The impact of climate variability on crop production in Central-Benin

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Abstract

One of the major factors determining crop production, and therefore food supply and security, is the physical resource endowment of a given area. Crops differ in their adaptability and productivity with respect to soil and climatic conditions.
The suitability of the climatic conditions of Central-Benin for six selected crops (maize, sorghum, cowpea, groundnuts, cotton and cassava) was evaluated in terms of minimal length of growing period, precipitation, temperature, air humidity, radiation and other particular climatic requirements.
Current land evaluation systems, e.g. those inspired by FAO´s land suitability classification approach, attach great importance to the climatic potential of the land and to the growing period characteristics a determining suitability ratings. The evaluation of climate is based on the parametric method. The climate characteristics are regrouped into 4 groups (characteristics related to rainfall, temperature regime, relative air humidity and radiation). In the parametric method a numerical rating is attributed to each characteristic. An index (I) is calculated by multiplication of the individual ratings.
Here the climate ratings are based on long-term rainfall data of twelve climate stations in the area. It can be seen that the main crop maize is far from being the most adapted to the area. On the other hand, it generally has a high yielding potential and is thus of interest for the local food production. However, crops such as groundnuts, sorghum and cowpea are more suitable.
The temporal variability of the climate rating has an impact on the land suitability of different crops. In years with high climatic rating the land index is higher and vice versa. Due to the variability of the climate rating, the variability of land indices for maize production is more marked than those of the cowpea production. This is attributed to the higher water demand of maize compared to cowpea.

Keywords: climate variability, climate evaluation, Central Benin

1 Introduction

One of the major factors determining crop production, and therefore food supply and security, is the physical resource endowment of a given area. Crops differ in their adaptability and productivity with respect to soil and climatic conditions. The objective of this study was to evaluate different crops with respect to their ability to cope with high climatic variability. The study area belongs to the transition zone between Subsudanian and guinean savanna (Adam and Boko, 1983; Walter and Lieth, 1967). The climate is intermediate between guinea-congolian and Sudano-guinean climate. The sudanian climate's influence is expressed by a short period of less rain in August. Rainfall pattern is monomodal, the rainy season being from April to October. The dry season lasts from November to mid March or April.

2 Material and methods.

The suitability of the climatic conditions of Central-Benin for six selected crops (maize, sorghum, cowpea, groundnuts, cotton and cassava) was evaluated in terms of minimal length of growing period, precipitation, temperature, air humidity, radiation and other particular climatic requirements.
Current land evaluation systems, e.g. those inspired by FAO´s land suitability classification approach, attach great importance to the climatic potential of the land and to the growing period characteristics for determining suitability ratings. The use of monthly data for the evaluation of the growing period is a common practice and has the advantage that it can rely on easily available climatic information. The evaluation of the climate was based on the parametric method. The climate characteristics are regrouped into 4 groups (characteristics related to rainfall, temperature regime, relative air humidity and radiation). In the parametric method a numerical rating is attributed to each characteristic. An index (I) is calculated by multiplication of the individual ratings:

$$I = A \times \frac{B}{100} \times \frac{C}{100} \times \frac{D}{100} \times \cdots$$

(I = climate index; A, B, C, D...= ratings)

For the total land evaluation the climate index I_c was transferred into a climatic rating R_c according to the following relations:

$$I_c < 25.0 \Rightarrow I_c \times 1.6 = R_c$$

$$25 \leq I_c \leq 92.5 \Rightarrow I_c \times 0.9 + 16.67 = R_c$$

$$I_c > 92.5 \Rightarrow R_c = I_c$$

Table 1: Optimal growing conditions (S1) for selected crops (Sys et al. 1993)

	Maize	**Sorghum**	**Groundnut**	**Cowpea**	**Cassava**	**Cotton**
Growing period (days)	90-120	90-130	90-140	80-110	270	150-180
Climatic requirements						
-Precipitation of GP (mm)	500-1200	400-900	400-1100	300-900	1000-2400	750-1400
-Precipitation of 1st month (mm)	100-295	nd	70-275	50-255	nd	> 65
-Precipitation of 2nd month (mm)	150-310	nd	100-225	100-255	nd	< 35
-Precipitation of 3rd month (mm)	150-310	> 100	100-275	100-255		100-400
-Mean temperature of GP (°C)	18-32	21-32	18-30	20-30	18-30	24-26
-Rel. humidity % gr.period (g) (h,m)	>50 (m)	< 75 (g)	< 80(g)	< 80(h)	Nd	< 65 (m)
Fraction of sunshine hours	>0.7	< 0.8	Nd	nd	>0.7	Nd

For the whole study area, rainfall data are available from 25 stations with daily values and with monthly average data over a 10 to 33 years period (ASECNA, CARDER-ZOU, 1998). The data for temperature, insolation, humidity and potential evapotranspiration are available from the two stations Bohicon and Savè.

Regarding the water demand by crops in Central Benin (Table 2) a sequence for the precipitation requirements can be established: **cowpea < sorghum < groundnut < cotton < maize < cassava.** The monthly distribution is more determining than the amount for the total growing period. Maize is most sensitive to moisture stress from the beginning of flowering until the end of grain filling.

3 Results and discussions

3.1 Rainfall variability in Central Benin

Mean annual rainfall (1964-1993) recorded at ASECNA amounted 1100-1200 mm, but more than 50% of it was received during four months (June to September Figure 1).

The temporal variability of rainfall is very high on the annual, monthly and daily time scales.

The total long term (1964-1997) average precipitation at Dassa is 1150 mm yr^{-1} , but the **interannual rainfall** fluctuation is very high (between 615 mm in 1983 and 1414 mm in 1979) (Figure 2). Bimodal distribution of rainfall is not as strongly developed as on the southern plateaus of Benin but still enough to allow two short season crops per each year. The monthly rainfall variation is more distinct since rainfall occurs during 5-7 summer months.

Monthly rainfall analysis for Savè (Table 1) shows the monomodal distribution during April-September and the increase up to July when the maximum is reached (120 to 170 mm). The figure 1 gives an idea about the standard deviation of monthly means for Savè, Dassa and Lonkly.

The variation and the evolution of the temperature, the insolation, the wind and of the relative humidity are responsible for the variation of the potential evapotranspiration. Annual potential evapotranspiration is 1.479 mm (Table 2).

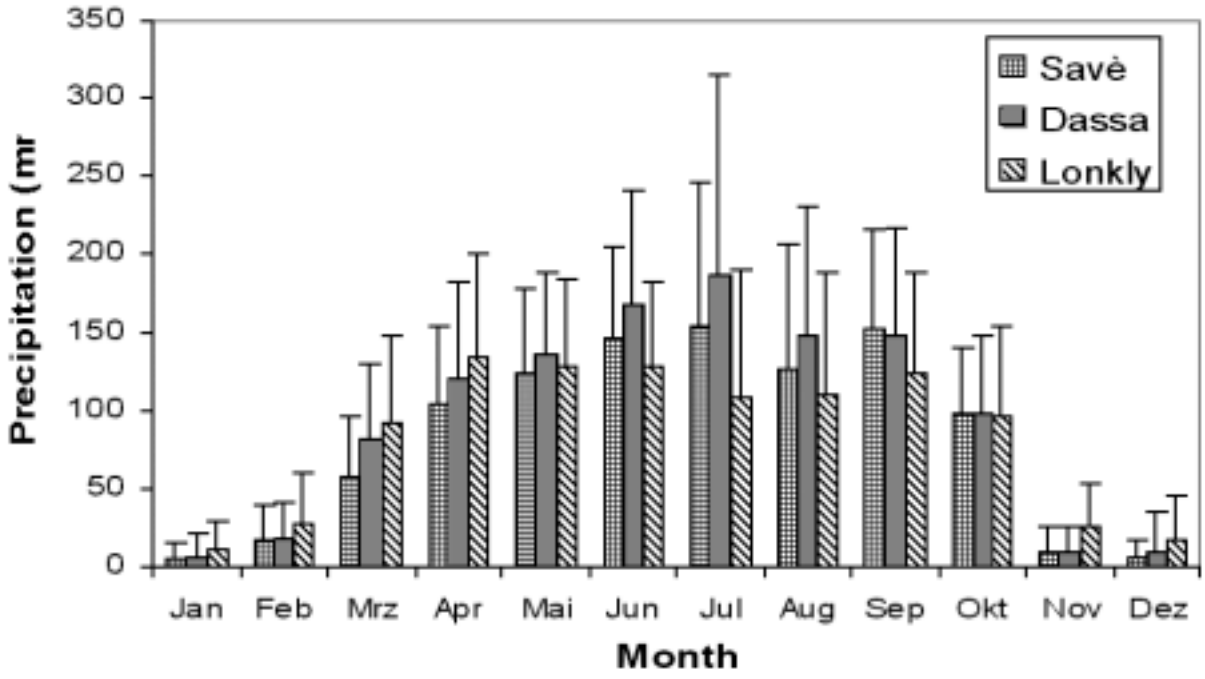

Figure 1: Average monthly rainfall in 3 locations of the study area (1964-1993, bars indicate standard deviation of monthly means)

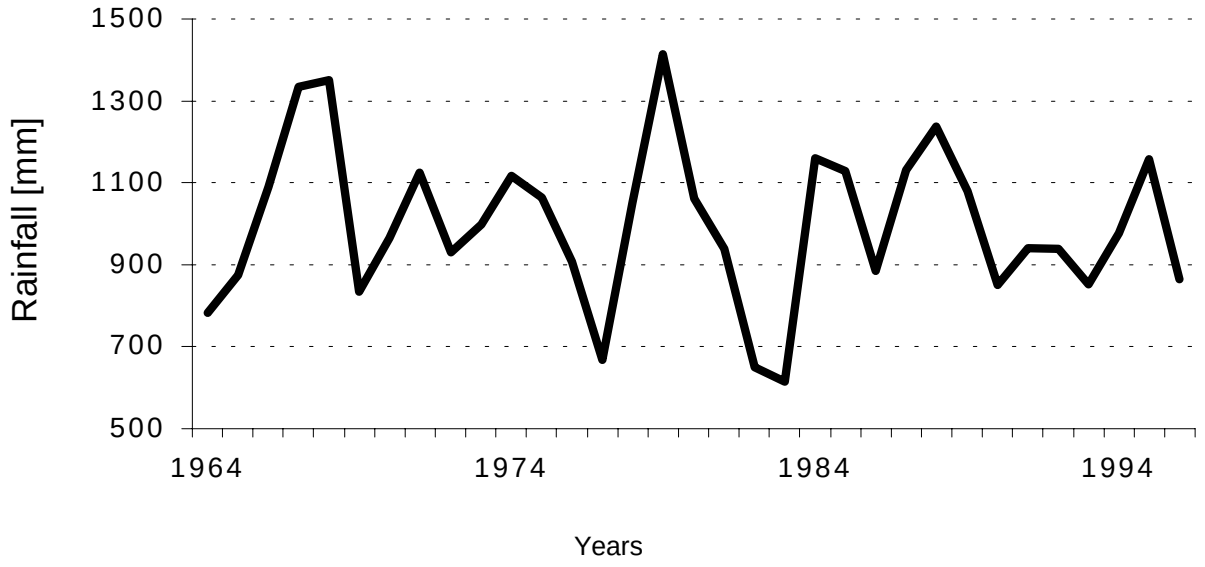

Figure 2: Variability of annual rainfall at Dassa (period 1964-1996)

Table 2: 20 years average means of maximum and minimum temperature (T.max. and T.min.), maximum and minimum humidity (H.max. and H.min.), insolation (Ins.), potential evapotranspiration (ETP) and rainfall (P) in Savè.

Months	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
T:max.	39	41	41	39	38	35	33	33	35	35	38	38	-
T:min.	15	19	20	19	20	19	20	19	19	19	17	17	-
H:max.	94	94	93	98	99	99	99	98	99	98	99	98	-
H.min.	7	4	3	30	40	44	51	50	50	45	18	11	-
Ins.(hours)	7	7	7	7	7	6	3	3	4	5	7	7	-
ETP:(mm)	124	128	147	142	141	120	111	107	109	120	113	117	1479
P (mm)	5	30	39	124	128	107	165	93	150	95	11	8	955

During the dry season occurs more than 40% of the total annual evapotranspiration. Although, in the rainy season the potential evapotranspiration does not considerably exceed precipitation, periods of drought do occur (CNA, 1976). The monomodal rainfall distribution (Figure 1) with a slight reduction of precipitation in August leads to an uneven soil moisture distribution over the year

3.2 Climate evaluation

In the subhumid region of Benin 30-40 different crops are cultivated. The six locally important food and cash crops were chosen for the parametric FAO/ITC-Ghent evaluation (Sys et al 1993).
The suitability ratings of the Central-Benin are average ratings for twelve rainfall stations in the area and were calculated with long-term mean climate data.
It can be seen that one of the main crops, maize, is far from being the most adapted to the area. On the other hand it generally has a high yielding potential and is thus of interest for the local food production. Field crops such as groundnuts, sorghum and cowpea replace maize, where it has reached its limit. Low rainfall during the second and last

month of the growing period are most often limiting followed by total rainfall of the growing period.
Concerning their temperature requirements the six crops are well suited (temperature rating > 72), showing the suitability sequence: **cotton** > **cassava , groundnuts > cowpea > maize > sorghum.**

Table 3: Average climatic ratings: average indices and main limitations of major crops in Central Benin

Crop	Planting Month	Climate Rating (Ø)	Main limitations (by order of their importance)
Groundnut	5	83	Low precipitation 2nd month, high mean temperature, high relative humidity of growing period
Sorghum	4	78	Low precipitation 3rd month, high mean temperature, high relative humidity of the growing cycle
Cassava	4	59	Low annual precipitation, long dry season, high mean temperature of growing cycle
Cowpea	4	70	High precipitation 4th month
Maize	4	48	Low precipitation 2nd and 3rd month, sunshine hours maturation stage, high rel. humidity at maturation/ at ripening, high mean temperature of growing cycle
Cotton	6	51	Low precipitation 5th month and growing period, high mean night temperature, high rel. humidity at maturation/ at ripening

The mean temperature of the growing period is most often above the optimum. Minor constraints due to high temperature exist for all crops. The relative humidity of the growing period has moderate constraints to cotton production and slight constraints to the other crops. The relative humidity at maturation and harvest causes slight constraints to cotton, maize, and cowpea.
The calculated climatic ratings show the following rating sequences: **groundnuts > sorghum > cowpea > cassava > cotton > maize**.
However, it must be pointed out again that these indices are means with considerable differences between the climate stations.

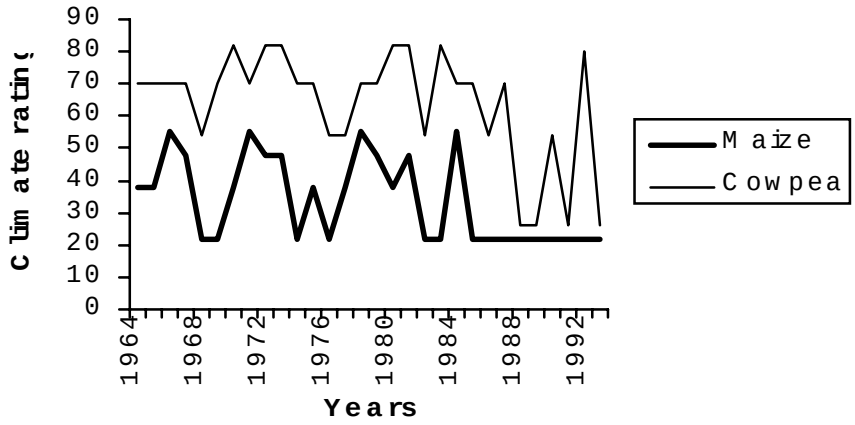

Figure 3: Variability of annual climate ratings for maize and cowpea production at Savè (1964-1993)

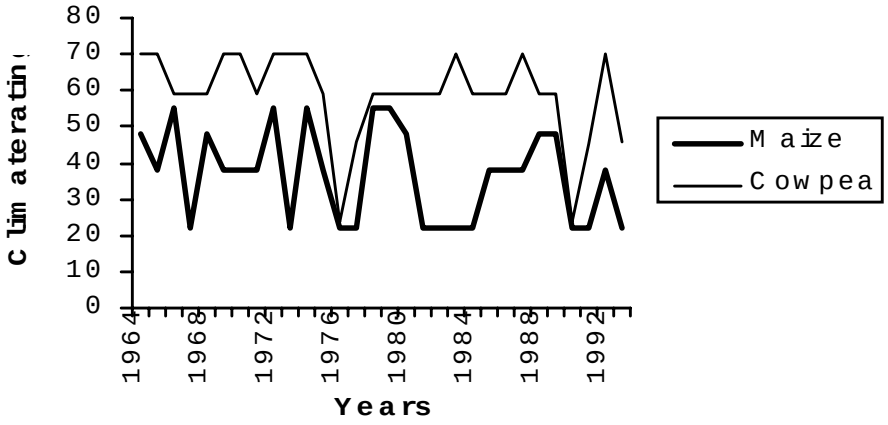

Figure 4: Variability of annual climate ratings for maize and cowpea production at Bohicon (1964-1993)

The comparison of climatic ratings for April and May as sowing date in the study area showed that the best sowing month is beginning of April for all crops except for cotton, which must be sown in June and groundnuts in April or May, when long-term mean climate data are considered.

At Savè, the climate evaluation for **maize production** based on annual rainfall data (Figure 3) shows that in 21 out of 30 years the climate rating

is lower than the mean rating (48) based on mean values of long-term climate data and only in 4 out of 30 years the rating is higher. The Lowest value (22) is obtained in 15 out of 30 years in the Savè and 11 years in Bohicon (Figure 4) for maize production. In the years 1985 to 1993 it was observed a constant climate rating of 22 in the Save station (long-term rating 48).

The climate evaluation per year for **cowpea production** (Figure 3) exhibits that lower values (26 to 54) as the long-term mean based on mean values of long-term climate data (70) are obtained in 10 out of 30 years only at Savè and in Bohicon lower rating (24 to 59) are obtained in 20 out of 30 years (Figure 4). Compared to the long-term value, a higher climate rating of cowpea (80 to 82) is obtained in seven out of 30 years only in Savè.

The calculated climatic ratings show the following rating sequences: **groundnuts > sorghum > cowpea > cassava > cotton > maize**. However, it must be pointed out again that these indices are means with considerable differences between the climate stations.

Another short-coming of the calculated ratings is the definition of the growing period. The normal crop growth cycle should in particular be able to fit into the growing period, i.e., during the time in the year that temperature or moisture promote plant growth and biomass production. For one and the same station the onset of the growing period necessary differ when calculated on the basis of either decade or monthly data. The use of a 10 days climatic interval is obviously relevant to define more accurately the beginning of the growing period. The use of monthly data for the evaluation of growing period is a common practice and has the advantage that it can rely on easily available climatic information. This may be cause evaluation failures because it may shorten or enlarge the estimated growing period by up to 50 days a year.

In addition, the use of monthly data mask not seldom important short-time hazards and, therefore, may result in an inaccurate or unrealistic evaluation of the effective growing period conditions. This refers in particular to critical moisture variations and/or stress conditions, which have a direct impact on (1) the reliable start of growing period for sowing

and germination of crops, (2) the occurrence (of interned) at dry spells within the growth cycle of the crops and (3) the soil moisture storage at the end of the rainy season, allowing to extend the growing period by some additional time (Testome and Verheye, 1992). This short time hazard could be handled separately as a factor of ecosystem stability. The temporal variability of the climate rating has an impact on the land suitability of all crops. Due to the variability of the climate rating, the variability of the land index for maize production is more marked than that for cowpea production.

At Savè mean climate ratings for maize are 48 (based on mean monthly values of long-term data) and 34 (average annual climate ratings over 30 years). For Cowpea the mean climate ratings are 70 and 64 respectively. This indicates the importance of calculating the climate index for a region as the average of annual climate evaluations (Igue et al 2000).

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