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Rainfall based parameters and yields of major *kharif* crops of Gujarat state

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ABSTRACT

This study was carried out to find the quantitative relationship between rainfall-based parameters and district level yield of three major *kharif* season crops of Gujarat, viz., groundnut, cotton and pearl millet (bajra). Two rainfall based indices, namely Generalised Monsoon Index, Yield Moisture Index were derived and correlated with the yield. Empirical relations were built between crop yields and rainfall parameters using stepwise regression technique.

Key words: Generalised monsoon index, yield moisture index, crop yield, groundnut, cotton, pearl millet

Gujarat state has a semi-arid agro climatic condition and most of the *kharif* crops in Gujarat, especially those in Saurashtra region, are grown as rainfed. The major *kharif* crops of Gujarat are groundnut, cotton and pearl millet. Considering the significant role of monsoon rainfall on crop yield, many workers have tried to develop rainfall based yield models for *kharif* crops in Gujarat. District level yield models have been developed for cotton crop (Ray *et al*., 1994) and groundnut (Sahu and Sastry, 1992; Pokharna *et al*., 1994; Chaudhury *et al*., 1999). These models either use rainfall data directly or actual evapotranspiration derived from soil moisture balance model based on rainfall data. Steyaert *et al*. (1981) and Achutani *et al*. (1982) suggested two agroclimatic indices, namely, yield moisture index (YMI) and generalized monsoon index (GMI). These indices have been used for crop yield forecasting (Prasad and Dudhane, 1989) and agroclimatic zoning (Kashyapi and Das, 1999).

Groundnut is mostly grown as rainfed crop in Gujarat (Saurahtra region), which requires 500 to 700 mm of rainfall to meet PET demand over the total growing period for a good yield. The sowing and flowering period is most sensitive to water deficit. Cotton is generally grown in middle Gujarat under rainfed conditions and needs 700 - 1000

Table 1 : Share of study districts in state's crop acreage and production

Crop	Districts	Combined Share (%) in State's	
		Acreage	Production
Groundnut	Amreli, Bhavnagar, Jamnagar, Junagarh, Rajkot	91	92
Cotton	Ahmedabad, Bharuch, Bhavnagar, Mehsana, Surendranagar, Vadodara	82	80
Pearl millet	Bansknatha, Bhavnagar, Kheda, Mehsana, Rajkot, Surendranagar	66	63

mm of water to meet its water requirements (PET). Pearl millet is mostly grown as a rainfed crop in Gujarat in sandy and often shallow soils having depleted fertility. Such areas are characterized by short and highly variable rainy season (2-4 months) with 200 to 800 mm of rainfall, high temperature and high potential evapotranspiration rates and thus agroclimatically unsuitable for other crops.

In this context, the present study was conducted, with an objective to study the relationship between the above two agroclimatic indices (YMI and GMI) with district level *Kharif* crop yield. The effect of three other rainfall-based parameters, the monthly rainfall, the seasonal rainfall (TRN) and the number of rainy days (TRD) during monsoon season, on crop yield was also evaluated.

MATERIALS AND METHODS

Data

District-level yield values for groundnut, cotton and pearlmillet crops for a period of 16 *kharif* seasons (1987-2002) were collected from Department of Agriculture, Gujarat for selected district (Table 1). Phenophase-wise normal water requirements for cotton, pearl millet and groundnut, which are specific to study area, were collected from India Meteorological department (IMD) crop weather calendars (Table 2). These parameters have been calculated based on weekly weather data. For calculation of YMI, crop coefficients were taken from Chaudhury *et al.* (1999).The coefficents for pearl millet were not available and hence YMI for pearl millet could not be computed. Rainfall and rainy days data for each district corresponding to the above-mentioned period were collected from

IMD.

Methodology

i) Generalised monsoon index (GMI) :

GMI is a simple tool to monitor rainfall conditions during the monsoon season. It is defined as (Steyaert *et al.*, 1981):

$$GMI = \Sigma\ W_i P_i \qquad (1)$$

Where, W_i is the GMI weight and P_i the actual monthly rainfall in the i th month, where i = 1, 2, 3 and 4 indicates the months of rainy season, i.e. June to September.

In order to compute the GMI, we require weighting factors for various months, which is given as follows:

$$W_i = R_i / \Sigma\ R_i \qquad (2)$$

Where, R_i is the monthly normal rainfall in the i th month and "R_i is the normal seasonal rainfall.

ii) Yield moisture index (YMI)

YMI is based on weighted monthly cumulative rainfall. The weights are functions of the crop water requirements and vary with the stage of crop growth.

YMI for any particular crop is defined as (Steyaert *et al.*, 1981):

$$YMI = \Sigma^{n}_{i=1} KC_i P_i. \qquad (3)$$

Where KC_i= the crop coefficient for i th crop stage

P_i = the rainfall (mm) during i th crop growth stage

n = total number of crop growth stages

Along with these rainfall-based indices, month-wise rainfall (June to September), total monsoon rainfall, and number of rainy days were used for analysis. Correlations were worked out between yield and the two indices and other parameters, for selected districts. Among these, only those cases, where the correlation coefficients were found significant, were considered for the stepwise regression analysis.

RESULTS AND DISCUSSION

The rainfed *kharif* crops in Gujarat, show very high variability in yield because of high variability in rainfall. The year-to-year variability of crop yields was also analyzed, as discussed below:

Variability in yield

The coefficient of variation (CV) in groundnut yield was very high and ranged between 48 per cent at Junagadh to as high as 107 per cent in Jamnagar

Table 2 : Phenophase-wise crop water requirement and crop coefficients for various crops in Gujarat

Crop	Stages	Standard Weeks	PET	Crop coefficients
Cotton	Sowing	22-27	160	
	Germination	28-31	122	0.91
	Vegetative & Flowering	32-40	401	1.64
	Boll Formation	41-50	298	
	Picking	51-02	80	
Pearl millet	Sowing	23-25	64	Not available
	Germination	26-28	107	
	Vegetative & Flowering	29-36	289	
	Grain Formation	37-39	67	
	Harvesting	40-42	69	
Groundnut	Sowing	22-25	103	------
	Germination	26-29	81	0.65
	Flowering/Pegging	30 -32	100	1.15
	Pod Formation	33-38	330	0.85
	Harvesting	39-42	96	0.55

(Table 3). Yields varied from as low as 3 kg ha^{-1} in Rajkot in 1987 to as high as 1990 kg ha^{-1} in 1998 at Junagadh. The CV for pearl millet yield ranged from 25 per cent in Kheda to 59 per cent in Rajkot. The variations were equally high for cotton yields (Table 3) but inter-district variability was less. During the period of study the CV of district-wise rainfall varied from 36 per cent in Vadodara to 74 per cent in Jamnagar. Rainfall was more variable in Saurashtra as compared to other parts of Gujarat (Table 3). Most of the districts in Saurashtra have very few sources of irrigation and thus the crops here are completely dependent on rainfall.

Relation between yield and weather parameters

The correlation analysis showed that, in the selected districts the groundnut yields were significantly correlated with number of rainy days (TRD) except for Rajkot where yield showed significant correlation with YMI and June rainfall. However, in case of pearl millet, yields were significantly correlated with seasonal rainfall for Rajkot, Surendranagar and Bhavnagar districts only. In case of cotton, yields were significantly correlated with YMI in Ahmedabad, GMI in Mehsana, TRD in Bhavnagar, seasonal rain in Surendernagar and September rain in

Table 3. : Coefficient of variation (%) of crop yields and seasonal rainfall

District	Coefficient of variation (%) in yield			Normal seasonal rainfall (mm)	Normal seasonal rainy day	C.V. of seasonal rainfall
	Groundnut	Cotton	Pearl millet			
Ahmedabad		46		659	98	42
Amreli	61			518	98	55
Banaskantha			52	630	86	59
Bharuch		37		857	111	37
Bhavnagar	66	52	46	566	105	37
Jamnagar	107			474	75	74
Junagadh	48			788	98	59
Kheda			25	831	100	38
Mehsana		42	36	677	90	50
Rajkot	95		59	575	92	54
Surendernagar		51	50	500	85	43
Vadodara		35		965	113	36

Bharuch. YMI and GMI indices did not show significant correlation with the yield in most cases for Groundnut. YMI indices were not attempted for Pearl Millet.

Yield estimation

The district-level empirical yield models, derived using stepwise regression technique, are presented in Table 4. As mentioned earlier, the empirical models were derived only for those cases where rainfall based parameters showed significant relations. In 5 cases the total rainy days (TRD) were considered in the equation, whereas the number of equations considering seasonal rainfall (TRN), YMI, GMI are four, two, and one, respectively. Thus 9 cases out of 13 were significantly correlated to TRD and TRN and only 3 cases were significantly correlated to YMI and GMI. This showed in case of rainfed crops in Gujarat the amount and the distribution of rainfall plays a significant role in determining the crop yield. The R^2 value ranged from 0.27 to 0.81. High R^2 values were mostly found for rainfed groundnut crop. The empirical equation explained more than 50 per cent of variation in groundnut yield through rainfall-based parameters. The F values ranged from 4.95 to 24.89, showing that all the

Table 4 : District level crop yield prediction equations using rainfall based indices

Districts	Prediction Equation for Yield	R^2	F
Groundnut			
Amreli	41.367*TRD-199.49	0.56	16.65
Jamnagar	67.767*TRD-464.942	0.51	13.39
Rajkot	2.351*YMI+1.756*Rjune-24.612	0.81	24.896
Junagadh	29.093*TRD+245.53	0.41	8.88
Bhavnagar	28.513*TRD-55.605	0.33	6.414
Cotton			
Ahmedabad	0.096*YMI+65.255	0.32	6.145
Bharuch	0.264*Rsep+108.411	0.47	11.88
Bhavnagar	6.95*TRD-7.766	0.40	8.79
Mehsana	0.609*GMI+25.607	0.49	12.54
Surendranagar	0.239*TRN+46.853	0.37	7.77
Pearl millet			
Bhavnagar	2.293*TRN+48.732	0.57	17.179
Rajkot	1.474*TRN+89.012	0.64	23.06
Surendranagar	1.287*TRN+331.97	0.27	4.951

equations presented in table 4 are statistically significant.

The forecast yields for various districts (Table 5) were matching well with the estimates of Department of Agriculture in four out of 13 cases for 2002–2003. They are for cotton in Mehsana and Ahmedabad, Pearl millet in Rajkot and Groundnut in Jamnagar.

The year 2002 was a rainfall deficient year for Gujarat as a whole. It was also declared as the first all India drought year after 1987. The rainfall departures were more than 20% from the normal. The distribution of rainfall was also skewed. There were total two spells

Table 5 : Actual and predicted yields of groundnut, cotton and pearlmillet for the year 2002-2003.

Districts	DOA yield in (kg ha^{-1})	Predicted yield in (kg ha^{-1})
Groundnut		
Amreli	717	338.28
Bhavnagar	862	400.60
Jamnagar	36	0.0
Junagadh	900	652.83
Rajkot	125	684.57
Cotton		
Bhavnagar	130	103.45
Bharuch	203	141.30
Mehsana	62	60.66
Surendernagar	55	137.50
Ahmedabad	102	110.88
Pearl Millet		
Rajkot	651	635.13
Surendernagar	640	820.14
Bhavnagar	2027	1778.11

of very heavy rains. Most of the districts in Saurashtra received excess rains in the last week of June. The month of July had scanty and no rains. The second spell of excess rains was received in the last week of August and there were no rains after that. This caused a variation between forecast yield and actual yield in case of Groundnut.

CONCLUSIONS

The study showed that the rainfall-based parameters were very efficient in predicting crop yields for Kharif crops in Gujarat, especially for Groundnut, which is mostly a rainfed crop. Among the rainfall based parameters, number of rainy days (TRD) and seasonal rainfall (TRN) were mostly related to crop yield, whereas YMI and GMI were significantly related to crop yield in only three cases. Though the empirical based models predicted the yield trends (decrease or increase) correctly, only in 4 out of 13 cases predicted yield was close to the actual yield.

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