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Agroclimatic delineation of dry land sowing periods : A case study for Karnataka

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ABSTRACT. The agrometeorological aspects of moisture availability for the seeding zone are detailed. A methodology for delineating, from weekly rainfall and number of rainy days, sowable periods is presented. The climatological picture obtained, for the period 1941-65, at representative stations in Karnataka is used to outline the sowing strategy in the different regions.

1. Introduction

The raising of kharif crops as early as possible is warranted, as an agronomic strategy to realise the significant contributions from rainfall towards crop water needs by way of (*i*) foliar interception and stem flow, (*ii*) absorption by leaves and dew roots near the ground surface of aerial moisture and light precipitation and (*iii*) nocturnal condensation on leaves of water evaporating from moist soil. Lack of available moisture in the surface layers of the soil leads to a sharp increase in the soil temperature and hence satisfactory emergence of crops is a serious problem in dry land agriculture. Again, in the raising of crops after an enforced early season fallow or in the raising of rabi crops, the ryot might be tempted to wait a little bit too long for a further spell of rain which may not come.

A physical examination of the adequacy of surface soil moisture for sowing might do as a practical measure. However, for crop planning it is necessary to know the earliest period when kharif crops can be sown with some reserve of soil moisture in the root zone for meeting the post-germination need. The period upto which rains would contribute to seed zone moisture re-charge is required to be known to fix up the latest period up to which rabi sowings can be done. The fixation of the sowing period is only the first step towards an analysis of rainfall adequacy for maturity of crops.

2. Earlier work

For a climatological delineation of the proper sowing period, it is necessary to balance the rainfall for amounts (*i*) likely to be lost from the surface soil layers as evaporation and runoff and (*ii*) required for field preparation. Surface runoff is likely to be small in the beginning of expendable.

Studies on the balancing of rainfall from this point of view are few. Analysis of daily falls of rain for moisture storage (Raman snd Venkataraman 1970) is technically sound but requires computer aids (Venkataraman *et al.* 1973) for large scale studies of spatial and time variations. Taking the beginning of the sowing period as the one in which rainfall equals a small fraction, say 1/10th, of the "potential loss" (Cocheme and Franquin 1967) is not satisfactory for the simple reason that though the water used up during germination is small, this water has to be moved past the top soil layers from which considerable amounts of water are lost through evaporation. Assumption of the evaporative loss over a short period, say a week, to be equivalent to the "potential loss" (Fitzpatrick and Nix 1969) can, as will be seen later, lead to incorrect estimates of the evaporative demand, if the number of rainy days is not taken note of. Again designating a week to be a dry one when rainfall for four or more continuous days is less than the "potential loss" (Swaminathan *et al.* 1970) or designating a period as a sowable one when and only when rainfall over seven days exceeds 25 mm with atleast one millimetre on five of the seven days (Raman 1974) have some obvious and practical short-comings. In the above the rainfall quantum in the week/period designated as wet or sowable would vary widely and such wet weeks/periods may not actually experience any soil moisture storage. Similarly, the weeks/periods designated as dry or unsowable may have enough soil moisture storage. This is due to the fact that a good spell of rain, in one or two days, may contribute enough seed zone moisture for germination while all the rain in a wet week/sowable period might get evaporated and/or the re-charge may be insufficient to reach the seeding zone.

TABLE 1

Rainfall requirements for germination

No. of rainy days	Minimum amount (mm)	Maximum amount (mm)
1	25	25
2	30	43
3	35	55
4	40	55
5	45	55
6	50	44
7	55	55

TABLE 1(a)

"The standard weeks" calendar

Week No.	Dates	Week No.	Dates
1	Jan 1-7	27	Jul 2-8
2	8-14	28	9-15
3	15-21	29	16-22
4	22-28	30	23-29
5	29-4	31	30-5
6	Feb 5-11	32	Aug 6-12
7	12-18	33	13-19
8	19-25	34	20-26
9	26-4*	35	27-2
10	Mar 5-11	36	Sep 3-9
11	12-18	37	10-16
12	19-25	38	17-23
13	26-1	39	24-30
14	Apr 2-8	40	Oct 1-7
15	9-15	41	8-14
16	16-22	42	15-21
17	23-29	43	22-28
18	30-6	44	29-4
19	May 7-13	45	Nov 5-11
20	14-20	46	12-18
21	21-27	47	19-25
22	28-3	48	26-2
23	Jun 4-10	49	Dec 3-9
24	11-17	50	10-16
25	18-24	51	17-23
26	25-1	52	24-31†

*In leap year the week No. 9 will be 26 February to 4 March, *i. e.*, 8 days instead of 7.

† Last week will have 8 days, 24 to 31 December

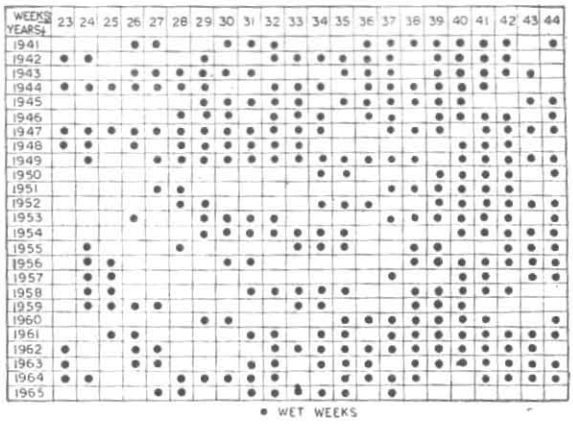
3. Agrometeorological aspects of the problem

Weekly data of rainfall amounts and rainy days are readily available at a number of agricultural stations. It was, therefore, thought that it would be useful if criteria for sowing could be laid down in terms of total amounts of weekly rainfall and number of rainy days. For this, consideration of the following facts was deemed necessary :

(*i*) The crop is sown at a depth immediately beyond the zone of evaporative desiccation.

TABLE 2

Occurrence of wet weeks at Bangalore, 1941-65



(*ii*) Because of the compensating effects of the depths of drying and moistue capacities of soil, the amount of water storage in the evaporating layer will nearly be the same for all soils (Staple and Lehane 1944) and for practical purposes may be taken as about 18 mm.

(*iii*) A day is reckoned as 'rainy' when the rainfall is greater than 2.5 mm. The evaporative power of the air, a measure of which is given by the evaporation from a pan evaporimeter, is much more than this value in the monsoon season. Hence, non-rainy days do not contribute to moisture storage.

(*iv*) To move into the sowing zone the rainfall must be sufficient to meet the "potential loss" on rainy days and fill the evaporative zone to field capacity.

(*v*) The water consumption during germination will be about 0.2 of the "potential demand" (Gangopadhyaya *et al.* 1969, Anonymous 1970).

(*vi*) Moisture for germination will mostly be drawn from a shallow layer of soil, of depth equivalent to that of evaporative desiccation.

4. Weekly rainfall requirements for germination

"Potential demand" in the kharif season is of the order of about 5 mm (Raman and Venkataraman 1970; Rao *et al.* 1971; Venkataraman and Krishnamurthy 1973). 7 mm is the weekly water need and 13 mm is the capacity of the evaporation layer to be made good after satiation of the potential demand on rainy days. This situation would obtain in case the rainy days when more than 1 are continuous. Thus the weekly rainfall requirement for proper germination in light of items (*iv*) and (*v*) of the above para will be equal to (the number of rainy days $\times$ 5) $+$13$+$7 mm/week.

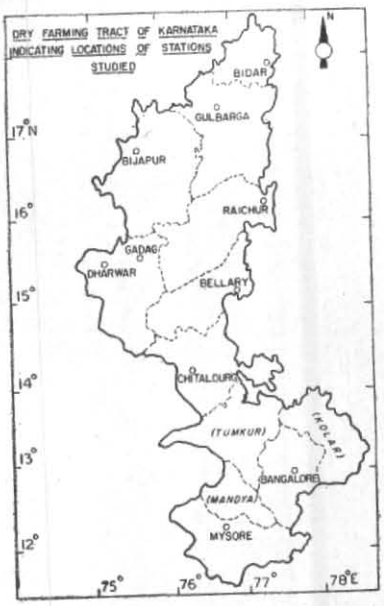


Fig. 1. Dry farming zone of Karnataka

TABLE 3
Schematic presentation of the frequency of occurrence of a 3-week dry spell centred round a week

WEEKS / STATION	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
BIDAR		○	●	●	●	●	○	○	●	●	●	○	○	○	○	○	●	◎	◎			
MYSORE															◎	●	○	○	○	○	●	◎
BANGALORE						●		◎	◎	●	●	●	●	●	◎	●	○	○	○	○	○	◎
GULBARGA		◎	●	●	◎	●	●	◎	◎	●	◎	○	●	●		◎	◎	◎				
RAICHUR			◎	◎	◎	◎	●	●	◎	●	●	◎	●	●	●	○	○	●	◎			
GADAG															◎	○	●	○	○	●	◎	
DHARWAR				◎	●	○	●	○	●						◎	●	○	○	●	●	●	◎
CHITALDURG																	●	○	○	●	●	
BIJAPUR		◎											◎	◎	●	○	○	○	◎	●		
BELLARY																●	●	○	●	●	●	◎

○ ≤ 10% ● 11 - 20% ◎ 21 - 30%

The above postulation will underestimate evaporative depletion if a rainy spell is interspersed with non-rainy or dry days. However, it is possible to fix the maximum possible evaporative depletion. For example, for 2 days it can only be 36 mm, for 3 days with rain occurring on every 3rd day and for 4 days with rain occurring on 1st, 4th, 6th and 7th day it can be 48 mm. When rainy days are 5 and 6, *i.e.*, extra drying for 2 days and one day respectively, the maximum requirement can be shown to be 48 mm only.

On the basis of this, a week could be classed as dry if it failed to meet the minimum requirement. A week would be classified as a wet week if rain in that period was above the maximum requirements. The minimum and maximum weekly rainfall needs for proper germination in terms of rainy days for this purpose would be as shown in Table 1.

The above postulation shows that by taking into account the No. of rainy days in a week, the data of weekly total rainfall can be used to fix up the weekly rainfall amount required for recharging the seed zone in the soil with moisture.

The total moisture availabe for the crop in the sowing and germination phases is 18 mm and the actual consumption is 7 mm/week, *vide* assumption Nos. (*vi*) and (*v*) set out above. Hence, the seeds can utilise the reserve when full for two weeks, *i.e.*, moisture can be carried over from one week to the succeeding week and render it into a wet one if the rainfall is in excess of 7 mm of the amount needed to meet the demand. Carry over of moisture for more than a week is not permissible since the moisture in the deeper layers cannot be used for germinaton. In fact, this is the crux of the field problem faced in ensuring adequate germination.

Whenever the amount specified was only 3 mm less than that in Table 1, that week and/or the succeeding dry week respectively can be taken as a moist week since enough water would be available to meet crop needs for atleast 4 days. The weeks rendered wet by carry over moisture would ensure that the soil temperature remains equable for good germination.

The amount of 18 mm allowed for retention in the surface layers together with the rain occurring earlier to the recharge should be adequate for preparing the field through light harrowing preceded by a dry to moist ploughing.

5. Application

The above criteria were applied in the analysis of the weekly rainfall data of ten representative meteorological stations located in the dry farming zones of Karnataka (Fig. 1). Over most of this tract the potential loss is of the order of 5 mm/day and the above evolved criteria are applicable. The period of data covered is 1941 to 1965 except for Dharwar for which data from 1946 only were available.

The weeky rainfall amounts and rainy days for the kharif season (from June beginning to end October) were got tabulated for the standard weeks 23 to 44 (Table 1a).

The first step in the analysis was to classify weeks as dry, moist and wet as per needs set out in Table 1. The second step was to examine the wet weeks for availability of carry over moisture and re-classify wherever appropriate the next succeeding dry week into a moist or wet one.

The third step was to mark out the weeks with rainy days 2, 3 and 4. For these weeks the daily data was examined as set out in reference (Anonymous 1970) to see the adequacy of rainfall for meeting in part or full the sowing needs and for carry over of moisture into the next week. The weeks were accordingly classified.

The above procedure considerably reduced the work of daily rainfall examination.

TABLE 4

Percentage occurrence of occasions of dry weeks

Station	Weeks																				
	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
Bidar	52	40	20	24	32	28	28	16	28	36	40	36	28	32	24	20	36	44	64	48	60	68
Mysore	72	64	80	76	72	60	64	84	68	72	76	80	80	84	60	36	32	28	20	28	36	40
Bangalore	72	56	72	60	60	56	48	52	44	36	44	40	40	52	36	36	28	16	16	24	48	36
Gulbarga	64	48	32	32	32	52	52	44	44	48	52	56	48	36	48	44	44	48	56	60	68	80
Raichur	68	68	48	48	40	56	60	52	36	40	44	72	44	32	40	20	20	40	40	56	56	64
Gadag	64	64	68	60	72	92	80	80	72	64	68	68	60	60	48	36	24	28	32	48	44	48
Dharwar	71	76	71	43	48	38	33	38	48	52	67	76	71	62	71	38	29	33	33	48	38	48
Chitaldurg	84	72	80	80	96	92	80	68	68	60	72	68	68	76	88	52	44	32	24	40	52	48
Bijapur	40	52	64	56	76	88	88	64	52	56	64	60	52	52	52	24	20	40	36	48	64	68
Bellary	76	76	84	72	72	92	88	76	72	68	76	80	64	72	76	40	20	32	40	36	32	64

TABLE 5

Percentage occurrence of occasions of a 3-week dry spell centred round a week

Stations	Weeks																				
	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
Bidar	36	8	12	16	12	12	0	8	16	16	16	8	8	8	4	4	12	24	28	36	44	52
Mysore	56	56	52	52	48	40	40	36	52	56	52	44	64	72	28	16	8	0	8	4	16	24
Bangalore	48	44	36	36	36	16	32	28	24	20	20	20	20	12	28	12	4	8	4	8	8	28
Gulbarga	44	28	20	12	24	20	16	24	28	20	28	24	16	20	36	28	28	24	32	36	48	64
Raichur	60	40	28	28	28	24	20	16	28	16	20	24	20	16	16	0	8	12	24	36	44	52
Gadag	52	40	36	44	52	56	72	60	52	44	44	36	32	40	24	8	12	4	8	12	28	36
Dharwar	71	62	33	29	19	0	19	29	14	33	43	62	48	43	29	19	5	0	14	19	14	29
Chitaldurg	72	64	56	68	76	80	60	48	36	36	32	48	48	60	44	32	16	8	4	12	20	40
Bijapur	36	24	32	40	48	64	60	47	36	40	36	32	24	24	20	4	8	4	24	20	36	60
Bellary	72	68	68	56	56	60	76	68	56	52	52	56	56	48	32	20	12	8	16	16	16	28

6. Results

The occurrence of dry and wet weeks in the 25-year period 1941-65 at Bangalore is shown schematically as a sample, in Table 2. The percentage occurrence of occasions of dry weeks computed from similar information at all the stations is given in Table 4 for each of the standard weeks 23-44 and for each station.

From the practical point of view it was felt that information on the percentage occurrence of occasions in a week in which moisture is not available for sowing in the preceding current or succeeding week would be highly useful. The same is, therefore, shown schematically in Table 3 and in detail in Table 5. Based on information in Table 5, the earliest and least risky period for kharif and rabi sowings and the latest week upto which rabi sowings can be carried out are shown in Table 6 for the ten selected stations. The figure in bracket indicate frequency probability for the indicated sowing period.

Before attempting an examination of the picture emerging from Tables 3, 5 and 6, it is necessary to know the normal dates of sowing of a dryland crop like jowar in the dry farming

TABLE 6

Sowing periods

Station	Earliest and least risky period for		Latest week for rabi sowing (week)
	Kharif sowing week	Rabi sowing week	
Bidar	23-25(92)	36-38(96)	40(56)
Mysore	29-31(64)	38-40(92)	43(64)
Bangalore	27-29(84)	38-40(96)	44(64)
Gulbarga	25-27(88)	35-37(80)	40(52)
Raichur	29-31(84)	37-39(100)	40(60)
Gadag	24-26(64)	37-39(92)	42(52)
Dharwar	27-29(100)	38-40(95)	43(62)
Chitaldurg	30-32(64)	39-41(92)	43(48)
Bijapur	23-25(76)	37-39(96)	42(52)
Bellary	26-28(44)	38-40(88)	43(68)

districts in which it predominates. Jowar is raised mainly as a rabi crop in the districts o Chitaldurg and Bellary where it is sown from mid-September to end-September. In the districts of Mysore and Mandya jowar is sown in the pre-monsoon period. In the districts of Raichur, Dharwar, Bijapur, Gulbarga and Bidar jowar is raised as a kharif and also a rabi crop.

TABLE 7

Weekly probable rainfall amounts (mm) at some Karnataka stations in mid-April to end-July

Week No.		Bangalore		Mandya		Chitaldurg		Gulbarga		Raichur		Tumkur		Kolar		Bijapur		Bidar		Bellary	
		50%	40%	50%	40%	50%	40%	50%	40%	50%	40%	50%	40%	40%	50%	50%	40%	50%	40%	50%	40%
Apr 16-22	16	4·6	8·3	2·6	9·3	..	1·6	..	1·6	..	..	..	4·2	..	3·2	0·0	0·0	..	0·6	..	1·3
23-29	17	6·6	11·0	3·8	8·3	4·0	7·1	..	2·0	..	..	4·5	8·1	1·5	5·2	1·7	4·2	..	1·0	2·7	5·3
30-6	18	9·7	15·4	10·4	16·8	6·2	11·2	1·7	5·0	..	1·1	11·0	16·1	..	4·8	0·0	2·6	2·5	5·3	3·5	6·1
May 9-13	19	7·2	12·8	13·9	22·1	3·6	7·6	..	1·6	..	0·7	5·5	10·9	..	6·4	0·0	0·9	..	..	2·5	5·4
14-20	20	20·1	28·1	27·4	37·5	13·7	20·8	1·0	3·6	0·5	2·7	15·7	22·3	11·2	19·1	0·0	2·3	..	2·7	7·0	11·5
21-27	21	18·1	24·8	18·2	25·8	13·8	21·4	..	4·2	3·6	7·0	17·3	23·3	20·0	26·3	4·7	9·5	2·1	5·1	8·2	13·8
28-3	22	19·4	25·5	17·0	23·0	5·9	10·7	2·1	6·2	4·1	8·3	13·0	19·7	11·8	19·2	5·4	10·4	1·6	4·7	3·9	7·8
Jun 4-10	23	13·6	18·6	10·9	17·2	11·8	17·7	14·8	21·1	12·5	18·7	13·3	23·0	9·4	14·8	23·1	23·1	13·9	20·7	7·1	12·3
11-17	24	8·8	12·9	..	2·8	5·6	8·5	14·1	20·7	10·5	15·0	6·4	11·8	..	2·7	7·1	11·2	17·4	24·2	..	3·4
18-24	25	8·8	11·5	..	..	6·1	8·5	20·8	27·4	16·6	22·0	8·7	12·0	..	3·3	7·3	12·7	29·9	41·0	..	2·9
25-1	26	9·6	13·4	..	2·9	8·3	11·9	19·6	27·6	18·3	25·1	10·4	14·3	2·3	6·7	7·8	12·7	32·2	42·0	4·9	7·6
Jul 2-8	27	17·8	23·4	..	6·7	11·3	14·7	19·2	25·8	18·5	25·2	11·0	16·8	4·7	9·7	8·0	12·5	28·0	37·8	3·6	6·1
9-15	28	14·6	20·4	2·0	5·6	10·7	14·3	23·1	30·5	16·0	21·1	13·5	23·7	5·1	10·4	7·4	11·2	29·4	40·2	5·6	9·1
16-22	29	18·7	24·5	2·2	5·9	12·8	16·8	22·7	31·1	19·6	25·9	14·6	19·2	7·8	12·7	6·5	10·4	32·9	45·4	5·6	9·2
23-29	30	16·3	22·8	2·9	6·2	16·0	20·3	23·4	31·7	22·6	29·7	18·1	23·8	9·1	14·1	10·2	16·3	40·4	53·6	4·4	7·8

The kharif sowings are done from mid-June to mid-July while the rabi sowings are carried out from beginning to end October.

In light of the above the minimum assured rainfall at 50 per cent and 40 per cent probability levels for the standard weeks 18-30 as worked out by the Dry Farming Research Unit of the Division of Agricultural Meteorology, Pune for the Karnataka stations (Table 7), the desirable sowing/cropping strategy in various regions of the dry farming tract of Karnataka are discussed below.

7. Discussion

(*i*) From Table 7 it is seen that in the pre-monsoon months agriculturally significant rains can be expected in the weeks 20 to 22 at Mandya, but the rains in subsequent weeks, even at the start of the kharif season are small. The variability of May rainfall in south of Bangalore is reported to be less (NCA 1976). The data from Table 3 relating to Mysore and Bangalore shows that rechargeable rains would continue till end of October.

In view of the above, pre-monsoon sowings may be done in districts south of Bangalore towards May end, when sufficient reserve of soil moisture to tide over a subsequent four week spell is available. As soil moisture availability can be expected to last till end-November, mixed cropping with a pre-monsoon crop and a mid-seasonal kharif crop, that can be harvested in November are indicated.

(*ii*) At Bidar mixed crops sown in early June and harvested by mid-November should be raised as a rule.

(*iii*) At Gulbarga and Raichur the crop season can start from mid-June and end-June respectively. In both districts similar cropping pattern may be adopted on identical soil types.

(*iv*) Although Gadag and Dharwar are close by, soil moisture recharge is poorer at Gadag. In this respect Gadag is similar to Mysore.

(*v*) At Dharwar there is likely to be a mid-season failure of soil moisture recharging rains. However, soil moisture recharge can be expected till October end. In view of this, it would be advisable to sow the crop in areas around Dharwar near the end of July.

(*vi*) At Bijapur good moisture recharging rains occur in week 23. This should be availed of to stir up the land so as to stimulate the germination of weeds, which could be subsequently removed. Here, only an early September sown rabi crop appears warranted.

(*vii*) At Chitaldurg and Bellary only a late September sown rabi crop, as is the local practice, is warranted.

A taluk-wise examination based on the quantum and duration of availability of soil moisture reserves is called for to review the current recommendation (Univ. Agric. Sci. 1973).

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