



Research Article

PYTHON-BASED RAINFALL ANALYSIS FOR INVESTIGATING SPATIAL VARIATION IN THE ONSET AND WITHDRAWAL OF MONSOON

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Abstract: The knowledge of onset of effective monsoon (OEM), its withdrawal and distribution of seasonal rainfall during monsoon month are essential for crop planning and management of rainfed farming. Daily rainfall data for the period 1998 to 2017 were analyzed for different talukas of Yavatmal district in Vidharbha region of Maharashtra state according to Ashok Raj (1979) for the study of OEM, withdrawal of monsoon and spatial variation maps for both parameters were developed. The average monsoon seasonal rainfall in different taluka stations varied from 556.75 mm to 890.64 mm with coefficient of variation of 25 to 49 percent. The mean dates of onset and withdrawal of effective monsoon varied from 18th to 29th June and 17th September to 4th October respectively at different taluka places in Yavatmal district. The average onset dates of the effective monsoon differ between early and delayed onset years, ranging from June 6th to June 14th for early onset years and from June 28th to July 14th for delayed onset years. Average date of withdrawal of monsoon during early and delayed withdrawal years varied from 31st August to 18th September and 9th to 19th October respectively. Spatial variation maps for mean dates of onset and withdrawal of effective monsoon in Yavatmal district were prepared which can be used for crop planning of the region. The mean date of starting of different category critical dry spells (CDS) varied in different monsoon months from 19th to 28th June, 13th to 24th July, 12th to 20th August and 6th to 19th September at different taluka places in Yavatmal district.

Keywords: OEM, Withdrawal, Spatial variation, Critical dry spells, Data analysis

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Introduction

Agriculture plays a dominant role in life of the majority of the rural population. In Indian situation, spatial and temporal variation of monsoon rainfall adversely affects the crop production. The greatest risk in agriculture production is attributed to the variability of seasonal rainfall, uncertainty in the amount of rainfall and its distribution in a given season. Drought occurrences are a common occurrence in various areas of the Vidharbha region in Maharashtra. With the increased utilization of water resources in recent years, there is a growing necessity for the prudent management of available rainwater to support agricultural practices and mitigate the risks associated with drought. Dry farming regions, among the diverse soil types in India, confront significant drought hazards, often resulting in low and unpredictable crop yields. The important characteristics of rainfall influencing agricultural production from rainfed areas are the date of onset of effective monsoon, the duration of dry spells, the time of occurrence of dry spells, the duration of wet spells and number of rainy days [1]. Knowledge of dry spells is important for crop planning in the given area and for planning of drought mitigation measures. Due to erratic and irregular rainfall pattern, crops suffer seriously and there is also a risk of crop failure under aberrant weather situation. There is a need for identifying onset of effective monsoon as the commencement of crop sowing rains in the district which is different from the premonsoon showers. Premonsoon rains cannot be considered as effective monsoon for agricultural operations, particularly for sowing of grains because these rains it followed by a long dry spell, may affect the germination of seeds resulting in crop failure when sowings are undertaken immediately after premonsoon showers. This study was conducted to generate information on spatial variation of onset and withdrawal of monsoon at taluka level and study of occurrence of dry spells in the district [2-10].

Material and Methods

The study of determination of OEM and its withdrawal at taluka level was undertaken in Yavatmal district which is situated between North latitude 19.26° to 20.42° and East longitude 77.18° to 79.90° and at an altitude of 445 m above MSL. The district has a geographical area of 13580 sq. km in western Vidharbha region of Maharashtra and is shown in [Fig-1]. Rainfall data spanning from 1998 to 2017, recorded at all 16 taluka stations within the Yavatmal district, as well as at various taluka stations neighboring the Yavatmal district from Nanded, Hingoli, Washim, Amravati, Wardha, and Chandrapur districts, were acquired from the official website of the Maharashtra State Government (www.mahaagri.gov.in/raifall). Daily pan evaporation data which was available for Yavatmal station for study period was obtained from Agro-Meteorological, Observatory, Department of Agronomy, Dr. PDKV, Yavatmal [11-15].

Onset of effective monsoon

The onset and end dates of the effective monsoon were estimated by conducting rainfall data analysis for various taluka locations, using a Python program formulated by adopting the concept developed by Ashok Raj (1979) [6] for the determination of the onset of effective monsoon and dry spells. According to this concept, the date of commencement of a seven days spell satisfying following three criteria was taken as the date of onset of effective monsoon.

- The first day's rain in the seven day spell should be more than the average daily evaporation (e) of the place.
- The total rain during the seven days spell should be at least $5e + 10$ mm.
- At least four out of these seven days should be rainy day(s) having rainfall more than or equal to 2.5 mm.

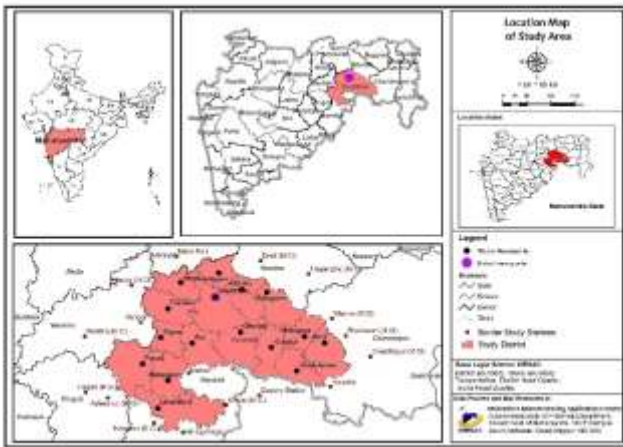


Fig-1 Location map of study area

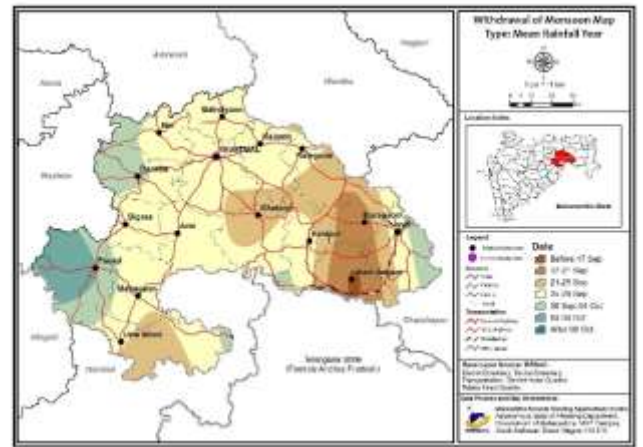


Fig-3 Spatial variation in mean date of withdrawal of monsoon in different talukas of Yavatmal district

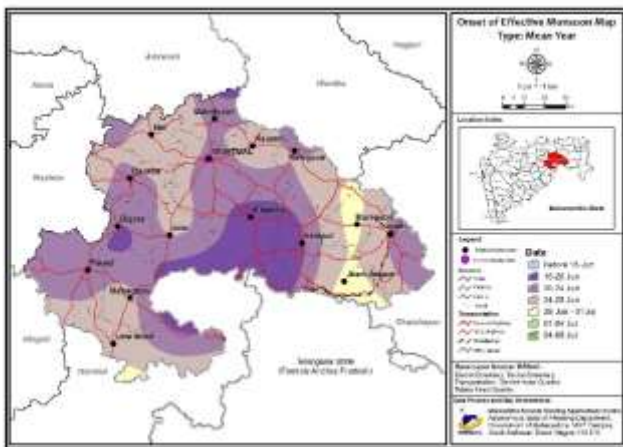


Fig-2 Spatial variation in mean date of onset of effective monsoon in different talukas of Yavatmal district

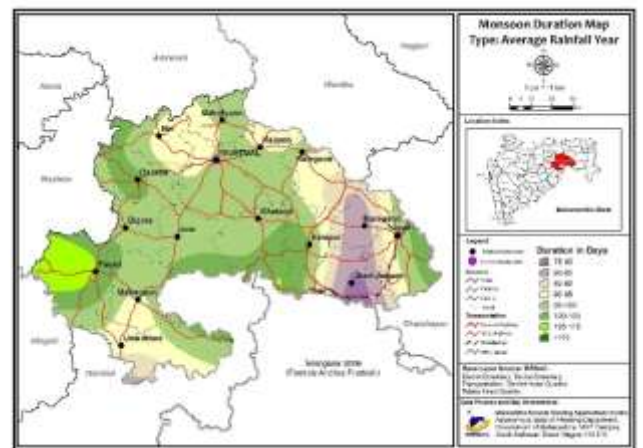


Fig-4 Spatial variation in average monsoon duration at different talukas in Yavatmal district

Statistical characteristics

Rainfall data were analyzed for following parameters viz., average, variance, standard deviation and coefficient of variation.

Withdrawal of monsoon

The withdrawal of monsoon was decided as the end of last wet spell in the last week of September, which may sometimes extended upto middle of October, depending upon the delayed pattern of withdrawal of Northwest winds in respective years.

Determination of dry spells

The dry spells were determined using python programme formulated by adopting the criteria suggested by Ashok Raj (1979). The period between the conclusion of the onset of the productive monsoon and the occurrence of another day with rainfall reaching or exceeding 5 mm, or the initiation of another continuous 7-day rainy period meeting the previously mentioned criteria, resulting in a cumulative rainfall of 5 mm or more, is termed as the initial dry spell. If the duration of such dry spell exceeds a certain value depending on the crop-soil complex of the region, this dry spell is called as the first critical dry spell; otherwise, this spell is included in the first wet spell. Likewise subsequent critical dry spells were determined by considering the duration limit of 11 days for this region according to Pawade (1982) [17].

Result and Discussions

Seasonal rainfall analysis

The monsoon seasonal rainfall during kharif season was estimated by taking the total of daily rainfall received from June to September or October considering the withdrawal of monsoon.

[Table-1] exhibits the seasonal precipitation data for various talukas in the Yavatmal district spanning a period of 20 years from 1998 to 2017.

It is revealed from [Table-1] that the average seasonal rainfall in different talukas of the Yavatmal district ranges from 556.75 to 890.64 mm with coefficient of variation in the range of 25 to 49 per cent. Ralegaon taluka experienced highest seasonal rainfall (1653.00 mm) during 2005. The highest average seasonal rainfall was observed at Ralegaon (890.64 mm) followed by Kelapur (872.53) and Ghatanji (869.90 mm). Amongst different talukas, Arni and maregaon shows highest coefficient of variation of 49 and 42 per cent respectively.

The dates of onset and withdrawal of monsoon for the study period at Yavatmal taluka is presented in [Table-2]. The onset of effective monsoon varies from 3rd June to 20th July. The mean date of onset of effective monsoon for Yavatmal taluka was found to be 23rd June with a standard deviation of 12 days. The earliest and delayed probable ($P=0.68$) OEM date is 10th June and 5th July respectively. The withdrawal date of effective monsoon in Yavatmal taluka was observed in between 31st August to 19th October. The mean date of withdrawal of monsoon is 26th September.

The results from the analyzed daily rainfall data for remaining talukas of Yavatmal district [Table-3] revealed that, the onset of effective monsoon in Arni taluka varies from 4th June to 25th July with mean date of onset of effective monsoon as 24th June ($SD = 14$ days). The earliest and delayed probable date ($P = 0.68$) of OEM is 10th June and 8th July respectively and the withdrawal date of monsoon varies in between 31st September and 24th October. The mean date of withdrawal of monsoon is 28th September.

The average date of earliest, mean and delayed onset of effective monsoon and withdrawal of monsoon at different taluka places of Yavatmal district as presented in [Table-3] indicated 4 to 12 days and 4 to 14 days variation in average date of onset and withdrawal of monsoon at different taluka stations.

Table-1 Seasonal rainfall (mm) at different talukas in Yavatmal district

Year	Yavatmal	Arni	Babulgaon	Darwha	Digras	Ghatanji	Kalamb	Kelapur	Maregaon	Mahagaon	Ner	Pusad	Ralegaon	Umarkhed	Wani	Jhari-Jamni
1998	701.40	693.70	755.70	734.60	679.00	851.25	844.80	776.42	603.97	883.03	956.00	789.10	886.01	604.00	809.31	594.63
1999	962.50	934.70	828.60	961.90	1205.00	915.40	905.90	977.18	612.66	870.70	874.40	990.10	1045.66	556.74	817.22	489.30
2000	613.00	811.50	743.50	917.50	895.20	884.00	556.60	885.00	644.00	641.00	1146.50	1131.30	1096.00	445.80	820.00	408.00
2001	931.50	656.50	876.10	909.20	827.70	817.00	740.10	887.94	567.56	828.64	720.10	979.20	943.86	490.68	761.60	420.08
2002	1078.80	604.00	690.00	995.80	887.40	1090.00	1174.00	1059.00	560.80	1038.90	405.00	1163.30	1023.00	597.70	658.30	566.00
2003	992.80	395.00	746.20	585.00	687.00	1115.00	1105.00	1169.00	769.00	1060.00	336.00	923.20	939.00	776.20	887.30	551.00
2004	593.40	279.10	418.80	433.70	438.00	430.00	389.10	781.00	329.00	438.40	310.00	360.20	517.30	325.50	505.10	331.50
2005	1104.10	556.00	813.10	855.60	847.00	1059.16	1187.00	996.06	762.50	1181.88	544.66	969.16	1653.00	640.33	1216.40	590.83
2006	1107.30	658.60	789.30	1066.00	1161.00	1175.00	1195.00	854.90	1074.00	950.00	895.20	1018.60	1132.10	835.10	1044.90	672.80
2007	865.90	460.10	772.00	803.50	788.00	1027.00	888.10	975.00	1197.00	932.50	697.00	673.50	1108.00	686.00	951.50	515.60
2008	678.40	495.00	449.50	546.70	473.10	753.00	422.00	616.10	1207.20	690.60	539.20	861.40	987.20	552.40	812.80	584.40
2009	463.00	301.10	366.50	360.80	637.70	500.20	256.00	646.50	521.00	566.70	417.00	552.10	695.20	574.40	483.00	381.70
2010	971.80	650.50	888.00	1027.00	1144.00	1462.00	708.00	1084.00	1440.00	1027.00	870.00	1203.80	1349.00	756.00	1332.00	813.00
2011	836.40	495.40	748.10	698.40	843.00	774.00	576.30	836.30	1062.00	839.40	887.00	816.00	860.00	863.00	793.00	534.00
2012	996.80	1257.00	884.40	776.00	899.40	1012.00	847.00	1243.00	884.60	839.00	754.10	962.00	776.50	732.00	1021.90	642.00
2013	974.70	1650.30	811.30	750.70	1098.40	1243.90	783.20	1385.30	1183.10	1403.90	821.60	973.70	1014.60	1416.70	1237.60	914.60
2014	517.30	451.10	601.20	578.70	493.40	502.50	638.20	516.10	488.70	355.10	512.50	378.60	365.90	437.60	484.50	548.40
2015	479.10	573.80	424.20	472.50	451.90	525.30	469.80	579.30	372.00	442.40	507.50	565.70	424.80	374.70	522.90	430.40
2016	602.80	811.60	658.30	635.70	816.20	754.70	627.50	673.40	681.80	957.60	716.20	851.10	595.90	641.40	980.20	687.50
2017	366.10	483.00	491.40	386.30	484.20	506.50	314.60	509.10	442.00	303.70	454.70	624.30	399.80	410.70	457.50	459.20
Average	791.86	660.90	687.81	724.78	787.83	869.90	731.41	872.53	770.14	812.52	668.23	839.32	890.64	635.85	829.85	556.75
SD	237.80	323.99	169.51	219.08	244.64	283.80	289.98	243.39	320.05	286.43	232.78	243.99	326.23	238.21	262.18	143.18
CV	30.03	49.02	24.64	30.23	31.05	32.62	39.65	27.89	41.56	35.25	34.84	29.07	36.63	37.46	31.59	25.72

Table-2 Dates of onset and withdrawal of effective monsoon for Yavatmal taluka

Year	Onset	Withdrawal
1998	04-Jul	29-Sep
1999	15-Jun	12-Oct
2000	03-Jun	15-Oct
2001	11-Jun	04-Oct
2002	18-Jun	19-Oct
2003	23-Jun	31-Aug
2004	13-Jul	07-Sep
2005	24-Jun	19-Oct
2006	25-Jun	02-Oct
2007	13-Jun	24-Sep
2008	20-Jul	22-Sep
2009	29-Jun	07-Sep
2010	16-Jun	18-Sep
2011	03-Jul	16-Sep
2012	16-Jun	13-Sep
2013	07-Jun	06-Oct
2014	12-Jul	11-Sep
2015	19-Jun	21-Sep
2016	19-Jun	10-Oct
2017	22-Jun	13-Oct
Mean	23-Jun	26-Sep

Table-3 The average dates for the earliest, median, and delayed onset and withdrawal of the productive monsoon in various talukas within the Yavatmal district are documented

Taluka place	Average date of onset of effective monsoon			Average date of withdrawal of effective monsoon		
	Earliest	Mean	Delayed	Earliest	Mean	Delayed
Arni	10-Jun	24-Jun	08-Jul	12-Sep	28-Sep	14-Oct
Babulgaon	10-Jun	23-Jun	05-Jul	11-Sep	26-Sep	12-Oct
Darwha	09-Jun	23-Jun	07-Jul	17-Sep	30-Sep	13-Oct
Digras	10-Jun	20-Jun	30-Jun	08-Sep	26-Sep	15-Oct
Ghatanji	09-Jun	18-Jun	28-Jun	01-Sep	24-Sep	17-Oct
Kalamb	12-Jun	25-Jun	08-Jul	10-Sep	28-Sep	15-Oct
Kelapur	10-Jun	19-Jun	28-Jun	14-Sep	26-Sep	09-Oct
Mahagaon	10-Jun	24-Jun	09-Jul	09-Sep	26-Sep	14-Oct
Maregaon	14-Jun	29-Jun	13-Jul	31-Aug	20-Sep	11-Oct
Ner	11-Jun	26-Jun	11-Jul	08-Sep	27-Sep	17-Oct
Pusad	06-Jun	21-Jun	05-Jul	18-Sep	04-Oct	19-Oct
Ralegaon	06-Jun	23-Jun	11-Jul	08-Sep	26-Sep	15-Oct
Umarkhed	13-Jun	26-Jun	10-Jul	07-Sep	26-Sep	15-Oct
Wani	13-Jun	23-Jun	03-Jul	08-Sep	28-Sep	18-Oct
Yavatmal	10-Jun	23-Jun	05-Jul	11-Sep	26-Sep	12-Oct
Jhari-Jamni	14-Jun	29-Jun	14-Jul	31-Aug	17-Sep	04-Oct

Critical dry spell analysis

The duration of dry spells at Yavatmal taluka place as presented in [Table-4], revealed that it varied from 11 to 40 days in different monsoon months. The total number of dry spells at Yavatmal taluka varied from one to three during different years of the study period. The average number of critical dry spells (CDS) at Yavatmal taluka is 2. The average CDS in different monsoon months starts from June, 25th with duration of 19th days, July, 18th with duration of 17th days, August, 13th with duration of 23th days and September, 19th with duration of 22th days. Similarly, the critical dry spells in different taluka places in Yavatmal district also varies from 1 to 4 in number with an average of 2 CDS, which are in confirmation with the results of Chavhan (2018). [Table-5] displays the average dates of significant dry spells across various talukas in the Yavatmal district during different monsoon months.

The result presented in [Table-5] revealed that, the number of critical dry spells at Arni station varies from 1 to 4 during different years. The average number of CDS comes out to be 2. At Arni station the CDS during different monsoon months starts

from June, 24 having mean duration of 17 days, July, 26 having mean duration of 19 days, August, 15 having mean duration of 27th days and September, 8 having mean duration of 30th days. For Babulgaon station, the number of critical dry spells varies from 1 to 3 during different years. The average number of CDS comes out to be 2 and the CDS during different monsoon months starts from June, 26 having mean duration of 18 days, July, 18 having mean duration of 17 days, August, 13 having mean duration of 23 days and September, 19 having mean duration of 23 days.

The number of CDS events during different monsoon months indicated a specific trend of higher number of events in the month of August followed by other monsoon months. The spatial variation in onset of effective monsoon during mean onset years as shown in [Fig-2] clearly indicates the early beginning during 16th to 20th June on southern side of the district in Ghatanji, Kelapur and parts of Arni and Umarkhed taluka which spreads in east, north and west direction in surrounding talukas and on eastern side on the district in Wani and part of Maregaon and Jhari-Jamni taluka by 28th June.

Table-4 Critical dry spell distribution during different years in Yavatmal taluka

Year	Critical Dry Spells(CDS)								No. of CDS
	June		July		August		September		
	Date	Days	Date	Days	Date	Days	Date	Days	
1998			10-Jul	14					1
1999	25-Jun	18			11-Aug	26			2
2000			23-Jul	17	27-Aug	30	27-Sep	17	3
2001	21-Jun	18			26-Aug	36			2
2002	30-Jun	19	20-Jul	12			07-Sep	40	3
2003									0
2004					07-Aug	29			1
2005					09-Aug	29	25-Sep	20	2
2006			06-Jul	12	17-Aug	21	20-Sep	11	3
2007					05-Aug	25			1
2008					12-Aug	14			1
2009			23-Jul	28					1
2010									0
2011									0
2012					06-Aug	11			1
2013					04-Aug	17			2
					27-Aug	13			
2014					08-Aug	14			1
2015	24-Jun	24			15-Aug	30			2
2016					14-Aug	31			1
2017	29-Jun	14	30-Jul	20	21-Aug	18			3
Mean	25-Jun	19	18-Jul	17	13-Aug	23	19-Sep	22	2

Table-5 Mean starting date and duration (days) of critical dry spells during monsoon months in different talukas of Yavatmal district

Taluka place	Date and duration of critical dry spell (CDS) during monsoon months								Avg. No of CDS per year
	June		July		August		September		
	Date	Days	Date	Days	Date	Days	Date	Days	
Arni	24-Jun	17(5)*	16-Jul	19(12)	15-Aug	27(15)	08-Sep	30(4)	2
Babulgaon	26-Jun	18(5)*	18-Jul	17(6)	13-Aug	23(15)	19-Sep	23(4)	2
Darwha	24-Jun	21(5)*	15-Jul	18(11)	14-Aug	23(16)	11-Sep	24(7)	2
Digras	23-Jun	19(6)*	16-Jul	20(10)	13-Aug	22(13)	16-Sep	21(8)	2
Ghatanji	23-Jun	17(7)*	20-Jul	17(9)	18-Aug	22(11)	18-Sep	20(7)	2
Kalamb	23-Jun	18(3)*	15-Jul	22(6)	12-Aug	22(13)	14-Sep	26(6)	1
Kelapur	24-Jun	15(3)*	17-Jul	18(6)	20-Aug	21(13)	11-Sep	20(5)	1
Mahagaon	19-Jun	21(5)*	22-Jul	18(7)	14-Aug	24(12)	12-Sep	28(5)	1
Maregaon	28-Jun	29(2)*	24-Jul	16(4)	16-Aug	20(9)	16-Sep	17(5)	1
Ner	24-Jun	22(4)*	20-Jul	20(8)	15-Aug	21(17)	17-Sep	21(8)	2
Pusad	23-Jun	20(5)*	17-Jul	17(9)	14-Aug	21(12)	14-Sep	20(11)	2
Ralegaon	21-Jun	22(3)*	16-Jul	16(7)	12-Aug	18(8)	11-Sep	19(11)	1
Umarkhed	23-Jun	24(4)*	16-Jul	22(6)	17-Aug	25(8)	06-Sep	31(6)	1
Wani	26-Jun	24(3)*	14-Jul	16(7)	18-Aug	27(7)	14-Sep	25(8)	1
Yavatmal	25-Jun	19(5)*	18-Jul	17(6)	13-Aug	23(15)	19-Sep	22(4)	2
Jhari-Jamni	22-Jun	16(2)*	13-Jul	20(8)	12-Aug	24(10)	13-Sep	27(3)	1

Late start of monsoon by 28th to 1st July was observed in central part of Jhari-Jamni and Maregaon taluka. Such spatial information on variation in starting of rainy season can be useful for planning of land preparation work, seed material availability and rainfed crop sowing operations and crop planning in general in different talukas of Yavatmal district.

Spatial variation in withdrawal dates of monsoon

The spatial variation of withdrawal of monsoon during mean withdrawal year as shown in [Fig-3.] indicate early withdrawal from Jhari-Jamni and Maregaon taluka before 17th to 21st September followed by parts of Wani, Maregaon, Kelapur, Ralegaon, Ghatanji, Yavatmal and Umarkhed taluka by 21st to 25th September. While normal withdrawal from 25th September to 29th September is observed in most of talukas in Yavatmal district except Pusad taluka and parts of Darwha and Wani talukas where withdrawal occurs slightly late by 4th to 8th October.

Spatial variation in average monsoon duration

The spatial variation of average monsoon duration in Yavatmal district is depicted in [Fig-4]. From [Fig-4], it is revealed that average monsoon duration (in days) at different talukas of Yavatmal district ranges from 75 days to more than 110 days and the monsoon duration of less than 95 days was mostly observed in areas of Jhari-Jamni, Maregaon, Wani and Ralegaon talukas. On an average the monsoon duration of 95 to 100 days was observed over most of the area of Digras, Mahagaon, Arni, Darwha, Yavatmal, Babulgaon, Kalamb, Ghatanji, and Kelapur taluka while same monsoon duration was observed partially in Umarkhed, Ner, Ralegaon and Wani taluka of Yavatmal district. Maximum area of Pusad taluka has longest monsoon duration ranging in between 100 to 110 days in Yavatmal district.

Conclusion

The mean dates of onset and withdrawal of effective monsoon varied from 18th to 29th June and 17th September to 4th October respectively at different taluka

places in Yavatmal district. Average date of onset of effective monsoon during early and delayed onset years varied from 6th to 14th June and 28th June to 14th July respectively. Average date of withdrawal of monsoon during early and delayed withdrawal years varied from 3rd August to 18th September and 4th to 19th October respectively. Spatial variation maps for mean dates of onset and withdrawal of effective monsoon in Yavatmal district were prepared which can be used for crop planning of the region. The mean date of starting of different category critical dry spells (CDS) varied in different monsoon months from 19th to 28th June, 13th to 24th July, 12th to 20th August and 6th to 19th September at different taluka places in Yavatmal district. This information regarding monsoon duration can be very much useful for selection of crop varieties in different villages of various talukas of the district.

Application of research:

1. For crop planning.
2. To plan contingent irrigation.

Research Category: Geoinformatics, Remote Sensing, Artificial Intelligence(Python built program)

Abbreviations: OEM - Onset of effective monsoon, CDS - Critical dry spell
MSL - Mean sea level, SD - Standard deviation

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****Principal Investigator or Chairperson of research: Dr G.U. Satpute**

University: Dr Panjabrao Deshmukh Krishi Vidyapeeth, 444104, India
Research project name or number: MTech Thesis

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Yavatmal district (MS)

Cultivar / Variety / Breed name: Nil

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

Ethical Committee Approval Number: Nil

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