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Assessment of quality of growing period in arid and semiarid ecosystems for crop production

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Abstract
Assessment of quality of growing period with weekly and monthly precipitation and potential evapotranspiration through water balance approach under arid and semiarid ecosystems, revealed that among the two areas in arid ecosystems, the extent of aridity varied. Besides, the quality of growing periods were also found to be different both temporally and spatially. Evaluation of the growing period based on weekly data also indicated that both moist (P/PET >0.5 & <1.0) and humid (P/PET=1) periods varied within the arid ecosystem.

In case of semiarid ecosystems, the quality of arid, moist and humid periods, the quantum of moisture storage over the period were also found to be different between the two areas. These variations in the quality of growing periods both within a ecosystem and also between the ecosystems could be effectively used for crop planning specific to an area.

Additional keywords: Humid period, moist period, dry period.

Introduction

Seasonal variation of moisture in the soils have a bearing on crop productivity and crop sustainability in any area more so in arid and semi-arid ecosystems. The agroclimatic analysis of growing period with the help of rainfall and potential evapotranspiration over a period in a calender year forms a guide for crop planning in an area. In addition, the available soil moisture stored in the solum contributes to an extension of the length of growing period.

The available soil moisture and storage capacity vary with soils. The available soil moisture depends mainly on soil volume, texture, kind and amount of clay minerals of soils.

The growing period is the period in which temperature (≥6.5°C) and moisture do not hamper plant growth. This temperature forms a threshold value for physiological activity of crops. Growing period is simulated through a water balance model and corresponds to the continuous period in the year where precipitation exceeds half potential evapotranspiration, extended by the time in

days that the soil moisture storage upto a maximum of 100 mm is depleted (FAO 1976, 1978; Kowal and Kassam 1978; Kassam *et al.* 1981; Brammer *et al.* 1988).

The length of the growing period through the water balance approach, and with the help of storage capacity of soils, actual and potential evapotranspiration (George and Alda Krishna 1969) provides a soil based length of growing period which usually varies with soils in an area (Teshome Yizengaw and Verheye 1992). This provides the water available period in each kind of soil for soil based crop planning. The length of growing period determined by consideration of heterogeneity of soils provides the spatial variation in an area whereas the growing period based on precipitation and potential evapotranspiration gives little emphasis to this parameter.

In addition the quantum of available moisture during various parts (phases) of growing period that determine the quality of growing period also varies spatially and temporally.

Thus, in an area not only the length of growing period but also the quality of growing period plays an important role for crop growth and crop planning. It is in this context that this study was undertaken to analyse the quality of growing period in arid (Anantapur and Bellary) and semiarid (Aurangabad and Sholapur) regions to highlight the critical periods for crop growth and crop planning.

Materials and methods

Monthly and weekly rainfall data from Anantapur, Bellary, Aurangabad and Sholapur were collected. The weekly potential evapotranspiration (PET) was calculated from monthly data through interpolation. With the help of soil information on available water capacity, the growing period was calculated (George and Alda Krishna 1969). The length and quality of growing periods under each situation and the different parts of the growing period i.e. dry period (P/PET <0.25), moderately dry period (P/PET ≥ 0.25 and ≤ 0.5), moist (P/PET ≥ 0.5 and <1.0) and humid periods (P/PET=1) were calculated. The lengths of different phases of growing period were assessed in the above regions.

Study Areas

1) Anantapur area: The study area is located between 14°45' and 15°00' N latitude and 77°15' and 77°30' E longitude at southern part of India in the state of Andhra Pradesh. It receives an annual rainfall of 563 mm and the potential evapotranspiration is 1858 mm. The annual rainfall received contributes to 30.3 per cent of the PET. The mean annual air temperature is 27.7°C with mean maximum of 32°C in May and mean minimum temperature of 23.5°C in December. The soil temperature regime is isohyperthermic and the moisture regime is aridic/ustic (Sehgal and Mandal, 1993). As per the climatic classification, this area belongs to Typic Aridic type.

2) Bellary area: It is located between 15°00' and 15°15' N latitude and 76°30' and 76°45' E longitude at southern part of India in the state of Karnataka. It receives an annual rainfall of 533.3 mm and the potential evapotranspiration is 1738 mm. The annual rainfall received contributes to 30.6 per cent of the PET. The mean annual temperature is 27.5°C with a mean maximum of 32.9°C in April and mean minimum of 22.2°C in December. The soil temperature regime is isohyperthermic and the moisture regime is ustic/aridic (Sehgal and Mandal, 1993). As per climatic classification, this area belongs to Typic Aridic type.

3) Aurangabad area: It is located in the central part of India in the state of Maharashtra between 19°45' and 20°00' N latitude and 75°15' and 75°30' E longitude. It receives the annual rainfall of 725 mm and the potential evapotranspiration is 1773.5 mm. The rainfall received contributes to 40.8 per cent of the PET. The mean annual temperature is 30.5°C with a mean maximum of 41°C in May and a mean minimum of 20°C in December. The soil temperature regime is isohyperthermic and the moisture regime is ustic (Soil Survey Staff 1975). As per the climatic classification, this area belongs to semiarid (dry) type.

4) Sholapur area: It is located in the state of Maharashtra between 17°30' and 17°45' N latitude and 75°45' and 76°00' E longitude. It receives an annual rainfall of 677 mm; and the potential evapotranspiration is 1801 mm. The rainfall received contributes to 37.6 per cent of the PET. The mean annual temperature is 27.1°C with a mean maximum of 33.7°C in May and a mean minimum of 20.5°C in December. The soil temperature regime is isohyperthermic and the moisture regime is ustic (Soil Survey Staff 1975). As per climatic classification, this area belongs to semiarid (dry) type.

Results and discussion

The monthly rainfall and potential evapotranspiration in arid and semiarid ecosystems and their ratios (Tables 1 and 2) indicate that these parameters vary both spatially and also temporally in arid and semiarid areas.

Arid ecosystem: Under the arid ecosystem (Sehgal *et al.* 1992), Anantapur and Bellary areas were selected. Anantapur area receives 563 mm rainfall while Bellary area receives 533 mm. The total annual potential evapotranspiration is higher in Anantapur area than that of Bellary area (Table 1). The rainfall in Anantapur area meets about 30.3 per cent of the PET and in Bellary area it satisfies about 30.6 per cent. In both the areas rainfall is in rabi season (in September and October months) through returning monsoon and accounts to a major portion of the annual rainfall in these areas. The annual moisture deficit is 1295 mm in Anantapur and it is 1204 mm in Bellary area. The quantum of deficiency shows a decreasing trend till September and it is increased from November onwards in both the cases (Table 1). In the month of October, Anantapur area showed no deficiency while Bellary area showed a little deficiency (Table 1). This indicates that the Anantapur area could sustain a crop better than the Bellary area irrespective of the existing arid climatic conditions. The P/PET ratio (Table 1) in both the areas also supports this observation since Anantapur area has one month of humid period (September) followed a month (October) of moist period. In Bellary area both the months show moist period only.

Table 1. Climatic parameters and growing period in arid ecosystem

Parameter	Location	Annual	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Rainfall (mm)	Anantapur	563.0	56.8	48.7	66.2	73 6	138.4	125.5	36.4	8.9
	Bellary	533.0	52.4	43.3	54.5	61.2	49.6	119.0	35.4	5.0
PET (mm)	Anantapur	1858	199.0	180.0	160.0	158.0	143.1	124.5	118.0	96.8
	Bellary	1738	200.4	167.0	156.0	123.0	138.0	123.0	106.0	104.0
Reserve or Deficiency	Anantapur	-1295	-142.0	-131.0	-94.0	-85.0	-4.6	1.0	-81.6	-87.9
	Bellary	-1204	-148.0	-124.0	-102.0	-62.0	-18.4	-4.0	-70.6	-99.0
P/PE	Anantapur	0.3	0.28	0.27	0.42	0.47	1.0	0.98	0.30	0.09
	Bellary	0.3	0.26	0.26	0.35	0.42	0.79	0.97	0.34	0.05
Max. storage in solum (mm)										
50	Anantapur				No storage is possible *					
	Bellary									
75	Anantapur				--------do--------					
	Bellary									
100	Anantapur				--------do--------					
	Bellary									
150	Anantapur				--------do--------					
	Bellary									
200	Anantapur				--------do--------					
	Bellary									
AET/PET	Anantapur	--	0.30	0.31	0.30	0.60	0.87	0.89	0.30	--
	Bellary	--	0.30	0.26	0.31	0.59	0.80	0.89	0.30	--
Growing period (days)	Anantapur	--	--	--	--	31	30	31	--	--
	Bellary	--	--	--	--	31	30	31	--	--

* Since accumulated potential water loss is highly negative.

Table 2. Climatic parameters and growing period in semi-arid ecosystem

Parameter	Location	Annual	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Rainfall (mm)	Aurangabad	725	17.0	134.0	174.0	123.0	170.0	47.0	31.0	8.9
	Sholapur	677	22.3	113.5	109.2	103.9	189.7	69.9	31.5	9.1
PET (mm)	Aurangabad	1773	250.0	179.0	124.0	123.0	122.0	135.0	111.0	96.8
	Sholapur	1801	220.8	165.0	139.3	136.4	127.2	139.5	123.9	113.7
Reserve or Deficiency	Aurangabad	-1048	-233.0	-45.0	50.0	--	48.0	-88.0	-80.0	87.9
	Sholapur	-1124	-198.5	-51.5	-30.1	-32.5	62.5	-69.6	-81.9	104.6
P/PE	Aurangabad	0.41	0.07	0.75	1.00	1.00	1.0	0.35	0.28	--
	Sholapur	0.40	0.1	0.69	0.78	0.76	1.0	0.50	0.25	--
Max. storage in solum (mm)										
50	Aurangabad	158.5	0.0*	0.0	49	49	50	8.5	1.7	0.3
	Sholapur	64.6	0.0	0.0	0.0	0.0	50	12.4	1.96	0.2
75	Aurangabad	208.0	0.0	0.0	49	49	75	23.0	8.0	2.5
	Sholapur	88.0	0.0	0.0	0.0	0.0	62.5	17.5	6.0	2.0
100	Aurangabad	263.0	0.0	0.0	49	49	97	39.0	17.4	7.0
	Sholapur	142.0	0.0	0.0	0.0	0.0	62.5	49.86	19.8	7.0
150	Aurangabad	263.0	0.0	0.0	49	49	97	39.0	17.4	7.0
	Sholapur	252.2	0.0	0.0	0.0	0.0	62.5	94.3	51.0	25.4
200	Aurangabad	263.0	0.0	0.0	49	49	97	39.0	17.4	7.0
	Sholapur	403.0	0.0	0.0	0.0	0.0	63.1	141.2	89.0	52.7
AET/PET	Aurangabad	--	--	0.75	1.00	1.00	1.00	0.78	0.50	0.20
	Sholapur	--	--	0.69	0.78	0.76	1.00	0.78	0.50	0.30
Growing period (days)	Aurangabad	--	--	30	31	31	30	31	30	--
	Sholapur	--	--	30	31	31	30	31	30	--

* Storage is nil, since accumulated potential water loss is highly negative.

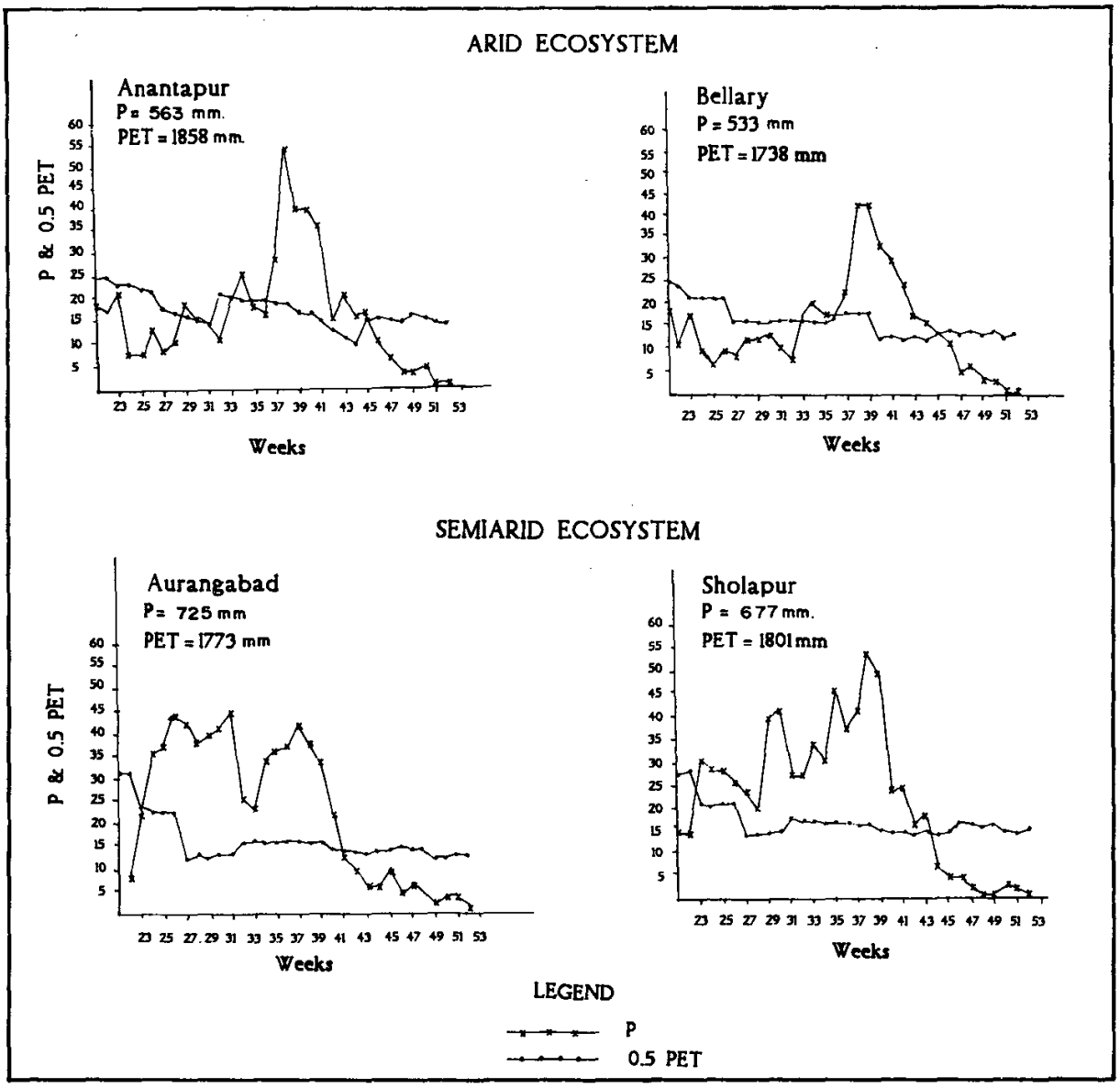

Fig. 1. Weekly rainfall and half potential evapotranspiration in arid and semiarid ecosystems.

Taking into consideration the kind of soils, their profile depth, available water retention capacity and monthly precipitation (P) and potential evapotranspiration (PET), the water balances were calculated. As such, in both areas the moisture effectively stored was found to be negligible throughout the year. However, the AET/PET monthly ratios in both areas, indicate that August, September and October months have ≥ 0.5. This indicates that these areas have a similar growing period for a crop under identical soil-site conditions.

In order to specify the weeks that show the growing period (Fig.1 and Table 3), the weekly rainfall and PET were studied. As per P/PET ratio the period was divided into dry, moderately dry, moist and humid periods (Table 3). It is observed that the Anantapur area has 40 weeks and Bellary area has 42 weeks of dry and moderately dry periods (P/PET <0.5). This clearly shows that Bellary area is dry for longer periods than the Anantapur area in spite of their classification in arid ecosystem. Conversely, the moist and humid periods in Anantapur area are more (8 and 4 weeks, respectively) as compared to Bellary area (6 and 4 weeks, respectively). Thus, the growing period (moist and humid period) in Anantapur area through weekly data analysis clearly indicates that it has 12 weeks from 29th to 45th standard weeks, with intermittent dry spells of about 5 weeks (Challa *et al.* 1990). On the contrary the Bellary area has a growing period of 10 weeks only from 34th to 45th weeks with dry spells in 36th and 37th weeks. Bellary area has less intermittent dry spell periods as compared to Anantapur area indicating less moisture stress for the growth of short duration crop during growing period than in Anantapur area.

Semi Arid ecosystem: Under semiarid ecosystem Aurangabad and Sholapur areas were selected. Aurangabad receives rainfall of 725 mm while Sholapur receives 677 mm. The PET is 1773 mm and 1801 mm, respectively in these areas. Maximum amount of rainfall is received from June to September. The annual rainfall contributes to about 40 per cent of the PET in Aurangabad area and it contributes to 37.6 per cent in Sholapur area. The annual deficit is 1047 mm in Aurangabad area and it is 1136 mm in Sholapur area. As in arid-ecosystem, the deficit decreases until June and again increases from October in Aurangabad area. In Sholapur area, the deficit is upto August and it increases from October. From P/PET ratios, it is evident that the precipitation is fully meeting the PET between July to September in Aurangabad and only the September month in Sholapur area. This indicates that the Aurangabad area can sustain a crop for a longer period without moisture stress as compared to Sholapur area.

Water balances were calculated for Aurangabad and Sholapur areas based on P, PET, and available water capacity of the soils (Table 2). This indicates that in both areas the AET/PET ratio ($\geq$0.5) extends from June till November, indicating a crop sustaining period of six months duration. However, the value of these ratios and the amount of available moisture for crop growth vary between Aurangabad and Sholapur areas over the months. Hence, the quality of the crop sustaining period (growing period) differs both spatially and temporally between these areas of semiarid ecosystem.

In order to comprehend the specific weeks for growing the crops, weekly rainfall and PET was considered (Fig.1 and Table 3). The P/PET ratios indicate that the duration of dry and moderately dry period in Aurangabad area is more (35 weeks) than the Sholapur area (31 weeks). In spite of higher annual rainfall in Aurangabad area the moist and humid periods which can sustain the crop growth are only 17 weeks while they are 21 weeks in Sholapur area (Fig.1 and Table 3). On the contrary, the humid period in Aurangabad area is 14 weeks and it is 8 weeks only in Sholapur area. This clearly indicates that crops in Aurangabad area

during this period have practically no moisture stress and this may not be true in Sholapur area. The longer the crop growing period in Sholapur area as compared to Aurangabad area could be ascribed to the distribution of rainfall under similar soil-site conditions.

Table 3. Moisture availability periods in arid and semiarid ecosystems

Moisture availability period	ARID ECOSYSTEM						SEMI-ARID ECOSYSTEM					
	ANANTAPUR			BELLARY			AURANGABAD			SHOLAPUR		
	Std. weeks	Period (weeks)	Total period (weeks)	Std. weeks	Period (weeks)	Total period (weeks)	Std. weeks	Period (weeks)	Total period (weeks)	Std. weeks	Period (weeks)	Total period (weeks)
Dry period (P/PET= <0.25)	1st to 19th	19	29	1st to 19th	19	29	1st to 22nd	22	31	1st to 20th	20	29
	24th to 27th	04		22nd	01		43rd to 44th	02		44th to 52nd	09	
	47th to 52nd	06		24th to 26th	03		46th to 52nd	07				
				47th to 52nd	06							
Moderately dry period (P/PET-0.25 to <0.50	20th to 23rd	04	11	20th to 21st	02	13	23rd	01	04	21st to 22nd	02	02
	28th	01		23rd	01		41st to 42nd	02				
	32nd	01		27th to 33rd	07		45th	01				
	33rd to 36th	04		36th to 37th	02							
	46th	01		46th	01							
Moist period (P/PET-0.5 to 0.99)	29th to 31st	03	08	34th to 35th	02	06	24th to 25th	02	03	23rd to 28th	06	13
	37th	01		42nd to 45th	04		40th	01		31st to 32nd	02	
	42nd to 45th	04								34th	01	
										40th to 43rd	04	
Humid period (P/PET= 1.0)	38th to 41st	04	04	38th to 41st	04	04	26th to 39th	14	14	29th to 30th	02	08
										33rd	01	
										35th to 39th	05	
Growing period (Moist period + Humid period			12			10			17			21

Conclusions

Thus this study indicates that Anantapur area is less arid than Bellary area eventhough these two areas are classified under arid ecosystem. In the case of Aurangabad and Sholapur areas under semiarid ecosystem, the former area is drier than the latter. As per the different stages of growing period from weekly data, Anantapur area is more moist and humid than Bellary whereas Aurangabad has a shorter moist period and more humid period than the Sholapur area. As such, the growing period (moist + humid period) in Anantapur area is 12 weeks suggesting the possibilities to grow a three months crop. In Bellary area it is only 10 weeks, suggesting the cultivation of short duration crop. In the case of Aurangabad and Sholapur areas, the former has growing period of 17 weeks and the latter has 21 weeks with intermittent dry spells.

In conclusion, this study indicates that the quality of the growing period varies spatially and temporally within an ecosystem, and this, however, is best expressed by using weekly data on rainfall and PET.

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