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Dryland farming under limited water resources

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सार — 70, 50 तथा 30 प्रतिशत स्तरों पर निश्चित साप्ताहिक वर्षा के लिए महाराष्ट्र राज्य के पांच चुने हुए जिलों के जलवायु संबंधी आंकड़ों का विश्लेषण किया गया है। विश्व वाष्पोत्सर्जन आंकड़ों से जल उपलब्धता में कमी निकाली गई है। इससे पता चला है कि पुणे, शोलापुर तथा अहमदनगर जिलों में पूरक सिंचाई के बिना बारानी खेती जोखिम भरी है। खरीफ के मौसम में फसल उत्पादन के लिए जलगांव व औरंगाबाद जिलों में अपेक्षाकृत बेहतर वर्षा वातावरण पाया गया। मध्य अगस्त में सिंचाई आवश्यकताओं की प्रागुक्ति की गई है। इसलिए उपलब्ध वर्षा ढांचे के अनुकूल अल्पावधि फसलों की सलाह दी गई है।

खरीफ फसल की बुवाई के लिए अनुकूल समय की प्रागुक्ति के लिए आर्द्रता उपलब्धता सूचकांक संकल्पना का उपयोग किया गया है। फसल बढ़वार की खास अवस्थाओं में जीवनदायी सिंचाई की आवश्यकता, उसके समय की सम्भावयताओं की भी प्रागुक्ति की गई है। यह जानकारी सस्य वैज्ञानिकों की फसल आयोजना तथा जल प्रबन्ध में उपयोगी होगी।

ABSTRACT. Climatic data of five selected districts of Maharashtra State have been analysed for assured weekly rainfall at 70, 50 and 30 per cent levels. The deficits of water availability have been calculated from the potential evapotranspiration data. It revealed that dryland agriculture without supplemental irrigation is highly risky in Pune, Solapur and Ahmednagar districts. Jalgaon and Aurangabad districts showed relatively better rainfall environment for crop production in the kharif season. Irrigation needs in mid-August are predicted. Shorter duration crops which fit in the available rainfall pattern are suggested.

Moisture availability index concept has been utilized to predict the suitable time of planting of kharif crops. The probabilities of needs of, and timing for the application of life saving irrigation at critical crop growth stages are predicted. The information would be useful to agronomists in crop planning and water management.

1. Introduction

In the semi-arid and arid regions where irrigation resources are limited, agricultural production depends mainly on the distribution of rainfall. Weather aberration, especially the erratic distribution of rainfall in these regions draws special attention to plan different strategies of crop production. Thus, crop production techniques on the basis of rainfall analysis and evaporative demand of the atmosphere are gaining importance.

Adequate amount of supplemental/protective irrigation water at the right time by right method of application is one of the important contributors to successful dryland argriculture. Even with adequate irrigation water, it is of great skill to plan it in such a way as more acreage could be brought under irrigation.

The harvesting of water and its reuse need more critical evaluation (Kanwar 1981). Maharashtra is having very limited irrigation resources (only 9.9 per cent of the gross cropped area). Even after tapping of all water resources, it may be possible to irrigate an area of 70.61 lakh hectares of which 52.61 lakh hectares will be from surface resources such as dams, tanks and any such reservoirs (Gandhi 1978).

Recent studies on dryland farming (Patil *et al.* 1981) have shown that some area comprising shallow and medium black soils under rabi crops needs to be diverted to kharif crops. In this study, attempt has been made to use the water availability index concept for predicting the suitable time of planting of kharif crops and timing the application of life saving irrigation at critical crop growth stages.

2. Materials and methods

The assured rainfall (R) values at 70, 50 and 30 per cent risk levels (Biswas and Khambete 1978) in respect of five stations, namely Aurangabad, Jalgaon, Ahmednagar, Solapur and Pune have been considered to give emphasis on the alternate production strategies. The monthly potential evapotranspiration values (Rao *et al.* 1971) computed by Penman's (1948) equation have been proportionately reduced to weekly values (PET) and have been used. The water availability index [R or $(R+\text{AWS})/\text{PET}$] values have been computed with probabilities of 30, 50 and 70 per cent for each meteorological week between June & mid-October. AWS is the available water of the soil. It is the difference between actual stored moisture in the root zone depth of the profile and wilting point moisture of the soil. This AWS

TABLE 1

General information of the study area (Sahasrabudhe *et al.* 1969)

District	Soil types	Depth of soil (cm)	Average annual rain-fall (mm)	Max.** capa-city (mm)	Crops grown in Kharif	Crops grown in Rabi	Average moisture content W/W (%) at different depths (cm) for June 7.5	15	30	45
Jalgaon	(*i*) Medium black soil (covers large area)	50			Jowar, Bajra,	—				
	(*ii*) Deep black soil (extends less area)	500 to 900	715	150	Pulses, Cotton, Ground-nut					
	(*iii*) Loamy soil	100								
	(*iv*) Sandy soil	100								
Ahmednagar	(*i*) Shallow	20			Bajra	Jowar,				
	(*ii*) Medium deep	100	575	150		Wheat				
	(*iii*) Deep black soils	More than 130								
Pune	(*i*) Light brown	50	(variable (rain-fall in the dist.)							
	(*ii*) Medium deep	100*	635 (in the study area)	150	Paddy (in high rainfall area)	Jowar, Bajra	16.0	17.3	18.4	19.3
	(*iii*) Deep black soils	More than100			Bajra					
Solapur	(*i*) Murmad and coarse soils	22					22.1	17.1	15.7	20.3
	(*ii*) Medium black	45	606	100	Bajra	Jowar, Bajra				
	(*iii*) Deep black	120								
Aurangabad	(*i*) Shallow black clay soils (extends less area)	30			Bajra, Pulses, Cotton, Jowar	Jowar, Bajra, Pulses, Cotton,				
	(*ii*) Medium black clay soil	100	702	250		Groundnut				
	(*iii*) Heavy black clay soil	150								

*Data obtained from the records of Agrimet Division. **Values decided on the basis of available water holding capacity information

becomes available to the plant when *R* falls short of PET. The maximum available water holding capacity of the soil (MAWS) of the five districts considered in this study is taken as 100 mm to 250 mm depending on the soil type and depth (Table 1). The values of field capacity and wilting point are obtained from different sources (*viz.*, Agricultural universities, available literature, ICAR, etc.) For a week when $R >$ PET, the difference of *R* and PET is added to the soil moisture. The excess water, after the soil moisture storage reaches field capacity, is allowed to go as runoff or deep drainage. When precipitation *plus* available soil moisture of a week is less than PET, the amount available for consumptive use is considered as actual evapotranspiration (AET). Weekly AET values have been computed using the book keeping method of Thornthwaite and Mather (1955). [*R* or $(R+\text{AWS})$/PET] represents the rate at which the

TABLE 2

Short duration kharif crop varieties suitable for drought-prone areas (Patil *et al.* 1981)

Crop	Variety	Duration (days)
Bajra	BJ 104	80-85
Setaria	Arjun	80-85
Groundnut	SB X I	100-115
Sunflower	EC 69874	80-85
Sesamum	D-7-11-1	80-85
Green gram	J 781	60-65
Black gram	T-9	75-80
Horse gram	K-42	110-120
Cowpea	C-152, K-11	80-85

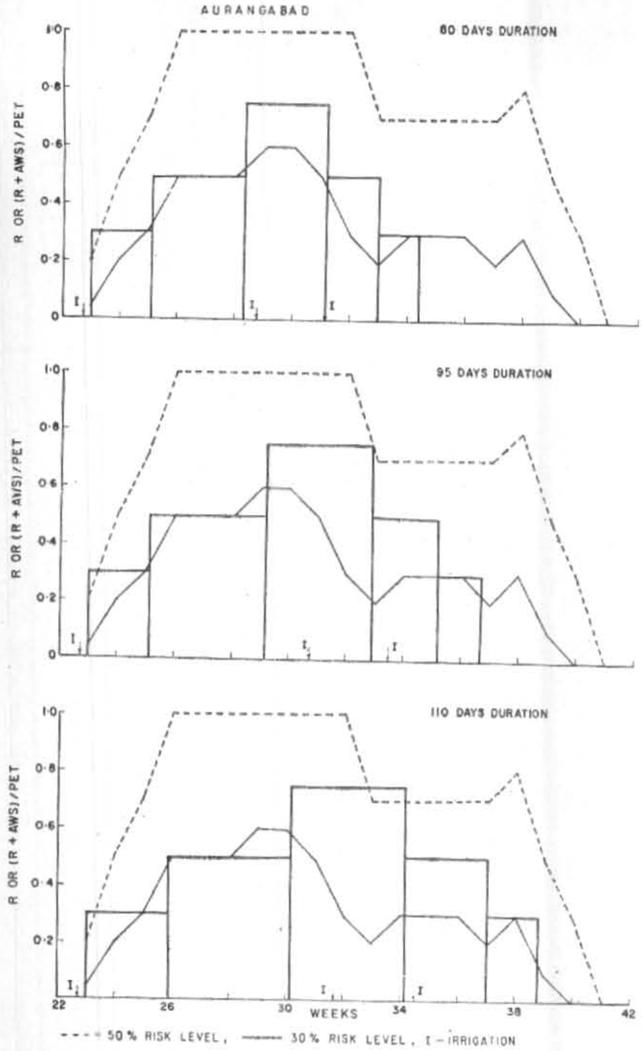

Fig. 1. [R or $(R+\text{AWS})/\text{PET}$] on the basis of assured rainfall at 50% & 30% risk level and fitting of growing periods of 80, 95 & 110 days crops

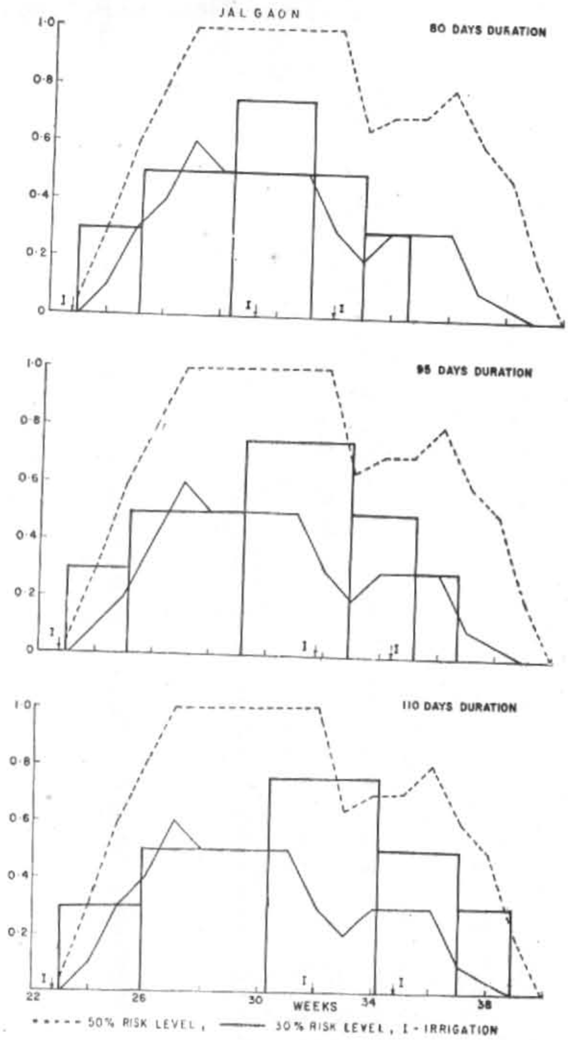

Fig. 2. [R or $(R+\text{AWS})/\text{PET}$] on the basis of assured rainfall at 50% & 30 % risk level and fitting of growing periods of 80, 95 & 110 days crops

water is supplied compared to the demand and therefore it is used as an index of water availability to the crops. At the beginning of crop season, soil moisture was equal to that of wilting point moisture. This was considered on the basis of the reported soil moisture observations (15-22%) and wilting point moisture (16-22%) of the study area (Table 1).

From available literatures, the [R or $(R+\text{AWS})/\text{PET}$] requirements during seedling, vegetative, reproductive, physiological maturity and harvest maturity stages of crop growth are considered as 0.3, 0.5, 0.75, 0.5 and 0.3 respectively (Virmani 1975, Biswas 1980). The values of [R or $(R+\text{AWS})/\text{PET}$] at 30, 50 and 70 per cent probabilities from 23rd to 42nd standard week are plotted separately for each station in Figs. 1-5. The [R or $(R+\text{AWS})/\text{PET}$] requirements at different growth stages of 80, 95 and 110 days duration crops are superimposed on the above diagrams. The planting schedules, deficits of water availability and timing for the application of life saving irrigation at critical water stress period of crops of 80, 95 and 110 days duration are worked out and shown in Figs. 1-5.

3. Results and discussions

It is seen from Figs. 1 and 2 that the peak period of water availability occurs from 26th to 32nd standard weeks. Thus, sowing of crops has to be adjusted in such a way as the reproductive and physiological maturity stages of crop growth coincide with the peak water availability period. The water requirements at different growth stages of 80, 95 and 110 days duration crops juxtaposed with the water availability periods revealed that kharif crops of 110 days duration can be grown with negligible amount of stress during reproductive phase. A good amount of rainfall during the week 27 to 32 will be stored in the soil profile to mitigate the water stress in the reproductive stage. Thus, short and medium duration crops of 80 to 95 days duration can have fair yield in 5 out of 10 years. The deficits of water availability at the emergence and seedling stages have emphasized the need of pre-sowing irrigation especially for longer duration crops. However, short duration crops

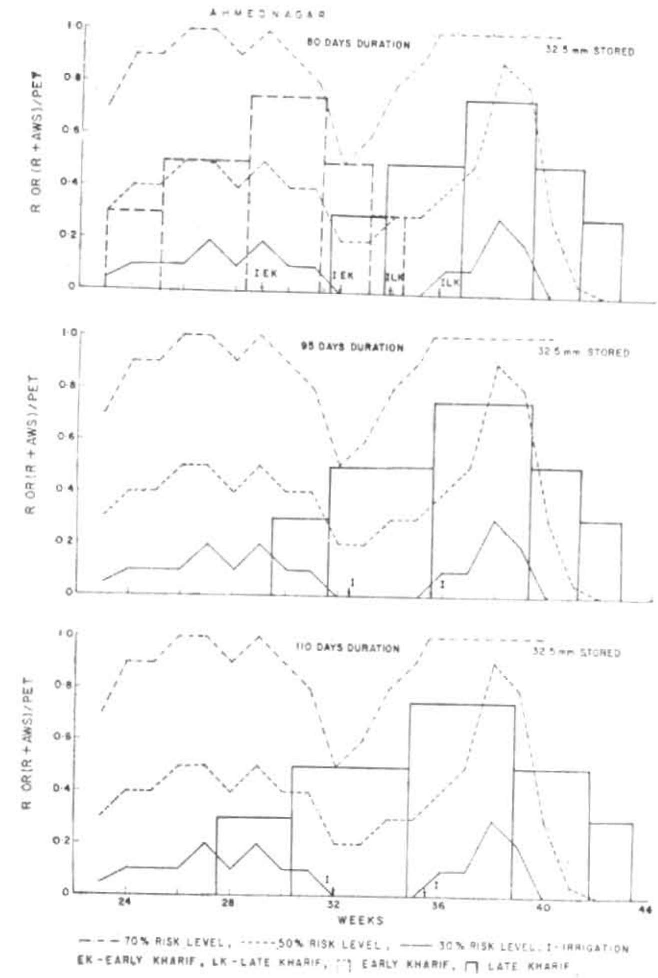

Fig. 3. [R or $(R+\text{AWS})/\text{PET}$] on the basis of assured rainfall at 70%, 50% & 30% risk level and fitting of growing periods of 80, 95 & 110 days crops

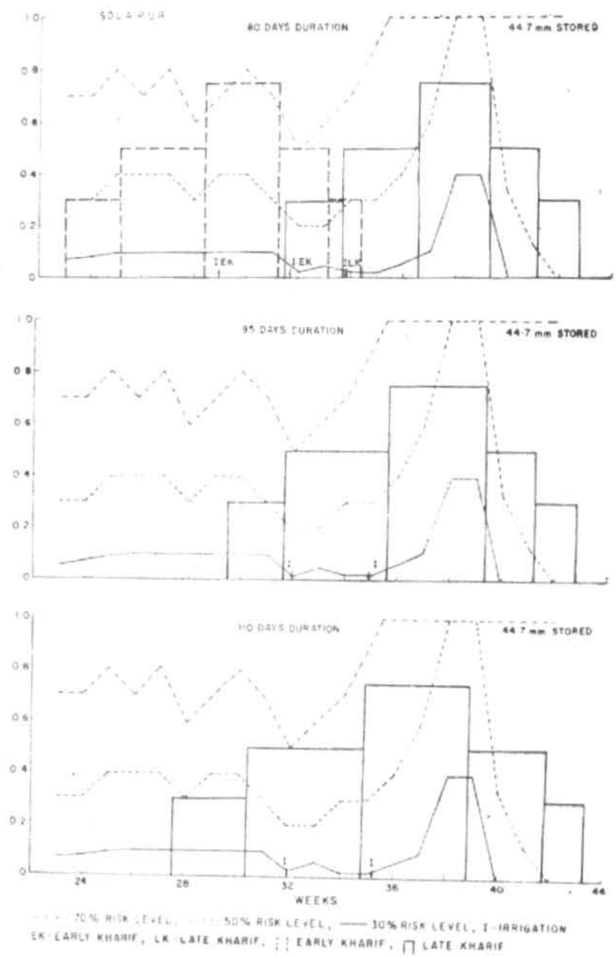

Fig. 4. [R or $(R+\text{AWS})/\text{PET}$] on the basis of assured rainfall at 70%, 50% & 30% risk level and fitting of growing periods of 80, 95 & 110 days crops

TABLE 3

Sources of water supply in each district (Season and crop report of Maharashtra 1976-77)

District	No. of wells used for irrigation purposes only				Total		Grand total
	Government		Private		Masonary	Non-masonary	
	Masonary (i)	Non-masonary (ii)	Masonary (iii)	Non-masonary (iv)	(v) (i)+(iii)	(vi) (ii)+(iv)	(vii)
Jalgaon	2	—	45786	2645	45788	2645	48433
Ahmednagar	—	51	55622	26769	55622	26820	82442
Pune	—	—	37505	21083	37505	21083	55588
Solapur	—	70	27377	28269	27377	28339	55716
Aurangabad	257	995	67182	5530	67439	6525	73964

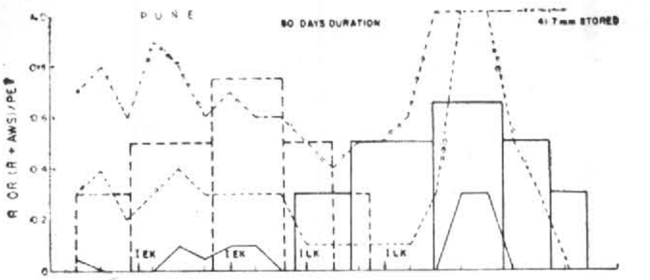

Fig. 5. [R or (R+AWS)/PET] on the basis of assured rainfall at 70%, 50% & 30% risk level and fitting of growing periods of 80, 95 & 110 days crops

can have fair yield in 7 out of 10 years with supplemental irrigations during reproductive and physiological maturity stages. The main crops grown in these two districts under rainfed conditions are jowar, bajra, kharif, pulses, cotton and groundnut. As the cropping season is restricted to 110 days, the chances for successful adaptation of long duration crops, *viz.*, cotton and groundnut are very less. Bajra and kharif pulses such as black gram or green gram should be sown simultaneously in the intercropping system for remunerative farming.

Figs. 3, 4 and 5 show that there are two peak periods of water availability in these districts. The primary peak occurs from 37th to 39th standard week and the secondary peak occurs from 25th to 30th standard week followed by a relatively dry period from 31st to 36th standard week. Thus sowing periods of early as well as late kharif crops should be adjusted in such a way that their flowering stages coincide with the primary and secondary peak water availability periods respectively. If sowings are done as per schedule shown in Figs. 3, 4 and 5, early as well as late kharif crops of short duration can have fair yield in 3 out of 10 years. Medium and long duration crops can also have fair yield in 3 out of 10 years. However, fair yield can be obtained in 5 out of 10 years with supplemental irrigations during early flowering and reproductive stages for medium and long duration crops.

The main crops grown in these districts under rainfed condition are bajra and kharif pulses as medium and short duration crops respectively in kharif season and jowar in the rabi season. As the water availability period is short, bajra and kharif pulses should be sown simultaneously in the intercropping system. Grain legumes can stand water stress during vegetative growth stage, hence a fair yield can be expected provided the water needs during the reproductive stage are successfully met through irrigation. Kharif pulses like green gram and other pulses as shown in Table 2 can be tried alongwith bajra for better economic returns. It would be rather difficult to convince the farmers to experiment this technique in place of age old practice of cultivating fairly assured rabi crops but certainly it could be tried first in Government demonstration farms and later on could be implemented in the farmer's field.

The sources of irrigation water and area under irrigation for each district are presented in Tables 3 and 4. Out of five districts under study, Ahmednagar has the highest percentage (18%) of total cropped area under irrigation. The lowest cropped area under irrigation is in Aurangabad district (12.4%), Pune, Solapur and Jalgaon districts are having 15.3, 13.7 and 13.4 per cent of total cropped area under irrigation respectively. It is seen from Tables 3 and 4 that only small fraction of the cropped land is under irrigation. Thus, to increase water resources in these districts of the semi-arid region, some strategies are required to be taken up. As shown by Gandhi (1978), 35 to 40 per cent of the land in villages can be assured of water for at least 8 months in a year through construction of small percolation tanks, farm ponds, nulla bunds and masonary/temporary earthern bandharas at suitable sites. More emphasis should be given for the construction of percolation tanks for the following reasons :

(*i*) Water, once stored underground, experiences less losses due to evaporation and seepage, than the one stored in village tanks.

(*ii*) Though 60 per cent of the annual rainfall is received in southwest monsoon, yet its distribution is well spread with lesser intensity compared to that of post monsoon rain. Attempts should, therefore, be made to store post monsoon rain within the village boundaries through percolation tanks of various capacities. Under favourable bed rock conditions, this stored ground water could be put into use for irrigation purposes in the next kharif season.

Symbol I alongwith arrow mark indicates the critical time when crops are to be irrigated. Average 50 mm irrigation is recommended. However, as recommended by Patil *et al.* (1981) protective irrigation of about 20 to 40 mm may be given where water resources are limited. It can be seen from Figs. 3, 4 and 5 that assured rainfall at Solapur, Pune and Ahmednagar districts is meagre and it becomes a gamble to plan a strategy under

TABLE 4

Net irrigated area in each district (in '00 hec) (Season and crop report of Maharashtra 1976-77)

District	Surface irrigation	Well irrigation	Total net area irrigated	Per cent of net area irrigated to net area sown	Area irrigated more than once in the same year	Total gross area of crops irrigated	Per cent of total irrigated to total cropped area
Jalgaon	245	754	999	12.3	239	1238	13.4
Ahmednagar	635	1317	1952	15.8	543	2495	18.0
Pune	628	709	1337	13.3	414	1751	15.3
Solapur	270	1011	1281	11.4	358	1639	13.7
Aurangabad	307	1120	1427	11.3	291	1718	12.4

circumstances of rainfall vagaries, supplemental and/or protective irrigations are probably the only alternative to stabilize crop production. Randhawa (1981), while tracing the history of research work of the 23 dryland research centres, mentioned that in comparison with an average rainfall 510 mm/year, Bellary received only 310 mm of rainfall during 1980-81. Even with this meagre rainfall, 25 per cent of any watershed could be given life-saving irrigation. Anderson (1976) also explained the importance of supplemental and minimal irrigation. He emphasized that the water in dry lands would always be inadequate and, therefore, the criterion should be the extra yield per unit of water.

At the end, it is worth mentioning that instead of surface irrigation, the novel method of drip irrigation and /or sprinkling irrigation would be adopted for dryland farming. This will bring more land under uniform irrigation.

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