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Assessment of Wet and Dry Spells Over North Western Zone of Tamil Nadu Using WASP

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Rainfall is the most dependent weather factor that decides the success or failure of a crop in a location. The behaviour of rainfall plays a major role in the selection of crop, cropping system and cropping pattern. It is also essential for planning of water resource management structures. Hence it is essential to study the anomaly in rainfall over a long period of time to identify the deviation in rainfall pattern over the region. Weighted Anomaly of Standardized Precipitation Index (WASP) is an index that can help in identifying the occurrence of dry or wet spells over different time scales (tri, hexa, nona and dodeca-monthly). The analysis was carried out for Salem district of Tamil Nadu over a period of 30 years (1991-2020) which has an average rainfall of 990 mm per year with bimodal distribution. The analysis shows an increase in near normal events, decrease in wet as well as dry events with 3 m, 6 m, 9 m and 12 m WASP. The 3 m-WASP indicates the north east monsoon have more variability in rainfall since more number of wet as well as dry events have occurred during this season. With 6 m WASP During, in all the 3 decades, the consecutive wet as well as dry events have been occurred during the winter and NE monsoon seasons. This shows the risk in crop cultivation during NEM season because of higher instability in rainfall. Considering the longer time scale of 9 m and 12 m WASP indicates the occurrence of prolonged extreme dry or extreme wet events to be very minimal. The negative effects of these events can be handled easily

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by adopting proper drainage, water harvesting and storage structure within the farms. These structures can also help in recharging the ground water table in addition to supplementing water needs for the crops.

Keywords: Crop planning; dry events; rainfall; Salem district; WASP; water harvesting; wet events.

1. INTRODUCTION

For sustaining agricultural productivity, rainfall is the most dependent weather parameter. Salem is a district that has bimodal rainfall. Salem is one of eight drought prone areas in Tamil Nadu [1]. There are four components that exhibits drought occurrence, its nature and severity. Those are rainfall, ground water level, water storage in reservoirs and the last is the crop condition [2]. The foremost is the rainfall, proper understanding about the distribution and probabilities of occurrence of extreme events is essential for crop planning as well as designing of water storage structures [3].

Sometimes the failure of crop is due to the severe droughts but majority of cases is due to lack of knowledge about the possibilities of dry spells as well as wet spells during the cropping season [4]. One another many reason is lack of proper water management viz., collection of excess run off during occurrences of wet spells and creation of localised storage structures to supplement the precipitation during dry spells [5].

Salem is a district that bimodal rainfall and also short term as well as prolonged dry spells and wet spells that affect the cultivation of crops are common. The possibility of predicting the occurrence with higher accuracy is difficult because of the higher variability in rainfall distribution, pattern, soil type and source of water availability for supplementing the crops. This in turn affects the socio economic quality of the farming community as well as food security. Also the ground water source of Salem district is not uniformly distributed [6-8]. Looking into the agricultural in terms of hydrological sources over Salem district and the importance of dry and wet spells in crop production, a study on the rainfall distribution for analysing the possibility of occurrence of dry and wet spells over different time slices is important [9].

There are a number of indices used for studying the rainfall deficit as well as excess over a region, WASP (Weighted Anomaly of Standardized Precipitation) is one of the simple index that can be used for studying the rainfall deficit as well as excess over the region with the long the monthly rainfall data at different time scales [10]. WASP can also be used to analyse the severity, duration as well as magnitude of dry and wet events [11]. The only short come is the requirement of minimum of 25 years of data for analysis. The advantage is that this index gives weightage for each month instead using annual averages over the months [12]. Also, the factor *Pi*/PA helps in highlighting the anomalies over the rainfall season. With the help of this index that is calculated over different scales, the possibility of occurrence of deficit or the excess of rainfall over short as well as long duration crops duration crops can be analysed. This kind of analysis is needed to understand the slowly evolving drought on crop production and water resources. Also the impact of wet and dry spells on the hydrological sources and need for development in the storage structures can also be spelled out. Hence, considering the above terms this index is taken for the study.

2. MATERIALS AND METHODS

2.1 Study Area

The Salem district is located between 11^{o} 14`N and $12^{o}$53`N latitude and between 77^{o}44` and $78^{o}$ 50`E longitude with a mean sea level of 278 m. The climate over this region is tropical sub humid with bimodal rainfall pattern. This district is one of the largest districts of Tamil Nadu with 20 blocks. The historical rainfall data is taken from the ordinary rain gauge that is installed at 11.65121 degree North latitude and 78.14531 degree East longitude is taken for the analysis.

The 30 years monthly rainfall data from January 1991 to December 2021 was taken for the study.

2.2 Weighted Anomaly of Standardized Precipitation index (WASP)

The Weighted Anomaly of Standardized Precipitation index as proposed by Lyon and Barnston [13] is considered for the study. The formula for calculation of WASP is:

$$\mathrm{WASP}_N = \frac{\mathrm{SUM}N}{\sigma_{\mathrm{SUM}N}}$$

$$\mathrm{SUM}_N = \sum_{i=1}^{N} \left(\frac{P_i - \bar{P}_i}{\sigma_i}\right) \frac{\bar{P}_i}{\bar{P}_A}$$

in which

P_i is the observed monthly precipitation,

$\overline{P_i}$ is the precipitation baseline climatology (1991−2021) for the *i*th month with respect to the month/year that is actually being computed,

σ_i is the monthly precipitation standard deviation and

P_A is the mean annual precipitation for a given grid point.

The SUM_N for a given *N*th month is obtained considering the preceding *N* months (where *i*=1 is the first, *i*=2 is the second, …, *i*=*N* is the current month). The WASP-Index allows a qualitative classification of dry and wet severity through its values, as described in Table 1. The time frequency of droughts affecting Coimbatore district will be assessed for four tri-decadal time periods.

Table 1. WASP-Index values and their corresponding classifications

WASP	Interpretation
WASP ≤-2	Severely dry
-2 < WASP <-1	Moderately dry
-1 ≤ WASP ≤ 1	Near Normal
1 < WASP < 2	Moderately wet
WASP ≥ 2	Severely wet

2.3 Intensity, Severity and Frequency of Dry/Wet Event

The magnitude of WASP index for each month defines the intensity of the event.

Severity of dry spells is calculated if there are 3 or more consecutive dry or wet events.

The probability of occurrence of dry or wet event is called as frequency of the event. The frequency of the occurrence of an event can be calculated using the formula,

$$Probability\ \% = \frac{Number\ of\ dry/wet\ months}{Total\ number\ of\ months} x100$$

3. RESULTS AND DISCUSSION

3.1 Rainfall Fluctuation (1991-2020)

The variation annual rainfall over Salem district is represented in the Fig. 1. The average annual rainfall over the study region of Salem district is 990 mm. There exist a slight decreasing trend in the total annual rainfall but the r-square value is not significant.

The normal seasonal rainfall over the study region is 5 mm, 173 mm, 484 mm and 328 mm during winter, summer, South West and North East Monsoon seasons, respectively (Fig. 2). There is a decreasing trend in rainfall during winter and NEM seasons; an increasing trend during South West and Summer seasons. But these trends are not statistically significant.

Considering the month wise distribution, the rainfall starts with April, reaches a peak during May, decreases till June and then again increases till October. Finally drops during December. This shows a good distribution in rainfall during all the seasons except winter months (Fig. 3).

3.2 3m-WASP

The number of extreme dry and extreme wet events during the 30 years period is 11, Moderate wet events is 34 and moderate dry events is 24. Seeing the overall scenario the number of wet events is more than that of dry events and is given in the Table 2. The results reveals that the number of near normal events are increasing from 1991-2000 to 2011-2020, with reduction in number of dry as well as events over the decades.

During the period of 30 years, in winter season there is only 2 wet events and all other month exhibit near normal. Summer season has recorded only one wet and no dry events. This might be due to summer rains or pre monsoon showers.

There are 11 moderate dry events and one extreme dry event in South West Monsoon during 1991-2020 and this is noticed to occur during either August or September months. There are 15 moderate wet events and 2 extreme wet events in the SWM period during the 30 year period. Out of these 17 wet events 12 have occurred during August and September months. This shows that during the South West Monsoon season the August and September months have higher variability in rainfall (Fig. 4).

During 1991-2020, North-east monsoon season (October to December) accounts for 12 extreme dry events out of 13 extreme dry events that have occurred during the entire period. 15 moderate wet events out of 33 moderate wet

events and 10 extreme wet events out of 12 extreme wet events have occurred during the North East Monsoon season. This shows that this is the season during which both water shortage as well as excess rainfall has been experienced in the past 30 years (Fig. 5).

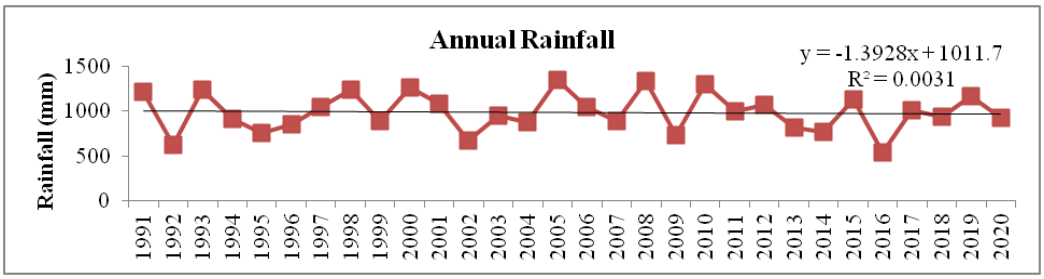

Fig. 1. Historical annual rainfall data over Salem

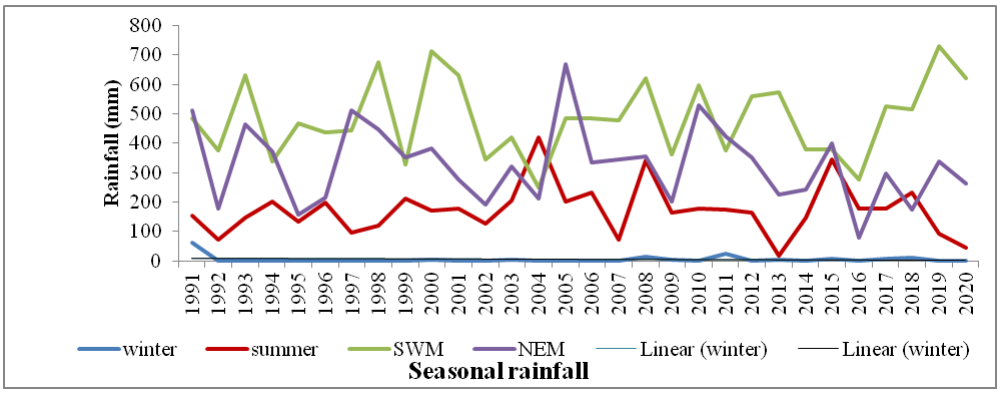

Fig. 2. Trend in seasonal rainfall over 30 years

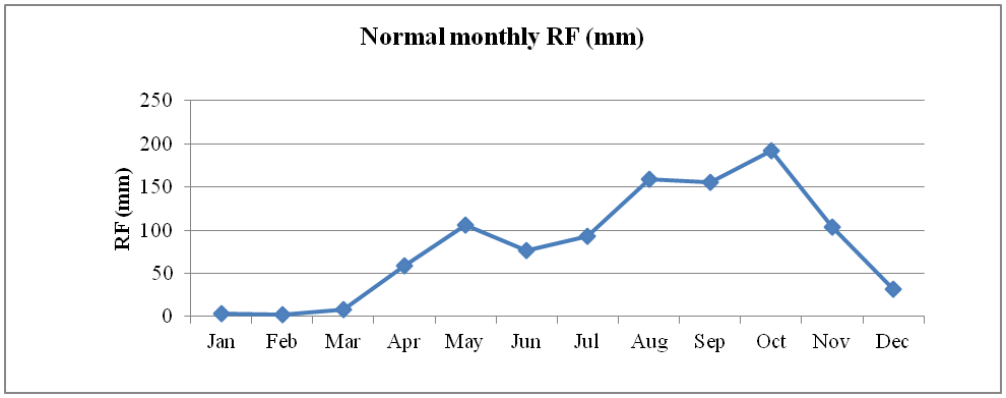

Fig. 3. Monthly rainfall normal (30 years average) over the study region

Table 2. Number of wet and dry events during 30 years (1991-2020) and decadal time scales (number in brackets is the probability of occurrence) with 3 m-WASP

	1991-2020	1991-2000	2001-2010	2011-2020
Extremely wet	12 (3.3)	6 (5)	4 (3.3)	2 (1.7)
Moderately wet	33 (9.2)	12 (10)	10 (8.3)	11 (9.2)
Near normal	277 (76.9)	83 (69.2)	96(80.0)	95 (79.2)
Moderately dry	23 (6.4)	9 (7.5)	7 (5.8)	7 (5.8)
Extremely dry	13 (3.6)	5 (4.2)	3 (2.5)	5 (4.2)

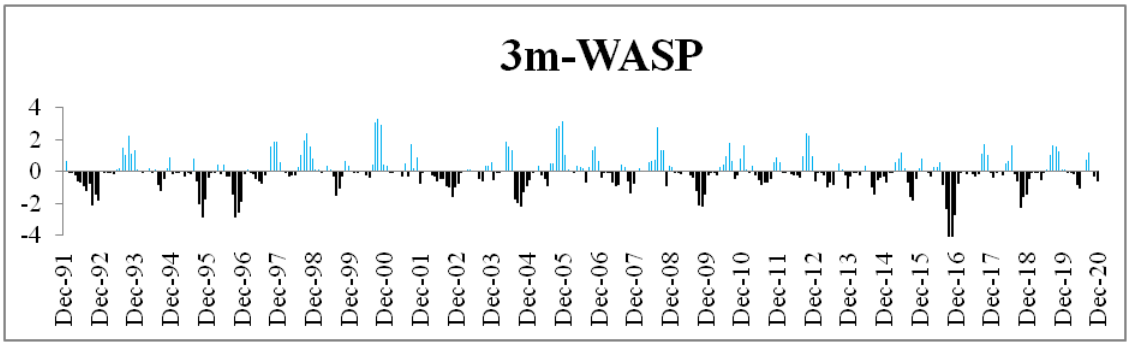

Fig. 4. The wet and dry spells over 30years periods with 3m-WASP

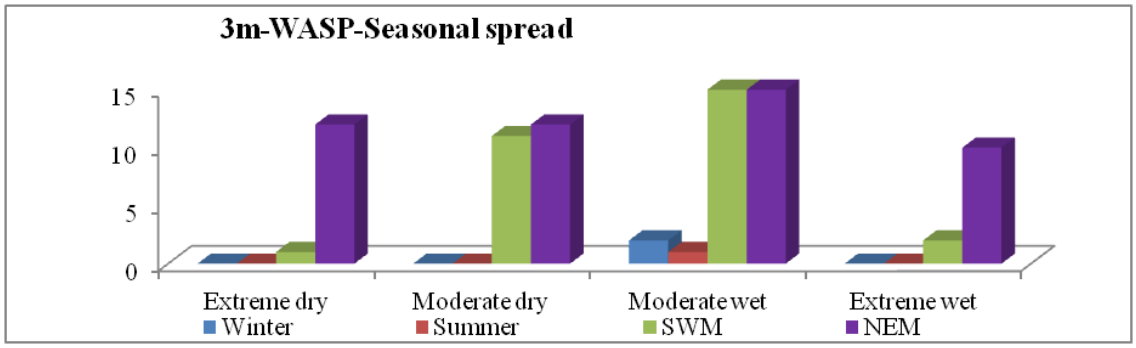

Fig. 5. Occurrence dry and wet events over different seasons with 3m-WASP

During the 30 years period, the number consecutive (3 months) dry event is 7 and consecutive dry events are 10. The decadal occurrence of consecutive events is presented in the Table 3. Looking into the decadal split the number of consecutive wet as well as dry events is found to reduce and also it is clear that the number of consecutive wet events to be higher at all the period. Most of consecutive wet or dry events have occurred during September to December months i.e. the North East Monsoon season [14]. This shows that these are months in which the variability in rainfall is higher and is mostly prone to short term drought as well as flood. So, proper prior contingency management strategies has to be planned to mitigate water shortage and also proper storage structures has to be erected to save the excess run off.

3.3 6m-WASP

The number of extreme wet events during the 30-year time slice is 10 and a moderate wet event is 47. Whereas the number of extreme dry events is 11 and moderate dry events is 32. This shows that the number wet events are more than the number of dry events. As in case of $WASP_3$, in six month time scales calculation of WASP also the numbers of near normal events are increasing while there is no trend in extreme wet or dry events. Whereas there exist a decreasing trend in moderate wet and moderate dry events. The distribution of wet and dry events over the 30 years of period is represented in the Fig. 6.

Out of 11 extreme dry events 7 have occurs during winter and 4 during NEM. Out of ten extreme wet events 3 occurs during winter and 5 during NEM season. More than 90 per cent of near normal events have occurred between April to September months over 30 years of time period. The decadal spread has been presented in the Table 4. This shows the instability in rainfall distribution during the winter and NE monsoon seasons. From the result it would also be concluded that during the south west monsoon season the rainfall is distributed well and hence the number of near normal events are more during this season when compared to that of the other three seasons. Also during the SWM season the number of moderate dry events are only two, moderate wet are 6 and only one extreme wet event over a period of 6 months' time slice is noticed. The number of dry and wet events distributed over different seasons is depicted in the Fig. 7.

Table 3. Decadal occurrence of 3 consecutive events for $WASP_3$

	1991-2020	1991-2000	2001-2010	2011-2020
Consecutive dry spells	7	3	2	2
Consecutive wet spells	10	5	3	2

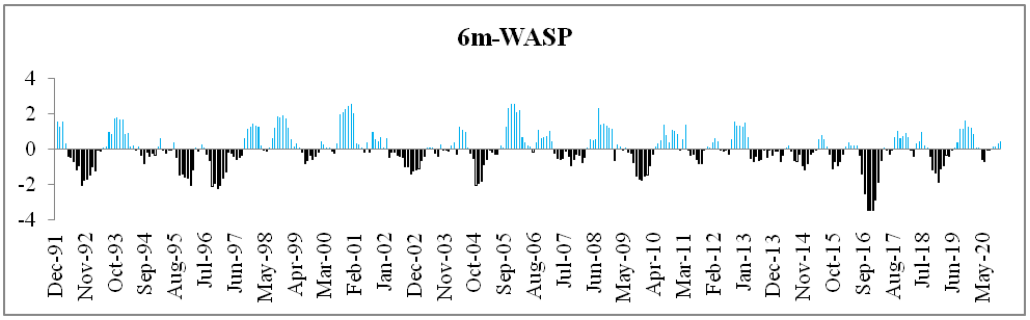

Fig. 6. The wet and dry spells over 30years periods with 6 m-WASP

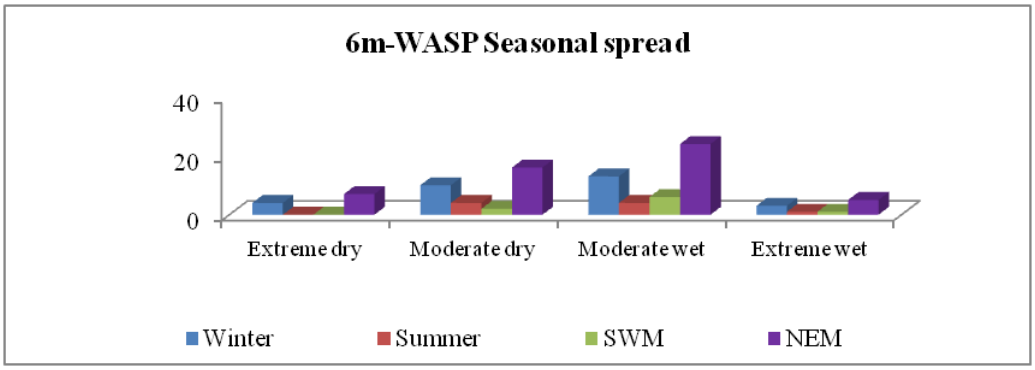

Fig. 7. Occurrence dry and wet events over different seasons with 6m-WASP

Table 4. Number of wet and dry events during 30 years (1991-2020) and decadal time scales (number in brackets is the probability of occurrence) with 6m-WASP

	1991-2020	1991-2000	2001-2010	2011-2020
Extremely wet	10 (2.8)	3 (2.5)	7 (5.8)	0
Moderately wet	47 (13.1)	21 (17.5)	14 (11.7)	12 (10)
Near normal	255 (70.8)	73 (60.8)	87 (72.5)	95 (79.2)
Moderately dry	32 (8.9)	13 (10.8)	11 (9.2)	8 (6.7)
Extremely dry	11 (3.1)	5 (4.2)	1 (0.8)	5 (4.2)

There is a decreasing trend in the number consecutive wet and dry spells (Table 5) from 1991-2000 to 2011 to 2020. During all the 3 decades, the consecutive wet as well as dry events have been occurred during the winter and NE monsoon seasons. This shows the instability in rainfall distribution during north east monsoon [15].

3.4 9m-WASP

The number of near normal, moderate wet, moderate dry, extreme wet and extreme dry events are given in Table 6. From the data it is clear that the number of near normal events is increasing and number of moderate dry and moderate wet events is decreasing along the decadal time scale. The spread of wet and dry events is shown in Fig. 8.

Considering the longer time scale of 9 months for calculating WASP clearly indicates that the occurrence of prolonged extreme dry or extreme wet events is very minimal.

Among seasons the extreme dry events have occurred during the north east monsoon (37.5%),

summer (37.5%) and winter seasons (25%). All the 8 extreme dry events recorded during the 2011-2020 decade have occurred during October 2016 to May 2017. The year 2016 is extreme drought year and this has been reflected in the Table 6.

Also it could be noticed that occurrence of extreme events which is calculated using accumulation over 9 month time scale is minimal (Fig. 9).

Table 5. Decadal occurrence of 3 consecutive events for 6m-WASP

	1991-2020	1991-2000	2001-2010	2011-2020
Consecutive dry spells	8	3	3	2
Consecutive wet spells	9	5	2	2

Table 6. Number of wet and dry events during 30 years (1991-2020) and decadal time scales (number in brackets is the probability of occurrence) with 9m-WASP

	1991-2020	1991-2000	2001-2010	2011-2020
Extremely wet	4 (1.1)	0	4 (3.3)	0
Moderately wet	61 (16.9)	29 (24.2)	22 (18.3)	10 (8.3)
Near normal	233 (64.7)	58(48.3)	78 (65.0)	97 (80.8)
Moderately dry	46 (12.8)	25 (20.8)	16 (13.3)	5 (4.2)
Extremely dry	8 (2.2)	0	0	8 (6.7)

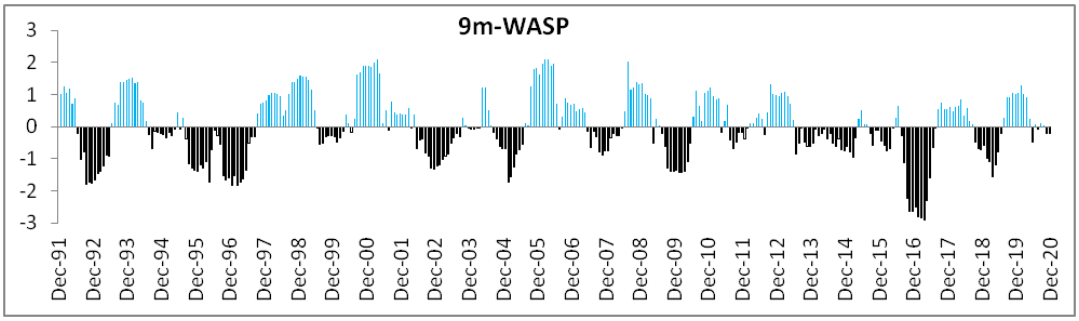

Fig. 8. The wet and dry spells over 30years periods with 9m-WASP

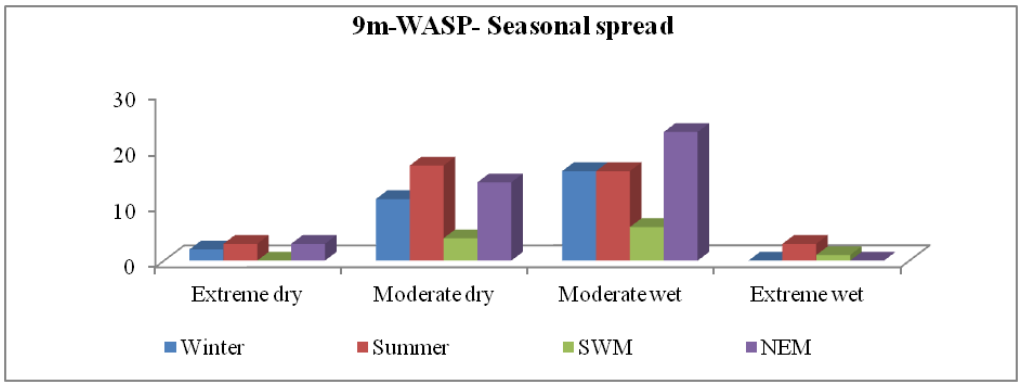

Fig. 9. Occurrence dry and wet events over different seasons with 9m-WASP

Table 7. Decadal occurrence of 3 consecutive events for 9m-WASP

	1991-2020	1991-2000	2001-2010	2011-2020
Consecutive dry spells	8	3	3	2
Consecutive wet spells	8	5	3	1

Table 8. Number of wet and dry events during 30 years (1991-2020) and decadal time scales (number in brackets is the probability of occurrence) with 12m-WASP

Time scale	1991-2020	1991-2000	2001-2010	2011-2020
Extreme wet	1 (0.3)	0	1 (0.3)	0
Moderately wet	57 (15.8)	27 (7.5)	27 (7.5)	3 (0.8)
Near normal	226 (62.8)	50 (13.9)	73 (20.3)	103 (28.6)
Moderately dry	55 (15.3)	32 (8.9)	19 (5.3)	4 (1.1)
Extreme dry	10 (2.8)	0	0	10 (2.8)

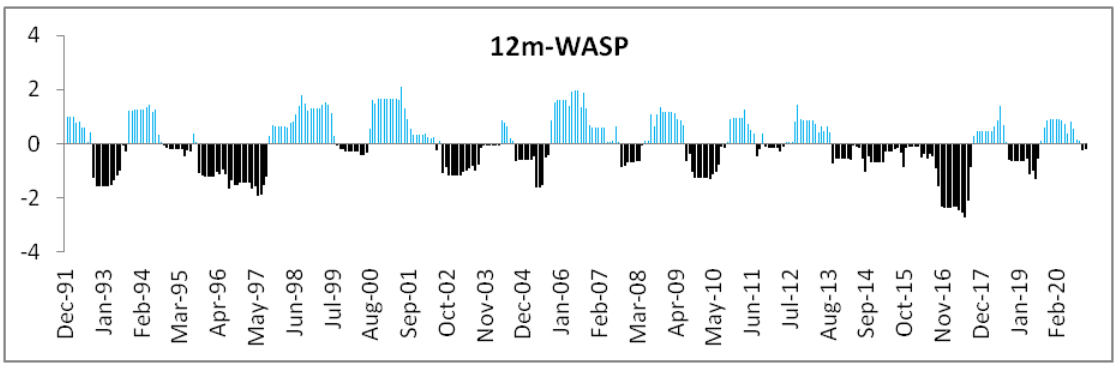

Fig. 10. The wet and dry spells over 30years periods with 12m-WASP

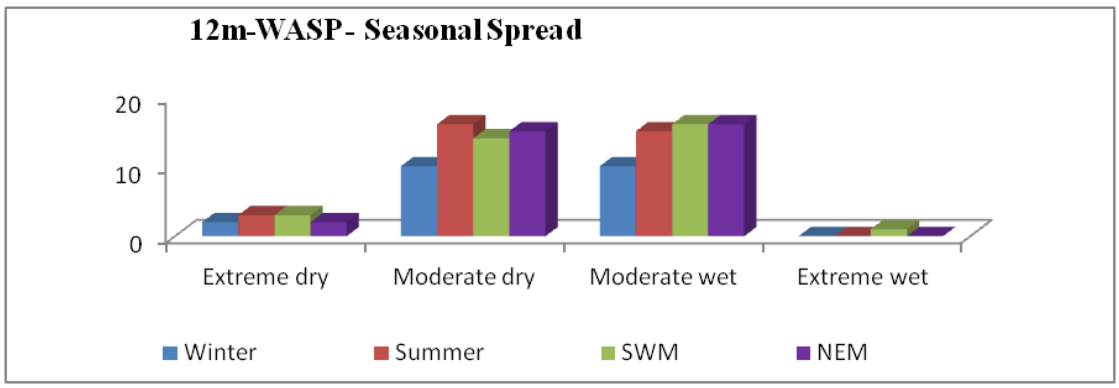

Fig. 11. Occurrence dry and wet events over different seasons with 12m-WASP

As in $WASP_6$, there is a decreasing trend in the number consecutive wet and dry spells (Table 7) from 1991-2000 to 2011 to 2020.

3.5 12m-WASP

The number of near normal, moderate wet, moderate dry, extreme wet and extreme dry events is given in Table 8. From the data it is clear that the number of near normal events is increasing and number of moderate dry and moderate wet events is decreasing along the decadal time scale. The value of 12m- WASP is depicted in the Fig. 10.

Considering the longer time scale of 12 months for calculating WASP clearly indicates that the occurrence of prolonged extreme dry or extreme wet events is very minimal. All the extreme dry periods have occurred during the recent decade (2011 – 2020) and it was due to the severe drought that has occurred during 2016.

Among seasons the moderate dry and moderate wet spells have spread almost equally (Fig. 11). This shows that the probability of 12 months cumulated extreme events over the study region is very minimal. But the moderate dry as well as wet evet occurrence is seen to be equally distributed over all the season. The negative effects of these events can be handled easily by adopting proper drainage, water harvesting and storage structure within the farms. These structures can also help in recharging the ground

water table in addition to supplementing water needs for the crops [16,17].

The outcomes of this study show that this drought index would be a good indicator of the moderate dry events which would have an impact on the rain dependent agriculture. Since droughts have deep impacts on water resources, agriculture and the environment, this is particularly relevant.

4. CONCLUSION

The analysis of dry events over 30 years in Salem showed a highest number of dry events and wet events have occurred during the NEM and winter seasons in case of 3m- WASP and 6m-WASP. This shows the higher variability in rainfall during these seasons. In case of longer term WASP the seasonal occurs are accumulated over longer periods and shows minimal extreme events. WASP has a higher efficiency in capturing dry events over short period that would have a much higher impact on agricultural crops production. Harvesting of rainfall that is excess during wet spells is essential for complementing the shortage during dry events. This also helps in recharging the ground water table in addition to supplanting the agricultural needs. This study helps in selection of suitable crop and variety based on the growth phases of the crop and the water requirement of the crop for the region. Also, based on the results construction of water harvesting structure for the region is possible for providing irrigation support as well as enhancing the ground water table levels in the changing climate for sustainability.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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