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Assessment of Rainfall of Northern Transitional Zone in Karnataka for Agricultural and Meteorological Drought

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A B S T R A C T

Rainfall assessment plays a major role in designing the mitigation measures and getting the sustainable yield in the dry lands. Weather cock software was used for the analysis and incomplete gamma test was conducted for measuring the probability of rainfall occurrence. Rainfall assessment of the Northern Transitional Zone has observed that, the zone has been often prone to meteorological and agricultural drought. 21st to 24th and 31 to 34th weeks are often prone to drought in *Kharif* and 41st to 47th weeks are affected in *Rabi.* Probability of getting normal rainfall of norther transitional zone was only 50 per cent. Government should strengthen the forecasting schemes and should make adoption of soil and water conservation measures to be compulsory.

Introduction

Rainfall is the respiratory system of agriculture, in India nearly 68 per cent of the area is under rain fed condition. Rainfed area is contributing considerably to the (44 %) to the total food grain production in the country (Vijayan, 2016).In recent years due to climatic aberrations, rainfall is varying both spatially and temporarily (Kumar *et al.*, 2010; Asharaf and Ahrens, 2015), these variations have worsened the agriculture situation along with the variation in temperature and these variations were amplified in 21st century (Guhathakurta and Rajeevan, 2008). Number of rainy days in a year were decreasing over the years i.e. rainy days with rainfall between 5mm – 10 mm were decreasing along with the increase in the heavy rainfall days (>10mm) and these variations are expected to increase in the coming days (Bal *et al.,* 2016). There by it is confirmed that the dry spell in a year is increasing, this effect is much higher in case of South-West Monsoons (Bal *et al.,* 2016) where 80 percent of the rainfall of the country is received and every farmer of the country will be cultivating. Similar observations were made in case of North-East

Monsoon season i.e. 2-5 percent increase in the extreme rainfall events, similar results were also identified for summer by Rajendran *et al.,* (2013) and from these studies it is cleared that dry spells were increasing in the country over the years. These variations in rainfall have worsened the situation of dryland farmers along with the other climatic complications like increase in temperature (Kumar *et al.,* 2009; Kumar *et al.,* 2013 and Kumar *et al.,* 2013). Hence, suitable action plans viz., weather based cropping system, short duration varieties, water conservation etc. needed to be developed for the betterment of the dry land farmers. Studies have shown that with the change in cropping pattern, water use efficient crop, soil and water conservation measures etc. have helped the dry land crops to overcome from the moisture stress conditions and added to achieve the desired yield and returns (Desai *et al.,* 2007; Chavai *et al.,* 2015). Hence, a detailed rainfall assessment of a particular place/region/ climatic zones are needed for designing the effective mitigation techniques and policy measures for dry spells and drought situations.

The present study has been carried out for Dharwad district which fall under Northern Transitional Zone of Karnataka for designing the effective agricultural planning and drought management. Northern Transitional Zone is a hot, dry and sub-humid region with an annual rainfall of > 850mm. Out of which 61 percent of the rainfall is received from south west monsoon and in the Kharif (430 mm) season, 19 per cent of rainfall from the northeast monsoon (Nandeesha, 2015), 15 per cent of rainfall in the pre-monsoon season and remaining as off season showers. Sorghum, maize, groundnut, onion, redgram and cotton are the important kharif crops and cotton (17.55 %) has area sown in kharif. In rabi, sorghum, chickpea and wheat were the important crops cultivated and chick pea is leading in rabi season. And the district has higher cropping intensity (155.27 %) compared to state and country (Tirlapur and Mundinmani, 2015). The present study has been conducted in order to analyze the spatial and temporal variability of rainfall in the Northern Transitional Zone of Karnataka and to identify the Meteorological and Agricultural droughts, assist the farmers and policy, makers.

Materials and Methods

Daily rainfall data recorded at the Main Agricultural Research Station Dharwad has been collected from 1985 to 2016 i.e. for the total period of 32 years. Meteorological drought and agricultural drought for agricultural planning were analyzed using weather cock.

Results and Discussion

Weekly rainfall in Fig 1, indicates thatnorth transitional zone receives rainfall throughout the year, weekly rainfall was more than 5mm in almost 34 weeks i.e. from 15th week and to 47th week. Rainfall showed increasing trend from 8th week and reaches highest in 31st week and after which reduces till 37th week and increases again for another few weeks. Highest rainfall has been observed in 40th week (39 mm) during South West Monsoon season and lowest rainfall was observed in last week of December and in the few weeks of January and March.34 weeks in a year are getting the rainfall more than five millimeter of rainfall. From the Fig 1 it is confirmed that rainfall is highest in *kharif* season (425 mm) and followed rabi (184 mm) and summer seasons (183 mm). In *kharif* season rainfall was high and it has increasing pattern till 31st week and later it took decreasing trend and the probability of occurrence of drought was also more. Comparatively summer season was having well distributed rainfall throughout the

season, whereas in *rabi* season rainfall was concentrated only in the few initial weeks.

Meteorological drought index was constructed based on the deviation of rainfall from its normal, if the deviation was between 0 and 25 per cent then it is considered as "Mild Drought" year (Table 1 and 2). Similarly, if the deviation is between 25 and 50 per cent it will be considered as "Moderate Drought" year and if the deviations is more than 50 per cent it will be considered as Severe Drought. In the 32 years of study, North-Transitional Zone has faced six per cent (2 years) severe drought years followed by13 per cent of mild drought years (4 years), 25 per cent of mild drought years (8 years) and there was No Drought in 56 per cent of the years (18 years). Among the severe drought affected years, 2003 (Table 2) was the worst drought affected year with -75.53 per cent deviation in rainfall and it was followed by 2001 (-65.14%). In the 13 per cent of the moderate droughts years 2002 was affected more (-49.48%) and least year was 2000 (-26.70%). In the mild drought affected years, 1989 (-24%) was the highly deviated year, it was followed by 1985 (-23.13%) and least deviated year was 2015 (0.19%).

Analysis of agricultural drought weeks has been done using the weather cock software for both *kharif* and *rabi* seasons. Dry spells or drought days for 4 or more consecutive weeks i.e. deviation in rainfall by>75per cent for continues 4 weeks were identified by using the weather cock. In the 32 years, 11 years have faced the agricultural drought in *kharif* season and 2002 have faced two periods of dry spells (Table 3). Normally drought has aroused from 22^{nd} week to 28^{th}week (4 times)or from 34^{th} week to 40^{th} week (5 times), the prior one was early drought and later one will be mid drought. The early drought is due to failure in onset of monsoon it will be generally from last week of May to first week of July where the major activities viz., land preparation and sowing of the crops will take place (Ramakrishna, 2007; Anonymous, 2019a). Early drought will affect the sowing of major crops of *kharif* season in the Northern Transitional zone which includes sorghum, maize, cotton, groundnut redgrametc (Tirlapurand Mundinamani, 2015; Kadapatti and Bagalkoti, 2014; Anonymous, 2019).Early drought affects the establishment of crops on field and it mainly affects the imbibition process and makes the seed to croak (Leila, 2007) and in later stages it affects the rooting of the crops by reducing the rooting length and thereby it also affects the shoot length or physiological process in the later stages(Shekari, 2000; Zareian, 2004). Biradar and Sridhar (2003) studied the impact of drought on agriculture in 2003 and were identified that sowing was not done in 50 per cent of the area in Karnataka and was due to early drought i.e. drought in 22nd week to 28th weekand similar results were also identified by Lokesh and Poddar (2014) and 53 per cent of the area was affected in Karnataka and similar results were observed for Vijayapura (Bijapur) District in 2012 where 42 per cent of the area was affected (Lokesh and Poddar, 2012). Hence in order to overcome early drought effects farmers should go for maintaining the community nursery and crops should be transplanted into the main field. Alternative crops/less duration varieties can also be used once the rainfall starts and if the drought issevere re-sowing can be taken up or if it is short-lived then gap filling recommended (Ramakrishna, 2008). Experiments conducted by Kiran and Lingaraju (2005), Vinchurkar and Ingole (2012), Radder *et al.*, (1991) showed that the sorghum could get the 34.19 per cent, 63.64 per cent and 68.87 per cent of increased yield comparatively to the yield under drought condition. Hence, it is advisable to the farmers to go for the moisture conservation technologies and water conservation

techniques which add to get the increased yield at the time of drought situation.

North transitional zone also faced in another phase of drought during *kharif* seasons i.e. from 34th week to 40thweek for 5 times in the 32 years of study period (Table 3). This phase of drought is also called as mid-season drought, it mostly coincides with booting stage, flowering stage or physiological maturity of the crops (Ramakrishna 2007, Anonymous, 2019a). Because of the mid-season drought, the physiological processes like stem development, photosynthesis, metabolism, stomatal closure and translocation of food materials, processes will be affected (Kabiri, 2010; Rahmani, 2006) also drought may lead to wilting and dying of plants. The mid-season drought decreased the 10 per cent rice yield (Moonmoon and Islam, 2017) and in sorghum, root length, weights were reduced and also it decreased the yield by 50 per cent (Matthews *et al.,* 1990; Mutava *et al.,* 2011).

Bidinger *et al.,* (1991) identified that 58 per cent of the agricultural income was decreased for the households in Andhra Pradesh because of the mid-season drought. In the previous weeks to the 31st week the possibility of getting good rains was high hence the farmers should collect and save the water (farm ponds) from the previous weeks to give the lifesaving irrigation to the crops. Hence drought mitigating measures like weed control and mulching or through long term measures like soil and water conservations should be adopted by the farmers. Government should look into this point of view and should make pass a bill related to soil and water conservation like farmers should be provided with all the subsidies only if farmers are adopting all these soil and water conservation measures on the field. Government should continue to promote the schemes like "KrishiBhagya", where the farmers are provided with the subsidy to adopt the water conservation structures also to divers the cropping and farming systems.

Drought has been identified for the Rabi season using the weather cock software, in the study period of 32 years, the North Transitional zone has faced 6 drought years (Table 4).Important crops grown in *rabi* season includes wheat, chickpea and safflower these crops are able to survive with lesser rainfall compared to *kharif* season crops. In *rabi* season, there was no experience of early droughts and this season has witnessed only mid-season drought hat was identified from 41st week to 47th week. Mid-season drought in *rabi* mostly coincides with vegetative stages of the crops, which affects the physiological processes and affects the biomass production.

A study conducted by Behboudian *et al.,* (2001) identified that drought occurrence in the vegetative stage or flowering stages of chickpea could reduce the biomass and crop yield by 23 per cent and 30 per cent respectively. Zhang *et al.,* (2018) identified that the wheat yield loss would be about 10-50 per cent and Sinha *et al.,* (2019)showed that the loss would be 25-75 per cent based on the severity of the drought. Sinha *et al.,* (2018) evaluated few Indian wheat line for drought resistant and showed that in drought, plant height, number of tiller, leaf area and days taken to maturity were highly affected in drought condition compared to the normal situation and authors also identified that yield characteristics were also differed compared to normal situation. In Karnataka wheat occupied an area of 1.98 lakh ha area with the production of 2.61 lakh tonneswith 25 per cent loss due to drought, the production will reduce to 1.96 lakh tonnes.

Table.1 Meteorological drought index

Drought Condition	No. of years	Drought
No Drought	18	56%
Mild Drought	8	25%
Moderate Drought	4	13%
Severe Drought	2	6%
Total	32	100%

Table.2 Meteorological droughts in Northern Transitional Zone 1985 – 2016

Year	Annual RF (mm)	Deviation (%)	Drought Condition
1985	551.30	-23.13	Mild Drought
1986	594.70	-17.07	Mild Drought
1987	626.00	-12.71	Mild Drought
1988	749.00	04.44	No Drought
1989	545.00	-24.00	Mild Drought
1990	730.50	01.86	No Drought
1991	1104.80	54.05	No Drought
1992	824.20	14.93	No Drought
1993	806.30	12.43	No Drought
1994	741.50	03.40	No Drought
1995	731.90	02.06	No Drought
1996	686.60	-04.26	Mild Drought
1997	760.30	06.02	No Drought
1998	753.80	05.11	No Drought
1999	435.70	-39.25	Moderate Drought
2000	525.70	-26.70	Moderate Drought
2001	250.00	-65.14	**Severe Drought**
2002	362.30	-49.48	Moderate Drought
2003	175.50	-75.53	**Severe Drought**
2004	586.60	-18.20	Mild Drought
2005	1011.10	40.99	No Drought
2006	866.20	20.78	No Drought
2007	1086.20	51.46	No Drought
2008	928.90	29.53	No Drought
2009	1125.00	56.87	No Drought
2010	952.50	32.82	No Drought
2011	922.70	28.66	No Drought
2012	520.50	-27.42	Moderate Drought
2013	748.00	04.30	No Drought
2014	961.90	34.13	No Drought
2015	715.80	-00.19	Mild Drought
2016	568.20	-20.77	Mild Drought

Table.3 Agricultural droughts aroused in *kharif* season

Year	Drought Week
1985	35 - 39
1986	34 - 37
1990	37 - 40
1997	35 - 39
1999	31 - 39
2000	24 - 27
2001	34 - 37
2002	23 - 31
	34 - 40
2003	22 - 39
2004	23 - 30
2015	28 - 34

Table.4 Agricultural droughts aroused in *rabi* season

Year	Drought Week
1985	42 - 47
1988	41 - 47
1989	40 - 45
2001	40 - 47
2003	41 - 47
2004	41 - 47

Week	90.00	75.00	50.00	Mean(mm)
1	0	1	2	1.70
2	1	1	1	0.20
3	1	1	1	0.10
4	1	1	1	0.20
5	1	1	1	0.00
6	0	0	2	1.90
7	0	0	0	0.10
8	0	0	1	0.70
9	0	1	1	0.60
10	0	1	2	3.20
11	0	1	2	1.90
12	0	1	3	5.80
13	0	1	3	3.60
14	0	1	3	3.70
15	0	2	5	8.40
16	1	2	8	3.40
17	1	2	6	8.60
18	1	2	9	5.40
19	1	3	11	6.70
20	0	2	7	3.40

21	1	2	8	4.50
22	2	5	15	2.30
23	2	6	17	6.80
24	4	9	19	3.10
25	4	9	20	6.60
26	2	7	18	7.40
27	2	5	14	9.90
28	3	8	20	8.50
29	4	11	25	4.30
30	5	12	27	6.10
31	4	11	27	7.00
32	4	9	21	8.20
33	4	8	16	9.10
34	2	5	12	5.20
35	2	6	15	1.00
36	2	4	11	4.50
37	1	3	8	3.00
38	1	4	15	7.10
39	2	7	22	6.60
40	4	11	28	1.40
41	1	4	13	2.00
42	1	4	14	6.70
43	1	3	10	7.60
44	0	1	4	5.90
45	0	1	4	8.00
46	0	1	5	8.40
47	0	1	4	8.40
48	0	1	2	1.90
49	0	1	2	1.20
50	0	1	2	1.90
51	0	1	2	2.70
52	0	1	1	0.50
Total	**62**	**182**	**486**	

Fig.1 Pattern of weekly rainfall in Northern Transitional Zone (1985 – 2016)

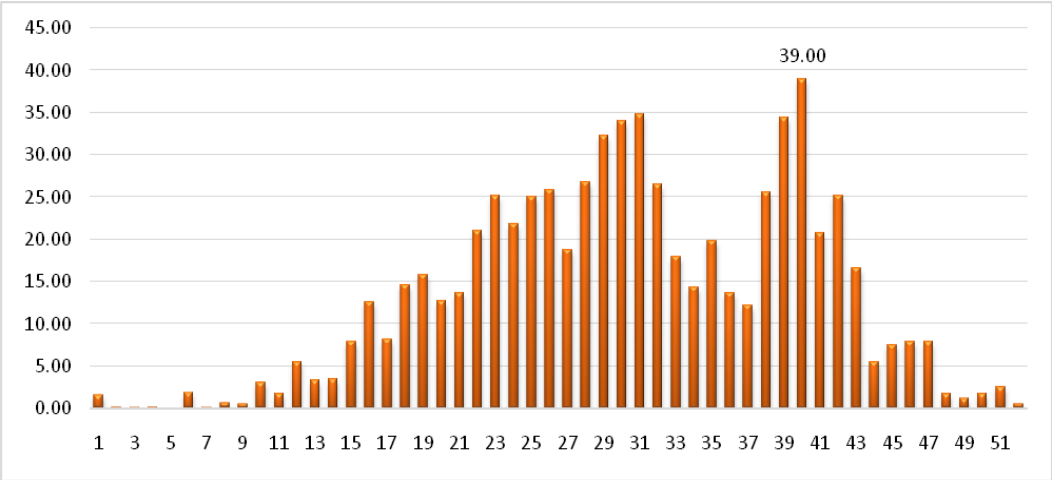
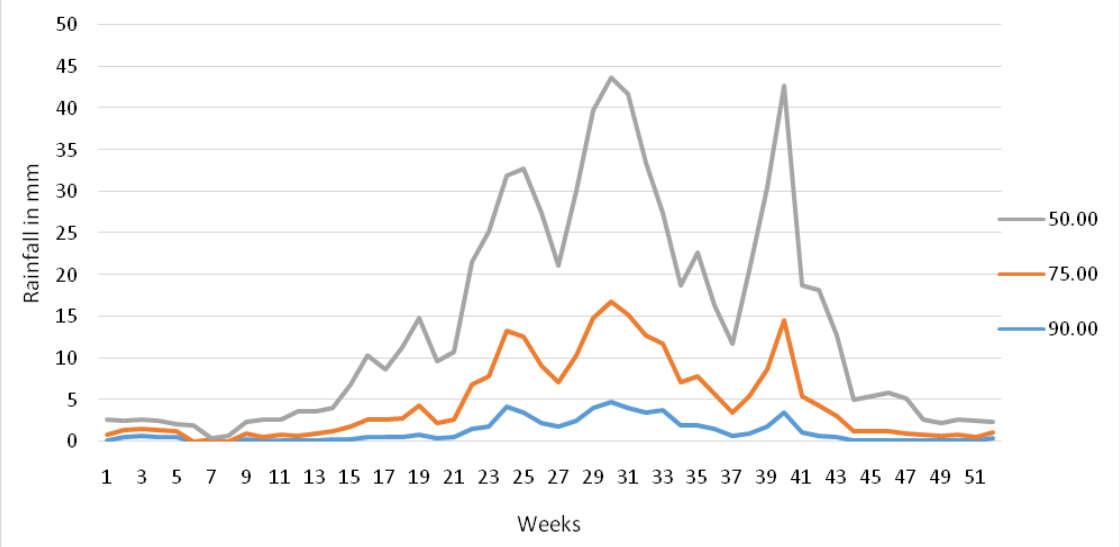


Fig.1 Weekly rainfall distribution level at different probability levels



Bengal gram occupied the area of 9.39 lakh ha area with the production of 6.74 lakh tonnes, if the crop exposed to drought there will be a loss of 2.82 lakh tonnes. Hence the drought situations should be mitigated with the different measures like increase the availability of soil moisture with mulching, weed control and loosening of the soil so as to affect the capillary movement of water (Ramakrishna, 2007). In the long run the farmers should be advised to go for adoption of farm ponds to catch the excessive rainfall of the previous weeks (Fig 1) and should be advised to go for short duration verities. Ghosh *et al.,* (2015) and Thippanagoudar (2012) conducted experiments on impact of life saving irrigation on crop yield of wheat at the time of drought seasons, the yield was increased from 48 per cent to 70 per cent in both the experiments respectively. Similar experiments were conducted by Patil *et al.,* (2015), Shirahatti *et al.,* (2016) and Thippanagoudar on chickpea, authors showed that the lifesaving irrigation and drought mitigation measures have increased the yield up to 36 per cent, 60 per cent and 121 per cent respectively. Similarly, Safflower was responded by increased yield of 29 per cent to the drought mitigation measures. Hence it is advisable to the farmers to go for the adoption of both long term and short term corrective and mitigation measures in order to sustain the yields at the drought situations.

Probability of occurrence of rainfall has been calculated by using incomplete gamma test, it was estimated at the probability of levels of 90 per cent, 75 per cent and 50 per cent (Fig 2). From the fig it is confirmed that probability of getting normal or good rainfall (≥486 mm) rainfall in every year is only 50 per cent. The cropping pattern of the region can be modified so as to adjust the minimum rainfall of 50 per cent or farmers should be advised to go for the soil and water conservation measures. The graph also confirms that the rainfall is reducing from 22nd week to 28th week, hence the rainfall in the previous weeks should be carefully collected to use at the time of drought situation. Similarly, the same practice can be followed between 34th to 40th week since the probability of getting good rainfall is only 50 per cent. In the *kharif* period probability of getting higher rainfall is less hence, rainwater harvesting structure like farm ponds, moisture conservation measures etc., can be planned effectively and implemented. So that

harvested rainfall water can be used for giving lifesaving irrigation of crops during the critical periods of crops.

In conclusion, rainfall assessment plays a major role in designing the mitigation measures and getting the sustainable yield in the dry lands. Farmers in the North Eastern transitional zone are mostly depending on the rainfall for the production. 22nd - 24th weeks and 34th to 40th weeks are facing the acute shortage of rainfall in the zone, rainfall collection from the previous heavy rainfall weeks helps to save the crops in this period. Similarly, in rabi 41st to 47th week drought prevails, hence these weeks are crucial period of crop cultivation. Probability of getting normal rainfall in every year is only 50 per cent in the zone, government needs to strengthen the forecasting measure in order to send the advanced reminders for the farming community so that they can save the excess rainfall. Adoption of Soil and water conservation measures should be made compulsory to the farmers who want to avail the Government benefits. The important schemes like "KrishiBhagya" should be continued and should ensure that it has reached every farmer.

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