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Agro climate characterization for sustainable rainfed crop planning in KBK districts of Orissa

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ABSTRACT

In this study we attempted to characterize agro-climate of KBK (Kalahandi, Bolangir and Koraput) districts of Orissa for sustainable crop planning. Rainfall analysis revealed that pre-monsoon shower may occur between 15th and 18th standard weeks, making off-season tillage and preparation of seedbeds for rainy season upland crops feasible then. Rainfed, low water requiring, direct seeded upland crops can successfully be grown in upland rice soils during 24th to 38th standard weeks and earliest sowing can be completed in 24th standard weeks (11th to 17th June) at 70% (dependable) probability level. In the first southwest monsoon month i.e., in June, 115 to 154 mm rainfall was observed at 70 % (most dependable limit) probability level in KBK districts (based on Weibull's method). Therefore, in the rainy season direct seeded crops can be sown and rice nurseries can be prepared in 24 to 25th standard week with the commencement of southwest monsoon in the region. In the month of July at 70 % probability level, 249-293 mm rainfall was projected, which could be utilized for rice transplanting starting from first fortnight of July in medium and low land rice ecosystems.

Key words: Agro-climate, rainfed crop, sustainable

Any pragmatic crop planning needs a thorough understanding of the climate and in particular, the rainfall (its variability in the amount, distribution and probability of occurrence), evaporative demand and air temperature etc. Rainfall and evapotranspiration ultimately determine water balance, water and irrigation requirements of different crops of the region. Studies of such climatic parameters are thus helpful in defining risk levels in arable agriculture, characterizing length of the period and cropping system and command area planning. (Kar *et al.*, 2004). Some earlier workers attempted agro-climate analysis for rainfed crop planning in different parts of India. Chattopadhaya and Ganesan (1995) studied variability of annual and seasonal rainfall pattern for coastal Tamil Nadu. Sarkar (1994) applied gamma distribution for fitting weekly rainfall to estimate assured weekly rainfall at 30, 40, 50, 60 and 70 % probability levels for crop planning in the low water holding capacity soils of eastern gangetic plains of West Bengal. Because of practical utility several research workers studied the rainfall probability using Normal, Log Normal, Log

Pearson Type III and Extreme Value Type-1 distribution (Rana and Thakur, 1998; Kumar *et al.*, 1998; Sharma *et al.*, 1979; Anil Kumar, 2000; Tomar and Ranade, 2001; Kar and Singh, 2002) for cropping system characterization in different parts of the country. Kar and Verma (2005) analyzed climatic water balance, length of the growing period, favourable thermal environments, probabilistic rainfall, reference evapotranspiration of agro-ecological region (AER) 12.0 of India using GIS and climatological models.

In this study we attempted to characterize agro-climate of KBK districts of Orissa for sustainable rainfed crop planning. The KBK districts of Orissa, which comprises of undivided Kalahandi, Bolangir and Koraput districts, now cover eight divided districts namely, Koraput, Malkangiri, Nawarangpur, Rayagada, Bolangir, Sonepur, Kalahandi and Nuapara are mostly inhibited by tribal and schedule cast population. These districts are the most vulnerable to recurring drought and highly underdeveloped. The main technological constraints of low productivity in the region are vagaries of southwest monsoon, occurrence of dry spells and drought. Therefore, proper understanding of the agro-climate in relation to sustainable crop planning is of paramount importance for KBK districts of Orissa.

MATERIALS AND METHODS

Rainfall analysis

For rainfall variability and probability analysis, mean monthly rainfall data of past 44 years (1960-2003) were collected from Board of Revenue, Cuttack. Monthly rainfall was predicted at 30%, 50% and 70% probability levels using different probability distributions *viz.*, Normal, Log Normal, Log Pearson and Extreme Value Type-1.

The rainfall predicted during southwest monsoon months (June-September) at 50% and 70% probability levels by different distribution was compared with that of the observed values (Weibull's formula) and the best-fit probability distribution was computed by performing chi-square (χ^2) test.

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

Where, O_i = observed rainfall (mm) based on Weibull's formula, E_i = estimated rainfall (mm) from different probability distributions.

Initial probabilities (probabilities of week considering being wet or dry) of occurrence of weekly rainfall were determined using the following relationship.

(i) Probability of week considering being wet, P (W) = F (W)/N, where F (W) is the frequency of wet weeks and N, the number of years of data used.

(ii) Probability of week considered being dry, P (D) = F (D)/N, where F(D) is the frequency of dry weeks and N, the number of years of data used.

The conditional probabilities

Table 1: Normal monthly rainfall (mm) of KBK districts of Orissa.

District	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept.	Oct	Nov	Dec	Total
Koraput	6.7	11.3	16.2	53.4	75.0	205.8	351.1	380.3	262.1	116.5	35.8	7.6	1521.8
Bolangir	13.9	18.2	13.9	18.7	29.1	233.7	391.7	407.1	232.0	65.6	15.9	3.7	1443.5
Kalahandi	11.5	15.4	13.6	23.7	33.7	228.3	343.5	384.6	220.9	81.9	17.9	3.2	1378.2

Table 2: Season wise distribution of rainfall (mm) in three districts of Orissa

District	Monsoon		Post Monsoon		Winter		Pre Monsoon	
Koraput	1199.3	(78.8)	152.3	(15.5)	25.6	(1.7)	144.6	(9.5)
Bolangir	1264.5	(87.6)	81.5	(5.6)	35.8	(2.5)	61.7	(4.3)
Kalahandi	1177.3	(76.2)	144.4	(9.4)	65.3	(4.3)	155.2	(10.1)

(probabilities of wet week followed by wet weeks were determined.

$$P\left(\frac{W}{W}\right) = \frac{F\,(W/W)}{F\,(W/W) + F\,(D/W)}$$

F(W/W) is the frequency of wet week given that previous week was wet and F(D/W) is the frequency of dry week given that the previous week was wet.

In this study, software has been developed using Visual Basic 6.0 programming language for computing reference evapotranspiration and the ET_0 computed by using Penman-Monteith method given by FAO. The water requirement (ET_0) of major crops in three districts was computed by multiplying the crop coefficients with ET_0 at different growth stages (Allen *et. al.*, 1998).

RESULTS AND DISCUSSION

Seasonal distribution of rainfall

From the normal monthly rainfall, (Table1), distribution in different seasons *viz.*, southwest monsoon (June-September), post monsoon (October-November), winter (December-February) and pre-monsoon (March-May) were computed (Table 2). Study revealed that about 61.7-155.2 mm rainfall occurred during pre-monsoon period which would be useful for summer ploughing to make the land ready for final land preparation in rainfed upland and direct sowing of rainfed lowland rice in medium deep and deep water rice ecologies.

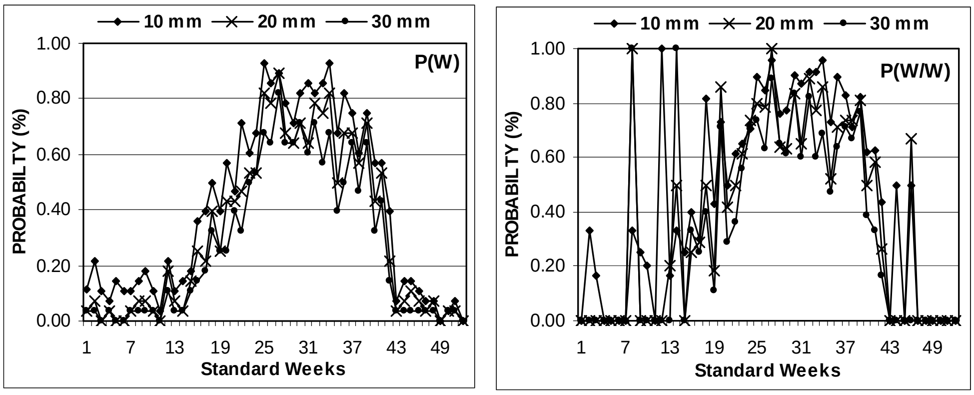

Fig 1 (a): Initial and conditional probabilities of weekly rainfall at Koraput

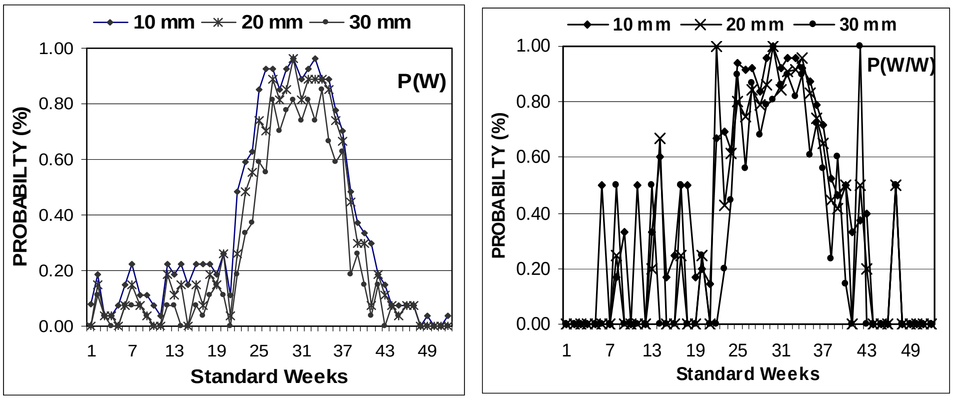

Fig 1 (b): Initial and conditional probabilities of weekly rainfall at Bolangir

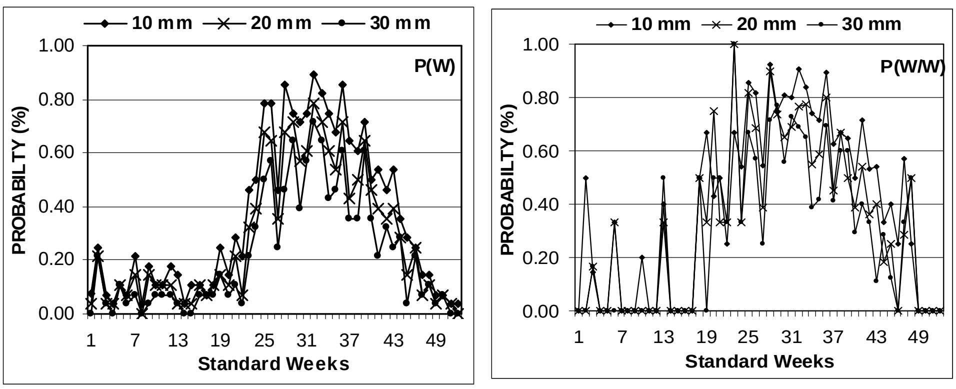

Fig 1 (c): Initial and conditional probabilities of weekly rainfall at Kalahandi

Table 3: Variability (%) in KBK districts of Orissa

District	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept.	Oct	Nov	Dec
Koraput	221	133	100	66	83	44	23	30	34	71	156	254
Bolangir	233	210	266	276	163	57	37	46	57	131	201	275
Kalahandi	271	157	189	88	98	51	36	39	52	105	171	343

The average rainfall during southwest monsoon months (June-September) is 1177-1264 mm (76.2-87.6%) but major part of this is generally lost through runoff, which can be utilized for providing supplementary irrigation to second crops. It can be used as life saving irrigation particularly in the years when rain during post monsoon season is low or also for growing short duration pulses like green gram, blackgram and oilseeds like mustard, linseed and groundnut in rainfed lowlands after rice during winter/summer season. A very good amount of rainfall (81.5-152.3 mm) is also received during post-monsoon season (October-November), which will be helpful for rainfed lowland rice because most of the long duration photo-sensitive rice varieties in the region *viz.*, Gayatri, Savitri, Durga and Sarala etc, are at flowering stage during late October or early November. Any deficit of rainfall during this period adversely affects the final yield of rainfed lowland rice. The winter rain is meager (1.7-4.3%) and crops like pea, linseed, lathyrus, blackgram and safflower can be grown by utilizing the residual soil moisture in rainfed shallow lowland valley fills. Growing of high value, high duty crops without supplementary irrigation during winter or dry season (December-April) would be risky.

Coefficient of variation of monthly rainfall

The coefficient of variation of monthly rainfall was computed for three undivided KBK districts and results are presented in Table-3. Study reveals that in a year, rainfall variability is less during southwest monsoon months for all the districts. Among different months, variability is low in July and August. The summer and winter rainfall are meager and highly variable. So growing of second crops during winter season after rainy season upland and medium land rice without supplementary irrigation would be risky. In lowland rainfed rice ecologies, second crops like pulses (greengram, blackgram, pea), oilseeds (linseed, safflower, niger) can be grown utilizing residual soil moisture.

Monthly rainfall at different probability levels

The probable date of onset of southwest monsoon in the region is 23rd standard meteorological week (10th June) and thus length of growing period (LGP) also generally starts from 23rd standard week. Hence sowing operation can be initiated from that week but prediction of amount of southwest monsoon rainfall in different seasons is of paramount

Table 4(a): Predicted monthly rainfall (mm) with different probability models at Kalahandi

months	Normal			Lognormal			Log Pearson			Extreme Values			Weibulls		
	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%
Jan	16.3	7.6	-	-	-	-	-	-	-	13.5	4.9	-	4.7	0.0	0.0
Feb	18.8	10.3	1.7	-	-	-	-	-	-	16.1	7.7	0.7	11.5	1.5	0.0
Mar	29.2	14.7	-	-	-	-	-	-	-	24.5	10.1	-	11.8	7.5	2.1
Apr	32.5	22.4	12.1	-	-	-	-	-	-	29.2	19.2	10.8	28.9	18.0	8.5
May	58.0	37.8	17.3	-	-	-	-	-	-	51.5	31.5	14.8	38.5	30.4	18.0
Jun	267.9	211.5	153.9	247.1	182.9	134.6	257.2	165.8	142.1	249.9	193.6	146.9	242.2	204.2	141.1
Jul	419.8	353.9	286.7	419.2	324.0	249.2	437.9	384.0	305.1	398.7	333.1	278.5	399.9	370.7	285.0
Aug	431.5	354.6	276.3	420.9	317.6	238.3	447.0	372.6	283.0	406.9	330.4	266.7	447.7	337.2	265.2
Sep	270.5	213.5	155.4	251.8	186.2	136.9	268.4	212.9	156.0	152.3	195.5	148.3	230.3	188.2	148.8
Oct	101.9	65.9	29.1	72.0	45.1	27.9	73.6	46.5	28.6	90.4	54.5	24.6	74.4	50.5	28.1
Nov	21.9	11.5	0.9	-	-	-	-	-	-	18.6	8.2	-	8.0	1.2	0.0
Dec	9.2	3.3	-	-	-	-	-	-	-	7.3	1.4	-	0.0	0.0	0.0

Table 4(b): Predicted monthly rainfall (mm) with different probability models at Bolangir

months	Normal			Lognormal			Log Pearson			Extreme Values			Weibulls		
	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%
Jan	33.3	15.1	-	-	-	-	-	-	-	27.5	9.3	-	10.1	0.9	0.0
Feb	33.3	15.9	-	-	-	-	-	-	-	28.8	3.1	-	17.4	5.2	0.1
Mar	57.1	23.9	-	-	-	-	-	-	-	48.5	13.5	-	19.2	4.7	0.4
Apr	91.6	37.6	-	-	-	-	-	-	-	74.3	20.6	-	23.7	11.9	7.2
May	87.4	47.3	6.5	42.5	21.3	10.6	44.0	22.5	11.0	74.6	34.7	1.5	38.7	25.2	12.2
Jun	237.1	183.4	128.7	208.5	161.8	125.0	200.3	154.2	121.3	219.9	166.5	122.0	192.6	160.4	115.5
Jul	376.8	315.8	253.6	-	-	-	-	-	-	357.3	296.5	246.0	372.0	331.6	248.8
Aug	405.0	326.8	247.1	-	-	-	-	-	-	380.0	302.1	237.4	368.2	316.9	266.0
Sep	231.8	178.8	124.8	217.2	144.1	94.8	237.6	178.2	118.1	214.9	162.1	118.2	221.8	165.9	120.7
Oct	81.3	48.3	14.7	-	-	-	-	-	-	70.8	37.9	10.6	49.7	28.0	15.0
Nov	23.2	11.3	-	-	-	-	-	-	-	19.4	7.6	-	13.0	0.2	0.0
Dec	8.5	3.5	-	-	-	-	-	-	-	6.9	1.9	-	0.3	0.0	0.0

Table 4(c): Predicted monthly rainfall (mm) with different probability models at Koraput

months	Normal			Lognormal			Log Pearson			Extreme Values			Weibulls		
	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%
Jan	17.2	8.0	-	-	-	-	-	-	-	14.2	5.1	-	3.9	0.5	0.0
Feb	16.5	9.8	2.8	-	-	-	-	-	-	14.4	7.6	2.0	1.3	4.0	0.5
Mar	25.3	16.6	7.8	-	-	-	-	-	-	22.5	13.9	6.7	19.3	11.5	5.7
Apr	54.6	40.7	26.5	47.6	32.3	21.7	50.5	35.6	23.6	50.2	36.3	24.8	52.8	30.7	25.2
May	101.9	71.1	39.8	-	-	-	-	-	-	92.1	61.4	35.9	68.6	54.0	46.1
Jun	252.1	204.9	156.8	236.3	185.4	144.8	241.0	191.0	148.2	237.0	190.0	150.9	232.2	174.9	154.3
Jul	385.2	344.6	303.2	378.8	335.8	297.1	380.3	337.8	298.4	272.3	331.8	298.1	394.7	327.4	293.3
Aug	382.1	318.8	254.4	380.7	285.2	212.4	405.3	334,9	252.1	361.9	298.9	246.5	384.8	343.0	267.4
Sep	270.4	237.7	187.6	257.5	217.6	183.2	254.2	214.0	181.2	257.3	216.4	182.5	258.5	207.6	174.8
Oct	131.6	95.8	59.3	110.9	73.1	47.7	116.7	79.2	51.0	120.2	84.5	54.9	107.2	83.6	53.7
Nov	39.7	22.0	4.0	-	-	-	-	-	-	34.0	16.4	1.8	22.9	7.1	1.9
Dec	16.7	7.2	-	-	-	-	-	-	-	13.6	4.2	-	2.0	0.1	0.0

importance for assessing rainfall at highly assured level to raise crops successfully. Hence, monthly southwest monsoon (June-September) rainfall was predicted at 30%, 50% and 70 % probability levels using different probability distribution [Table-4 (a-c)]. In the first southwest monsoon month i.e., in June, 115 to 154.3 mm rainfall was observed at 70 % (most dependable limit) probability level in KBK districts (based on Weibull's method). Therefore, in the rainy season direct seeded crops namely groundnut (*Arachis hypogea* L.), pigeonpea [*Cajanas cajan* (L.) Millsp.], cowpea [*Vigna unguiculata* (L.) Walp], maize (*Zea mays* L.) and blackgram (*Phaseolus mungo* L.) can be sown and rice nurseries can be prepared in 23rd to 24th standard week with the commencement of southwest monsoon in the region. The rainfall at dependable level during June can be utilized for upland direct seeded crop planning. In the month of July at 70 % probability level, 248.8-293.3 mm rainfall was projected, which could be utilized for rice transplanting starting from first fortnight of July in medium and low land rice ecosystems. The transplanting of rainy season rice in the first week of July will have additional advantage of assured rain during August and September.

To increase the rainwater use efficiency and productivity of light textured rainfed upland, rice can be substituted with other low water requiring crops through sole or intercropping. If in any case maize, groundnut, pigeonpea and direct seeded rice based intercrops could not be sown by the end of June or fail to establish in June due to dry spell or aberrant weather, late sowing of these crops results in crop failure or very low productivity. The crops like blackgram, cowpea, and sesamum can be sown successfully up to last week of July. Since the rainfall after October is uncertain and erratic, sowing of high value winter crops without supplementary irrigation is not possible in the region.

Best-fit probability distribution

The rainfall predicted during southwest months (June-September) at 50% and 70% probability levels by different distributions was compared with that of the observed values (Weibull's formula). The best-fit probability distribution was computed by performing chi-square (χ^2) test. The lowest chi-square value was observed when rainfall was predicted using Log Pearson Probability distribution for Koraput and Bolangir (Table 5). For Kalahandi district, the Extreme Value Type-1 distribution was found the best fit.

Wet-dry spell analysis

The week in which initial probability of receiving 20 mm or more rainfall exceeded the most dependable limit (70% probability) is considered as wet week. The first week after the onset of southwest monsoon in the region can be considered as sowing week of direct seeded upland crops. In Koraput [Fig. 1(a)], initial probability, P(W) of receiving 20 mm or more rainfall exceeded most dependable limit (70% probability) in the 24th to 36th

Table 5: χ^2-square test of observed and predicted monthly rainfall in three KBK districts of Orissa.

(a) Koraput

Months	Normal		Lognormal		Log Pearson		Extreme Value Type-1	
	50%	70%	50%	70%	50%	70%	50%	70%
Jun	4.4	0.0	0.6	0.6	1.4	0.3	1.2	0.1
Jul	0.9	0.3	0.2	0.0	0.3	0.1	0.1	0.1
Aug	1.8	0.7	11.7	14.2	0.2	0.9	6.5	1.8
Sep	3.	0.9	0.5	0.4	0.2	0.2	0.4	0.3
Total	10.9	1.9	13.0	15.3	2.1	1.5	8.1	2.3

(b) Bolangir

Months	Normal		Lognormal		Log Pearson		Extreme Value Type-1	
	50%	70%	50%	70%	50%	70%	50%	70%
Jun	2.9	1.4	0.0	0.7	0.2	0.3	0.2	0.3
Jul	0.8	0.1	-	-	-	-	4.2	0.0
Aug	0.3	1.4	-	-	-	-	0.7	3.4
Sep	.9	0.1	3.3	7.1	0.8	0.1	0.1	0.1
Total	4.9	3.0	3.3	7.8	1.0	0.4	5.2	3.9

(c) Kalahandi

Months	Normal		Lognormal		Log Pearson		Extreme Value Type-1	
	50%	70%	50%	70%	50%	70%	50%	70%
Jun	0.3	1.1	2.5	0.3	8.9	0.0	0.6	0.6
Jul	0.8	0.0	6.7	5.1	0.5	1.3	4.2	1.3
Aug	0.9	0.4	1.2	3.0	3.4	1.1	0.1	0.1
Sep	3.0	0.3	0.0	1.0	2.9	0.3	0.3	0.2
Total	4.9	1.8	10.4	9.5	15.6	2.8	5.2	2.2

Table 6 : Computed reference (ET_0) crop evapotranspiration (mm)

Districts	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kalahandi	84	95	149	180	198	156	112	115	108	112	84	74
Bolangir	96	109	149	207	242	174	115	118	111	18	90	81
Koraput	77	87	136	156	170	132	93	99	93	103	78	71

standard weeks after onset of southwest monsoon, so the 24th standard week (11th to 17th June) can be considered for final land preparation and sowing of the upland crops in the region. For other two districts, viz., Bolangir and Kalahandi, initial probability, P(W) of receiving 20 mm or more rainfall exceeded most dependable limit (70% probability) in the 25th standard week after onset of monsoon, so the 25th standard week (18th to 24th June) can be considered for final land preparation and sowing of the upland crops in those districts [Fig. 1 (b-c)].

The conditional probability [wet week followed by wet week, P (W/W)] of receiving 20 mm or more rainfall followed almost same trend, and occurred from 23rd to 36th standard weeks. At 15-18th week (during pre monsoon shower), initial probability, P(W) of receiving 10 mm or more rainfall exceeded 70% probability, so in those weeks light showers can be expected which can be utilized for off season tillage in rainfed upland rice area.

In general, from weekly rainfall probability analysis it can be said that (i) pre-monsoon shower may occur between 15th to 18th standard weeks, making off-season tillage and preparation of seedbeds for rainy season upland crops feasible then (ii) rainfed, low water requiring, direct seeded upland crops can successfully be grown in upland rice soils during 24th to 38th standard weeks and earliest sowing can be completed in 24th standard weeks (11th to 17th June) at 70% (dependable) probability level.

Reference evapotranspiration and crop water requirements

Software was developed to compute potential or reference evapotranspiration of the region with 20 climatological models. Using the software, users can choose any method for computing potential or reference evapotranspiration depending upon the location and availability of weather data set. In this study Penman-Monteith method of the software was used to compute ET_0 and the results of three KBK districts are presented in Table 6. Study revealed that the highest ET_0 was observed in the month of May with the monthly values being 198 mm, 242 mm and 170 mm in Kalahandi, Bolangir and Koraput, respectively (Table 6). The lowest ET_0 was computed in the month of December. Using the derived ET_o, the water requirements of different major crops of the region were computed by multiplying their K_c values (Allen *et. al.,* 1998) with reference evapotranspiration using CROPWAT 4.0 software. (Table 7).

CONCLUSION

The study amply revealed the usefulness of agro-climate analysis for cropping system and crop planning in a region. The rainfall variability and probability studies will be useful for characterizing length of the growing period and rainfed cropping system. The computation of reference evapotranspiration will be easier and faster with our developed software

Table 7: Computed crop water requirement (mm) of major crops using CROPWAT 4.0 model

Crop	Kalahandi	Bolangir	Koraput
Blackgram(K)	330	324	282
Blackgram(R)	248	279	232
Cowpea	323	351	275
Greengram(K)	330	359	282
Greengram(R)	248	279	232
Groundnut(K)	396	427	339
Groundnut(R)	343	386	282
Maize(K)	304	330	259
Maize(R)	235	264	220
Pigeonpea(K)	445	479	385
Sesamum	194	207	178
Sugarcane	1585	1760	1391
Summer rice	667	754	595
Winter rice	580	623	508
Spring Wheat	353	397	326

where users can choose any of the 20 climatological methods depending upon the location and availability of data. With the software net radiation can easily be computed for any location using basic weather data.

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