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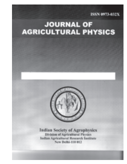

Research Article

Rainfall Probability Analysis of the Western Odisha Plateau Region for Sisal (*Agave sisalana* Perrine ex Engelm.) based Cropping System

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ABSTRACT

Daily rainfall and temperature data of recent past 10 years (2001 - 2010) recorded at the Meteorological Observatory of Sisal Research Station (23.05°N, 84.23°E, and 256.03 m above MSL), Bamra, Sambalpur, Odisha were analysed to understand the variability and probability of rainfall for sisal based cropping system in the tribal dominated western Odisha. The mean annual rainfall was 1230.6 mm from 59 rainy days. The maximum contribution of rainfall was in the *kharif* season (90.4%). Among standard meteorological weeks (SMW), 26-29 SMW received the highest rainfall (465.1 mm) which is 38% of the total rainfall. In a single week the highest rainfall was in the 29th week (140.4 mm). It was computed that 42.5% of the months were normal months and 32.5% of months faced water deficit situation. Only four months in a year (June to September) had 100% probability of getting 100 mm rainfall. Expected monthly rainfall of 250 mm is obtainable only in July and August. Therefore, sowing of *rabi* crops need to be completed in early October to get the benefit of residual soil moisture from August rain as well as to utilize the rain received in October. Mustard can be sown in October utilizing the available moisture; however, it needs assured irrigation during November-December when the probability of getting 50 mm rainfall is very low (4-10%). In a year, there are two phases of deficit rainfall for sisal and sisal based cropping system and they are January to May (Phase-I) and October to December (Phase-II). During June to September, the rainfall is much excess to the ETc demand for sisal and therefore, care is to be taken to remove the excess water from the sisal field having little natural slope for achieving better growth and fibre yield.

Key words: Rainfall analysis, Cropping system, Sisal (*Agave sisalana* Perrine ex Engelm.), Western Odisha

Introduction

The western Odisha zone is spread between 19.5 to 22.18°N latitude and 82.33 to 88.78°E longitude falling in the Northern Plateau Physiographic Zone comprising three agro-climatic zones namely north western plateau, western undulating zone and western central table (Anon., 2012a). In these zones the rainfall widely varies and the main crop of paddy is traditionally grown during *kharif* season (Saha and Rao, 2008). The foremost problem that Odisha agriculture faces is the shortage of water in many areas particularly in western part of the state. Lack of irrigation facilities in these drought prone areas create great impediments to the agriculture (Anon., 2012a). As the *kharif* paddy is wholly dependent on monsoon rains, the yield is highly uncertain and seldom touches economically profitable zone. The topography, soil condition

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and climatic variables of this zone are not appropriate for profitable rainfed paddy based farming. Moreover, the traditional way of growing *kharif* paddy (mono-crop) reduces the cropping intensity as well as profitability from a unit holding. It was earlier opined (Saha and Rao, 2008) that the western part of Odisha needs crop diversification/ substitution by low water requiring crops such as green gram, black gram, pigeon pea, horse gram and several others.

Centuries ago, Sisal (*Agave sisalana* Perrine ex Engelm.) was introduced in the drier tracts of peninsular region of India including western part of Odisha state also. Now a days, the crop is grown in an unorganized way mostly by the tribes as well as other farmers of all social strata. The crop of sisal is well suited under the changing climatic situation characterised by elevation of average temperature, erratic and insufficient rainfall and can sequester carbon even during prolonged dry periods (Sarkar *et al.*, 2010). Though sisal is able to survive and grow with less water, but it responds well to favourable soil moisture conditions resulted from rainfall or irrigation (micro). As rainfall is the single most source of water in rainfed production system, understanding of rainfall patterns of a region is of utmost importance for successful planning of crops in a profitable farming mode. Keeping these considerations in view, the present analysis of daily rainfall and rainy day data for a decade (2001-2010) of this region was done to understand the variability and probability of rainfall which may guide to successfully venturing in to the sisal based cropping system for the tribal dominated western Odisha (43.1% of rural). Similar analysis of rainfall probability were reported earlier for Assam (Sarkar, 2002), Koraput (Sudhishri *et al.*, 2004), West Bengal (Barman *et al.*, 2012; Das, 2012) and other regions.

Materials and Methods

Daily rainfall and temperature data of recent past 10 years (2001-2010) recorded at the Meteorological Observatory of Sisal Research Station (23.05° N, 84.23° E, and 256.03 m above MSL), Bamra, Sambalpur, Odisha were used for the analysis. The daily rainfall data were analyzed for weekly, monthly, seasonal and annual values through standard deviation (SD), standard error (SEm±), co-efficient of variation (CV%). Probability was calculated as described by Panse and Sukhatme (1985) as follows:

a) Calculation of normal deviate = $(X - \mu) / \sigma$, where 'X' is the given observation, 'μ' is the mean value and σ = standard deviation.

b) The table value of ½ $(1 + \alpha)$ corresponding to the values of normal deviate was computed.

c) Probability (%) = [1 – table value of ½ $(1 + \alpha)$] × 100

Monthly and yearly events were then classified as used by Sudhishri *et al.* (2004) (termed as Revised IMD Method), where drought was assessed on the basis of percentage deviation of rainfall (Di) from the long-term mean rainfall. Di = {(Pi – PM)/PM}*100, where, 'Pi' is the rainfall in the time period 'i' (i.e., week, month) and PM is the long-term mean rainfall. The percentage deviation of rainfall and the category of drought assessment are given below:

IMD classification of drought

Percentage deviation (Di)	Class	Category
> 0	M0	No drought
0 to -25	M1	Mild drought
-25 to -50	M2	Moderate drought
< -50	M3	Severe drought

There are three distinct crop seasons based on the rainfall pattern in western Odisha. The seasons are Summer/*Zaid* (05 March - 03 June), *Kharif* (04 June - 07 October) and *Rabi* (08 October - 04 March). For water balance study, crop coefficient and crop evapotranspiration were used. Procedure for estimating reference crop evapotranspiration i.e., ET_0 (mm/day) was considered as described by Hargreaves (1994) which requires the maximum and minimum temperature data for the study period.

$$ET_0 = 0.0022 * RA * (Tc + 17.8) * (TD)^{0.5} \quad \ldots(1)$$

where, RA = extra-terrestrial radiation (mm/day), Tc = mean temperature (°C); TD = difference between maximum and minimum temperature

Table 1. Monthly extra-terrestrial radiation (mm d^{-1}) for Bamra

Latitude of Bamra	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
23.05°N	10.45	12.10	14.05	15.45	16.35	16.50	16.35	15.80	14.55	12.80	10.90	9.95

(°C). The actual crop evapotranspiration (ETc) was calculated by ETc = ET_0 *Kc, where Kc is the crop coefficient. The monthly RA values expressed in equivalent evaporation (mm d^{-1}) for Bamra were extrapolated from the Table of Doorenbos and Pruitt (1977) as given in table 1. The crop coefficient for sisal (Kc= 0.55) was considered as reported by FAO (Anon., 2012b).

Results and Discussion

Maximum and Minimum Temperature

The mean maximum temperature was recorded in May (40.9°C) and the mean minimum temperature was in January (8.6°C) (Fig 1). The mean maximum temperature varied between 25.4 and 42.6°C (range = 17.2°C) and the minimum temperature varied between 5.5 and 27.3°C (range = 21.75°C). The highest difference of 19.9°C between the maximum and minimum temperature was recoded in April and the lowest difference of 8.3°C was recorded in August. During the monsoon months (July to September), the maximum and minimum temperature reach a plateau as the maximum remain within a narrow range of 30.8 to 31.7°C (i.e. a variation of 0.9°C only); similarly the meagre variation in the lowest temperature was recorded which lies between 22.2 and 22.6°C (range = 0.4°C).

Annual and Seasonal Rainfall

Analysis of the decade's (2001-2010) rainfall data revealed that the average annual rainfall was 1230.6 mm with a wider range between 777.8 and 2025.0 mm (Table 2). During the period, the annual average rainy days were 59 days. Out of the total rainfall, maximum contribution of rainfall was in the *kharif* season (90.4%) followed by *rabi* season (5.9%) and summer (3.7%). The highest number of rainy days were recoded in *kharif* (50.5). The coefficient of variation (CV) in annual rainfall during the analysed period was 29.2% with about 12% variation in rainy days. The most stable season as per the variation in rainfall was concerned was the *kharif* which showed CV=29.6%; whereas, *rabi* and summer CV values were 95.5% and 78%, respectively. Higher CV values in *rabi* and summer season indicated that there was low predictability of rain during both the seasons and therefore, planning

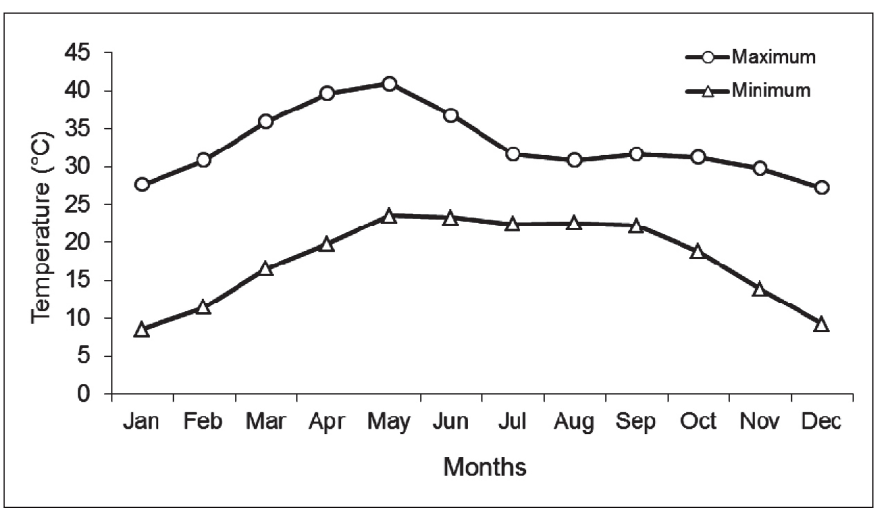

Fig 1. Mean maximum and minimum temperature during 2001-2010 at Bamra

Table 2. Seasonal and annual statistics of rainfall (mm) and rainy days (number) at Bamra, Sambalpur, Odisha

Year	Summer (SMW 10-22)		*Kharif* (SMW 23-40)		*Rabi* (SMW 41-09)		Annual	
	Rainfall (mm)	Rainy day	Rainfall (mm)	Rainy day	Rainfall (mm)	Rainy day	Rainfall (mm)	Rainy day
2001	99.1	9	1910.1	58	15.8	2	2025.0	69
2002	1.0	0	1012.4	60	17.8	2	1031.2	62
2003	30.9	2	1100.0	56	183.4	10	1314.3	68
2004	95.2	8	862.5	50	25.0	2	982.7	60
2005	24.4	2	1087.5	35	128.5	10	1240.4	47
2006	86.6	6	1300.0	49	152.0	8	1538.6	63
2007	12.6	2	1254.8	53	116.5	5	1383.9	60
2008	17.2	2	975.0	49	0.0	0	992.2	51
2009	39.8	2	738.0	49	0.0	2	777.8	53
2010	53.6	4	882.7	46	83.2	9	1019.5	59
Mean	46.0	3.7	1112.3	50.5	72.2	5	1230.6	59.2
SD	35.97	2.98	329.45	7.08	68.95	3.88	359.66	7.09
SEm±	11.37	0.94	104.18	2.23	21.8	1.22	113.74	2.24
CV%	78.15	80.62	29.62	14.01	95.47	77.74	29.22	11.97

for rainfed crop is difficult. Marked variation in annual rainfall was recoded from year to year during the period of study (Fig. 2). The highest positive deviation in annual rainfall was observed in 2001 (+64.6%) and the maximum negative deviation was noted in 2009 (-36.8%). During the decade, in two years namely, 2003 (+6.8%) and 2005 (+0.8%), the average annual rainfall were near normal. The mean annual rainfall of the decade was plotted linearly. The trend of annual rainfall (Fig 3) of the decade showed that the amount of rainfall might be decreasing over the years (y = -66.2*x + 134104; where, 'y' = annual rainfall (mm), 'x' is the year in Gregorian format, say 2010, 2011 and so on). However, as the R^2 value of the regression equation is low, the predictability of the line for amount of rainfall that will be received in a future year may not be very accurate for the location.

Monthly Rainfall and Rainy days

There was remarkable variation in monthly rainfall (3.89 to 425.21 mm) and rainy days (0.4 to 17.6 days) during the decade (Table 3). The

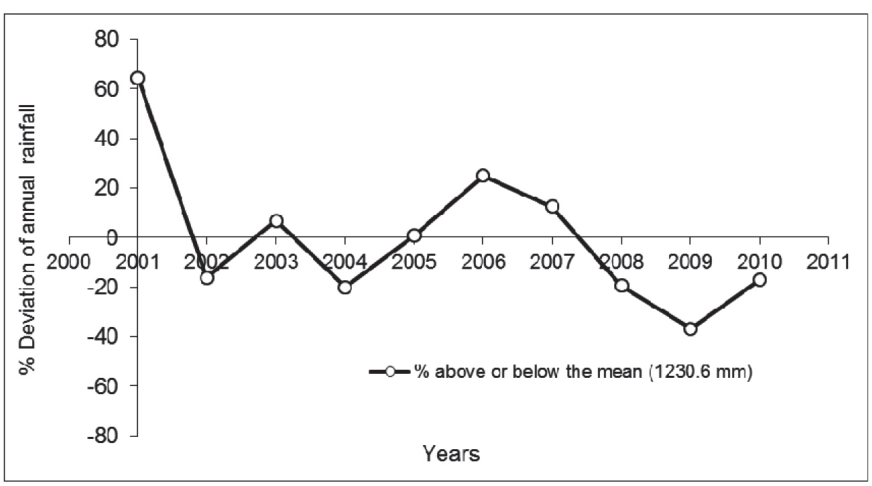

Fig. 2. Deviation (%) of annual rainfall over 10 years from the mean (1230.6 mm) at Bamra

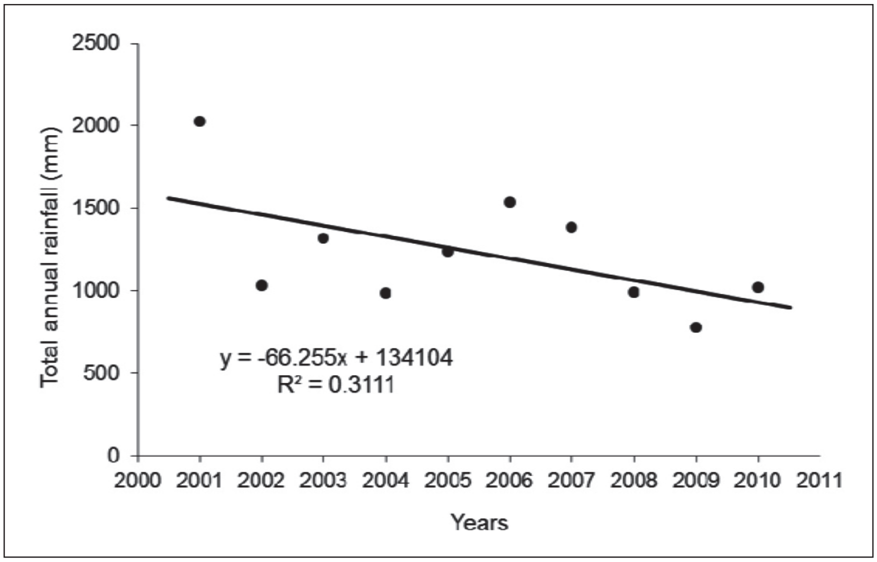

Fig 3. Trend of annual rainfall during 2001-2010 at Bamra

month of July was the wettest month having a rainfall of 425.21 mm, which contributed 34.55% of the total annual rainfall and January was the driest month (3.89 mm). The lowest variability of rainfall was recoded in August (CV = 31.1%) followed by June (CV = 56.6%) and July (CV = 61.6%). The monsoon months (July-August) having comparatively lower CV values proved the assurance of rainfall during the season of a year. The highest aberration in rainfall was measured in March (CV = 197%). From November to May, the CV values were always >100%, hence, assurance of rainfall was uncertain. In July, rainfall occurred in >17 days and there were about 15 rainy days in August. These two months (July and August) contributed 55% of the annual rainy days. Like other similar climatic regions of the country, a straight line relation between the rainfall and rainy days was computed (y=23.2*x – 12.03, where, x = rainy days, y = rainfall in mm) and the relation was strongly predictable (R^2 = 0.987).

Table 3. Monthly rainfall and rainy days statistics at Bamra, Odisha during 2001 to 2010

Month	Rainy days	Mean Rainfall (mm)	% of total	SD	SEm±	CV%
January	0.4	3.89	0.32	6.91	2.18	177.82
February	0.9	13.06	1.06	20.63	6.52	157.93
March	0.4	5.79	0.47	11.41	3.61	197.11
April	1.4	16.81	1.37	18.79	5.94	111.73
May	1.8	19.58	1.59	21.62	6.83	110.42
June	9.2	215.74	17.53	122.11	38.61	56.60
July	17.6	425.21	34.55	261.90	82.82	61.59
August	14.9	302.94	24.62	94.28	29.82	31.12
September	7.7	150.10	12.20	108.09	34.18	72.01
October	3.1	48.52	3.94	36.99	11.69	76.22
November	0.9	12.66	1.03	21.46	6.78	169.49
December	0.9	16.26	1.32	26.85	8.49	165.18

Weekly Rainfall and Rainy Days

The weekly rainfall plotted against the standard meteorological weeks (SMW) revealed that the rainfall values were skewed during the monsoon weeks (SMW 23-40) (Fig 4). Among those weeks, SMW 26-29 received the highest rainfall (465.1 mm) which is 38% of the total rainfall. In a single week the highest rainfall was in the 29th week (140.4 mm) showered in 4.5 days. The rainy days curve against the SMW also showed similar pattern as of rainfall. It was clear from the plot that the monsoon rain started in full in 23rd week (39.9 mm), reached to a climax in 29th week (140.4 mm) and ceases after 40th week (22.15 mm). There was strong positive correlation (r = 0.92) between the weekly rainy days and the amount of rainfall and the relation was expressed as y = 22.66*x, where, y= weekly rainfall (mm) and x = rainy days in a week (Fig 5).

Categories of Drought

It was calculated that during the period of analysis about 42.5% of the months were normal

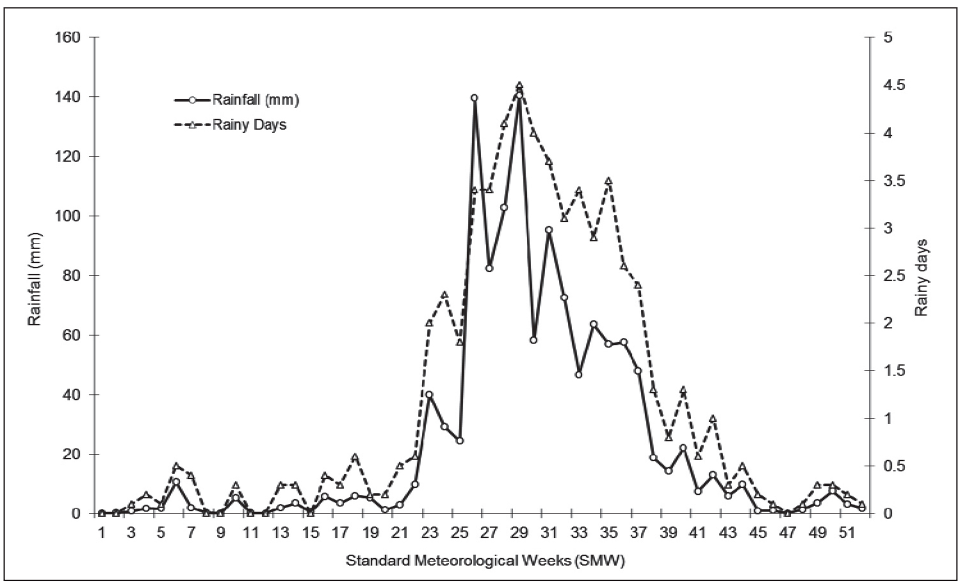

Fig 4. Weekly distribution of rainfall and rainy days at Bamra, Sambalpur, Odisha

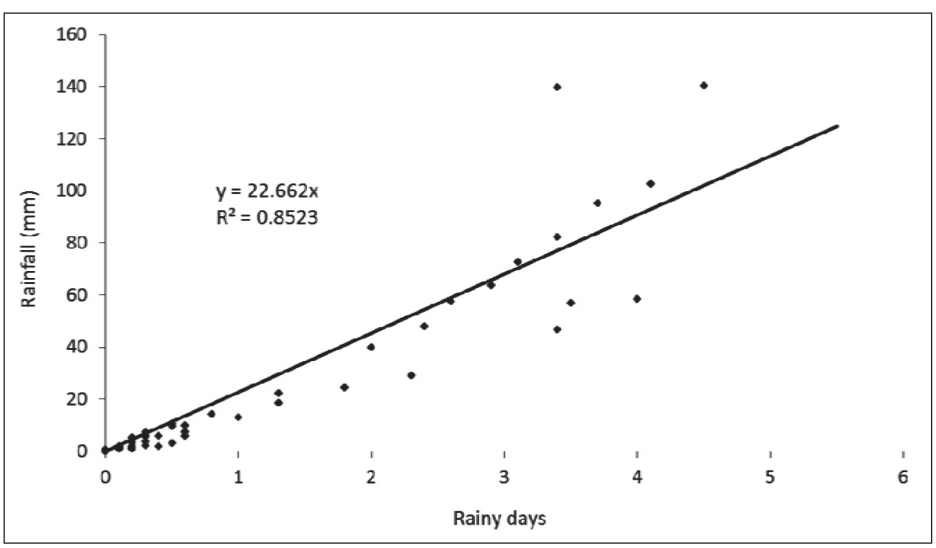

Fig. 5. Relation between weekly rainy days and rainfall at Bamra, Sambalpur, Odisha

months and 32.5% of months were water deficit (Table 4). About 12.5% months each were grouped under mild and moderate drought. Very severe drought months were January (70%) followed by February (60%) and December (60%) in a year. While considering the year values, 50% of the analysed years were normal (no drought), 40% of the years were exposed to mild drought and 10% were moderate drought. No severe drought year was found during the decade under consideration.

Monthly Rainfall Probability and Crop Planning

Probabilities of getting 25, 50, 100, 150, 200, 250, 300, 400 and 500 mm of monthly rainfall in any month are presented in Table 5. It was observed that probability of getting a meagre rainfall of 25 mm in a month was as low as 7% in March followed by February and November (28%), April (33%), December (37%) and May (48%). Only four months in a year (June to September) could expect 100% probability of

Table 4. Percent distribution of different categories of drought months

	No drought (M_0)	Mild drought (M_1)	Moderate drought (M_2)	Severe drought (M_3)
January	30	0	0	70
February	40	0	0	60
March	70	0	0	30
April	40	0	30	30
May	50	0	10	40
June	30	30	20	20
July	40	50	10	0
August	50	30	10	10
September	30	30	30	10
October	40	10	40	10
November	50	0	0	50
December	40	0	0	60
Monthly Average	42.5%	12.5%	12.5%	32.5%
Year	50%	40%	10%	-

Table 5. Monthly rainfall probability (%) at different expected level of rainfall at Bamra

Month	Expected level of rainfall amounts (mm)								
	25	50	100	150	200	250	300	400	500
January	--	-	-	-	-	-	-	-	-
February	28	4	--	--	--	--	--	--	--
March	7	--	--	--	--	--	--	--	--
April	33	4	--	--	--	--	--	--	--
May	40	8	--	--	--	--	--	--	--
June	100	100	100	100	100	39	24	6	1
July	100	100	100	100	100	100	100	100	38
August	100	100	100	100	100	100	100	15	2
September	100	100	100	50	32	18	8	1	--
October	100	48	8	--	--	--	--	--	--
November	28	4	--	--	--	--	--	--	--
December	37	10	--	--	--	--	--	--	--

getting 100 mm rainfall. Expected monthly rainfall of 250 mm is obtainable only in July and August. There is 100% probability of getting 400 mm rainfall and 38% probability of getting as high as 500 mm rainfall in July. Therefore, appropriate drainage system need to be created well ahead and should be in operation during July to save crops (other than paddy) such as sisal and *kharif* legumes in this region of Odisha. In October, there is only 48% probability of getting 50 mm rainfall. Therefore, sowing of *rabi* crops need to be completed in early October to get the benefit of residual soil moisture as well as to utilize the rainfall received during the month. Crop like mustard can be sown in October utilizing the available moisture (either from soil or from expected rainfall); however, for achieving higher productivity it needs assured irrigation during November-December when the probability of getting 50 mm rainfall is very low (4-10%).

Water Balance for Sisal

It is known that sisal, a leaf fibre producing plant of Cassulacean Acid Metabolism (CAM) type, requires low water and thrives in comparatively higher temperature than C_3 or C_4 plants. The evapotranspiration of sisal (ETc) and the monthly rainfall was plotted against the months (Fig 6). It was calculated that the ETc in May was as high as 127.76 mm which is much higher than the average monthly rainfall for May (19.6 mm). Being a semi-perennial crop, sisal is conveniently grown for 8-10 years and the leaf remains green throughout the years. Although during the winter months (December and January) due to low temperature, the rate of leaf growth is restricted. In a year, there are two phases of deficit rainfall for sisal and sisal based cropping system. The first water deficit situation is from January to May and the 2nd water deficit phase is at the end of a year coinciding with winter (October to December) and this 2nd phase water deficit situation affect the growth of sisal little. The 1st water deficit phase is more acute and the situation is aggravated by elevated temperature (sometimes goes beyond 46°C); so needs management for better fibre productivity of sisal. In contrast, during June to September, the rainfall is much excess to the ETc demand. During the surplus phase, care is to be taken to remove the excess water from the non-sloppy sisal fields as the presence of excess water/ inundation will hamper the growth of sisal and water stagnation (if any) may completely eradicate the legume

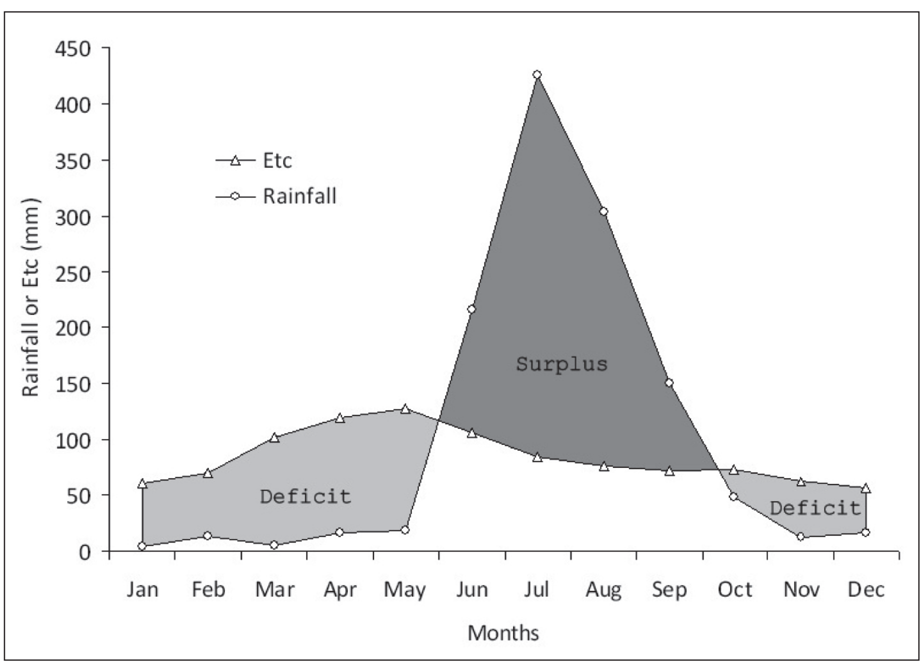

Fig. 6. Water balance of sisal crop at Bamra, Sambalpur, Odisha

intercrops having *rhizobium* root nodules such as cowpea, black gram, horse gram etc. which are grown in between the sisal rows during the first three years of the plantation for augmenting economic return. At the same time, excess water received as huge precipitation during July-August may be stored in native water harvesting structures such as natural depression/ ditches/ low-lying areas available or created in the landscape for specific use later. Researchers expressed that in western Odisha, *in situ* rain water conservation by storing the harvested rain water in lower elevation during July to September will be of great help for utilization during scarce period (Saha and Rao, 2008).

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