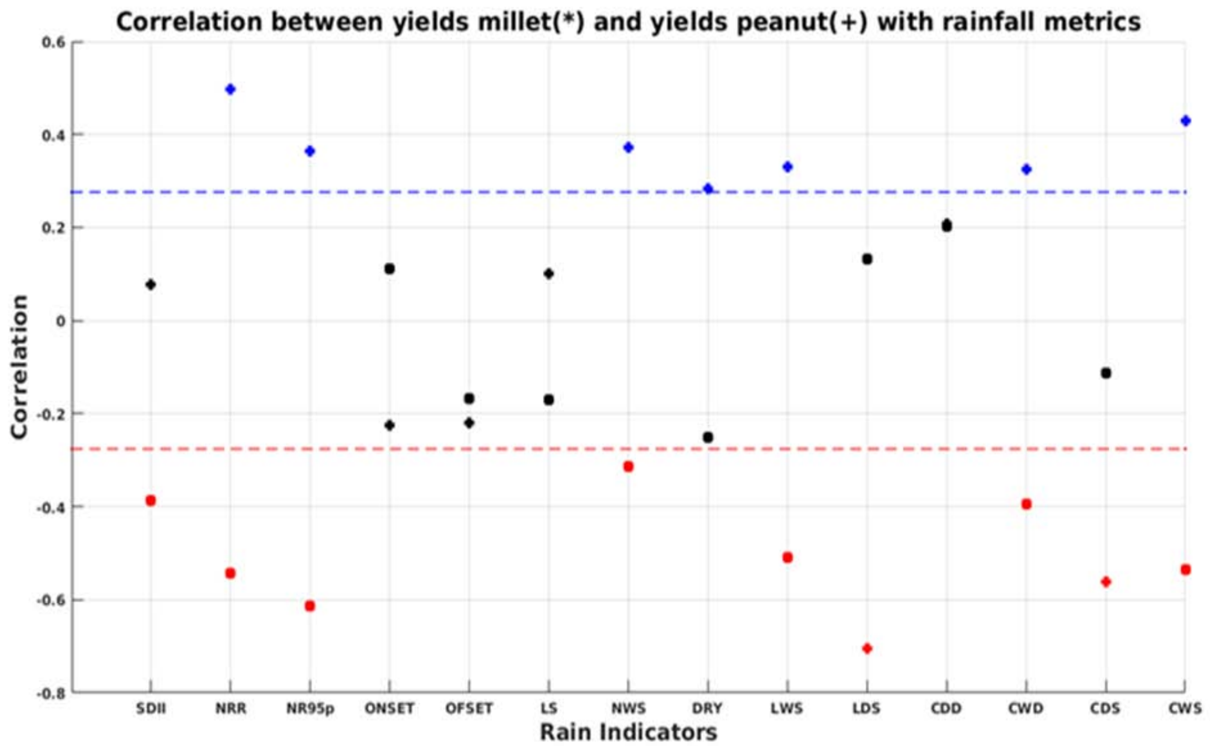

Figure 5. Correlation of millet (*) and groundnut (+) yields with rainfall metrics. Positive correlations in blue and negative correlations at the bottom

For groundnut, nine rainfall metrics are significantly correlated (NRR, NR95p, NWS, LWS, CWD, CWS, DRY, CDS, LDS). Thus, metrics of rain length and intensity would contribute to increasing yields except that the length of dry sequences and the consequent distribution of these sequences increase with groundnut yield.

Table 4. Summary of the results obtained by the Stepwisefit method, which defines the metrics likely to contribute to the regression. In red are metrics that were not correlated on their own, in bold are metrics that alone already contribute to agricultural productivity of millet or groundnut yields. In yellow, the metrics selected by the indicator selection method for regression

Stepwisefit results with the five-year moving average method		
Rainfall metrics	**Groundnut**	**Millet**
LDS	IN	IN
LWS	IN	IN
NWS	IN	OUT
NDS	OUT	OUT
SDII	IN	OUT
NR95p	OUT	IN
NRR	IN	OUT
LS	IN	OUT
ONSET	OUT	OUT
OFFSET	IN	OUT
CWS	IN	OUT
CDS	OUT	IN
CWD	OUT	IN
CDD	OUT	OUT

Metrics of rain length and intensity would be determinant to millet productivity and would appear to be more sensitive to wet sequences over long periods of time. Thus, seven rainfall metrics such as intensity (SDII), number of rainy days (NRR), 95% extreme rainfall (NR95p), number of wet sequences (NWS), length and consecutive wet sequences (LWS, CWD, CWS) would contribute to decreasing millet productivity (significantly negative correlation).

The length and distribution of rainfall throughout the season are key factors for some dry cereals (Salack et al. 2011). However, the combination of these indices would give more credibility to the results obtained. To do this, a multi-regression model is used to assess the combined effects of these metrics on yields.

For groundnuts, eight metrics (LDS, LWS, NWS, SDII, NRR, LS, Offset, CWS) are combined, while for millet five rainfall indices (LDS, LWS, NR95p, CDS, CWD) contribute to agricultural productivity (e.g. Table 4).

The results obtained with the regression of the selected metrics are satisfactory for millet and groundnuts. The correlations obtained for groundnut and millet are 0.81 and 0.69, respectively. In other words, metrics of rainfall intensity, length and distribution (LDS, LWS, NWS, SDII, NRR, LS, Offset, CWS) would account for 66% of the change in groundnut yield. While those of millet (LDS, LWS, NR95p, CDS, CWD) would contribute 48% of the millet yield.

3.2.1. Composite Analysis: Wet and Dry Year Comparisons

The average length of growing seasons is 93 days in wet years and 83 days in dry years, a difference of about 10 days (e.g. Figure 7). Wet years are marked by very early starts and late ends. The number of rainy days is greater during wet periods (e.g. Figure 8). However, these two periods are more differentiated by the occurrence of extreme events such as rain breaks and dry and wet sequence lengths, among others.

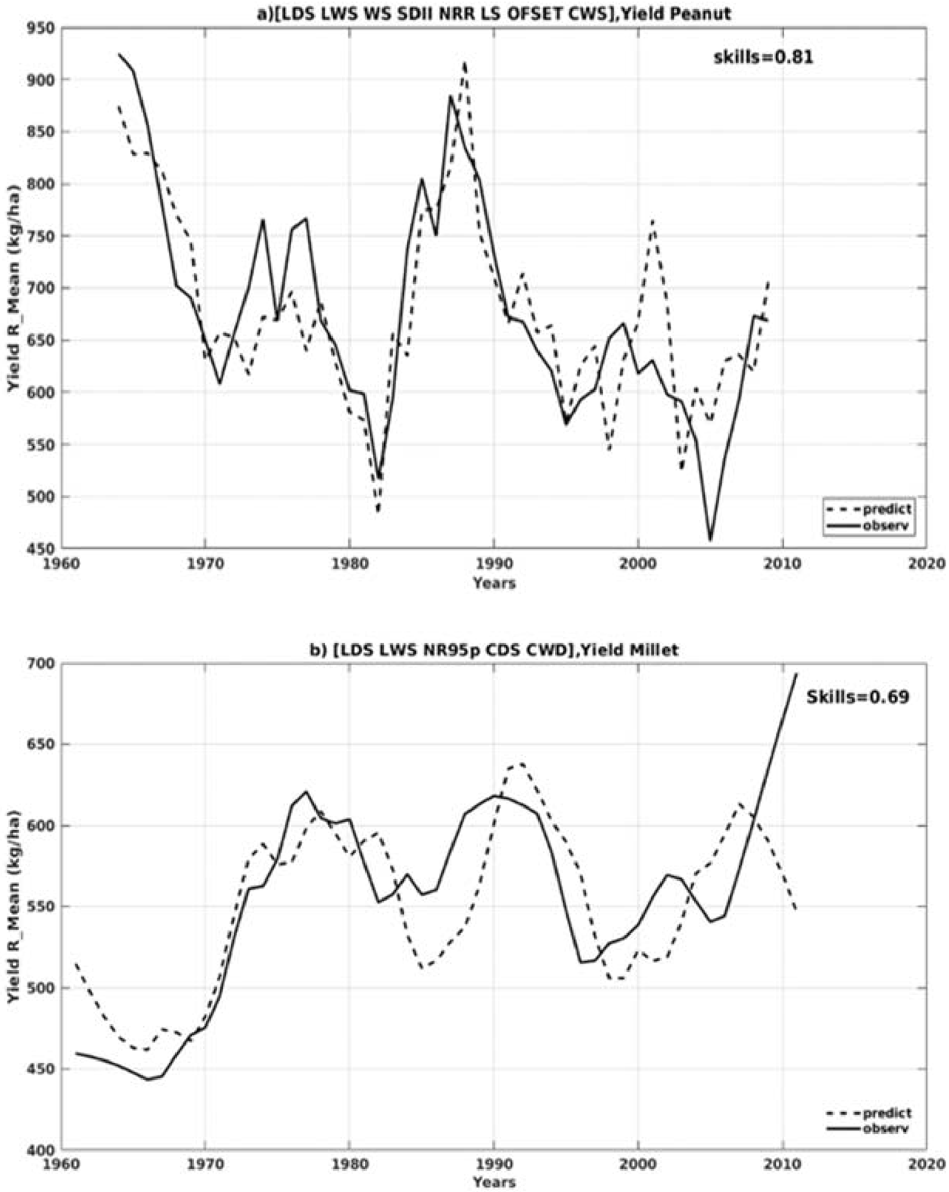

Figure 6. Model reconstruction curves of in situ groundnut (a) and millet (b) yield data based on rainfall metrics. Continuous line the in situ data, discontinuous line the model obtained with the metrics selected by the stepwise method for each speculation.

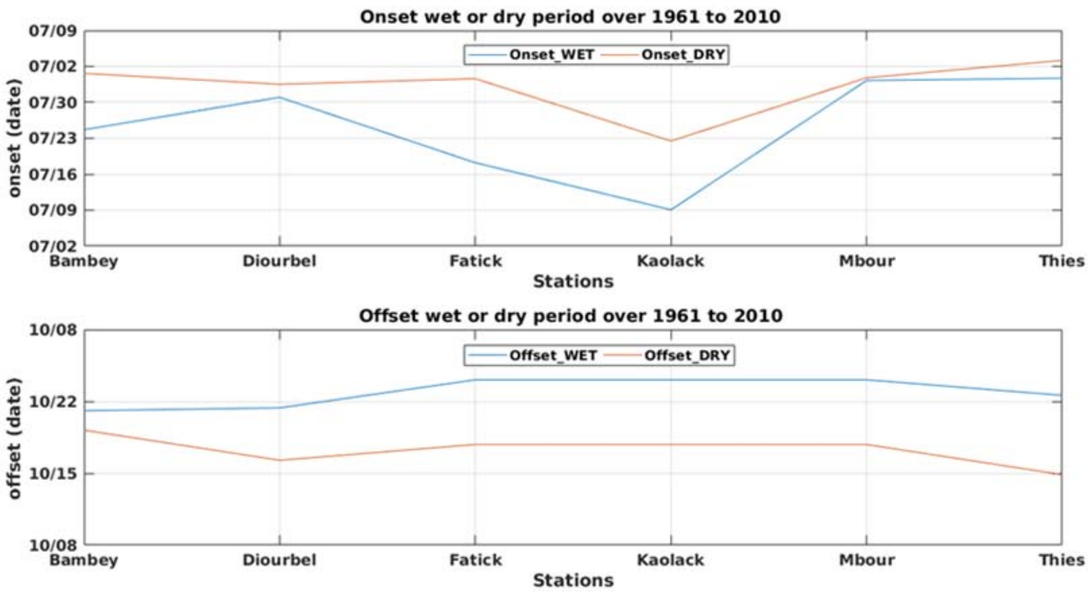

Figure 7. Comparison of Onset and Offset metrics of dry and wet years for six departments for the period 1960 to 2011

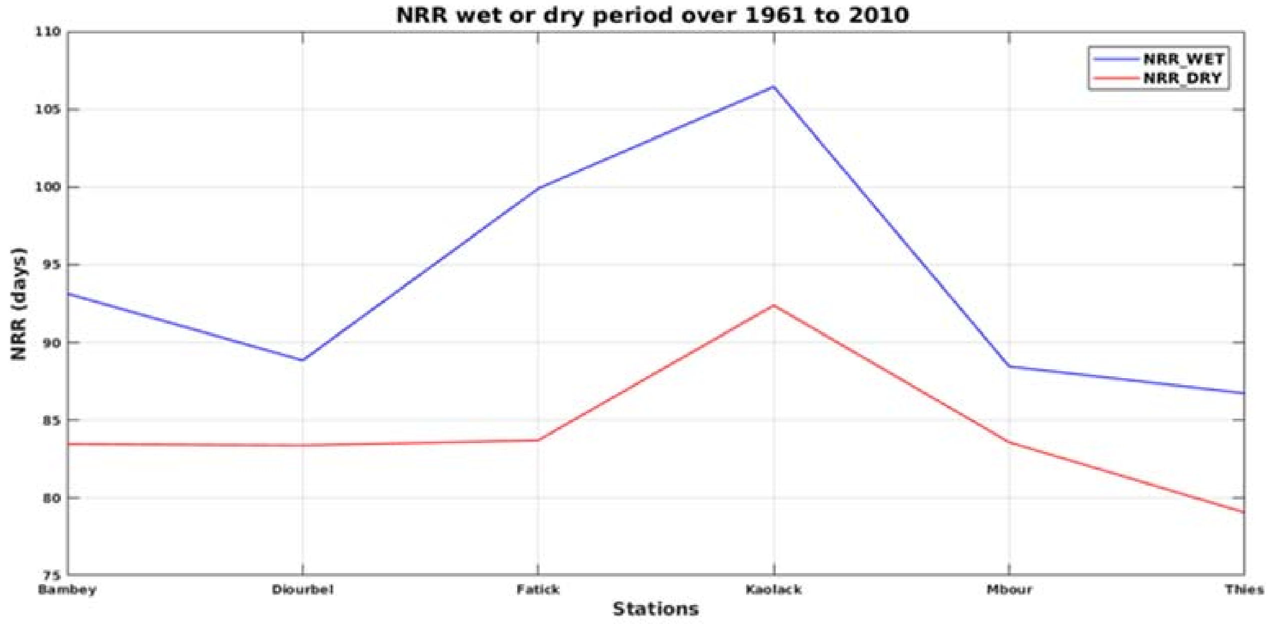

Figure 8. Comparison of the number of wet and dry year NRR rainy days for six departments for the period 1960 to 2011

Table 5. Comparison of Onset and Offset (left) and NRR (right) metrics of dry and wet years for six departments for the period 1960 to 2011

Area	LS Wet Period (day)	LS Dry Period (day)	Diff (Wet-Dry) (day)	Onset For Wet	Onset For Dry	Offset For Wet	Offset For Dry
Bambey	92	83	9	June 10th	June 18th	10 Sept.	9 Sept
Diourbel	88	83	5	June 15th	June 16th	11 Sept.	7 Sept.
Fatick	99	83	16	June 6th	June 17th	13 Sept.	8 Sept
Kaolack	105	92	13	May 31st	June 8th	13 Sept.	8 Sept
Mbour	88	82	6	June 17th	June 18th	13 Sept.	8 Sept
Thiès	86	78	8	June 17th	June 20th	11 Sept.	6 Sept
Mean LS	93	83	10				

Kaolack and Fatick had maximum day lengths of 99 and 105 days respectively, exceeding the wet year average of 93 days (Table 4). On the other hand, only the Kaolack station is in excess of the 83-day dry year average. The number of rainy days is much higher in wet periods and at all stations. The length of (dry/wet) growing periods affects groundnut and millet yields.

Average yields in wet years are significantly higher than in dry years for all millet and groundnut speculations (e.g. Figure 9). Average yields for wet and dry years are 734 kg/ha to 600 kg/ha for groundnuts and 551 kg/ha to 503 kg/ha for millet. Thus, they decrease by 18% for groundnuts and 10% for millet, which is more resistant to rainfall deficits. Figure 9 shows the situation obtained according to the dry or wet period. In both cases, groundnut have a higher yield despite the considerable drop noted during the dry period. However, millet, which is a dry cereal, is more likely to withstand water stress

In wet years, for groundnuts, the wet sequence distribution and length metrics (NR95p, LWS, CWD, CWS, NRR, NWS, SDII) are important in increasing yield (e.g. Figure 10). On the other hand, the length and occurrence of dry sequences (LDS, CDS) tend to reduce groundnut productivity. In addition, millet is more sensitive to the length of the season (LS) and the end date of the season (Offset). However, during wet periods, extreme rainfall (NR95p) and other wet sequences are determinant to yield development. For this purpose, it is important to know that millet can undergo the photoperiodism effect if the insolation is not sufficient for its chlorophyll. Reference [18] have shown that traditional millet crops are more sensitive to photoperiods. However, millet appears to be more resistant to future climatic conditions.

In dry years, only consecutive wet sequences can save groundnut yields. However, consecutive lengths and sequences slow down productivity. For millet, the same metrics mentioned above in wet years contribute with a lower degree.

In both cases, the metrics are more sensitive in wet periods than in dry periods. It is good to take into account the contribution of certain indices which remain much more determining and specific according to the given speculation. In this regard, groundnut are most affected by the length and intensity of wet sequences. Its performance increases considerably with the increased input of these metrics despite the inverse phenomenon caused by the length and frequency of the dry sequence. In addition, frequently used varieties such as North (55 - 33, 80 days), Central (55 - 437, 90 days and Flower 11, 90 - 95 days, 73 - 33, 105 - 110 days), South 69 - 101 (105 - 110 days) are more exposed to this yield reduction. The same observation is noted for both short-cycle and long-cycle millet. On this basis, varieties with a short growing cycle and resistant to water stress must be multiplied for better resilience to climate change.

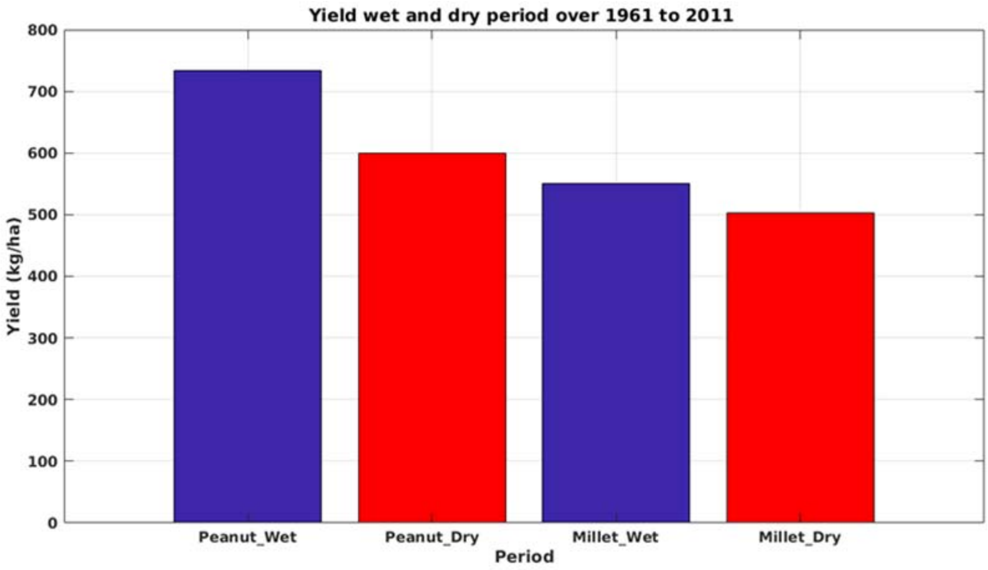

Figure 9. Comparison of millet (orange) and groundnut (blue) yields in dry and wet years.

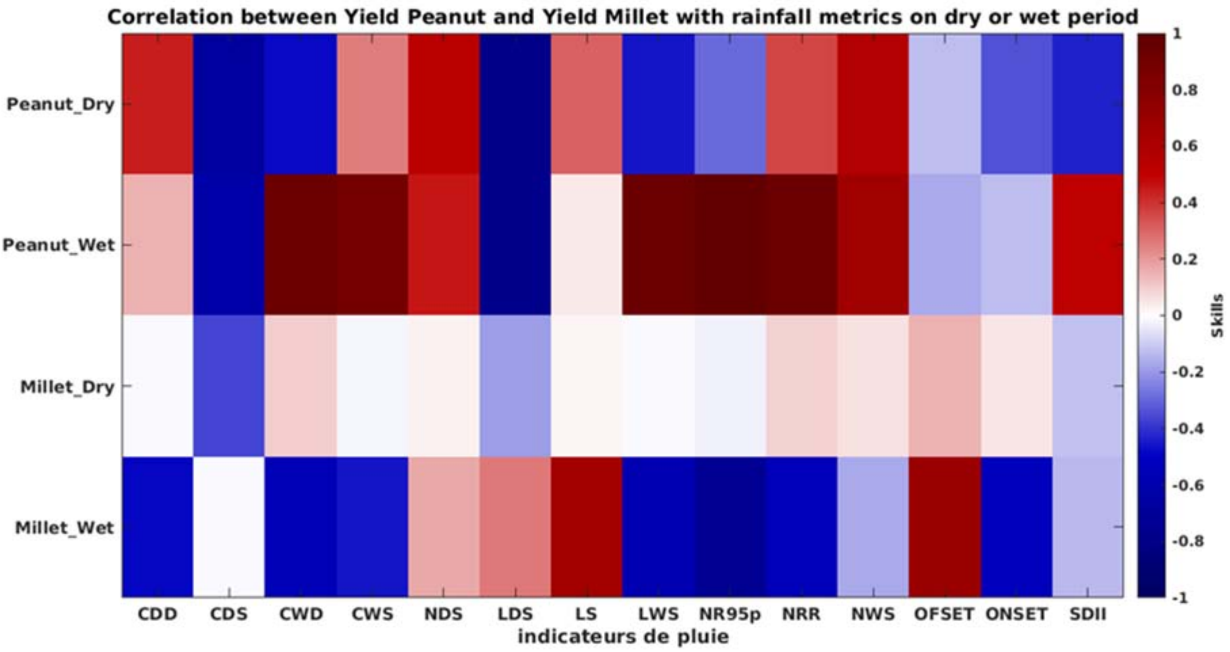

Figure 10. Correlation of metrics in dry and wet years for millet and groundnut yields

4. Conclusion and Discussion

This study proposes a descriptive analysis of the relationships between climatic parameters (temperature and rainfall metrics) on groundnut and millet yields in the groundnut basin of Senegal over the period 1961 to 2011. Climatic data from the National Agency for Civil Aviation and Meteorology (ANACIM) and agronomic data from the Directorate of Analysis and Forecasting of Agricultural Statistics (DAPSA) were used. With regard to rainfall, in addition to the total accumulation index, 14 other rainfall indicators indices were calculated and compared with speculative returns. The direct correlations of each index were first examined and then with a multilinear regression model, the combined influences of several metrics on the speculation were documented. A dry/wet year composite analysis was also carried out to analyse the sensitivity of speculation to the metrics.

The results show an increase in temperatures in our area. A trend that is consistent with the decline in groundnut yields according to Reference [18]. The latter claim that the probability of yield reduction appears to be greater in the Sudanian region (southern Senegal), due to an exacerbated sensitivity to temperature changes compared to the Sahelian region (northern Senegal). However, if we consider millet, which is a dry cereal, the downward trend is not very marked.

In addition, rainfall metrics play an important role and are closely linked to agricultural yields. Also, the change in productivity depends to a large extent on the sensitivity of these indices to such speculation. Moreover, the trend shows that groundnuts are the speculation that is most affected by these metrics, while millet is more resistant. The rainfall intensity, length and distribution metrics (LDS, LWS, NWS, SDII, NRR, LS, Offset, CWS) and (LDS, LWS, NR95p, CDS, CWD) would contribute 66%

and 49% to the change in groundnut (r=0.81) and millet (r=0.69) yields respectively. However, some varieties with a short growing cycle, due to their ability to adapt, remain less sensitive to deficits in rainfall intensity and distribution.

Also, the decrease in crop yields is considerable during dry periods (18% for groundnuts and 10% for millet) due to the occurrence of long dry spells and low rainfall distribution. In order to face the major future challenges, it is essential to ensure that they are effectively taken into account in agro-climatic model simulations in order to reduce the uncertainties in projections. Thus, the potential of the green economy must be expressed in the fight against climate change and for the resilience of ecosystems, populations and economies in terms of governance and institutional and political capacities (e.g. [36]).

The impact of the metrics on these agricultural yields creates doubts about the projections that metrics impacts agricultural productivity (e.g. intra-seasonal dry spells that have a differential impact depending on the phenological stage of the crop according to reference [5])) in the future. On this basis, these determinants need to be incorporated in order to refine future projections. Also, oceanic teleconnections with these indices remain a major challenge to gauge their relationship and create synergy with agricultural yields. Already, according to reference [37], there is an interrelationship between groundnut yields, interannual variability in rainfall and sea surface temperature. However, it is important to look at the rainfall metrics to see how they relate to these three parameters. For example, reference [38] showed that oceanic forcing associated with Sahelian rainfall vary with rainfall intensity. Reference [14] have also shown that long dry spells (dependent on false starts) are also sensitive to the combined warming of the entire tropical Atlantic and equatorial Pacific and Indian regions.

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