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A COMPARISON OF METHODS TO DETERMINE THE ONSET OF THE GROWING SEASON IN NORTHERN NIGERIA

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ABSTRACT

In the sudan savanna of northern Nigeria, with its semi-arid climate, the ability to determine effectively or predict the start of actual productive rains cannot be overemphasized. Several methods exist for calculating the date of onset of the rains that may be taken as the start of the growing season. Five methods currently in use, which are relatively easy to apply on a large scale, were selected for comparison. One is a traditional technique (Ramadan method), two use accumulated rainfall totals (Walter's and Sivakumar's methods), and two use rainfall–evapotranspiration relationships (Kowal's and Benoit's methods). For the period 1961–91, the traditional technique performed most poorly. Walter's method gave quite early onsets and Sivakumar's method gave very late onsets, thereby seriously shortening the growing season. Kowal's and Benoit's determinations fell most often in between the results of Walter's and Sivakumar's methods in their performance. However, although generally to a lesser extent than the other methods, they are still significantly affected by false starts. To avoid incorrectly predicting the growing season's onset as far as possible, but to prevent an unacceptable shortening of the growing season, a combination of Kowal's and Sivakumar's criteria was used to develop an improved technique. This proved to work well for determining the onset date in the study area. However, because some false starts remain when using average onset dates, it is suggested that an operational advisory team should be constituted by the government. This team would be responsible for calculating onset dates in any year, on-line for the ongoing season, in a participatory approach with farmers, and for disseminating such dates to the farmers. This could be done for any place for which the appropriate data can be made available. In the future, improved climate prediction skill may replace the classical probabilistic approaches presently suffering from increasing rainfall variabilities. Copyright © 2002 Royal Meteorological Society.

KEY WORDS: dry spells; growing season; methods to determine the onset of the growing season; Nigeria (northern); onset of rains; rainfall climate; sudan savanna

1. INTRODUCTION

Agriculture in the sudano-sahelian zone is largely rainfed, with a highly variable annual rainfall, rainfall distribution and seasonal onset of the rains. One of the major limiting factors to agricultural production, after soil fertility, is therefore water supply deficiencies (Hargreaves and Zamani, 1982; Forest and Lidon, 1984; Lal, 1991; Wallace, 1991; Oladipo, 1993b). The amount of water available to plants depends on the seasonal onset, length and termination of the rainfall, as well as on water movement over the land and within the soil and on soil evaporation. The heavy dependence of agriculture on the seasonal characteristics of rainfall in this region, and the increasing evidence of decreasing rainfall in northern Nigeria (Anyadike, 1992; Hess *et al.*, 1995; Ati, 1996), mean that it is essential that these characteristics are predicted effectively on-line, i.e. for the directly forthcoming or ongoing season. According to Walter (1967), the agriculturist is only interested

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in a high probability that, at a certain point in time: (i) the rains will become fairly continuous and sufficient to ensure enough moisture in the soil at the time of planting and (ii) this level will be maintained or even increased as the season advances.

The purpose of this paper is to compare several proposed methods for the determination of the onset of the growing season in northern Nigeria, with the aim of finding the best method that can also be used for predictions. The onset of the rains and the start of the growing season have been taken here as identical and are defined as receipt of sufficient rain for survival of seedlings after sowing. Because false starts appear to be an increasingly serious problem (e.g. Hess *et al*., 1995), this has to be taken into account without shortening the growing season beyond the necessary length for the crop varieties selected.

This paper considers the onset characteristics, because, according to Stewart (1991), the onset date is a key variable to which all other seasonal rainfall attributes are related. It is the onset relations that determine how the season's rainfall is expected to behave. In the sudan savanna the start of the rains is seldomly abrupt. It is usually preceded by a succession of isolated showers of uncertain intensity with intermittent dry periods of varying duration. These may be false starts and be followed by prolonged dry spells whose duration may last for one, two or more weeks. This dries out the top soil and prevents the germination or emergence of plants. Conversely, yields can decline or fail completely with late planting. These calamities are the result of a shortened growing season (Benoit, 1977; McCown *et al*., 1991; Oladipo and Kyari, 1993; Jolliffe and Sarria-Dodd, 1994). In general, yields may suffer significantly with either a late onset or early cessation of the growing season, as well as with a high frequency of damaging dry spells within the season, making the rainfall distribution unreliable. This situation calls for at least the ability to predict effectively the actual start of the season.

This study was initiated for the benefit of farmers in the area of the Yambawa shelterbelts, parallel strips/woodlots of eucalyptus trees planted to combat desertification (Onyewotu *et al*., 1998). These belts and the surrounding regions are located within the sudan-savanna bio-climatic zone (Onyewotu *et al*., 1998). The wider area covers old Kano State (now Kano and Jigawa States, see Figure 1). The climate of the area is of the savanna type with alternating wet and dry seasons. The rainfall is less than 1000 mm year^{-1}, more recently less than 800 mm year^{-1} (Dietz *et al*., 2001) and generally occurs in a 5-month period, especially between May and October. Rainfall is highly variable and the onset of the rains is erratic. The rainfall intensity is very high in the months of July and August. The region suffers from frequent agricultural drought, i.e. a (period of the) growing season with abnormally low rainfall that reduces the final yields below the average of the area. This was particularly witnessed during the 1968–74 and 1983–87 periods (Oladipo, 1993a). The daily sunshine duration is 7–8 h. The air temperatures are constantly high, with high evaporative demands. The potential evapotranspiration is only exceeded by actual rainfall in June, and not very often even in that month (Mortimore and Wilson, 1965; Oguntoyinbo, 1983; Sivakumar *et al*., 1991; Falola *et al*., 1993).

Most farmers concerned have no electricity and no other resources than land; they certainly have no access to the internet, and most often do not have access to reliable telephone connections either. Communication lines are therefore either by centralized radio contacts, like for transmissions within the weather services, or by (communal) radio broadcasting. Specially trained agricultural extension workers may play a role as intermediaries here. The determination of a less risky planting date or planting method, or the sowing of less risky types/varieties or crops is what our research facilitates (Stewart, 1991). In full response farming, a method of identifying and quantifying the seasonal rainfall variability and (un)predictability, knowledge on the early phases of previous rainy seasons is applied to advise also on such management as the use, type, rates and timing of fertilizer additions and on adapting sowing densities/patterns and, later in the season, on planting densities by thinning (e.g. McCown *et al*., 1991).

2. DATA AND METHODS

2.1. Calculation methods

Eight stations in the old Kano State with varying record lengths of rainfall were used. Most of the stations are close to the shelterbelts at Yambawa near Danbatta (see Figure 1), where some results were used (Onyewotu

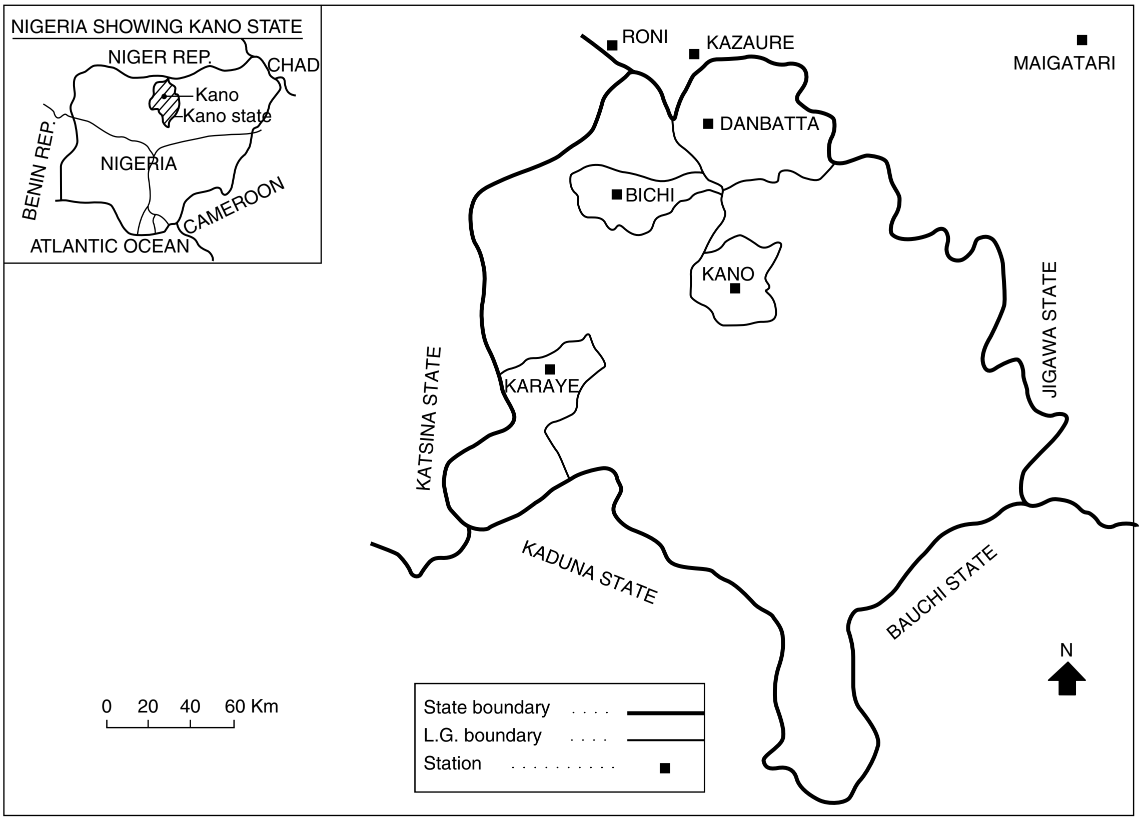

Figure 1. Stations of Table I in Kano State and Jigawa State. Kano State is also shown as an inset of the map of Nigeria. (State boundaries after Falola *et al.*, 1993)

et al., 1998), and some are far away from the belt area. Table I presents the mean annual precipitations and their standard deviations for the stations and the different periods mentioned.

Several models have been proposed for determining the date of onset of the rainy season. These range from the traditional to semi-empirical and scientific techniques, using monthly, decadal or, for the determination of the length of dry spells, daily rainfall (e.g. Ati, 1996). For the present analysis, five methods were chosen that were particularly developed for regions of or close to northern Nigeria.

The traditional Ramadan method used in the Kano region is named after the Muslim fasting period. This rule states that planting can begin with the first good rain after Ramadan provided that it is at least 7 months

Table I. Stations, their geographical coordinates and rainfall statistics (SD: standard deviation; CV: coefficient of variation)

Station	Latitude	Longitude	Period	Mean rainfall (mm)	SD (mm)	CV (%)
Kano	12° 1′	8° 32′	1961–91	728	179	25
Maigatari	12° 47′	9° 22′	1986–91	403	149	37
Gadanya	11° 54′	8° 26′	1978–91	678	110	16
Danbatta	12° 32′	8° 27′	1961–91	619	186	30
Roni	12° 58′	8° 06′	1986–91	609	154	25
Kazaure	12° 40′	8° 25′	1978–91	541	184	34
Bichi	12° 15′	8° 15′	1986–91	924	292	32
Karaye	11° 44′	7° 48′	1978–91	816	178	22

from the last effective rain of the previous season. If these dates are not close, a 7 months' rule is applied and planting is advised to be 7 months after the last effective rain of the previous season.

The methods based on accumulated rainfall totals assume that, after a particular level of rainfall is reached, the probability of a long dry spell that leads to crop failure is relatively small. Based on Nigerian data, Walter (1967) described the onset date OD as

$$\mathrm{OD} = D(50.8 - F)/R \tag{1}$$

where D is the number of days in the first month with effective rain (MER). The MER is the first month in which the accumulated rainfall totals equal or exceed 50.8 mm (2 in). F (mm) is the accumulated rainfall total of previous months; R is the total rainfall in the MER. This relationship is semi-empirical and, therefore, it does not satisfy all situations. For example, it does not account for all dry spell situations in semi-arid areas. This shortcoming was discussed by Olaniran (1983). He postulated that the model can only be accepted if it is not followed by a month with less than 50.8 mm of rainfall. If it is less, the rainfall of the MER is disregarded and the formula becomes:

$$\mathrm{OD} = D(50.8 - F_{\mathrm{x}})/R_{\mathrm{x}} \tag{2}$$

where F_{x} is the rainfall of the succeeding month to the MER and R_{x} is the rainfall of the second month after MER.

Sivakumar (1988) described the onset date in the southern sahelian and sudanian climate zones of West Africa as the date after 1 May when rainfall accumulated over three consecutive days was at least 20 mm and when no dry spell within the next 30 days exceeded 7 days.

The rainfall–evapotranspiration models assume that rainfall equal to or more than half the potential evapotranspiration and maintained throughout the season would be enough to sustain growth. The two methods chosen for use were Benoit's and Kowal's methods. The Blaney–Morin–Nigeria evapotranspiration model, the superiority of which has recently been confirmed, was selected for estimating potential evapotranspiration (Ati, 1996).

Benoit (1977) defined the onset date for northern Nigeria as the date when accumulated daily rainfall exceeded 0.5 of the accumulated potential evapotranspiration for the remainder of the season, provided that no dry spell longer than 5 days occurs immediately after that date. Kowal and Knabe (1972) defined the onset date as the 10-day in which rainfall is equal to or greater than 25 mm, but where the subsequent 10-day rainfall total is greater than 0.5 of the potential evapotranspiration. For the purpose of calculation, the onset date in this paper was taken as the sixth day from the beginning of the 10-day concerned.

To confirm the reliability of each method further, they were subjected to a test for dry spells after the calculated onset date. A dry spell of longer than 7 days within the next 30 days after the date of onset was taken to lead to crop failure (Sivakumar, 1988; Kasei and Afuakwa, 1991; Jolliffe and Sarria-Dodd, 1994).

2.2. *Climatological context*

Figures 2 and 3 respectively show the annual variation in the rainfall series for Kano with its 10 year running mean and the annual variation in the onset of the growing season in Kano for the same period, with the same running mean (Ati, 1996). These data first show what has also been observed in Sudan (Mohamed, 1998), east of our area, to Niger (Stewart, 1991), Burkina Faso, southern Mali and northern Ghana, west of our area, with also a large north–south range (Dietz *et al*., 2001), that rainfall periodicities, including onset relations, are changing, sometimes (almost) abruptly. With the increasing climate variability presently experienced, as a basis for responsive farming even periods of 15 to 20 years may be too long for use in policy studies using rainfall periodicity and related phenomena (Stewart, 1991; Stigter *et al*., in preparation).

There are strong indications that trends with higher rainfall totals in the latter part of the period that we report on (Figure 2) have continued during most of last decade throughout the West African region (Dietz *et al*., 2001). Figure 3, for the period until the mid-1980s, already shows a span of almost 3 weeks in the

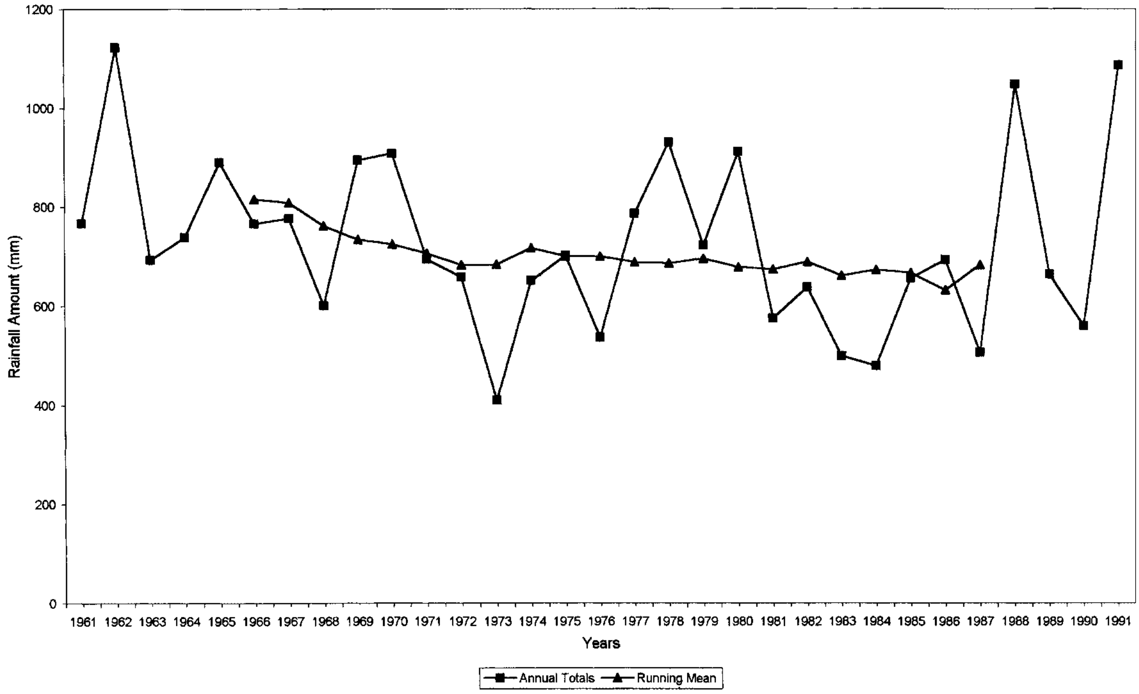

Figure 2. Annual rainfall for Kano from 1961 to 1991. The smooth curve is the 10 year running mean

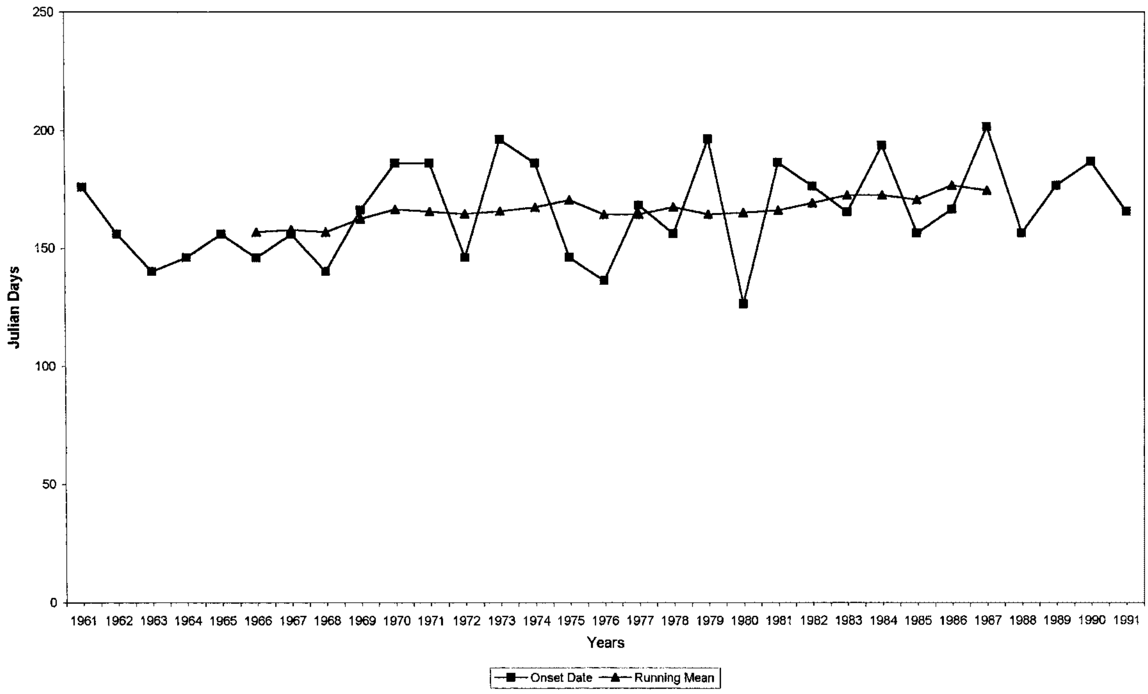

Figure 3. Annual onset of the growing season for Kano from 1962 to 1991. The smooth curve is the 10 year running mean. Julian days give the number of the day of the Julian calendar of that year

10 year running mean onset date over the last 30 years, with a variability of extremes for single years of 75 days and for consecutive years of 70 days. Such data may lead to the conclusion that, at present, the most reliable yardstick for advising farmers is the rainfall data of the ongoing season at sufficient spatial resolution, making use of agronomic knowledge of seedling and crop response and perhaps some other historical data from the immediate past. Our hybrid method may be the best applicable here for the first step. This conclusion is strengthened by an increasing mean duration of dry spells during the rainy season as reported by Hess *et al.* (1995) for northern Nigeria. Additional information may be added to this in the future based on improved climate prediction for the area (Nnaji, 2001). Improved response farming may also be developed from such new climate forecasting.

3. RESULTS AND DISCUSSION

3.1. Onset dates

The mean dates of onset calculated by the methods are presented in Table II. Onset dates between stations are never comparable because of the highly variable rainfall distributions between stations, and here even more so because of different data periods. However, the methods are intercomparable for the same station, and that is what we do with the data in Table II and in all the figures on onset dates. The annual onset dates are graphically represented for Kano, Danbatta and Karaye in Figures 4–6. Because of missing data, gaps exist for Danbatta. Oladipo (1993a) concludes that the seasonal north–south shift in the intertropical discontinuity is not likely to be the most important causal mechanism of drought in the region. However, rainfall gradients within rainy seasons may still be expected to run roughly north–south. This has prompted the selection of the three stations, together with the number of years for which data were available.

From Table II and Figures 4–6, it follows clearly that the Ramadan rule generally gave the earliest onset dates at all the eight stations. Apart from Kano, where it came after Kowal's method, close to Benoit's method, Walter's method was closest to the Ramadan rule. Sivakumar's method for all the stations gave by far the latest mean onset dates.

Benoit's and Kowal's methods were generally close to each other in their behaviour, and mean dates by these methods were in most cases between those obtained by Walter's and Sivakumar's methods, but much closer to Walter's results.

The standard date for calculating the onset by Sivakumar's method was changed from 1 May to 1 April, but for the eight stations there was no single year that the onset date was altered by this change. The main problem was that the three consecutive days of rainfall required by the method could not be satisfied for most of the years until well into the season. In some cases, the whole year could pass without a period fulfilling the condition.

Table II. Mean onset dates calculated by the six methods

Station	Ramadan	Walter	Sivakumar	Benoit	Kowal	Hybrid
Kano	6 May	26 May	1 July	2 June	22 May	13 June
Maigatari	14 May	23 June	7 August	23 June	7 July	10 July
Gadanya	5 May	22 May	20 July	4 June	1 June	11 June
Danbatta	18 May	6 June	19 July	18 June	20 June	27 June
Roni	8 May	8 June	26 July	14 June	18 June	22 June
Kazaure	25 May	14 June	7 July	25 June	26 June	1 July
Bichi	17 May	25 May	21 July	13 June	16 June	22 June
Karaye	8 May	22 May	2 July	28 May	21 May	10 June

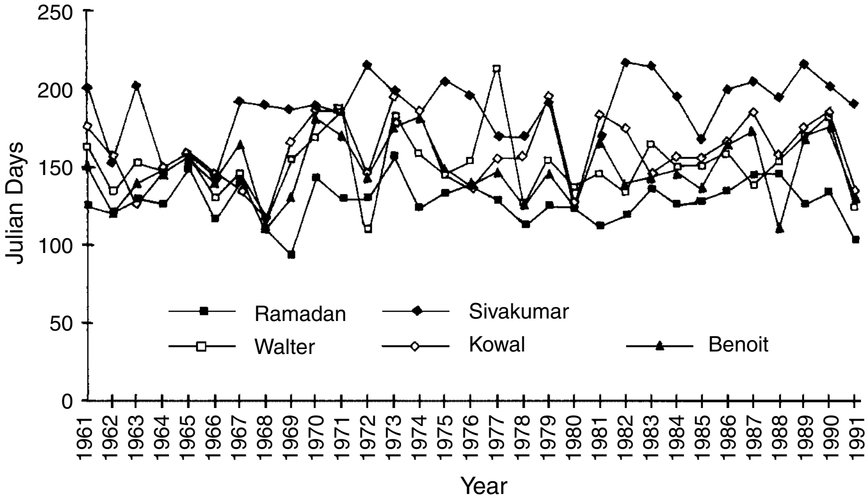

Figure 4. Dates of onset of the growing season from each of the five selected methods, for Kano (1961–91). Julian days give the number of the day of the Julian calendar of that year

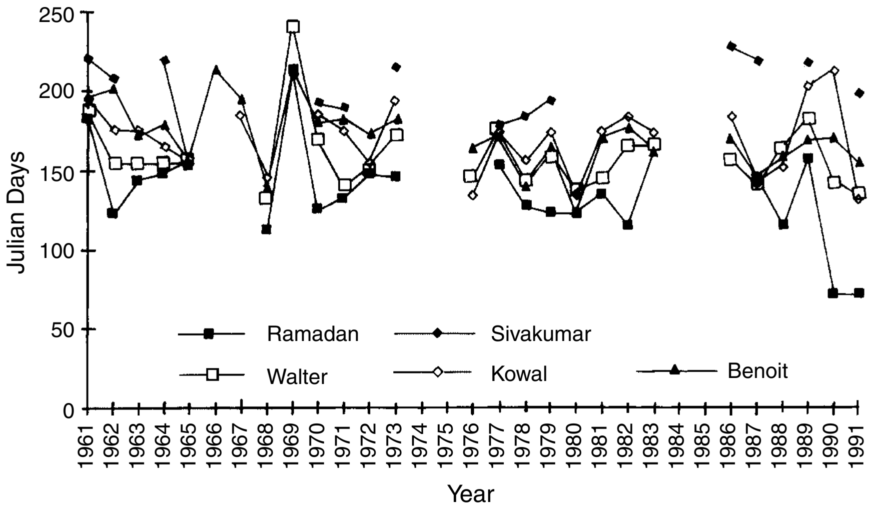

Figure 5. Dates of onset of the growing season from each of the five selected methods, for Danbatta (1961–91, with some years missing). Julian days give the number of the day of the Julian calendar of that year

3.2. Test for false starts

Four of the five methods were additionally subjected to a test for the occurrence of false starts by determining how often dry spells of more than 7 days occurred after an onset date was determined. In Sivakumar's method the 7 day dry spell criterion was already applied. Results of the analysis are presented in Table III using mean and actual onset dates. The Ramadan method generally leads to the occurrence of a greater number of false starts than the other methods. This was in most cases followed by Walter's method. Benoit's and Kowal's methods were less affected and did not differ much from each other, particularly for stations with more than 10 years' of data. However, all data show the necessity of a test for false starts.

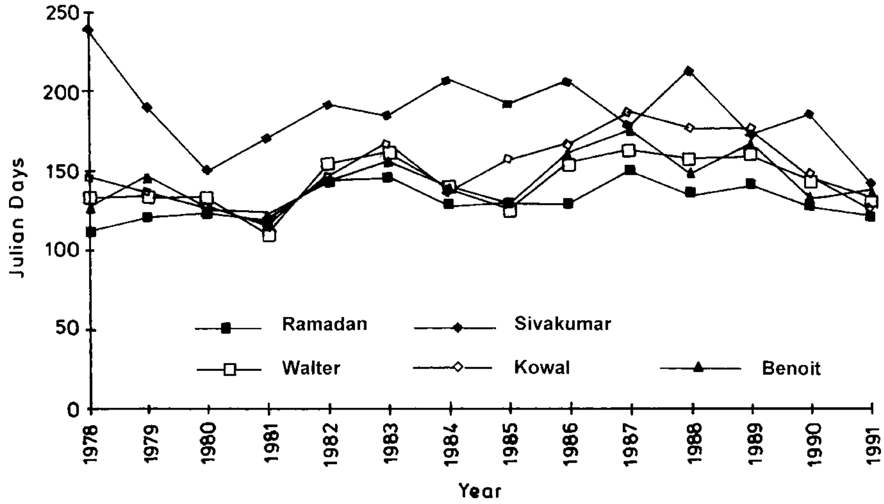

Figure 6. Dates of onset of the growing season from each of the five selected methods, for Karaye (1978–91). Julian days give the number of the day of the Julian calendar of that year

3.3. Proposal of a new hybrid method for calculating the onset date in the study area

To reduce the problems of false starts, on the one hand, and of too short a growing season, on the other hand, the dry spell factor from Sivakumar's method was introduced into Kowal's method to give a more reliable onset date for the area. This proposal is based on the fact that the evaporative demands of the crop may have been satisfied at a calculated date of onset, but that a dry spell of more than 7 days shortly after planting would be disastrous for the crop.

Therefore, the onset date can now be defined as the 10 day period in which rainfall is greater than 25 mm and where a subsequent 10 day rainfall total is greater than 0.5 of the potential evapotranspiration (the actual date, for the purpose of calculation, taken to be 6 days from the start of that 10 day period) and where there is no dry spell of more than 7 days within the next 30 days from the date as determined above. If such a dry spell occurred, a new onset was determined as the date satisfying the Kowal rainfall criterion after the dry spell. The results have been added to Table II. The average onset dates determined this way were always between those of Kowal and Sivakumar. This remains true in many cases for annual onset dates, as again illustrated for Kano, Danbatta and Karaye (Figures 7–9).

The hybrid method eliminated false starts, particularly when annual onset dates are considered instead of average onset days. For Karaye none of the years experienced any false starts after the new mean date of onset. For Kano, 5 years (16%) out of the 31 years still recorded false starts. All the years involved (1973, 1974, 1982, 1984 and 1987) were obvious drought years, although drought was retreating in 1974 (Oladipo, 1993a). For Danbatta, 7 years (33%) of the 23 years still recorded false starts. Based on the annual onset dates, only one of the years recorded a false start.

Of course, the above calculations are retrospective and, in reality, to wait for 30 days to know whether a dry spell is occurring or not, is shortening the growing season too much. A planting risk may be taken based on Kowal's criteria, but seeds for a later additional sowing after a prolonged dry spell should then be available. Alternatively, daily rainfall data should be used, and, as soon as 25 mm has fallen within 10 days, the next 10 days should be used for checking on the robustness of the evapotranspiration–rainfall relationship. These 10 days should be included as part of the 30 day waiting period for the dry spell of more than 7 days. On average, this will reduce the waiting period for dry spells by half compared with using routine 10-day rainfall starting on the first of every month.

Table III. The degree of false starts experienced by each method (calculated using mean onset dates, resulting in the first figure under II and III, and using actual onset dates, resulting in the second figure under II and III; I: total number of years analysed; II: number of years with false starts; III: percentage of years with false starts

	Ramadan	Walter	Kowal	Benoit
Kano				
I	31	31	31	31
II	28/28	17/11	13/10	10/11
III	90/90	55/36	42/32	32/36
Danbatta				
I	23	25	25	27
II	21/20	17/19	19/10	17/10
III	91/87	68/76	76/40	63/37
Karaye				
I	14	14	14	14
II	10/10	11/9	10/7	11/8
III	71/71	79/64	71/50	79/57
Roni				
I	13	14	14	14
II	11/10	9/7	7/6	6/6
III	85/77	64/50	50/43	43/43
Gadanya				
I	14	14	14	14
II	14/12	8/7	6/4	6/3
III	100/86	57/50	43/29	43/21
Kazaure				
I	5	6	6	6
II	4/4	2/3	3/3	3/1
III	80/80	33/50	50/50	50/17
Maigatari				
I	5	6	6	6
II	5/5	4/2	4/4	2/3
III	100/100	67/33	68/67	33/50
Bichi				
I	4	5	5	5
II	4/3	4/3	2/3	1/2
III	100/75	80/60	40/60	20/40

4. CONCLUSION AND FINAL REMARKS

The traditional method for determining onset dates was shown to be unreliable for the region. Methods based on accumulated rainfall totals could be misleading for calculating the date of onset. Because the methods based on rainfall–evapotranspiration relationships consider crop water requirements, they give more realistic onset dates. However, for the environment under consideration, a large number of false starts was still recorded.

For determination of the onset date, a method was needed that would greatly reduce false starts due to the occurrence of damaging dry spells. After a comparison of the methods selected, a hybrid method combining the rainfall–evapotranspiration criteria of Kowal and the dry spell criterion of Sivakumar was used for retrospective calculations.

As a very general weather advisory for the determination of the onset date of the rainy season in the study area, Kowal's original method was used successfully to advise farmers on the optimum planting date in

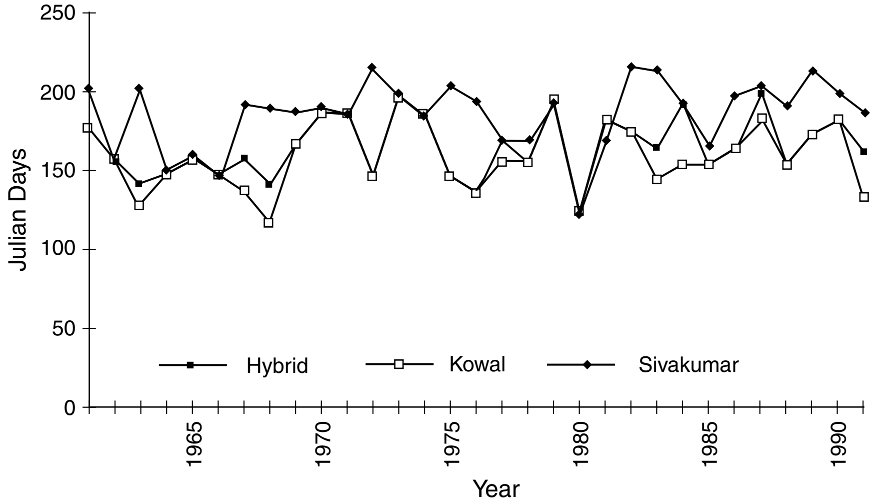

Figure 7. Dates of onset of the growing season based on Sivakumar's, Kowal's and the hybrid method, for Kano (1961–91). Julian days give the number of the day of the Julian calendar of that year

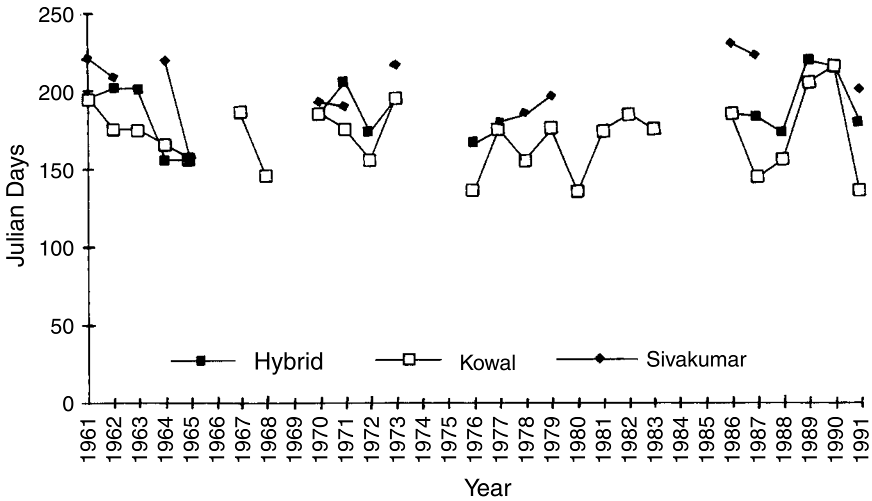

Figure 8. Dates of onset of the growing season based on Sivakumar's, Kowal's and the hybrid method, for Danbatta (1961–91, with some years missing). Julian days give the number of the day of the Julian calendar of that year

1993 and 1994 (Onyewotu *et al.*, 1998). No false starts occurred in these years when using the actual onset dates.

In ideal practice, an agrometeorological advisory body should be formed by the government and would be responsible, in a participatory approach with farmers and specially trained research workers, for predicting the onset dates 'on-line', to be disseminated to the farmers for decision making on (preparation of) sowing and on the safest types/varieties of crops to be selected. For such work the suggested hybrid method using actual daily rainfall could be used. From accumulated experience for each station for which such calculations are made, it could then be investigated whether the waiting period for dry spells could be further reduced or whether increasing climate variability makes this impossible (e.g. Salinger *et al.*, 2000). Use of predicted safe planting dates is only the first stage in responsive farming, where knowledge of previous rainfall season patterns is also incorporated in decision making. Recent developments in improved climate prediction have

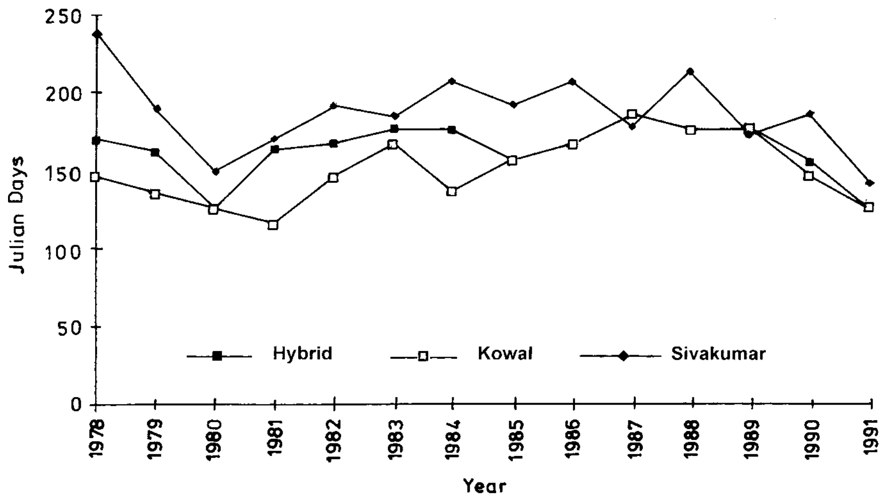

Figure 9. Dates of onset of the growing season based on Sivakumar's, Kowal's and the hybrid method, for Karaye (1978–91). Julian days give the number of the day of the Julian calendar of that year

to be closely followed for operational applications in this context. These approaches have recently been advocated for urgent attention (Olufayo *et al.*, 1998; Stigter *et al.*, 2000). Some have already been used for such purposes (e.g. WMO, 2000).

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