Bulletin of Pure and Applied Sciences
Geology (Geological Science), Vol.43F, No.2,
July-December 2024: P.64-82
Original Research Article

Print version ISSN 0970 4639
Online version ISSN 2320 3234
Available online at www.bpasjournals.com

Assessment of Rainfall in Monsoon Season 2023: A Case Study of Maharashtra State

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Received on 22.07.2024, Revised on 28.10.2024, Accepted on 18.11.2024

How to cite this article: Golekar R.B. and Diwate P. (2024). Assessment of Rainfall in Monsoon Season 2023: A Case Study of Maharashtra State. *Bulletin of Pure and Applied Sciences- Geology,* 43F (2), 64-82.

Abstract:
The monsoon season plays a crucial role in the landscape of Maharashtra, India, affecting crop yields, water resources, and livelihoods. This research paper presents a comprehensive analysis of the rainfall patterns during the critical monsoon season of 2023 in Maharashtra, with a specific focus to determine the meteorological drought or not. Using historical rainfall data, satellite imagery, and agricultural statistics, we examine the spatio-temporal distribution of rainfall, its impact on crop production, and the meteorological indicators of drought stress. El Nino and La Nina are the warm and cool phases, respectively, of the El Nino-Southern Oscillation, a recurrent temperature trend throughout the tropical Pacific Ocean. This year, La Nina's three-year control came to an end, and El Nino made his appearance known. "The lack of favorable intra-seasonal weather patterns that increase monsoon rainfall (rainfall in July 2023) and the developing El Nino have a clear impact on this. Our findings reveal a complex inter-play of meteorological and agricultural factors, suggesting that the drought conditions experienced in the 2023 monsoon season in Maharashtra are influenced by a combination of meteorological deficits and agricultural practices. This research contributes to a better understanding of the complex nature of drought in agricultural regions, providing insights for more effective drought mitigation and resource allocation strategies.

Keywords: *Monsoon 2023, Maharashtra, rainfall, drought, irrigation, farmers.*

INTRODUCTION

Globally the definition of meteorological drought is based on the departure of precipitation from the long-term climatological average for a specific region. This definition focuses on the statistical characteristics of precipitation over a period of time, rather than the impacts of the drought. In the definition, meteorological drought is typically characterized by a prolonged period of below-average precipitation. The specific criteria for defining a meteorological drought can vary depending on the region and the dataset being used. Still, it often involves comparing the observed precipitation over a certain period (e.g., a month or a year) to the long-term average precipitation for that same period. If the observed precipitation falls significantly below

the long-term average, it may be considered a meteorological drought.

It's important to note that meteorological drought is just one aspect of drought, and it doesn't consider the impacts of the drought on water resources, agriculture, or society. Other types of droughts, such as hydrological drought (related to water supply) and agricultural drought (related to impacts on crops and vegetation), are often considered in addition to meteorological drought to provide a more comprehensive assessment of drought conditions.

In summary, the definition of meteorological drought is based on the departure of precipitation from the long-term climatological average and is primarily a measure of the deficit in rainfall over a specified period.

The India Meteorological Department (IMD) provides a specific definition for drought in India. In India, drought is classified into three categories: meteorological, hydrological, and agricultural. Here's a brief overview of each: Drought has several definitions and types, such as meteorological (based on rainfall deficiency), agricultural (based on crop loss), and hydrological (based on groundwater availability) drought. Drought declaration is also complex (Zarei, 2019). It is an administrative process and varies at the sub-national level. Many states in India consider factors such as negative rainfall deviation of more than 25% from the annual average in the district or tehsil/villages, crop loss estimation, a decline in the crop sown area, and migration before identifying and declaring drought. Despite the threshold rainfall deficit, drought may not be officially announced, but there may be similar distress (drought-like situation) in the economy. Moreover, the state government may declare a drought in some areas only at the sub-district (tehsil or village) level. Most of the states in India follow the meteorological definition of drought (rainfall deficiency) for declaration of droughts and disbursing financial relief.

Meteorological drought in India is defined based on the deviation of rainfall from the long-term average for a particular region. IMD considers a meteorological drought to have occurred when there is a departure of more than 10% from the long-period average (LPA) of rainfall for a specified period (usually a season or a month). This deviation indicates a rainfall deficiency that can potentially lead to other forms of drought. Hydrological drought in India is related to the availability of water in rivers, reservoirs, and groundwater. It is characterized by a prolonged period of below-average water availability. The assessment of hydrological drought takes into account factors such as streamflow, river discharge, and water storage levels in reservoirs. The Central Water Commission (CWC) in India is responsible for monitoring hydrological drought conditions. Agricultural drought is specific to the impact of moisture deficiency on crop growth and agricultural activities. It is assessed by considering factors like soil moisture levels, crop health, and the availability of water for irrigation. The IMD, along with the Indian Council of Agricultural Research (ICAR), plays a role in assessing agricultural drought conditions. It's important to note that these definitions and classifications help in assessing and monitoring drought conditions in India. Each type of drought (meteorological, hydrological, and agricultural) has its own set of criteria and parameters for evaluation, and they are interrelated, as prolonged meteorological drought can lead to hydrological and agricultural drought conditions. Accurate monitoring and timely information are crucial for drought management and mitigation efforts in the country.

Monsoon rainfall received during the June to September months is the backbone of the rainfed cultivation of crops in India (Mishra et al., 2012, Singh et al., 2019). The irrigated cultivation of crops, which primarily, depends on irrigation projects through canal or lift irrigation schemes and some land irrigated from groundwater sources has been also affected by the decline in monsoon rainfall.The latest report of the Intergovernmental Panel on Climate Change (IPCC, 2021) has reported that the frequency and intensity of heavy rainfall events have increased since the 1950s in most areas and the human-induced changes in the climate system have contributed to increases in droughts (agricultural and ecological) in some regions due

to increased rates of evapotranspiration. The changes in rainfall patterns driven mainly by a rise in the global surface temperature @ 0.74 ± 0.18°C throughout 1906-2005 (IPCC, 2007) have dropped the availability of fresh water during the middle of the 21st century.

Recent studies on the Indian Summer Monsoon (ISM) have depicted a decreasing trend in rainfall during the second half of the 20th century in central India (Bollasina et al., 2011; Mishra et al., 2012). The monsoon current is established and strengthened by the warming of the Indian subcontinent which builds up a low pressure that helps strengthen the movement of moisture-laden winds from the Indian Ocean (Bollasina, 2014). Since the middle of the 20thcentury, the greenhouse gas (GHG) induced warming of the Indian Ocean sea surface and the concomitant dampening of warming over the Indian subcontinent due to aerosols (Das et al., 2015) and land-cover changes (Dirmeyer et al., 2010) has led to a weakening trend of the Indian monsoon (Singh et al., 2019; Seth et al., 2019).

In summary, while meteorological drought is primarily about the deficiency of precipitation and its statistical assessment, agricultural drought is more concerned with the real-world impacts of reduced moisture on crops and farming practices. Meteorological drought can be a precursor to agricultural drought, as prolonged periods of low precipitation can lead to soil moisture deficits and negatively impact crop growth, which, in turn, triggers agricultural drought conditions. Both types of drought are important to monitor and manage, as they can have significant socioeconomic and environmental consequences.

DATA AND METHODOLOGY

Meteorological drought is important to announcing of financial assistance for the overcome drought impact on agricultural and other allied sectors. Authors have tried to show the severely drought-affected district in the state of Maharashtra in the monsoon season 2023-24. For the present study, authors has used rainfall data from the Indian Metrological Department (IMD) and percentage live storage data of irrigation projects from the Water Resource Department, Government of Maharashtra (WRD).

RESULTS

Analysis of Monsoon Rainfall Data for Maharashtra (01-06-2023 to 30-09-2023)

In this section, authors has analysis of the monsoon rainfall data for the state of Maharashtra during the period from 01-06-2023 to 30-09-2023. The data is presented at both the state and subdivision levels, providing insights into the performance of different regions within Maharashtra. The key parameters examined include actual rainfall (in mm), normal rainfall (in mm), and the percentage departure (% DEP) from the normal values. At the state level, Maharashtra experienced a total rainfall of 965.7 mm during the monsoon season of 2023, which was slightly below the normal rainfall of 994.5 mm, resulting in a negative departure of -3%. This indicates that the state, as a whole, received below-average rainfall during this period.

Mumbai City recorded a significant departure from normal rainfall, with actual rainfall measuring 1983.0 mm, compared to the normal of 2094.5 mm, representing a negative departure of -5%. This suggests that Mumbai City witnessed a drier monsoon season than usual.The Suburban Mumbai area experienced a substantial departure from normal rainfall, with actual rainfall measuring 2978.3 mm, significantly higher than the normal of 2318.8 mm, resulting in a positive departure of 28%. This indicates a wetter monsoon season in Suburban Mumbai. Thane also received above-average rainfall during the period, with actual rainfall measuring 3099.1 mm, compared to the normal of 2433.3 mm, indicating a positive departure of 27% (Fig. 1A and Fig.1B).

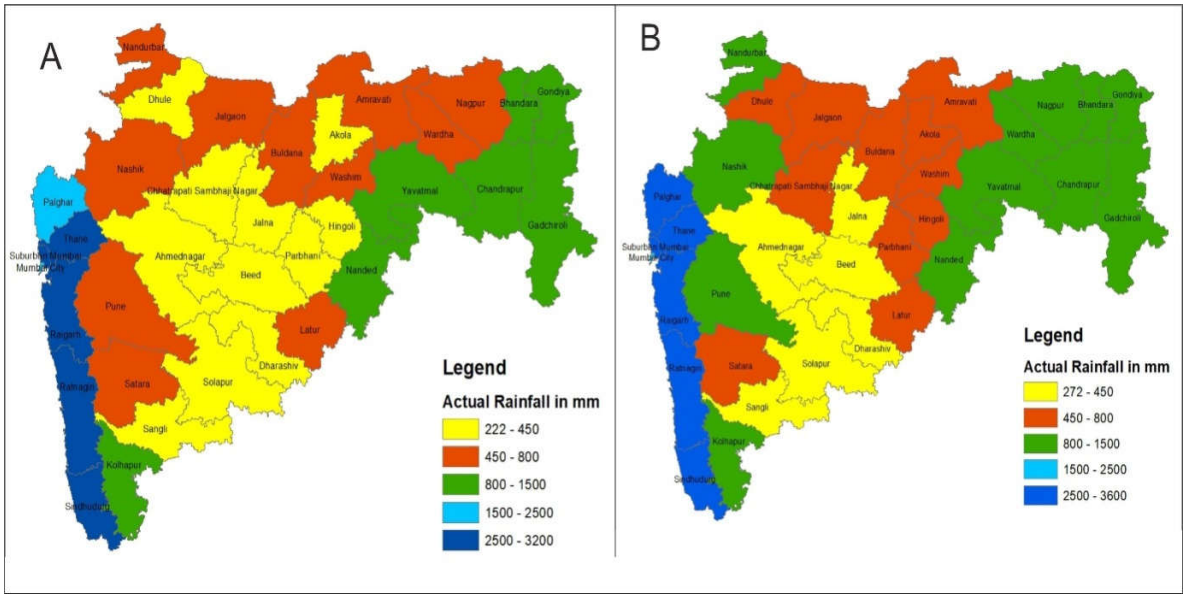

Figure 1: (A) Monsoon Rainfall Data for Maharashtra (01-06-2023 to 10-09-2023) (B) Monsoon Rainfall Data for Maharashtra (01-06-2023 to 30-09-2023)

Figure 2: Severely damaged representative Kharip crops due to low moisture and scanty rainfall (Location: Purushottampuri Taluka Majalgaon District Beed, Maharashtra. Date: 19 September 2023)

The Madhya Maharashtra subdivision faced a challenging monsoon season with an overall negative departure of -12%. Several districts within this subdivision experienced below-average rainfall. Sangli and Satara districts witnessed significant rainfall deficits, with departures of -44% and -37% respectively. These districts faced severe water scarcity conditions during the monsoon season.

The Marathwada subdivision also recorded a negative departure of -11%, indicating a drier monsoon season in this region. Nanded district in Marathwada, however, stood out with a positive departure of 23%, receiving more rainfall than normal, which could have a positive impact on agricultural activities in the area. Representative photographs taken from the village Purushottampuri Taluka Majalgaon District Beed dated 19 September 2023 witnessed that the soyabeen and Tur crops were severely damaged due to low moisture and scanty rainfall (Fig. 2 and Fig. 3).

Figure 3: Severely damaged representative Khaip crops due to low moisture and scanty rainfall (Location: Purushottampuri Taluka Majalgaon District Beed, Maharashtra. Date: 19 September 2023)

In Vidarbha, the overall departure from normal rainfall was relatively modest at -2%. While some districts saw below-average rainfall, others experienced surpluses. Yavatmal district in Vidarbha stood out with a positive departure of 14%, indicating above-average rainfall in the region.

In conclusion, the monsoon season of 2023 exhibited considerable variability in rainfall distribution across different subdivisions and districts of Maharashtra. While some areas experienced below-average rainfall, others received surpluses. It is crucial for the state government to closely monitor and manage water resources, especially in districts facing significant rainfall deficits, to mitigate the

impact on agriculture and water supply. Additionally, preparedness for potential flooding in areas with above-average rainfall is essential. Further analysis and planning are required to ensure sustainable water management and agricultural resilience in the face of varying monsoon patterns.

El Nino and La Nina are the warm and cool phases, respectively, of the El Nino-Southern Oscillation, a recurrent temperature trend throughout the tropical Pacific Ocean. This year, La Nina's three-year reign came to an end, and El Nino made his appearance known. "The lack of favorable intraseasonal weather patterns that increase monsoon rainfall (rainfall in July 2023) and the developing El Nino have a clear impact on this (Table 1). It is imperative to examine the precipitation forecasts and actual realizations for the months of June through September 2023. These forecasts play a crucial role in the assessment of India's monsoon patterns, as they have a profound impact on various sectors, including agriculture, water resource management, and overall socio-economic conditions. The data shows that while June and August 2023 witnessed below-normal rainfall at 91% and 64% of the Long Period Average (LPA), respectively, July and September exhibited significant deviations from the forecasts. July's actual rainfall exceeded expectations, reaching 113% of LPA, while September witnessed a similar anomaly, also reaching 113% of LPA, thanks in part to the prediction of Low Pressure Systems and extended range forecasts. When assessing the cumulative rainfall for August and September 2023, the findings reveal a below-normal performance at 83% of LPA, but it is important to note that these deviations from forecasted values warrant a comprehensive investigation and underline the inherent uncertainties in monsoon predictions. This research seeks to shed light on the implications of such discrepancies and their potential consequences for various sectors reliant on monsoon rains.

Table 1: Performance of monthly Rainfall Forecast during Monsoon 2023 Month Forecast Realized June 2023 Rainfall to be below normal (Source IMD reports)

Month	Forecast	Realized
June 2023	Rainfall to be below normal.	91% of LPA
July 2023	Rainfall to be normal but on positive side of the normal (100-106 % of LPA).	113% of LPA
August 2023	Rainfall to be below normal.	64% of LPA
Sept 2023	Rainfall to be normal (91-109 % of LPA). However extended range forecast indicated good rainfall in Sept. Also predicted formation of Low Pressure Systems one after another to cause good rainfall over Central and South India.	113% of LPA
August-September 2023	Rainfall to be normal but on negative side of the normal (94 to 99% of LPA).	83% of LPA

Table 2: Live storage data of Major Irrigation Projects from the Maharashtra State on dated 30 September 2023
(Source: Water Resource Department, Government of Maharashtra)

1. Sr. No.	2. Name of the dam	3. Designed Dead storage (Mcum)	4. Designed Live storage (Mcum)	5. Designed Gross storage (Mcum)	6. Live storage (Mcum) as on 30/09/2023	7. Gross storage (Mcum) as on 30/09/2023	8. % of live storage as on 30/09/2023	9. % of live storage on same day of last year i.e. 30/09/2022	10. Catagory
Nagpur Region									
Bhandara									
1	Bawanthadi	62.92	217.32	280.24	205.78	268.7	94.69%	97.34%	Very Good
2	Gosikhurd	405.91	740.17	1146.08	496.98	902.89	67.14%	68.90%	Good
Chandrapur									
1	Asolamendha	10.64	52.33	62.97	52.33	62.97	100.00%	100.00%	Very Good
Gadchiroli									
1	Dina	5.21	67.54	72.75	67.54	74.17	100.00%	94.46%	Very Good
Gondiya									
1	Dhapewada	0	44.05	44.05	7.04	7.04	15.98%	26.59%	Large Deficits
2	Itiadoh	63.71	317.87	381.59	317.87	381.59	100.00%	100.00%	Very Good
3	Kalisarar	2.47	26.04	28.52	25.23	27.7	96.89%	94.84%	Very Good
4	Pujaritola P.U.Weir	14.93	43.53	58.46	42.09	57.01	96.69%	96.69%	Very Good
5	Sirpur	11.32	159.78	171.1	155.7	167.02	97.45%	97.44%	Very Good
Nagpur									
1	Kamthi Khairy	39	141.98	180.98	141.98	180.98	100.00%	97.50%	Very Good
2	Khindsi	0	103	103	103	103.09	100.00%	100.00%	Very Good
3	Nand	9	53.18	62.18	50.94	59.94	95.79%	95.44%	Very Good
4	Totladoh	150	1016.93	1166.93	1016.88	1166.88	100.00%	99.99%	Very Good
5	Wadgaon	16.6	134.9	151.5	131.98	148.58	97.84%	100.00%	Very Good
Wardha									
1	Bor	11.32	127.42	138.74	117.21	128.53	91.99%	92.09%	Very Good
2	Lower Wardha	36.47	216.87	253.34	190.18	226.65	87.69%	96.78%	Very Good

Total for Nagpur Region		**839.5**	**3462.92**	**4302.42**	**3122.72**	**3963.74**	**90.18%**	**91.28%**	**Very Good**
Amravati Region									
Akola									
1	Katepurna	11.32	86.35	97.67	70.23	81.55	81.33%	100.00%	Very Good
2	Wan	1.51	81.96	83.46	78.06	79.57	95.24%	95.95%	Very Good
Amravati									
1	Upper Wardha	114.22	564.05	678.27	564.04	678.26	100.00%	98.20%	Very Good
Buldhana									
1	Khadakpurna	67.21	93.4	160.61	15.04	82.25	16.10%	93.15%	Large Deficits
2	Nalganga	2.54	69.32	71.86	29.66	32.2	42.79%	80.36%	Deficits
3	Pentakli	7.38	59.98	67.36	31.69	39.07	52.83%	97.10%	Good
Yavatmal									
1	Arunavati	28.72	169.67	198.39	169.67	198.39	100.00%	100.00%	Very Good
2	Bembla	19.39	183.94	203.34	129.13	148.52	70.20%	90.07%	Good
3	Isapur	315	964	1279	793.95	1108.95	82.36%	99.41%	Very Good
4	Pus	22.66	91.26	113.92	91.25	113.91	99.99%	75.16%	Very Good
Total for Amravati Region		**589.95**	**2363.93**	**2953.88**	**1972.72**	**2562.67**	**83.45%**	**96.54%**	**Very Good**
Marathwada Region									
Chhatrapati Sambhajinagar									
1	Apegaon H L B	0	7	7	3.62	3.62	51.71%	91.21%	Good
2	Paithan (Jayakwadi)	738.11	2170.93	2909.04	962.65	1700.76	44.34%	99.71%	Deficits
Beed									
1	Borgaon Anjanpur	0.01	1.5	1.51	0	0	0.00%	0.00%	Large Deficits
2	Dhanegaon High Level Barrage	0.34	10.98	11.32	5.42	5.76	49.36%	78.32%	Deficits
3	Dongargaon H L B	0.01	7.89	7.9	4.01	4.02	50.82%	95.97%	Good
4	Majalgaon	142.3	311.34	453.64	39.2	181.5	12.59%	96.78%	Large Deficits
5	Manjara	47.13	176.96	224.09	48.83	95.96	27.59%	64.49%	Deficits
6	Roshanpuri H L B	0.03	6.3	6.33	4.38	4.41	69.52%	98.33%	Good
7	Sirasmarg L L B	0	2.06	2.06	0	0	0.00%	65.58%	Large Deficits

8	Wangdari L T B	0	0.84	0.84	0.69	0.69	82.14%	99.64%	Very Good
Hingoli									
1	Siddeshwar	169.89	80.96	250.85	77.19	247.08	95.34%	96.97%	Very Good
2	Yeldari	124.67	809.77	934.44	504.34	629.01	62.28%	100.00%	Good
Nanded									
1	Amdura	0.51	23.2	23.71	23.2	23.71	100.00%	80.13%	Very Good
2	Dhalegaon H L B	1.37	13.5	14.87	9.45	10.82	70.00%	88.00%	Good
3	Digadi H L B	0	10.44	10.44	1.23	1.23	11.78%	7.24%	Large Deficits
4	Digras H L B	0.28	63.57	63.85	44.88	45.16	70.60%	51.46%	Good
5	Hiradpuri H L B	0	9.69	9.69	0.96	0.96	9.91%	91.58%	Large Deficits
6	Jogladevi H L B	0	10	10	6.79	6.79	67.90%	90.88%	Good
7	Kinwat (Mangrul) H L B	0	10.57	10.57	0.06	0.06	0.57%	0.29%	Large Deficits
8	Lonisawangi H L B	0	29.98	29.98	13.87	13.87	46.26%	81.20%	Deficits
9	Lower Manar	8.71	138.21	146.92	100.48	109.19	72.70%	100.00%	Good
10	Mangrul H L B	0	25	25	7.71	7.71	30.84%	93.00%	Deficits
11	Mudgal H L B	0.51	11.36	11.87	7.75	8.26	68.22%	95.33%	Good
12	Rajatakli H L B	0	25	25	12.9	12.9	51.60%	90.55%	Good
13	Vishnupuri	2.76	80.79	83.55	80.79	83.55	100.00%	93.27%	Very Good
Dharashiv									
1	Aurad K.T. Weir	0	3.67	3.67	2.69	2.69	73.30%	59.13%	Good
2	Gunjarga L T B	0	1.37	1.37	1.08	1.08	78.83%	15.18%	Very Good
3	Killari 2 L T B	0	1.3	1.3	0.16	0.16	12.31%	94.00%	Large Deficits
4	Limbala L T B	0	0.29	0.29	0.28	0.28	96.55%	97.24%	Very Good
5	Lower Terna	29.97	91.22	121.19	23.65	53.61	25.93%	98.46%	Deficits
6	Madansuri L T B	0	1.74	1.74	0.97	0.97	55.75%	42.41%	Good
7	Rajegaon L T B	0	0.59	0.59	0.03	0.03	5.08%	92.71%	Large Deficits
8	Sina kolegaon	74.25	76.18	150.43	0	43.66	0.00%	100.00%	Large Deficits
9	Tagarkheda L T B	0	0.77	0.77	0.6	0.6	77.92%	0.00%	Very Good
Latur									

1	Bhusani	0	1.49	1.49	1.49	1.49	100.00%	100.00%	Very Good
2	Bindgihal L T B	0	1.35	1.35	0.06	0.06	4.44%	96.30%	Large Deficits
3	Karsa Pohregaon	0	3.41	3.41	2.99	2.99	87.68%	93.72%	Very Good
4	Khulgapur	0	9.72	9.72	3.26	3.26	33.54%	92.89%	Deficits
5	Nagzari L T B	0	3.48	3.48	3.48	3.49	100.00%	96.72%	Very Good
6	Sai	0	3.47	3.47	1.06	1.06	30.55%	96.05%	Deficits
7	Shivni	0.04	9.77	9.81	0.54	0.58	5.53%	97.41%	Large Deficits
8	Takalgaon-Deola	0.09	1.83	1.92	1.35	1.44	73.77%	64.59%	Good
9	Wanjarkheda High level Barrage	0	3.6	3.6	3.6	3.61	100.00%	96.94%	Very Good
Parbhani									
1	Lower Dudhana	102.6	242.2	344.8	69.02	171.62	28.50%	75.05%	Deficits
Total for Marathwada Region		**1443.57**	**4495.3**	**5938.86**	**2076.72**	**3489.7**	**46.20%**	**94.87%**	**Deficits**
Nashik Region									
Ahmadnagar									
1	Bhandardara	8.5	304.1	312.6	303.72	312.22	99.88%	100.00%	Very Good
2	Mula	127.42	608.81	736.23	511.46	638.89	84.01%	99.88%	Very Good
3	Musalwadi Tail Tank	0	5.36	5.36	1.64	1.64	30.60%	100.07%	Deficits
4	Nilwande-2	3.82	232.18	236	230.8	234.62	99.41%	95.40%	Very Good
Jalgaon									
1	Upper Tapi Hatnur	133	255	388	229.2	362.2	89.88%	94.71%	Very Good
2	Waghur	76.79	248.21	325	248.21	325.29	100.00%	90.74%	Very Good
Nashik									
1	Arjunsagar	2.76	36.99	39.75	36.71	39.47	99.24%	99.23%	Very Good
2	Bham Dam	5.66	69.76	75.42	69.76	75.42	100.00%	100.00%	Very Good
3	Bhavali	3.96	40.79	44.75	40.62	44.58	99.58%	99.59%	Very Good
4	Chankapur	11.24	68.72	79.96	55.18	66.42	80.30%	81.73%	Very Good
5	Darna	0	202.42	202.42	202.42	202.42	100.00%	100.00%	Very Good
6	Gangapur	0.68	159.42	160.1	158.5	159.18	99.42%	100.00%	Very Good
7	Girna	84.9	523.55	608.45	296.78	381.68	56.69%	100.00%	Good

8	Kadwa	6.68	47.79	54.47	47.79	54.47	100.00%	100.00%	Very Good
9	Karanjwan	9.34	152.09	161.43	152.09	161.44	100.00%	99.18%	Very Good
10	Mukane	9.18	204.98	214.16	204.98	398.69	100.00%	100.00%	Very Good
11	Ozarkhed	7.64	60.32	67.96	56.66	64.3	93.93%	100.00%	Very Good
12	Palkhed	1.64	18.49	20.13	18.44	20.08	99.73%	97.54%	Very Good
13	Punegaon	2.82	17.57	20.39	16.98	19.8	96.64%	99.66%	Very Good
14	Tisgaon	2.7	12.76	15.46	8.97	11.67	70.30%	100.00%	Good
15	Vaitarna H. E. P.	22.65	331.31	353.96	329.39	352.04	99.42%	99.83%	Very Good
16	Waghad	2.54	65.18	67.72	65.18	67.73	100.00%	100.00%	Very Good
17	Waki Dam	5.23	70.57	75.8	62.32	67.56	88.31%	100.00%	Very Good
Total for Nashik Region		**529.16**	**3736.37**	**4265.53**	**3347.82**	**4061.81**	**89.60%**	**98.31%**	**Very Good**
Pune Region									
Kolhapur									
1	Dudhaganga	40.01	679.11	719.12	652.74	692.75	96.12%	90.92%	Very Good
2	Radhanagari H E P	16.82	219.97	236.79	216.33	233.15	98.35%	97.53%	Very Good
3	Tillari (Dhamne)	21.24	85.41	106.65	83.74	104.98	98.04%	97.91%	Very Good
4	Tulshi	6.37	91.92	98.29	78.85	85.22	85.78%	99.51%	Very Good
Pune									
1	Nira Deoghar	5.26	332.13	337.39	327.85	333.11	98.71%	99.61%	Very Good
2	Dimbhe	28.3	353.75	382.05	353.75	383.78	100.00%	100.00%	Very Good
3	Bhama Askhed	13.37	217.1	230.47	217.1	230.65	100.00%	93.92%	Very Good
4	Yedgaon	14.15	79.28	93.43	65.8	79.96	83.00%	98.49%	Very Good
5	Chaskaman	27.19	214.5	241.69	214.5	241.69	100.00%	100.00%	Very Good
6	Pimpalgaon Joge	125.19	110.15	235.34	101.79	226.98	92.41%	93.32%	Very Good
7	Wadaj	2.83	33.11	35.94	33.11	35.97	100.00%	100.00%	Very Good
8	Manikdoh	19.81	288.1	307.91	229.09	248.9	79.52%	90.34%	Very Good
9	Ghod (Chinchani)	61.5	154.8	216.3	135.7	197.2	87.66%	96.07%	Very Good
10	Pawana	31.16	274.32	305.49	241.11	272.27	87.89%	89.41%	Very Good
11	Bhatghar	7.08	665.57	672.65	655.5	662.58	98.49%	99.66%	Very Good

12	Khadakwasla	30	55.91	85.91	55.91	85.91	100.00%	98.14%	Very Good
13	Panshet	9	301.61	310.61	301.61	310.61	100.00%	100.00%	Very Good
14	Warasgaon	12.23	363.13	375.36	363.13	375.36	100.00%	100.00%	Very Good
15	Gunjawani	0.21	104.48	104.69	101.33	101.54	96.99%	100.00%	Very Good
16	Temghar	2.95	105.01	107.96	83.13	86.08	79.16%	99.18%	Very Good
17	Mulshi Tata	230	522.76	752.76	558.8	788.8	106.89%	100.00%	Very Good
18	Lonavala Tata	0.06	11.72	11.78	2.94	2.99	25.09%	19.07%	Deficits
19	Walwan Tata	0.28	71.84	72.12	63.34	63.63	88.17%	86.56%	Very Good
20	Shirawta Tata	0.87	197.28	198.15	187.64	188.51	95.11%	88.20%	Very Good
21	Thokerwadi Tata	11.06	352.64	363.7	352.64	388.97	100.00%	100.00%	Very Good
22	Kundali Tata	0.8	6.34	7.14	4.76	5.56	75.08%	68.08%	Very Good
Sangli									
1	Warna	194.84	779.35	974.19	779.35	974.19	100.00%	99.65%	Very Good
Satara									
1	Dhom Balkawadi	3.4	112.13	115.53	106.43	109.83	94.92%	100.00%	Very Good
2	Tarali	0.25	165.46	165.71	157.01	157.26	94.89%	97.94%	Very Good
3	Dhom	51.27	331.05	382.32	236.38	287.66	71.40%	100.00%	Good
4	Koyna	145.14	2835.54	2980.68	2492.81	2637.95	87.91%	99.64%	Very Good
5	Kanher	14.32	271.68	286	218.31	232.63	80.36%	99.78%	Very Good
6	Urmodi	8.87	273.27	282.14	152.71	161.58	55.88%	99.77%	Good
7	Veer	12.09	266.4	278.49	163.73	175.82	61.46%	100.00%	Good
Solapur									
1	Bhima (Ujjani)	1802.81	1517.2	3320.01	495.92	2298.73	32.69%	100.00%	Deficits
Total for Pune Region		**2950.74**	**12444.02**	**15394.75**	**10484.83**	**13462.77**	**84.26%**	**98.22%**	**Very Good**
Kokan Region									
Palghar									
1	Dhamni	8.96	276.35	285.31	275.04	284	99.53%	99.29%	Very Good
2	Kawdas P. U. Weir	3.74	9.96	13.7	9.96	14.49	100.00%	100.00%	Very Good
3	Middle Vaitarna	8.57	193.53	202.1	189.29	197.86	97.81%	94.10%	Very Good
Raigarh									

1	Dolwahal weir	8.23	6.5	14.74	1.91	10.14	29.38%	22.58%	Deficits
Sindhudurg									
1	Tillari	14.8	447.37	462.17	406.61	421.41	90.89%	93.45%	Very Good
Thane									
1	Barvi	1.64	338.84	340.48	333.51	335.15	98.43%	68.78%	Very Good
2	Bhatsa	34	942.1	976.1	937.98	971.98	99.56%	99.21%	Very Good
3	Lower Chondhe	0.48	2.73	3.21	0.92	1.4	33.70%	68.32%	Deficits
4	Modaksagar	30.19	174.79	204.98	174.73	204.92	99.97%	96.93%	Very Good
5	Tansa	12.08	172.52	184.6	171.58	183.65	99.46%	99.05%	Very Good
6	Upper Ghatghar	0.68	5.14	5.82	4.27	4.95	83.07%	89.55%	Very Good
Total for Kokan Region		**123.37**	**2569.83**	**2693.21**	**2505.81**	**2629.97**	**97.51%**	**93.41%**	**Very Good**
Grand Total for all Major Projects		**6476.28**	**29072.36**	**35548.65**	**23510.62**	**30170.65**	**80.87%**	**95.44%**	**Very Good**

List of Abbreviation: Mcum:- Million Cubic Meter, HLB:- High Level Barrage, LLB :- Low Level Barrage, LTB:- Latur Type Barrage, PU Weir :- Pick Up weir

DISCUSSIONS

Most of the Kharif season crops were damaged due to deficient rainfall in most of the districts ofthe State of Maharashtra. Even rainfall received after this tragedy it will not be useful for the Kharif Season crops because these crop's growth is not good and loss is beyond 50 to 75 %. In the year 2023-24 monsoon will not receive sufficient amount in most of India. India is a leading agricultural producer country and most food grains crops, cereals, pulses, and oil seeds have beencultivated during the monsoon season (June and July) and it will be harvested in September and October. In India, 63.3 percent of agricultural lands depend on monsoon and ultimately it becomes rainfed agriculture. And those agricultural land are irrigated it also depends on good rainfall during the period of monsoon season to fill the reservoir and recharge the groundwater system.

But this year monsoon rainfall arrived at late i.e. 21st June 2023. IMD was declared monsoon in India on 7th June 2023 but actual rainfall comes in Maharashtra on 24th June 2023. In the last week of June monsoon reached in most parts of India but in the state of Maharashtra its intensity is very low in Maharashtra may be due to Biparjoy cyclone conditions in the 3rd week of June (Fig. 4). Hence the cultivation of the Kharip crop in Maharashtra was started in the 1st week of July means that the season of cultivated sowing was delayed 15 days and its major impact of decrease the productivity of Kharip crops. This year month of July received good rainfall in the country as per the country level % departure. However most of the districts from the state of Maharashtra do not receive sufficient rainfall even in July except the Konkan and Vidharbha subdivisions.

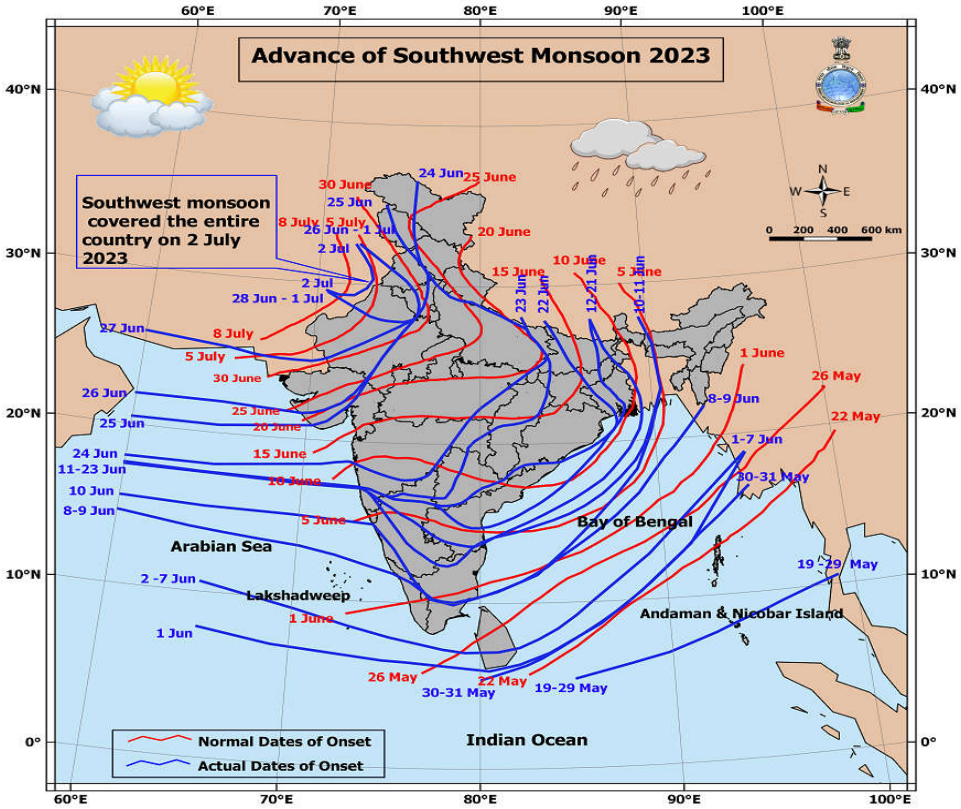

Figure 4: Onset map of southwest monsoon 2023 (Source: IMD Website)

This year (2023) the distribution of rainfall is highly variable during the last 3 months. The part of the Maharashtra state are dried during August and also in most time in June even heavy rainfall areas havea shortfall of the rainfall i.e. at Pachgani Taluka Mahabaleshwar district Satara has only received 17 % rainfall (865 mm) against the average mean rainfall till date 10/09/2023 was 5084 mm. There is a strong correlation between these years monsoon sign is of droughts in the state of Maharashtra. Also the monsoon withdrwal from state the Maharashtra is on time hence there is no additional rainfall recived during the withdrwal of the monsoon 2023 (Fig. 5).

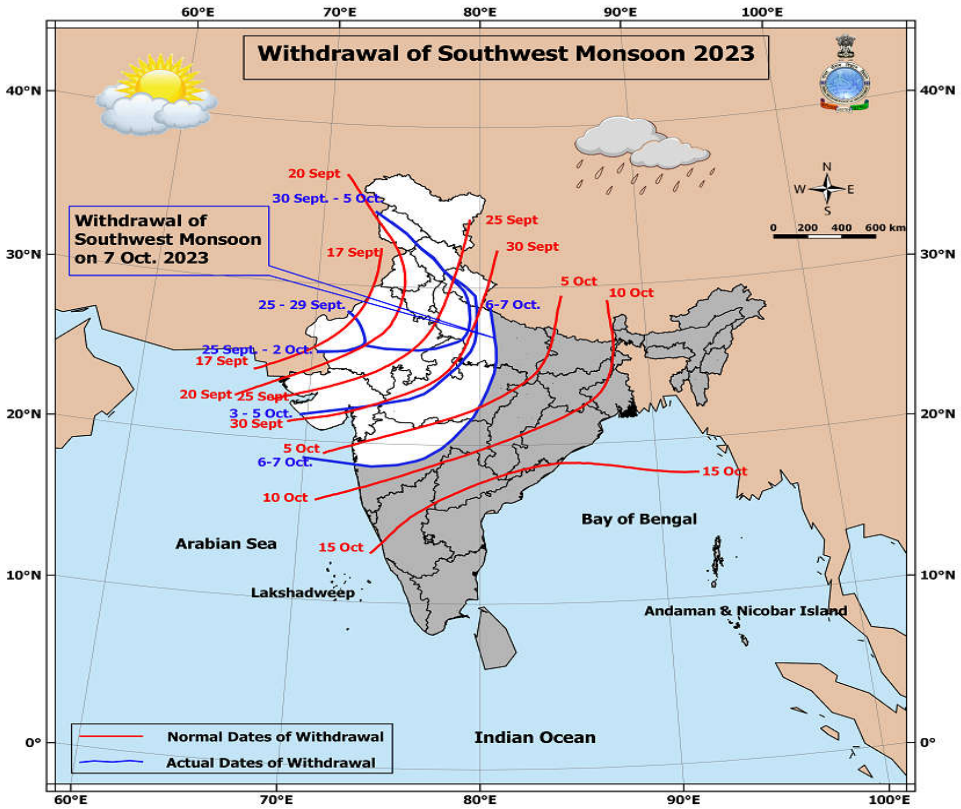

Figure 5: Withdrawal of Southwest Monsoon 2023 (Source: IMD Website)

At least 60 to 100 mm rainfall is required for good germination of Kharif crops which is depends on monsoon only but in the state of Maharashtra the District Ahmadnagar, Sangli and Solapur from Madhya Maharashtra subdivision and Beed, Jalna, Dharashiv, Chhatrapati Sambhajinagar, Parbhani and Hingoli district from Marathwada subdivision and Akola, Amravati and Buldhana district from Vidhrbha subdivision have received scanty rainfall in June- July and August which now belongs the deficient rainfall district from state of Maharashtra where deficient of rainfall (-20 to -60 %) as on dated 10 September 2023. As per the IMD data of 10/09/2023, the district mentioned in Table 1 where the lowest rainfall received in the state of Maharashtra. Some of the districts from the State of Maharashtra have received less than 300 mm rainfall up to 10/09/2023 viz. districts namely Ahmadnagar, Sangli, Solapur, Beed, Jalna, Chhatrapati Sambhajinagar and Dharashiv. This district is a leading producer of food grains, pulses, and cereals so the loss of gross agricultural productivity of the state of Maharashtra. This district receives less than 300 mm of rainfall which will huge impact on the loss of Kharip crop productivity it will also high impact on the production of Sugarcane because this district is also leading from the cultivation of sugarcane due to scanty rainfall and the growth of sugarcane is not at optimum level hence

the sugarcane industry from this district is also hampering in the season 2023-24 an ultimately its impact on entire Sugarcane industry of the State of Maharashtra.

This districts where the rainfall is less than 300 mm and where is the % departure between -20 to -60 % most of the crop loss beyond 50 % due to scanty rainfall means 50 % of the crop loss already goes from the farmer's hand from these districts. As the policy maker role of government is very crucial to overcome this drought condition in these districts. Good planning is needed such as priority of use of water for drinking, and irrigation as well as planning for feed for cattle in this scanty rainfall region should be proper and management is required otherwise the loss of farmers will again increase and then the situation is very bad in coming month of these districts.

The irrigation project live storage data reflect that no one irrigation project has been sufficient live storage in the Beed, Dharashiv, Jalna, and Solapur districts of the state of Maharashtra. The Jayakwadi Irrigation project situated at Paithan District Chhatrapati Sambhajinagar is the lifeline of most part of the Marathwada subdivision but in year 2023 dam was only fill with 45.18 % of live storage on dated 30/09/2023. Due to less availability of water in the Jayakwadi dam its one of the major adverse effect on the farmers from Marathwada region whose farmland dependes on either irrigated by canal and or from lift irrigation from this irrigation project.

Another important irrigation project in Maharashtra i.e. Bhima it's also called as Ujani Dam which situated in the Solapur district which also deficit of live storage i.e. only fill 36.75 % as on dated 30/09/2023. This Bhima dam is lifeline of the Madhya Maharashtra including part of Pune, Solapur and Dharashiv district which is also a adverse effect on the farmers of this region whose farmland depends on this irrigation project. Two major projects from Beed district from the state of Maharashtra have 0 % live storage as of 30th September 2023 namely Borgaon Anjanapur and Sirsmarg. Also Majalgaon Dam is one of the Major Irrigation Projects which situated in Beed District is also deficiency water i.e. only 12.59 % live staorage was available on 30th September 2023. This indicates that Beed districts are suffering from crop loss as well as hydrological drought in the year 2023 as per data from the Water Resource Department. Three major projects from Dharashiv district and Two major projects from Latur district have also live storage is less than 25 as on dated 30/09/2023. In other hand Ahmadnagar District received less than 300 mm rainfall but most of the dams was fill with good live storage due the good quantity of rainfall received in their catchment areas. Sangli district also faces the same problem as the Marathwada region because in the district only have one major irrigation project i.e., Warna which was good storage i.e. 100.00. However most of the Sangli district farmland depends on monsoon rainfall where the irrigation facility is not available and ultimately this farmland is severely affected due the deficiency of rainfall in 2023. Table 2 shows that live storage of Major projects in the State of Maharashtra.

The authors has classified these major irrigation projects based on its live storage percentage on 30th September 2023 into 04 categories viz. Very Good Storage (>75%), Good Storage (50 -75%), Deficits Storage (25-50 %) and Large Deficits storage (less than 25 %). The live storage data of the irrigation projects from the Maharashtra state observed that the Marathwada region is suffering deficits of water storage on 30 September 2024 (i.e. 46. 20 %). The spatial map of percentage of deficiency/excess in actual rainfall in the various district of Maharashtra from the period 01/06/2023 to 10/09/2023 has depicuted in Fig. 6.A while and the spatial map of percentage of deficiency/excess in actual rainfall in the various district of Maharashtra from the period 01/06/2023 up to 30/09/2023 has depicted in Fig. 6 B.

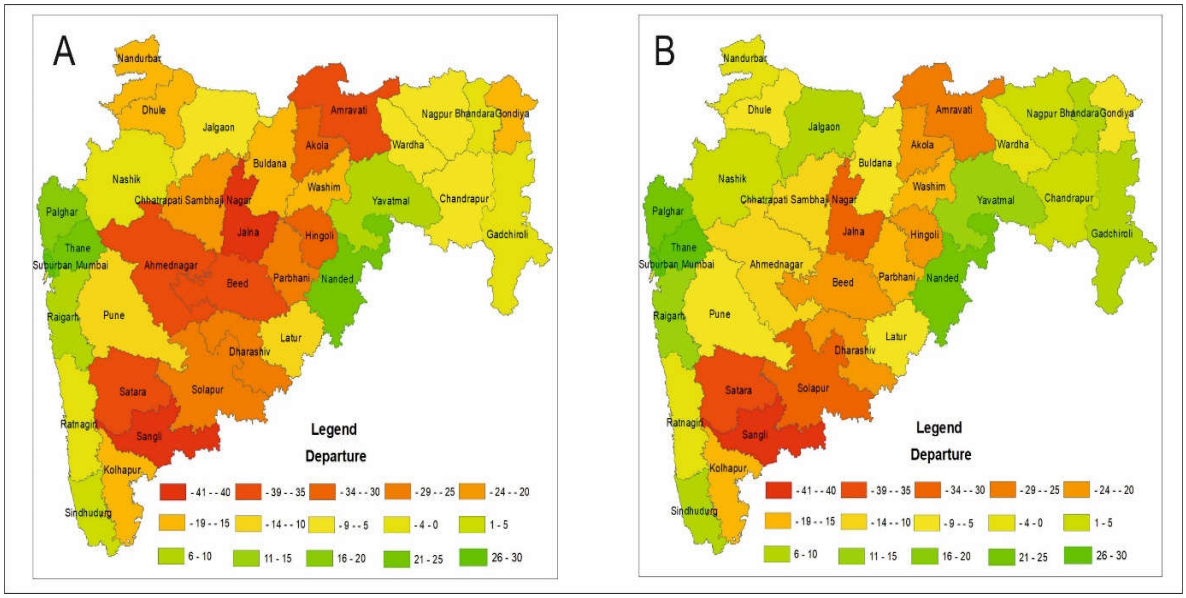

Figure 6: (A) Percentage of deficiency/excess in actual rainfall in the various district of Maharashtra from 01/06/2023 up to 10/09/2023; (B) Percentage of deficiency/excess in actual rainfall in the various district of Maharashtra from 01/06/2023 up to 30/09/2023

The Possible causes of 2023 drought in Maharashtra State

This year it is cyclone Biparjoy which has disturbed the monsoon flow and led to moisture diversion. Also, the monsoon current was itself weak (Kumar, 2023). IITM Pune, also told in their interview taken by media, the impact of the cyclone on delaying monsoon. They said that this type of weak monsoon situation also happened in 2019 that year's monsoon onset was most delayed in Pune in 2019 when it has arrived on 24 and this year it also arrived in last week of June. Both these year have common connections with cyclones in the ArabianSea. In 2019, Cyclone Vayu in the Arabian Sea disturbed the monsoon current flow leading to half in the monsoon progress in its initial phase and the same thing happened in 2023 monsoon delaying and week during its initial due to Cyclone Biparjoy. Another one more important cause of the weak monsoon in August because El Nina'seffects were strong during the second half of August even in half of September 2023.

Also this year El Nino effect is strongly correlateswith the weak monsoon in August and the first half of September 2023. The Director general, of India's meteorological department stated that El Nino phenomenon that developed in July has remained weak but has affected rainfall in August due tochanges in atmospheric conditions, they also said that the El Nino effect will turn moderate in September which suggests that good monsoon will be received in September (Mint, Business News, 29 August 2023). Mean El Nino effects are one of the causes of deficient rainfall in August in most parts of Maharashtra as well as part of India.

In Maharashtra, the state has received an average cumulative rainfall that falls within the normal range. However, despite this seemingly favorable meteorological condition, there exists a persistent long-term gap between the expected and actual rainfall patterns. This discrepancy has cast a shadow over the livelihoods of countless farmers across the region. As we move into the year 2023, Maharashtra is on the precipice of a looming agricultural crisis. The cumulative impact of years of insufficient rainfall has begun to take its toll on the agricultural sector, jeopardizing crop yields and the well-being of farming communities. Given the prolonged adversity faced by the agricultural community, we must recognize the situation as an agricultural drought. Doing so will facilitate targeted interventions and support measures to mitigate the hardships faced by the

state's farmers and ensure food security in the region.

In Maharashtra, the state has received an average cumulative rainfall (965 mm) against its average rainfall (994 mm) which falls within the normal range. The cumulative impact of years of insufficient rainfall has begun to take its toll on the agricultural sector, put at risk crop yields. Given the prolonged adversity faced by the agricultural community, we must recognize the situation as an agricultural drought. Doing so will facilitate targeted interventions and support measures to mitigate the hardships faced by the state's farmers and ensure food security in the region.

CONCLUSION

Based on received rainfall from 01/06/2023 to 30/09/2023 and the percentage of live storage in irrigation projects from the Beed, Jalna, Chhatrapati Sambhajinagar, Dharashiv, Parbhani, Hingoli and Latur districts from Marathwada subdivision were severely affected. Ahmadnagar, Sangli and Solapur district from Madhya Maharashtra and Akola and Amravati and Buldhana districts from Vidharbha subdivision is also affected due to deficiency of rainfall. During the monsoon season, most of cereals, pulses and food grains were cultivated as main crops in the state of Maharashtra. Sugarcane is also one of the important crops which are leading cash crops of farmers from Maharashtra. The area under sugarcane cultivation in the state of Maharashtra is about 13.5 lakh hectares. Also, Maharashtra is one of the leading fruit producer statesin the India. These all-crops productivity will be severely damaged due to deficient rainfall in the year 2023. Even rainfall received after 10/09/2023 it is only useful for the increase in the percentage of live storage in the irrigation projects. It will not be useful for saving the existing Kharif crops which was already severely damaged due to low soil moisture as on 10/09/2023. The cumulative effect of the scanty monsoon rainfall and very high cropping intensity indiscriminate use of groundwater for irrigation is pushing the water scare state towards the water deficit desert.

Acknowledgment

Authors acknowledged to the India Meteorological Department, Government of India and Water Resources Department Government of Maharashtra for easy accessible data of rainfall and dam live storage, respectively.

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