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Determination of potential lengths of the crop growing period in semi-arid regions of Senegal

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ABSTRACT

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A study of rainfall data from the Senegal semi-arid region shows that one of the major components of the deterioration in rainfall in the Sahel is the very marked reduction in the length of the rainy season since 1970. This reduction means that lengths of the crop growing period have to be reviewed for each region. A study method is described which takes into account the inherent climatic, economic and technical constraints in Sahelian agriculture. It enables potential lengths of the growing period to be determined, adapted to each region. Among the various means used to study drought, this method, in particular, enables the setting of plant breeding targets. It has been applied to the case of the Senegal semi-arid region.

INTRODUCTION

Rainfall totals since the start of the 1940s show that in India, the drought is the result of significant rainfall fluctuations from year to year, with no overall drop. However, for the Sudan-Sahel region of Africa and for Australia, a tendency towards lower rainfall began during the 1950s, with an apparent stabilisation from 1972-1973 onwards. This also applies to North and South hmerica, particularly northeastern Brazil, since 1945, and, more recently, for eastern and southern Africa (UNESCO, 1984).

In Africa, there is statistical evidence for a degree of periodicity as regards series of rainfall figures. The previous two dry periods occurred during the 1910s and 1940s, both of which lasted for a shorter time than the current drought. Nonetheless, this periodicity is of no value in forecasting, owing to random phase modifications of these chronological series (UNESCO, 1984).

The dynamic causes of drought are little known, as climatologists still have great diffculties distinguishing causes from correlated effects which may be synergistic. Some partial explanations have been put forward, such as in-

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creased soil reflectivity and variations in the surface temperature of the oceans, the latter being a result of modifications in ocean current dynamics.

It is now established that human activity, through overgrazing, deforestation and poor farming practices, plays a decisive role in the drought and desertification process. It seems that such adverse activity may lead to an irreversible deterioration in the Sahel.

Taking the case of the Senegal semi-arid region, which stretches northwards to Gambia, this article sets out (i) to show that one of the major components of the drought in the Sahel is the shortening of the rainy season, (ii) to examine the consequences of this on determining lengths of the crop growing period, with the use of a simple study model.

DISCUSSION

The rainfall data used in this study have been provided by the Agroclimatology Service of ISRA. They represent 36 years, from 1953 to 1988, and have been collected from ten different locations with very few missing values.

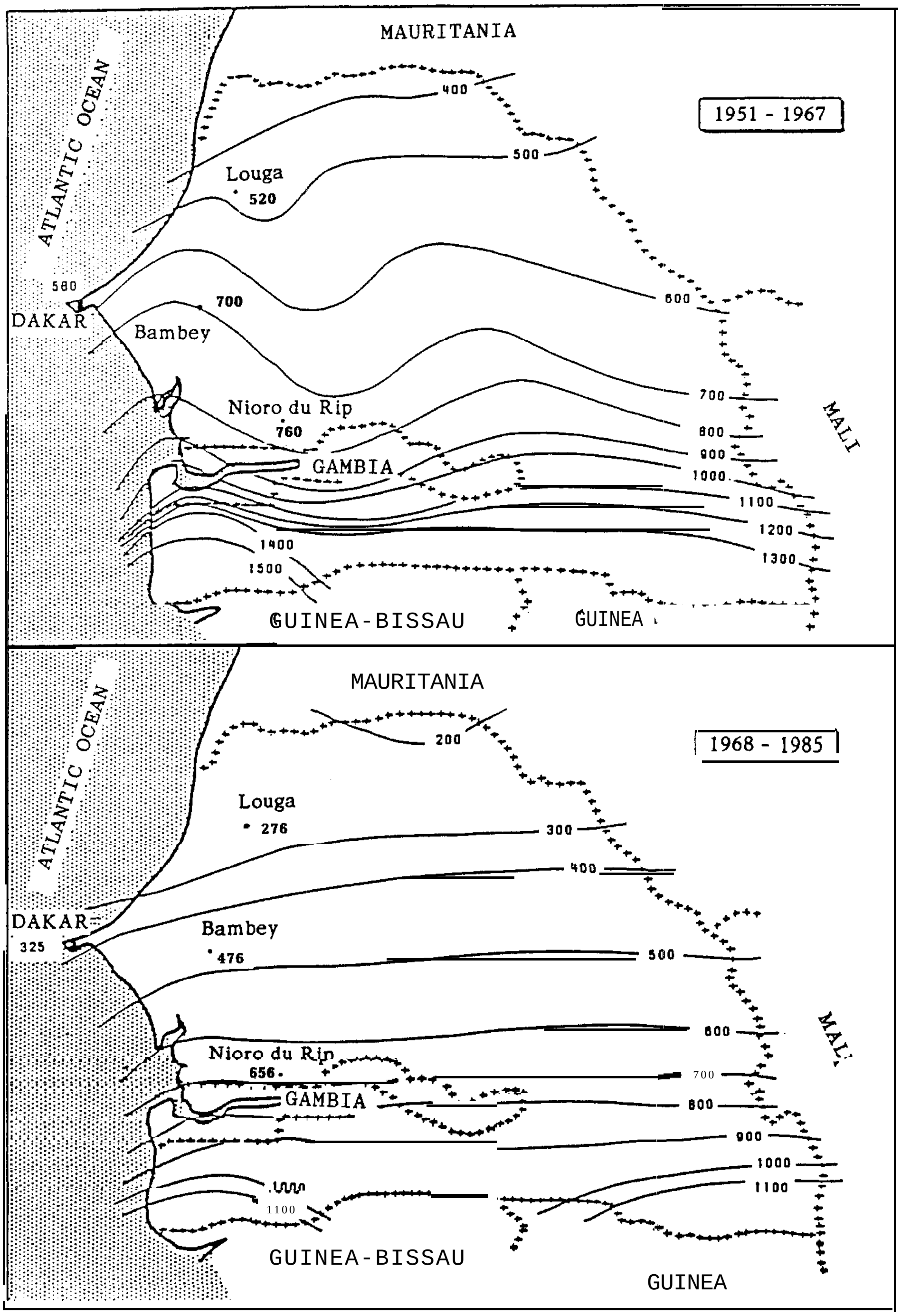
Reductions in annual rainfall

For Senegal, a comparison of the isohyet chart for the period 195 1- 1967 with that for the period 1968-1985 (Fig. 1) shows a north-south slide, corresponding to an overall reduction in rainfall (Diagne, 1988).

Figure 2 gives mean annual rainfall figures for ten sites representative of the dry region in Senegal, for the years 1953-l 986. It is clear that the drop in rainfall began around 1970. The inter-annual mean fell from 588 mm during the 'wet period' to 4 10 mm during the 'dry period', i.e. a drop of 178 mm, representing a 30% reduction. A statistical comparison of these two means indicates that the difference is very highly significant ($P < 0.00$ 1). However, a comparison of variances for the two periods shows that they are not significantly different. Inter-annual variation is therefore the same for the two periods. This indicates that the drop in rainfall does not stem from the appearance of extremely dry years, but rather from a general decrease in the level of rainfall.

Reduction in the 'useful length' of the rainy season

In the semi-arid region in Senegal, rainfall data over 36 years (1953-1988) for three locations (Louga in the north, Bambey in the central-north region and Nioro-du-Rip in the central-south region; Fig. 1) serve to illustrate the phenomenon of the reduced 'useful length' of the rainy season. The so-called 'useful length' (Khalfaoui and Annerose, 1987) is defined as the number of days between 'the first rain enabling sowing' and 'the last useful rainfall'.



(Source: Bioclimatology Service (ISRA))

Fig. 1. Isohyet chart for Senegal for the periods 1951-1967 and 1968-1985 (mm).

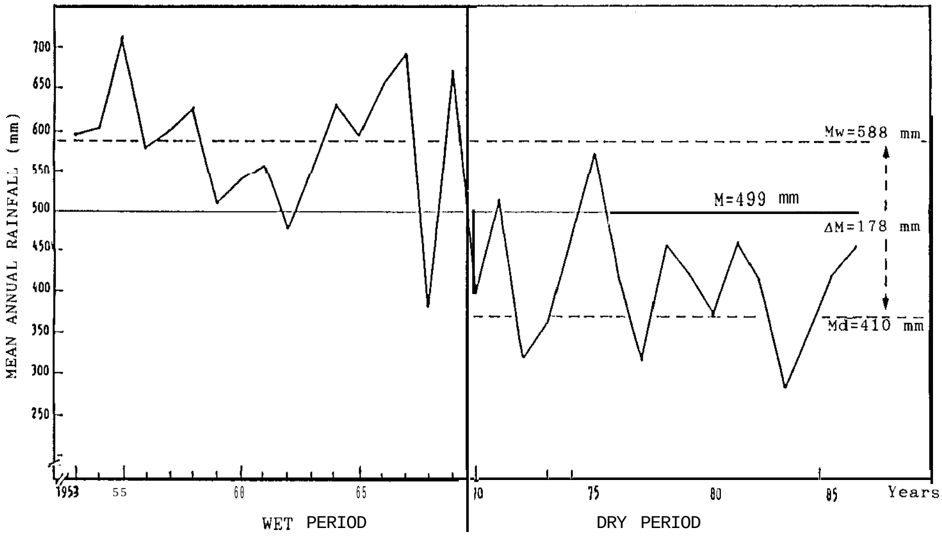


Fig. 2. Mean annual rainfall for 10 locations representative of semi-arid regions in Senegal, for years 1953-1986.

"The first rain enabling sowing" (Forest and Dancette, 1982) is defined, in accordance with the time that has elapsed since the possible star-t of the rainy season, as the minimum amount of precipitation that will enable a crop to become well established if sowing is carried out after this rain. This idea only concerns crops such as sorghum, groundnut and cowpea, which are sown just after rain, and not millet, which is sown "dry" before the start of the rainy season. With this crop, the idea of deciding when to sow depending on precipitation does not exist, and that of the "first rain enabling sowing" corresponds to the "first successful rainfall after dry sowing". Since the chances of success are less the earlier in the season sowing takes place, the minimum amount of rain in the first fall enabling sowing will be higher the earlier in the season the grower wishes to sow. Table 1 was produced by Forest and Dancette (1982).

"The last useful rain" is defined as the last precipitation that participates in supplying water to a crop sown after the first rain enabling sowing.

At Louga (Fig. 3), it is evident that the rainy season has shortened since 1970. A comparison of the mean useful length of rainy season for the years prior to 1970 with those for the years after 1970, shows that this drop – 25 days on average – is very highly significant ($P<$ 0.00 1) . However, a comparison of variance for season length during the two periods indicates that they are not significantly different, and thus that the useful length of the rainy season is no more irregular after 1970 than before that date.

At Bambey (Fig. 4), the reduction in the useful length of the rainy season from 1970 onwards is significant (Pc 0.05), and represents 12 days on aver-

TABLE 1

Minimum amount of rain required to enable successful sowing, according to region and date in the semi-arid region in Senegal

Site	Sowing period	Rain enabling sowing (mm)
North region (Louga)	1-15 June	>60
	16-30 June	>30
	1-20 July	>20
	20 July onwards	>15
Central-north region (Bambey)	1-15 June	>40
	16 June- 15 July	>20
	15 July onwards	>15
Centre-south region (Nioro-du-Rip)	1-10 June	>40
	11 June- 10 July	>20
	10 July onwards	>15

After Forest and Dancette (1982).

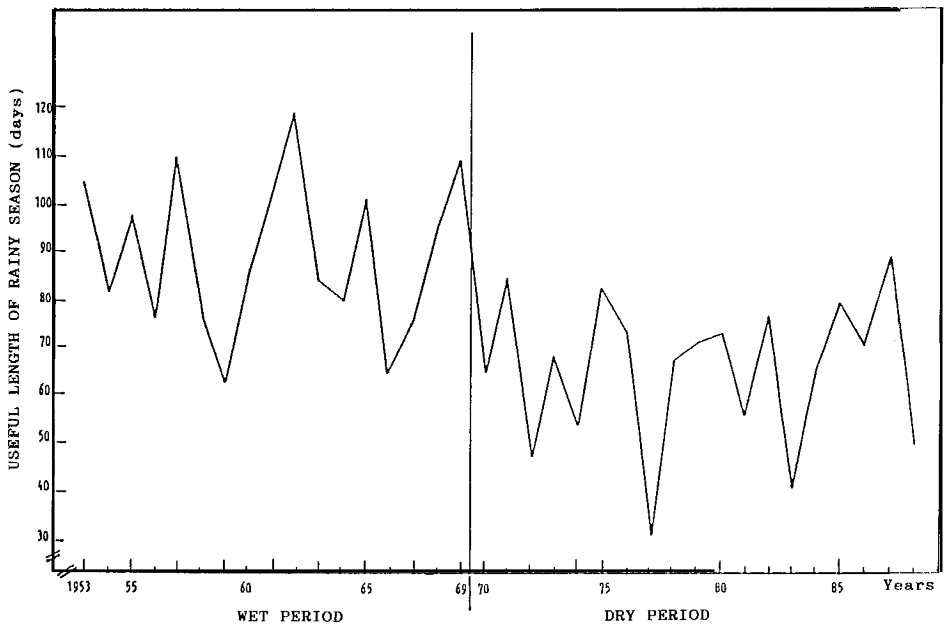


Fig. 3. Useful length of the rainy season at Louga for the years 1953-1988.

age between the wet period and the dry period, without significantly modifying inter-annual regularity.

At Nioro-du-Rip (Fig. 5), a sharp and highly significant fall ($P < 0.1$) in

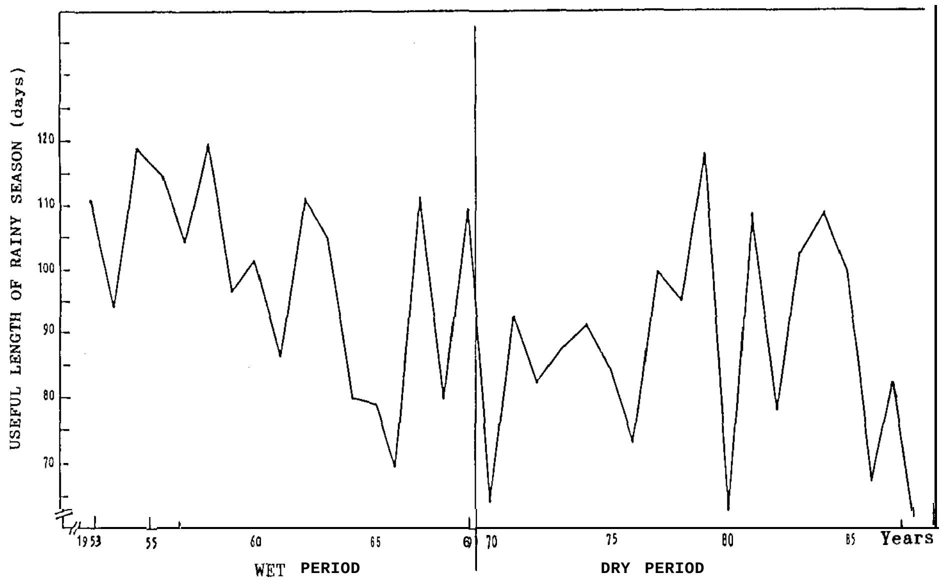


Fig. 4. Useful length of the rainy season at Bambey for the years 1953-1988.

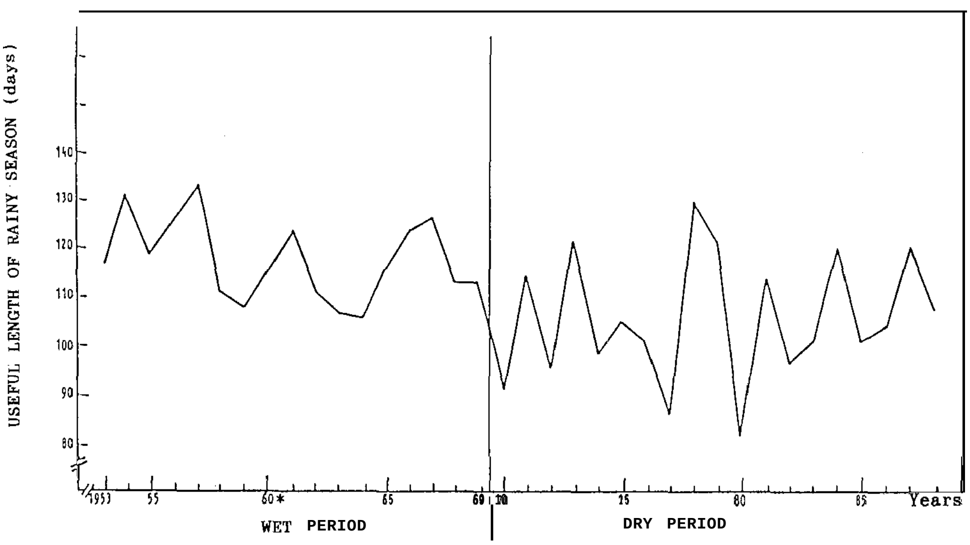


Fig. 5. Useful length of the rainy season at Nioro-du-Rip for the years 1953-1988.

the useful length of the rainy season is seen from 1970 onwards. The drop is 12 days on average, and does not signifkantly modify inter-annual regularity.

Betermining the optimum length of the crop growing period

Principle

The reduction in the useful length of the rainy season means that the length of the growing period for crops grown in the region has to be revised. A simple method, based on bioclimatological data, enables an optimum growing period length for each region to be determined. It is sufficiently general to be applied to all crops, and can be adapted to each species by coupling it with a mode1 simulating crop water balance.

One basic principle should be retained: it is generally acknowledged that a reduction in the cycle length of cultivars leads to a fall in production potential. In order to optimise the crop, the length of the cycle should coincide as closely as possible with that of the rainy season.

The main constraint lies in the marked inter-annual fluctuation in the length of the rainy season, which makes it difficult to determine the length of growing period to be adopted. In the case of useful lengths of the rainy season over the period 1953– 1988 for the towns of Louga, Bambey and Nioro (see Figs. 3-5), the coefficients of variation are 24%, 18% and 13%, respectively. It can be seen that as we progress northwards, rainfall totals decrease and the inter-annual variations increase. This constitutes one of the components of the increased climatic risk in the northern regions. Optimisation is therefore necessary, and consists of identifying the proportion of years in which the growing period would fit into the rainy season, which is equivalent to choosing the probability of success. This choice should first and foremost take account of the following two economic factors.

(1) On an individual level, the economic situation of farmers in developing countries is characterised by the lack of inter-annual financial resources, preventing them from speculating on ventures with a fairly high risk of failure. Some of these ventures would yield a higher overall productivity, but would involve large fluctuations in annual income, particularly if national agricultural development policy is based on agricultural credit, meaning that they have to make repayments on loans.

(2) On a national level, market stability, hence that of production levels, is an economic priority for all countries, especially developing countries, where agricultural product processing, distribution and marketing networks, already in existence or yet to be set up, need to be safeguarded, owing to their 'fragility'.

These two economic factors mean that a low risk of failure which may be brought about by sufficiently short growing periods, should be ensured. This will also mean that the farmer is able to safeguard his crop by guarding against 'false starts' to the rainy season, i.e. sowing after the first heavy fall of rain, early in the season, which may be followed by a waiting period before the rainy season really begins (Forest and Dancette, 1982). This implies taking a 'safety margin' into account in the determination of sowing time.

The length of the growing period should also take account of the farming calendar at the beginning and the end of the rainy season, which represents a period of heavy workload for the farmer. Cultivars with a cycle length slightly shorter than the rainy season would fit most years, and provide work flexibility by enabling the farmer to stagger sowing and harvesting. Furthermore, these cultivars would enable wet ploughing which, if applicable, is an effective crop technique that conserves and makes best possible use of water (Dancette, 1985). This approach demands a 'degree of freedom' with regard to the choice of technique to be used.

Model

The 'potential length of the crop growing period' is defined in the following way: the useful length of the rainy season, plus the time, after the last useful fall of rain, during which the crop is able to draw water from the soil's reserves, minus 5 days, corresponding empirically to the 'safety margin' plus the 'degree of freedom' with regard to technique.

The length of time during which the soil's usable water reserves can be used is evaluated using the total rainfall over the previous month. During the month, the daily evapotranspiration is fixed at approximately 2 mm. This value corresponds to the water supply needed at the end of the growing period, calculated by the method of Fréteaud et al. (1984), and weighted by an index of minimal satisfaction equal to 50%, compatible with a satisfying termination of the crop. Therefore, the consumption is 60 mm for the month as a whole. Total rainfall over the month minus 60 mm gives an estimate of available water reserves, which are used at a rate of 3.5 mm day^{-1}, with evaporation increasing after rainfall. This value is calculated according to the method described above.

Given that a is the useful length of the rainy season (days), b is number of days during which the crop can draw on soil water reserves and c is total rainfall over the previous month of the rainy season, then: Potential length of the crop growing period $= a + b - 5$ (in days)
where

$$b=\frac{c-60\text{ mm}}{3.5\text{ mm}}(\text{days})$$

Given the flexibility that some crops show, it is acknowledged that there may be no adverse effects on production when, for a given year, the potential length of the growing period is up to 5 days shorter than the theoretical duration of the crop.

Application to the case of Senegal

The potential length of the growing period was determined for each year in the period from 1953 to 1988, for each of the three locations in the semi-arid region in Senegal (Figs. 6-8) .

From 1970 onwards, a reduction in the potential length of the growing period was seen for all three localities: at Louga there was a reduction of 26 days ($P < 0.001$); at Bambey a reduction of 16 days ($P < 0.05$); at Nioro-du-Rip a reduction of 17 days ($P < 0.05$).

Table 2 shows the variability in the length of the growing period in the three regions of the semi-arid zone in Senegal during the wet period (1953-1 969) and the dry period (1970– 1988). It reveals the marked reduction in the lengths of the growing period in each region, caused by the drought from the end of the 1960s onwards.

The rainfall data for 14 locations over the whole of the semi-arid region in Senegal enable a map to be drawn up of inter-annual average potential growing period length during the dry period of 1970– 1986 (Fig. 9). This does not, however, make it possible to select a value for the length of growing period which is effective in the various regions, as it does not include the probability of success, which takes account of inter-annual variations.

However, the choice of potential length can be based on the map of the lengths of growing period satisfied in at least 80% of years, i.e. 14 out of the 17 years in the dry period (Fig. 10).

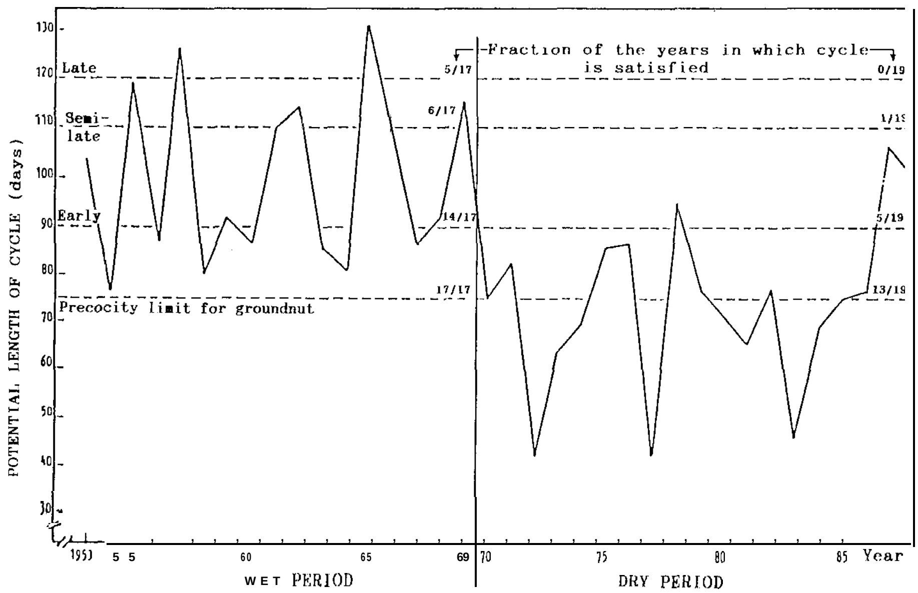


Fig. 6. Potential length of the crop growing period at Louga for the years 1953-1988.

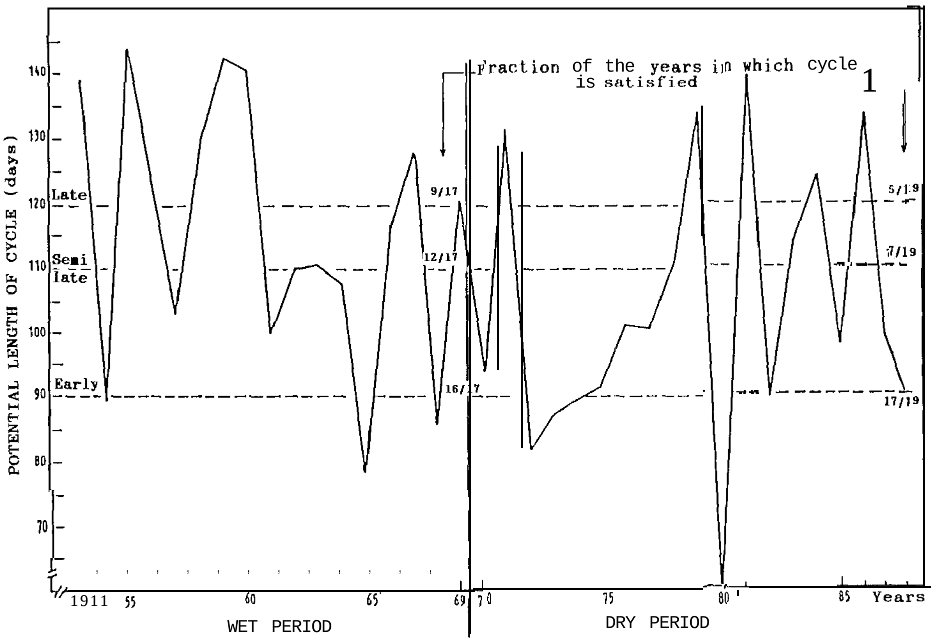


Fig. 7. Potential length of the crop growing period at Bambey for the years 1953-1988.

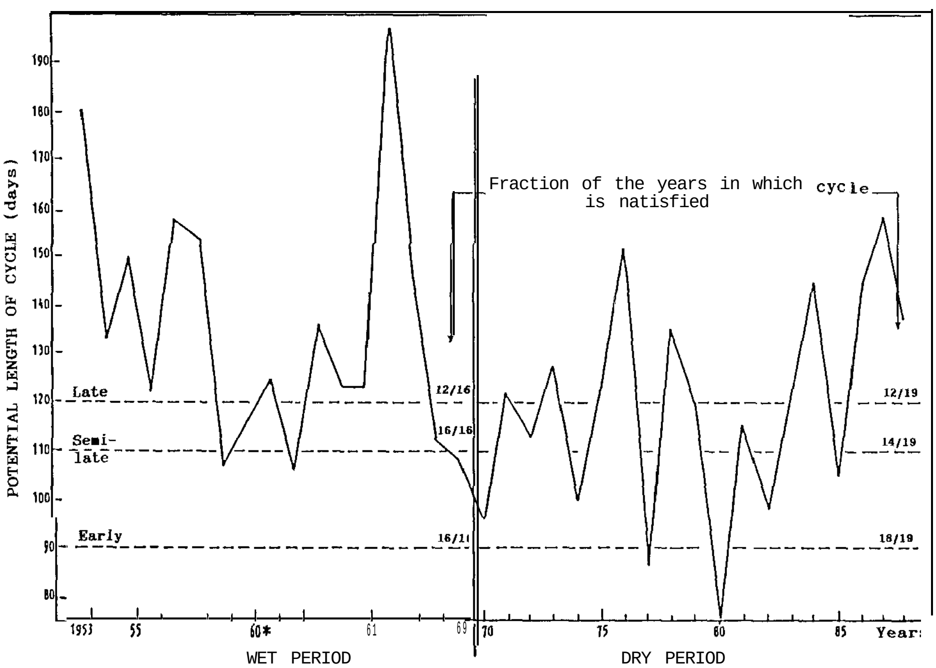


Fig. 8. Potential length of the crop growing period at Nioro-du-Rip for the years 1953-l 988.

TABLE 2

Adaptability of various lengths of crop growing period for three regions in the semi-arid zone of Senegal. Data are given for the periods 1953-1969 and 1970–1988

Region	Length of crop growing period (days)	Percentage ofyears in which length of crop growing period fits into the potential length	
		1953-1969	1970–1988
North (Louga)	120	29	0
	110	35	5
	90	82	26
	75	100	68
	70	100	84
	60	100	84
Central-north (Bambey)	120	59	26
	110	71	37
	95	88	84
	90	94	89
Central-south (Nioro-du-Rip)	120	75	63
	110	100	74
	105	100	79
	90	100	95

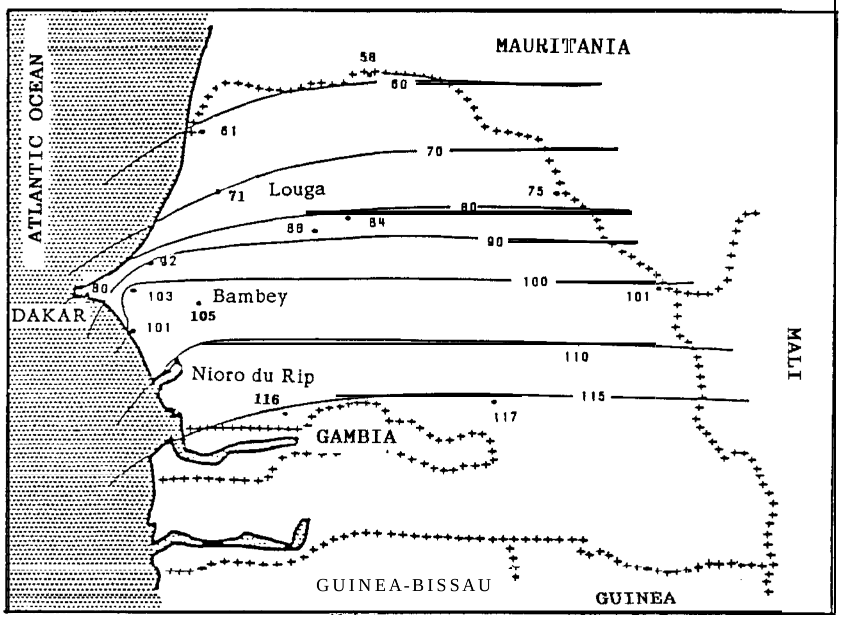


Fig. 9. Map of inter-annual means for potential lengths of the crop growing periods for the period 1970-l 986 in the semi-arid region of Senegal (days).

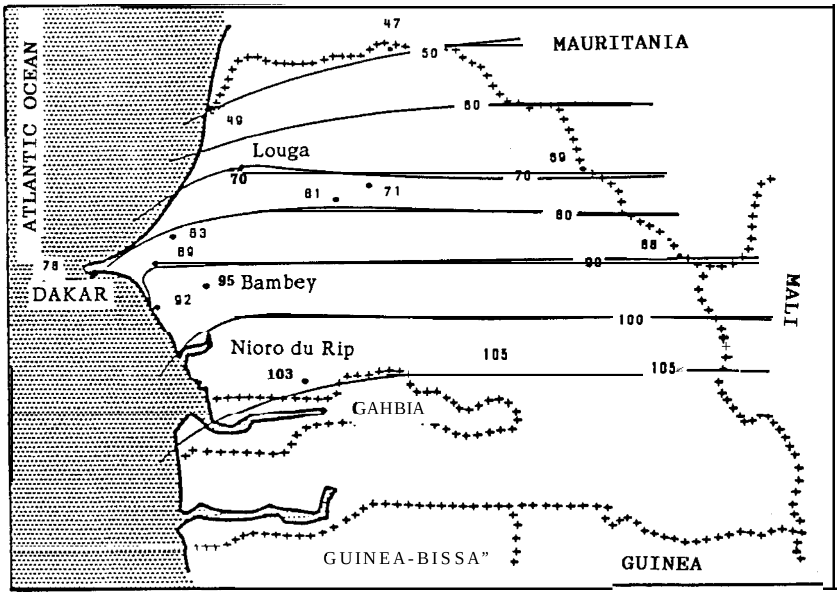


Fig. 10. Map of lengths of the crop growing period satisfied in at least 80% of years for the period 1970– 1986 in the semi-arid region of Senegal (days).

Implications for the case of plant breeding

The reduction in the length of the rainy season makes a certain number of currently extended cultivars poorly adapted to these regions, as their cycle lengths have become too long. This means that targets for new cultivars to be obtained either by varietal creation or by the introduction of already existing genotypes or new crops, need to be revised. This is illustrated by the case of groundnut, cultivated in the Louga region. The cultivar released has a short cycle (90 days). Examination of potential lengths of the crop growing period for the years 1953– 1988 (Fig. 6) indicates that this cultivar was able to reach the end of its growing period in 14 out of 17 years during the wet period but only 5 out of 19 years during the dry period.

Determining potential cycles using rainfall data means that the best possible choice of cycle length can be made, adapted to each region, whereas this choice is usually empiric.

Taking a safety margin regarding sowing date and degree of freedom of choice of technique into account, in this case 5 days, means that the following can be allowed for: inter-annual variations in the length of the rainy season and the farmer's calendar, and that effective farming techniques to control drought can be used, such as ploughing at the end of the cycle.

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