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Addressing the Drought Induced Yield Variability in Karnataka Using Dry Spell Index (DSI)

Thimmegowda M. N., Manjunatha M. H., Pooja R. S., Lingaraj Huggi, Jayaramaiah R., Sowmya D. V., Satish G. S., Nagesha L. and Arpitha V.

AICRP on Agrometeorology, University of Agricultural Sciences, GKVK, Bengaluru (560 065), India

Corresponding poojars1167@gmail.com

0009-0008-5661-1659

ABSTRACT

The experiment was conducted during December, 2023 at the AICRP on Agrometeorology, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India to study Dry spell and drought conditions for different districts of Karnataka. In this study, Dry Spell Index (DSI) was used to analyse annual and seasonal dry spells at 7- and 10-days' time scale and its impact on crop productivity across different districts of Karnataka using long term rainfall data (1980-2020). The analysis of spatio-temporal distribution of average DSI-7 for annual rainfall during the period 1980–2020 in Karnataka revealed that a greater number of years falls under <4 average DSI with the range of 17 (Raichur)–40 years (Chamarajanagar, Mysore). During *kharif* and *rabi* season, most of the districts experienced more than 84 consecutive dry days for a season, indicated critical water stress that adversely affect crop performance. The impact of dry spells was found to be significant on crops such as sugarcane, ground nut, bajra and maize. Sugarcane, in particular, showed a negative correlation with DSI due to its long growth cycle and high-water demand. In contrast, drought-tolerant crops like pulses exhibited a significant positive correlation with DSI, highlighting their resilience and suitability for dryland farming. The study emphasizes the importance of selecting drought-resilient crops and adopting region-specific water management strategies to mitigate the risk of crop failure. These insights are crucial for promoting sustainable agricultural production and enhancing resilience against climatic variability in Karnataka's dry zones.

KEYWORDS: Rainfall variability, dry spell index, productivity loss, Karnataka

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1. INTRODUCTION

Agriculture is the primary source of livelihood, which plays an important role in the growth of economy in Karnataka, contributes 37% of the total state domestic product. Karnataka is a rainfed agrarian state accounting nearly 66% of the cultivated area under rainfed agriculture (Ningoji et al., 2021), and food production is mainly depending on the south-west monsoon rains, which is characterized by uneven and erratic distribution due to climate change (Sharma et al., 2023). Rainfed areas contribute 55% of food grain and 75% of oilseed production to the state production (Venkateswarlu and Prasad, 2012). However, in rainfed areas, magnitude and distribution of rainfall both in space and time is very crucial (Simane and Struick, 1993). Rainfall distribution decides the cropping pattern of rainfed areas. High variability in rainfall hampers the crop growth and yields (Barron et al., 2003). Deficit or no rainfall for consecutive days causes dry spell condition which is highly related to success or failure of crops (Bal et al., 2022).

A dry spell is defined as the period of consecutive dry days (Tebaldi et al., 2006), where a dry day is a day with precipitation is less than a preselected threshold. As per India Meteorological Department (IMD) criteria, the threshold value of a rainy day is 2.5 mm day^{-1} (Anonymous, 2020). The two or more consecutive dry weeks causes moisture stress to the crops due to inadequate stored soil moisture. Crops perform well with uniform light rains than with a few heavy rains with intermittent dry spells, which shortens the vegetative growth of the crops and ultimately affect the yields.

A comparison study of DSI and SPI was done by Bal et al., 2022 for major dry regions of India and reported that dry spells have higher significance on rainfed crops compared to total rainfall. The information on duration of dry spells is helpful for deciding a particular crop or crop variety, and breed varieties of various crop durations for a particular location (Sivakumar, 1992). Bal et al., 2024 analysed dry spell impacts on kharif crop yields in semi-arid Andhra Pradesh (1998–2019) using the Dry Spell Index (DSI), revealed a strong negative correlation with crop productivity. A detail on dry-spell length is used for adaptation of management pratices viz., supplementary irrigation and field operations in agriculture (Tebaldi et al., 2006). Prior knowledge of dry spells is used for estimation of the irrigation water demand (Mathlouthi and Lebdi, 2021). Virmani et al., 1982 made a comprehensive study on rainfall probability and distribution and reported that these are very essential for taking weather sensitive agricultural operations. Sushama et al., 2014 analysed dry spell characteristics over India (1951–2007) using IMD and APHRODITE datasets, highlighting spatial-temporal patterns and dataset agreement. And reported consistent trends in dry day frequency but notable differences in dry spell duration, especially across northern India. Jarrett et al., 2023 analysed global dry spell study (1979–2016) demonstrates that 4–5 week dry spells during peak heat periods significantly reduce aggregate crop production, with effects intensified by concurrent drought, aridity, and heat waves.

Karnataka, a state in India known for its agriculture-based economy, dry spell analysis is vital for sustainable water resource management (Lakshmikanthamma, 1997). Water scarcity is the major problem in Karnataka, especially during dry spells, which has significant impact on crop yields (Sawant and Kukkemane, 2024). The detailed study on historical rainfall patterns is helpful for understanding dry spell and drought condition and their impacts, which is essential to develop strategies for drought mitigation, improved water management practices, and the development of drought-tolerant crops (Verma et al., 2018).

2. MATERIALS AND METHODS

2.1. Study area

The analysis was conducted during December, 2023 for different districts of Karnataka state to study Dry spell and drought conditions. Karnataka state is located in southwest part of India, which includes 30 districts. The study area was geographically located between 11.40° and 18.27° N latitude and 74.25°and 78.50° E longitude covering an area of 1,91,791 sq km which accounted for 5.83% of total area of the country. The major field crops grown in the state are cereals viz., ragi, paddy, maize, jowar, and bajra; pulses viz., pigeonpea, chickpea, field bean, cowpea, horsegram, green gram, black gram etc; oilseeds viz., groundnut, soybean, sunflower, castor, safflower, sesame, niger etc, cash crops viz., cotton, sugarcane; plantation crops viz., coconut, areca nut etc.

2.2. Data used

Daily rainfall data for 30 districts of Karnataka was collected from India Meteorological Department for the long-term period of 41 years (1980–2020) and crop productivity data was collected from Directorate of Agricultural Economics and Statistics.

2.3. Mean rainfall

Total rainfall observed in a year was divided by 12 (12 months in a year) to arrive at the Mean monthly rainfall.

$$\text{Mean rainfall} = \sum_{i=0}^{n} \text{TRF}/n \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where, TRF = total rainfall of the year and n = total number of months (12).

Other descriptive statistics on rainfall such as Maximum, Minimum, Standard Deviation (SD), Standard Error (SE) and Coefficient of Variation (CV) were computed to analyse the variation in rainfall over a period of time. Spatial analysis of the same was also performed.

2.4. Standard deviation

Standard deviation is the best measure of dispersion. It gives more weight to extreme items and less to those which are near the mean. It is defined as the positive square root of the arithmetic mean of the squares of the deviations of the given values from the arithmetic mean.

$\sigma=\sqrt{(\sum(Xi-\overline{X})^2/(n-1)}$……………………..(2)

Where,

σ=Standard deviation

Xi=Variables

$\overline{X}$=Mean

N=Total number of variables

2.5. Coefficient of variation

The coefficient of variation is the percentage of variation in the mean, the standard deviation being treated as the total variation in the mean. The coefficient of variation (CV) is a statistical measure of how the individual data points vary about the mean value and was calculated using the formula

$CV=(\sigma/X)\times100$ ……………………(3)

Where,

CV=Coefficient of variation

σ=Standard deviation

$\overline{X}$=Mean

2.6. Dry spell index

DSI is a drought index was very simple in the calculation process but has several advantages, including easy calculation and flexible observation duration. Based on average daily reference evapotranspiration over the study area, soil texture, rooting depth and total available water at root zone, the moisture stress may start by 5 consecutive dry days for shallow rooted crops (groundnut) in light textured soils and it may extend up to 10-day consecutive dry days for deep rooted crops (pigeon pea, cotton etc.) in heavy textured soils (Bal et al., 2022). In order to make the study simple and uniform as well as to estimate the response of crop productivity towards the dry spells in a common scale 7 and 10 consecutive days receiving rainfall less than 2.5 mm as a dry spell for all the selected crops in the study. DSI is calculated using the following equation (Narasimhan and Srinivasan, 2005):

$DSI=\frac{1}{LP}\sum_{(i=1)}^{NDD}W_1$ ………………………..(4)

Where, LP is the dry spell scale, NDD is the number of consecutive dry days and is the weighting factor assigned to each dry day within dry spell that linearly increase as the dry spell's duration. The higher DSI the more severe drought.

2.7. Correlation

Correlation refers to a process for establishing the relationships between two variables. The correlation coefficient, r, is a summary measure that describes the extent of the statistical relationship between two interval or ratio level variables. The correlation coefficient is scaled so that it is always between -1 and +1. Correlation coefficient was calculated by using following formula,

$r=cov(x,y)/(\sigma_x\ \sigma_y)$ ……………………(5)

Where,

$cov\ (x, y)=\frac{1}{n}\sum_{(i=1)}^{n}(X_1-\overline{X})\ (Yi-\overline{Y})$

r=Karl Pearson's correlation coefficient

cov (x, y)=Co-variance of variable x and y

σx=Standard deviation of variable x

σY=Standard deviation of variable y

3. RESULTS AND DISCUSSION

3.1. Rainfall variability

In Karnataka, the annual mean rainfall during the historical 41 years (1980–2020) ranged from 540.83 to 3855.75 mm (Table 1). The maximum rainfall varied from 950.50 to 6299.60 mm and the minimum rainfall was in the range of 336.30 to 2581.10 mm. The maximum annual rainfall of 6299.60 mm was recorded in Udupi district during 1990 due to higher SW monsoon as well as the post monsoon rainfall in that year and the lowest rainfall of 336.30 mm was noticed in Bijapur district during 2001. Thimmegowda et al., 2023 reported similar results of highest annual rainfall in three coastal districts, Udupi, Dakshina Kannada, and Uttara Kannada, received more rainfall during the crop growth period (194.4, 164.0, and 118 mm, respectively). It was observed that; the annual rainfall was maximum during 1990–91 in 19 out of 30 districts and the minimum annual rainfall was during 1994 and 2001 in most of the districts in the state.

The variability of annual rainfall indicated by the coefficient of variation ranged from 14.88 (Belgaum) to 25.01 (Yadgiri)%. Similar variation was noticed in the research findings of Rajegowda and Gowda, 1990. Across different districts, the Standard deviation of annual rainfall was observed in the range of 135.86 (Bagalkote) to 708.51 (Udupi). The state's mean annual rainfall for the period of 41 years (1980–2020) was 1141.42 mm. However, the State's mean annual rainfall for the period from 1901 to 1950 was 1204 mm (Rajegowda and Gowda, 1990). The mean annual rainfall declined from 1901–2000 (Panduranga et al., 2006). The annual rainfall was lower during some years due to failure of monsoon.

Table 1: District wise annual rainfall characteristics for historical period of 41 years (1980–2020)

District	Mean RF (mm)	Maximum RF		Minimum RF		SD	CV (%)
		(mm)	Year	(mm)	Year		
Bagalkote	611.41	982.90	2004	349.80	2014	135.86	22.22
Belgaum	1123.41	1485.70	1990	756.10	2001	167.19	14.88
Bellary	592.40	950.50	1991	342.50	2005	124.59	21.03
Bidar	904.22	1382.40	1993	411.40	2001	212.79	23.53
Bijapur	639.73	1037.60	2004	336.30	2001	148.15	23.16
Bangalore Rural	746.48	1070.00	2020	421.60	1994	150.11	20.11
Bangalore Urban	776.10	1147.60	2020	459.50	1994	154.54	19.91
Chamarajanagar	927.95	1277.60	1991	625.60	1994	147.71	15.92
Chikkaballapur	667.36	964.10	2004	411.80	1994	136.35	20.43
Chikkamagalur	1738.88	2669.80	1990	1248.80	2005	283.83	16.32
Chitradurga	540.83	878.90	1991	270.80	2005	116.67	21.57
Davanagere	690.35	1234.00	1991	361.50	2005	140.07	20.29
Dharwad	971.18	1686.50	1991	602.20	2014	203.03	20.91
Dakshina Kannada	3295.64	5445.00	1990	2278.60	2016	579.51	17.58
Gadag	631.55	1160.10	1991	350.00	2014	140.29	22.21
Gulbarga	803.66	1185.00	2004	381.90	2001	175.45	21.83
Hassan	1054.75	1510.20	1991	612.90	1994	176.81	16.76
Haveri	805.24	1762.40	1991	514.60	2014	196.75	24.43
Kodagu	2295.02	3714.40	1990	1614.90	2016	382.77	16.68
Kolar	716.99	1097.80	2020	447.50	1994	141.96	19.80
Koppal	604.30	1022.90	2004	370.10	2014	137.88	22.82
Mandya	763.02	1407.80	1991	402.60	1994	173.50	22.74
Mysore	1191.73	1628.60	1991	799.90	1994	203.47	17.07
Raichur	660.67	1162.10	2004	408.80	2001	155.07	23.47
Ramanagara	811.02	1174.80	1991	446.70	1994	161.81	19.95
Shimoga	2136.49	3287.70	1990	1605.30	2005	344.28	16.11
Tumkur	639.21	1041.60	1991	342.70	1994	134.55	21.05
Udupi	3855.75	6299.60	1990	2581.10	2016	708.51	18.38
Uttara Kannada	2337.86	3534.90	1990	1776.70	2001	382.35	16.35
Yadgiri	709.52	1253.00	2004	406.00	2001	177.43	25.01

During SW monsoon season, the maximum monsoon seasonal rainfall of 5315.60 mm was observed in Udupi district during 1990 and the minimum of 171.80 mm was observed in Bangalore urban district during 1986. The mean rainfall across different districts ranged from 300.58 to 3379.39 mm (Table 2). The variability of South-West monsoon season rainfall as indicated by the coefficient of variation ranged from 16.89 to 35.97% across different districts of Karnataka. Similar variation of 21.85% recorded in Mandya was reported by Thimme Gowda et al. (2015).

In the year 1991, nine districts namely Bellary, Chamarajanagar, Davanagere, Dharwad, Gadag, Haveri, Mandya, Mysore and Ramanagara recorded maximum SW monsoon seasonal rainfall. The lowest SW monsoon rainfall was noticed during 1981 in six districts namely Bellary, Gadag, Haveri, Koppal, Raichur and Yadgiri out of 30 districts in the state. Mandya (35.97%) recorded the maximum variability followed by Haveri (31.01%) and minimum variability was observed in Belgaum (16.89%).

Table 2: District wise monsoon seasonal rainfall characteristics for historical period of 41 years (1980–2020)

District	Mean RF (mm)	Maximum RF		Minimum RF		SD	CV (%)
		(mm)	Year	(mm)	Year		
Bagalkote	397.13	654.20	1993	220.00	2014	96.39	24.27
Belgaum	871.62	1161.10	1988	590.10	2001	147.21	16.89
Bellary	369.63	543.90	1991	152.20	1981	90.26	24.42
Bidar	737.33	1285.20	1984	313.80	2001	201.48	27.33
Bijapur	443.77	694.00	1993	210.10	2001	106.87	24.08
Bangalore Rural	380.62	600.90	2017	181.80	1986	104.25	27.39
Bangalore Urban	394.81	582.70	1993	171.80	1986	100.99	25.58
Chamarajanagar	441.60	742.60	1991	280.40	2019	105.37	23.86
Chikkaballapur	355.54	653.30	2017	201.20	1986	98.54	27.71
Chikkamagalur	1361.75	2128.20	1990	861.70	2016	261.46	19.20
Chitradurga	300.58	501.10	2017	144.90	2005	83.96	27.93
Davanagere	430.52	783.70	1991	194.10	2005	106.65	24.77
Dharwad	694.00	1199.40	1991	421.00	2014	154.26	22.23
Dakshina Kannada	2791.04	4516.20	1990	1749.00	1991	543.86	19.49
Gadag	385.91	715.40	1991	170.30	1981	102.35	26.52
Gulbarga	624.29	972.50	1984	276.30	2001	151.90	24.33
Hassan	696.97	1000.00	1988	447.10	2005	140.77	20.20
Haveri	531.39	1283.30	1991	273.00	1981	164.79	31.01
Kodagu	1778.25	2910.50	1990	1085.00	2016	345.92	19.45
Kolar	358.00	557.20	2017	177.50	2009	92.20	25.75
Koppal	389.75	566.70	2010	161.80	1981	92.35	23.69
Mandya	368.53	890.70	1991	182.20	2005	132.56	35.97
Mysore	720.52	1067.90	1991	426.60	2019	156.91	21.78
Raichur	470.29	679.90	2012	224.30	1981	111.87	23.79
Ramanagara	399.90	677.20	1991	176.90	1986	118.42	29.61
Shimoga	1794.42	2684.40	1990	1307.50	2016	323.79	18.04
Tumkur	330.98	570.00	2017	173.80	2019	99.84	30.17
Udupi	3379.39	5315.60	1990	2083.90	1991	676.72	20.02
Uttara Kannada	2029.76	2891.70	1990	1511.40	1995	368.18	18.14
Yadgiri	526.59	816.30	2012	268.00	1981	133.74	25.40

3.2. Annual and seasonal dry spell analysis at 7 and 10 consecutive dry days' time scale

Dry Spell Index (DSI) was computed at 7-consecutive day time scale for the districts of Karnataka for annual, *kharif* and *rabi* season (Figure 1). The spatio-temporal distribution of average DSI for annual rainfall during the period 1980–2020 in Karnataka maximum number of years fell under <4 average DSI with the range of 17 (Raichur) –40 years (Chamarajanagar, Mysore) and Haveri district showed maximum number of years (20 years) followed by Shimoga (17 years) in 4.1–6 DSI category. Similar results were noticed in the findings of Bal et al., 2022. Bidar and Gulbarga districts showed 10–12 average DSI category with one year out of 41 years which indicated that, there were 70–84 consecutive dry days out of 365 days in those districts. Under <4 average DSI category, it was observed that the number of years ranged from 1 (Chikkaballapur, Chitradurga, Kolar, Koppal and Tumkur) to 40 years (Dakshina Kannada, Shimoga, and Uttara Kannada) in *kharif* season and 1 year (Chamarajanagar and Mysore)

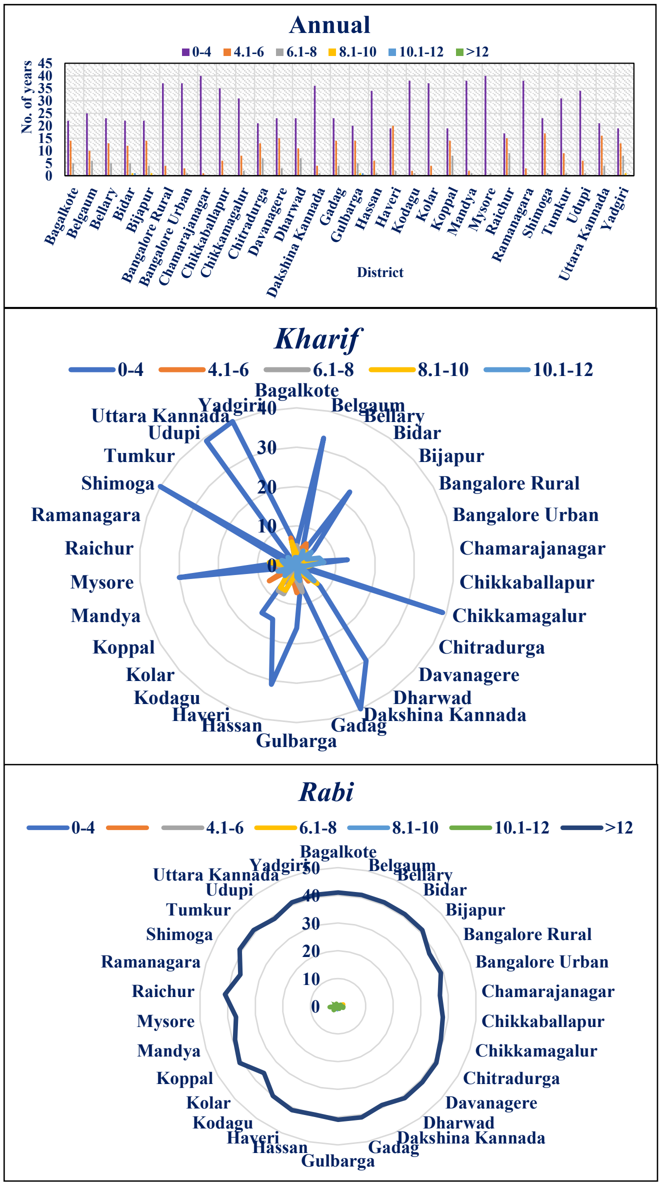

Figure 1: Number of years under different categories of average DSI-7 of annual, *kharif* and *rabi* season across different districts of Karnataka

during *rabi* season.

During *kharif* season, Koppal district showed higher number of years (8 years) with 4.1-6 DSI category, Chitradurga and Tumkur districts fell in >12 DSI category for 35 years out of 41 years, which indicated more than 84 consecutive dry days occurred out of 122 days, which led to agriculture drought condition causes non-availability of soil moisture to the crops, which increases the rate of leaf senescence and drooping, scorching, leaf rolling and brittleness, closed flowers and flower sagging, etiolation, wilting, turgidity, premature fall, senescence and yellowing of leaves and ultimately, failure of crops (Khan et al., 2018). During *rabi* season, most of the years (37–41 years) in all the districts showed more than 84 consecutive dry days occurred out of 92 days (>12 DSI category), led to drop in soil moisture can be attributed to the increase in the temperature which may have significant consequences on crop yields, and irrigation requirements (Mishra et al., 2014).

Dry Spell Index (DSI) for the annual, *kharif* and *rabi* season was calculated on 10-consecutive dry day time scale (Figure 2). For annual analysis, the highest number of years in different districts of the state falls under the <4 DSI category, ranged from 32 (Yadgiri) to 41 years (Bangalore Rural, Chikkaballapur, Kolar and Ramanagara).

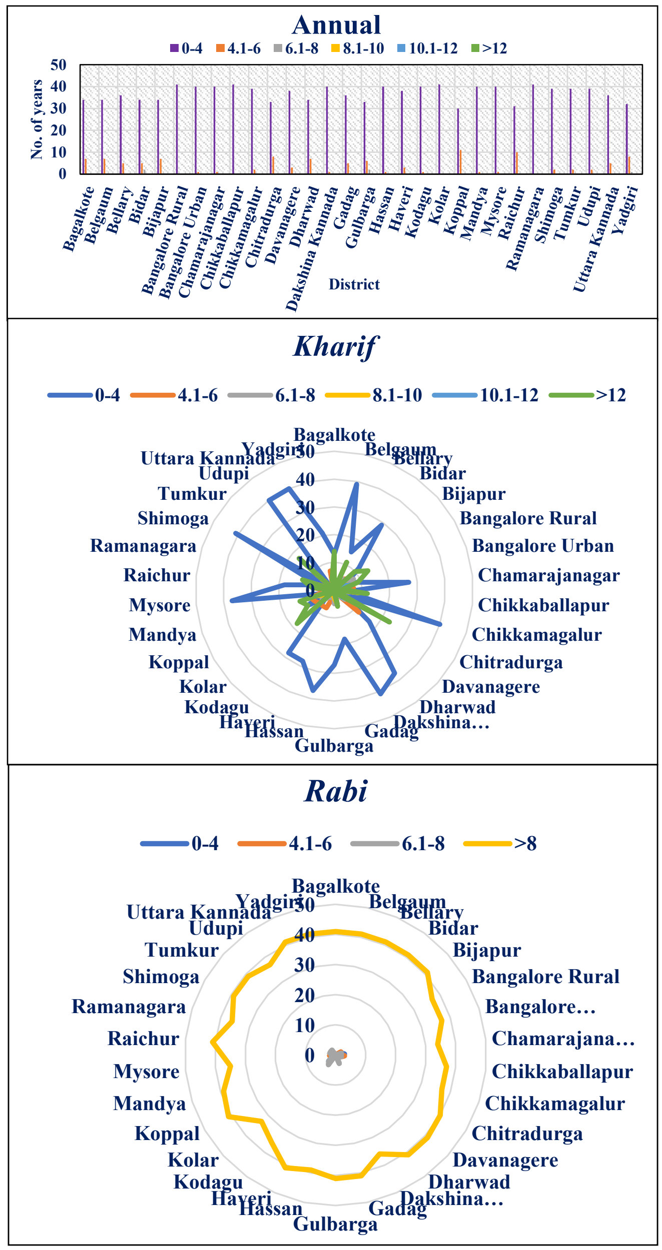

Figure 2: Number of years under different categories of average DSI-10 of annual, *kharif* and *rabi* season across different districts of Karnataka

Koppal and Ramanagara districts experienced 41–60 (4.1-6 average DSI category) consecutive dry days annum^{-1} for 11 and 10 years out of 41 years (1980–2020), respectively. Bidar and Hassan districts experienced 61-80 days (6.1-8 average DSI category) of consecutive dry days 365 days^{-1} for 2 years out of 41 years. During *kharif* season, most of the districts experienced less than 40 consecutive dry days 122 days^{-1} (<4 average DSI category) in the years ranged from 2 (Tumkur)–41 years (Dakshina Kannada and Shimoga), indicated there was less dearth of rainfall in Dakshina Kannada and Shimoga districts during main crop growing season, which has beneficial impact on agriculture production. Davanagere experienced 41–60 consecutive dry days (4.1-6 average DSI category) for 12 years out of 41 years of study period. Chitradurga district experienced 120–122 consecutive dry days during southwest monsoon season, which was a main crop growing season for more than half of the study period (23 years), and hence, this led to crop failure, due to cessation of monsoon rainfall (Huggi et al., 2020). During rabi season, most of the years in all the district fell in >8 average DSI category, indicating, all the district experienced >80 consecutive for the years ranged from 35 (Kolar) to 41 years (Bagalkote, Belgaum, Bellary, Bidar, Bijapur, Davanagere, Dharwad, Gadag, Gulbarga, Haveri, Koppal, Raichur, Uttara Kannada and Yadgiri).

3.3. Relationship between crop yield and DSI

The results of an analysis using the coefficient of correlation about the impact of dry spell index on major crops yield for the different districts in the dry zones of south Karnataka was presented in Table 3 and 4. It was observed that most of the crops in all the districts except Sugarcane in Bijapur during *kharif* season showed positive response to the DSI, as explained by the coefficient of correlation ranged from 0.5 to 0.76.

Bengal gram during *rabi* season in Bellary showed higher correlation coefficient with both DSI-7 and 10, indicated the yield of Bengal gram was significantly higher as the dry spells occurred. This was because of the climate requirements of the crop, which is primarily a short-duration crop that can withstand drought and normally took 90–100 days from seed to harvest with less ability to utilize rainwater.

Even though rice was water loving crop, the correlation coefficient is higher it does not mean that the productivity of rice is increased with increase in DSI. Rice is majorly grown where the sufficient external source of water such as bore wells, dam or reservoir water source is available since it requires more water for growing under submergence condition. Rahman et al., 2017 reported that even though dry spell condition occurred, the crop gets irrigated from any of the external source hence the productivity is not much affected by dry spell condition.

Table 3: Positive relation between dry spell index and productivity of crops across different districts of south Karnataka

District	Crop	DSI	r	*p*
Bagalkote	Bengal gram-R	7	0.59**	0.01
		10	0.6**	0.01
Bellary	Bengal gram-R	7	0.76**	0.001
		10	0.75**	0.001
	Safflower-R	7	0.57*	0.02
		10	0.58*	0.02
Bidar	Bajra-K	7	0.57*	0.02
	Wheat-R	7	0.5	0.06
	Sunflower-A	7	0.51*	0.05
	Cotton-A	7	0.51*	0.04
Gadag	Ragi- K	7	0.67**	0.005
		10	0.64**	0.009
Haveri	Black gram-K	7	0.55*	0.03
		10	0.55*	0.03
Koppal	Safflower-R	7	0.57	0.03
		10	0.58*	0.03
Mandya	Sugarcane-K	7	0.58*	0.02
		10	0.59*	0.02
Mysore	Tur-K	7	0.5*	0.05
		10	0.5*	0.05
Raichur	Rice-K	7	0.59*	0.02
		10	0.57*	0.03
Ramanagara	Green gram-K	7	0.53*	0.04
		10	0.59*	0.04
Shimoga	Ragi-R	7	0.53*	0.04
		10	0.52*	0.05
	Cotton-K	7	0.56**	0.003
		10	0.66**	0.008
Uttara kannada	Tur-R	7	0.51*	0.05
		10	0.51*	0.05
	Bengal gram-R	7	0.56*	0.03
		10	0.57*	0.03

*p=0.05; *p=0.01; K: *Kharif*; R: *Rabi*; A: Annual

From the analysis, the significant positive correlation between DSI and crop productivity was observed in pulses. Because pulses are short duration crops and requires less amount of water (200 to 250 mm) compared to other crops and are generally tolerant to water stress condition (Pradhan et al., 2019).

Table 4: Negative relation between dry spell index and productivity of crops across different districts of south Karnataka

District	Crop	DSI	r	District	Crop	DSI	r
Bagalkote	Bajra-K	7	-0.3		Groundnut-A	7	-0.45
		10	-0.28			10	-0.45
Belgaum	Groundnut-K	7	-0.4	Gulbarga	Rice-K	7	-0.3
		10	-0.37			10	-0.32
	Soyabean-K	7	-0.42	Hassan	Green gram-R	7	-0.37
		10	-0.33			10	-0.36
	Cotton-K	7	-0.31		Black gram-R	7	-0.45
	Sugarcane-A	7	-0.42			10	-0.45
		10	-0.42	Kolar	Rice-K	7	-0.5
Bijapur	Maize-K	7	-0.33			10	-0.48
		10	-0.33		Tur-K	7	-0.46
	Bajra-K	7	-0.41			10	-0.46
		10	-0.39	Koppal	Rice-K	7	-0.46
	Sunflower-K	7	-0.3			10	-0.42
	Sugarcane-K	7	-0.51*	Mandya	Sunflower-K	7	-0.31
		10	-0.49			10	-0.33
Chamaraj nagar	Ragi-A	7	-0.39		Groundnut-K	7	-0.43
		10	-0.39			10	-0.43
	Groundnut-A	7	-0.35	Ramanagar	Maize-K	7	-0.35
		10	-0.35			10	-0.36
Chitradurga	Sunflower-A	7	-0.42	Shimoga	Groundnut-A	7	-0.46
		10	-0.41			10	-0.46
Davanagere	Green gram-A	7	-0.42	Tumkur	Groundnut-A	7	-0.33
		10	0.42			10	-0.33
Dharwad	Sunflower-A	7	-0.49	Uttar Kannada	Maize-K	7	-0.28
		10	-0.49			10	-0.47

*p=0.05

Pulses are a better choice than many crops in drought-prone areas due to their relative tolerance and physiological adaptations like closing of stomata and osmolyte accumulation helped to reduce the water loss through pores and helps to retain water content in the plant cells. However, drought could still significantly reduce their yield.

The negative significant coefficient of correlation with DSI-7 and 10 among different crops across different districts was noticed in Sugarcane in Bijapur (Table 4) which could be attributed to longer crop growth period. As it was prevalent crop during *kharif* season, and extends to *rabi*, and improved high yielding varieties generally takes minimum 9–10 months to mature from planting to harvesting, so it has higher potential to efficiently utilize the whole seasonal rainfall down pouring from June to September during the crop growth period. Dry spells led to water deficit condition to the crop which harshly affect cane yield resulting in low sucrose yield. Similar findings of cessation of sucrose production due to dry spells was reported by Singels et al., 2010

The weak negative correlation of crop productivity with DSI was observed in case of bajra in Bagalkote followed by maize in Uttar Kannada during *kharif* season. Bal et al., 2024 reported the negative correlation with pearl millet yield in Kurnool. Bajra is known for its excellence drought tolerance due to physiological adaptations to thrive in dry conditions such as waxy leaf surface, Crassulacean Acid Metabolism and deep and prolific root system helps to minimize water loss through the plants during dry spell. Maize also moderately tolerant to dry condition by partially closing stomata and root system (Barron et al., 2003). Hence, both crops' yields having lower association with DSI.

4. CONCLUSION

Dry spell index was used to analyse the annual and seasonal dry spells and cumulative impacts of dry spells on major crops in different districts of Karnataka at two different consecutive dry days' time scales with long term rainfall data. Across the study area, a greater number of years fell under lower DSI (>4) value for annual rainfall and correlation analysis revealed that sugar cane exhibited the strong significant negative correlation with DSI.

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