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Research Article

Dry and Wet Spells Evaluation in Different Districts of Punjab by Using Markov Chain Model

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ABSTRACT

The initial and conditional probability of dry and wet spells have been analyzed for 20 districts under different agroclimatic zones of Punjab using Markov Chain model method. Rainfall data of 68 years from 1951 to 2018 has been used for study which was collected from India Meteorological Department, Pune. The limit of 20 mm has been used to evaluate the frequency of wet spells, dry spells, wet spell followed by wet spell and dry spell followed by dry spell. It has been recorded that frequency of dry spells and dry spell followed by dry spell were more as compared to wet spells and wet spell followed by wet spell. It has been observed that for Gurdaspur, Hoshiarpur and Rupnagar, dry weeks were above 75% from 1st to 22nd SMW, whereas, for Amritsar, Fatehgarh, Faridkot, Jalandhar, Kapurthala, Ludhiana, Patiala, SAS Nagar and SBS Nagar number of dry weeks were more than 80%. More than 90% dry weeks were recorded for Barnala, Bathinda, Ferozepur, Mansa and Moga. The conditional probability for most of the districts showed that probability of wet spells followed by wet spells was maximum after 27th SMW followed by decrease. The conditional probability displayed that probability of wet spells preceded by wet spells was 100 per cent during 49th SMW for Patiala and SAS nagar, 45th SMW for Gurdaspur, 48th SMW for Rupnagar, 20th week for Fatehgarh Sahib, 46th SMW for Kapurthala, 47th SMW for Ferozepur, Ludhiana and Tarn Taran, 52nd SMW for Bathinda and Moga and 41st to 52nd SMW for Mukatsar.

Key words: Probability, Agroclimatic zones, Dry spell, Wet spell, Punjab

Introduction

Water plays a vital role in agriculture, daily domestic use and in various kind of industries, so it is the one of the important natural resources. The amount of precipitation received over the region is the crucial aspect in evaluating the amount of water that is available to meet the demands of various sectors like agriculture, power generation and human activities. The analysis of rainfall behavior over the long period helps to identify the changing pattern of precipitation (Ibeje *et al.,* 2018). As, globally rainfed agriculture accounts for approximately 80% of the total cultivated area under agriculture and contributes near about 60% to the food production (Rockstrom *et al.,* 2007). India has first rank out of those counties which practice rainfed farming in both aspects i.e., in terms of extent (86 Mha) and production. In Punjab, agriculture is mainly dependent upon amount of rainfall. So, the information about dry and wet spells of a particular location helps to choose the right crop. As the climate variability is increasing day by day the pattern of rainfall becomes unpredictable. Arpna *et al*. (2023) observed the increasing or decreasing trend and rate of increase or decrease of rainfall in Punjab and Mann Kandall test showed the decreasing trend of rainfall during the months of January, July, August and an increasing

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trend of rainfall has been noticed during February, April, May, June and September. The demand of quick growing urbanization and industrialization will reduce the share of water available for agriculture in the future (Mandal *et al.*, 2013) and also machine learning techniques are useful for prediction of rainfall in India (Sarkar *et al*., 2024). For the better utilization of rainfall, it is necessary to plan the agriculture on the scientific basis and also essential to evaluate the frequency of dry as well as wet spells for the particular region. The estimate of dry and wet spells for various agricultural operations and crop planning help farmers for the improvement of cropping intensity and productivity. The sequence of wet and dry spells are also beneficial to determine the withdrawal and onset of monsoon. The rainfall before the monsoon period (pre-monsoon) useful for the preparing land and sowing crops during rainy season.

Kingra *et al.* (2013) analyzed the weekly rainfall data from 1984 to 2010 of sub mountain zone and revealed that probability of wet spells was 4-23%, 65-85% and 26-35% during 1-22, 26-35 and 39-52 SMW. Sheoran *et al.* (2008) analyzed the rainfall data of 21 years (1984-2004) and concluded that at Ballowal Saunkhri, Nawanshahr (SBS Nagar) district, the probability of dry spells was highest during 1-22 SMW except for 8th week. The probability of wet spells remains high during 26th to 35th (except 34th SMW) SWM, i.e., 71% to 86%. Chand (2019) concluded that Ballowal Saunkhri during 1971-2017, the initial probability of dry and wet spells was highest as 80% during 1st -22nd SMW (except 90% during 17th SMW) and 30th (83%) SMW followed by 28th32nd and 33rd (80%) SMW. At Amritsar (1971-2017), the initial probability of dry and wet spells was highest as 80% during 1st-22nd SMW (except 11th SMW) and 28th (72%) SMW followed by 30th and 31st (68%) SMW, respectively. Goyal *et al*. (2013) reported lowest rainfall probability at Ludhiana during 22nd SMW for 5, 10 and 20 mm rainfall during the month of June. Singh *et al* (2004) worked the rainfall data of 26 years (1977-2002) of Bathinda and recorded that probability of dry spells were above 92% for first 22 SMW except 4th, 7th and 8th week and the probability of wet spells was highest during 27th SMW (62%). The conditional probability of wet spells followed by wet spells was highest during 28th (64%) SMW followed by 32 (57%) SMW. Chand (2019) recorded that in Bathinda dry spells probability was highest above 90 per cent during 1-22 SMW and probability of wet spells was highest during 31st (52%) and 29th (49%) SMW. The conditional probability of wet spell followed by wet and dry spell followed by dry spell was highest during 28th (55%) SMW and 90% during 1st to 23rd and 41st to 52nd SMW, respectively.

Markov chain probability model was used to determine the long-term frequency behaviour of dry and wet spells (Victor and Sastry, 1979; Gobin and Vyver, 2021). Keeping these points in view for the evaluation of wet and dry spells, initial and conditional probability of rainfall for the different agroclimatic zones of Punjab have been worked out on weekly basis using Markov Chain model approach.

Methodology

Study area

Punjab is divided into 5 agroclimatic zones i.e., Sub-mountain zone, Undulating plain zone,Western plain zone, Western zone and Central plain zone which are lying between 30°09′ to31°06′ N latitude and 74°55′ to 76°23′ E longitude respectively and 211-355 m above the mean sea level. As the study involved 20 districts of the state according to different agroclimatic zones, so they are mentioned as follow:

1) Sub- Mountain Undulating Zone - Gurdaspur and Hoshiarpur
2) Undulating Plain Zone- Rupnagar, SBS Nagar and SAS Nagar
3) Central Plain Zone- Amritsar, Fatehgarh sahib, Jalandhar, Kapurthala, Patiala, Tarn Taran and Ludhiana
4) Western Plain Zone- Ferozepur and Faridkot
5) Western Zone- Muktsar, Mansa, Barnala, Moga, Bathinda and Sangrur

Data collection and analysis

The rainfall data from 1951-2018, of different districts were collected from India Meteorological Department, Pune and analysis of dry and wet spells have been done for all the districts by using Markov

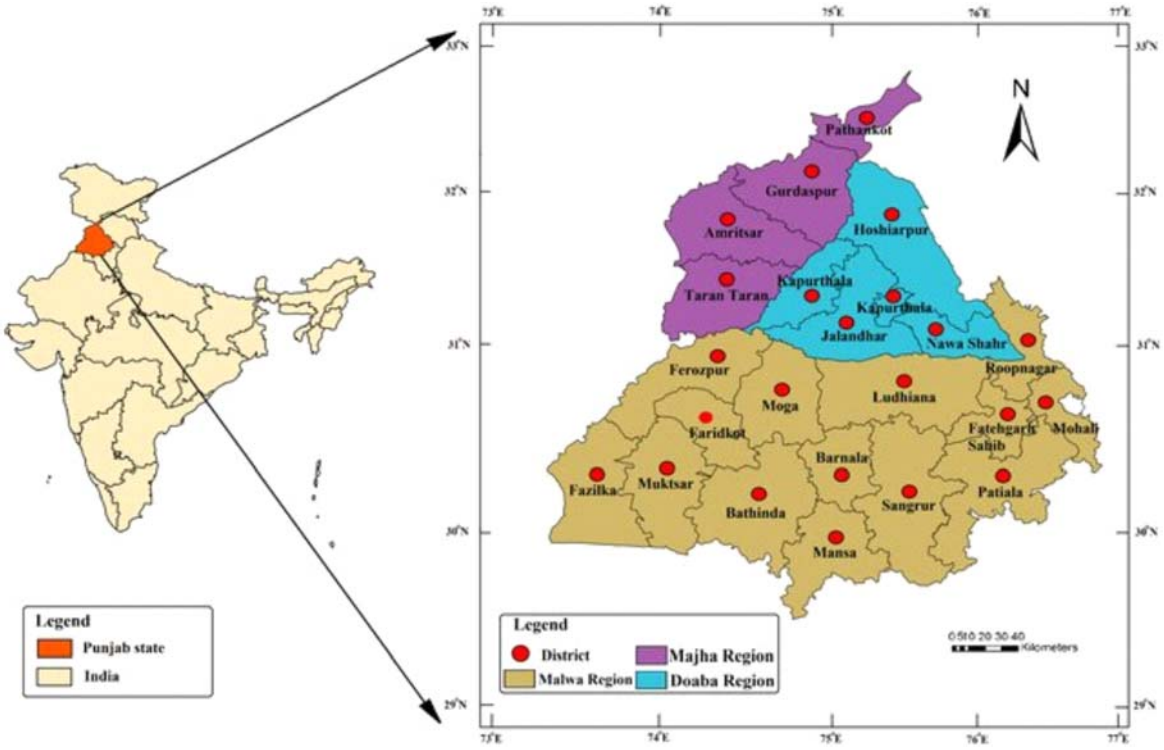

Fig. 1. Different districts of Punjab state

chain model. Markov chain model is used to determine the weekly rainfall probability for dry and wet spells by using long term rainfall data of the given districts. If the rainfall received 20 mm or more rainfall in a week it is known as wet week and less than 20 mm rainfall was considered as dry week. The formula for calculating initial and conditional probability was developed by Robertson (1976). The probabilities will be worked out for rainfall as.

1) Initial probability

$$P_D = \frac{FD}{N} \qquad P_W = \frac{FW}{N}$$

2) Conditional probability

$$P_{DD} = \frac{FDD}{N} \qquad P_{WW} = \frac{FWW}{N}$$

Where,

P_D = Probability of the year being dry

P_W = Probability of the year being wet

N = Number of years of data,

F_D = Number of dry years

F_W = Number of wet years

P_D = Probability of the year being dry

P_{DD} = Conditional Probability (conditional) of a dry year preceded by a dry year

P_{WW} = Probability (conditional) of a wet year preceded by a wet year

F_{DD} = Number of dry year preceded by another dry year

F_{WW} = Number of wet year preceded by another wet year

3) Transition probability matrix

These probabilities were organized into a Transition Probability Matrix (T) to describe the transition between states:

$$T = \begin{bmatrix} P_{DD} & 1 - P_{DD} \\ 1 - P_{WW} & P_{WW} \end{bmatrix}$$

Where:

Row 1 represents transitions starting from a dry week (DDD).

Row 2 represents transitions starting from a wet week (WWW).

Results and Discussion

Sub-mountain undulating zone

The initial probability of dry and wet weeks has been worked out by Markov Chain model. At Gurdaspur occurrence of dry weeks was above 75% from 1 to 22nd SMW except 3rd (73), 7th (69) and 8th (69) week but after the 24th SMW the probability of dry spells decreased up to 19% in 30th SMW, then again it increased and reached upto 97% in 47th SMW. The chances of occurrence of wet spells were highest (88%) during 29th week followed by 30th and 31st week (86%). The conditional probability for Gurdaspur showed that probability of wet spells followed by wet spells was maximum during 28th week (90 per cent) followed by 30th week (88%) and it was 0% during 14th, 17th, 19th, 21st, 41st to 48th SMW. Probability of dry spell followed by dry spell was near about 80 per cent till 22nd SMW week then decreased to 0 per cent during 30th SMW and then increased again up to 100 per cent during 45th SMW (Fig. 2).

At Hoshiarpur, existence of dry weeks were above 75% on or after 1st to 23rd SMW except 7th SMW (72%) afterwards the 23rd SMW the probability of dry spells decreased and touched up to 16% in 33rd SMW, but again it improved and reached till 97% during 49th SMW. The probability of occurrence of wet spells were highest during 32nd week i.e., 91 percent followed by 31st (89%) and 30th week (88%). The conditional probability for the district showed that, probability of wet spells preceded by wet spells was maximum during 28th week (92%) followed by 31st week (91%) and it was 0 per cent during 14th, 16th, 17th 19th and 20th SMW and 41st to 46th SMW. Probability of dry spell reduced to 0 per cent in 31st SMW and after that increased again up to 100% during 46th SMW (Fig. 3).

Undulating plain zone

At SAS Nagar occurrence of dry weeks were above 85 per cent from 1st to 22nd SMW excluding 9th SMW (79%). The probability of dry spells decreased and touched up to 16% in 33rd SMW, but then again it enhanced and reached up to 100% during 46th SMW. The probability of wet spells was highest during 28th and 33rd week i.e., 83 per cent followed by 31st (80%). The conditional probability displayed that probability of wet spells preceded by wet spells was 100 per cent during 49th week followed by 27th week (85%) and it was remained 0 per cent from

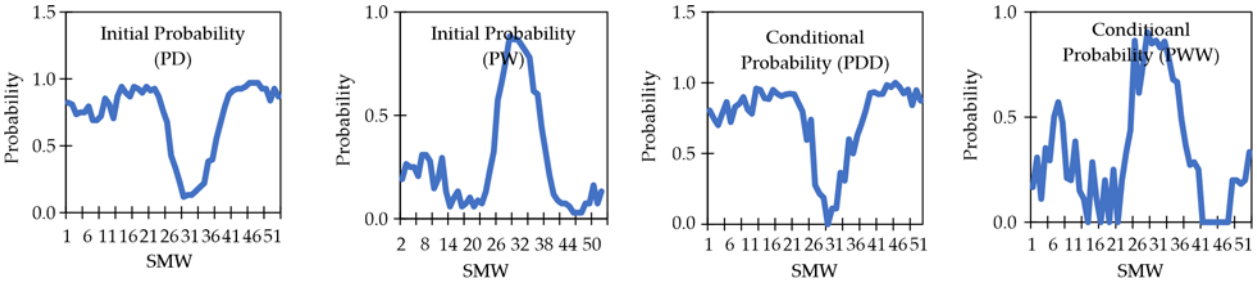

Fig. 2. Initial and conditional probability of rainfall at Gurdaspur

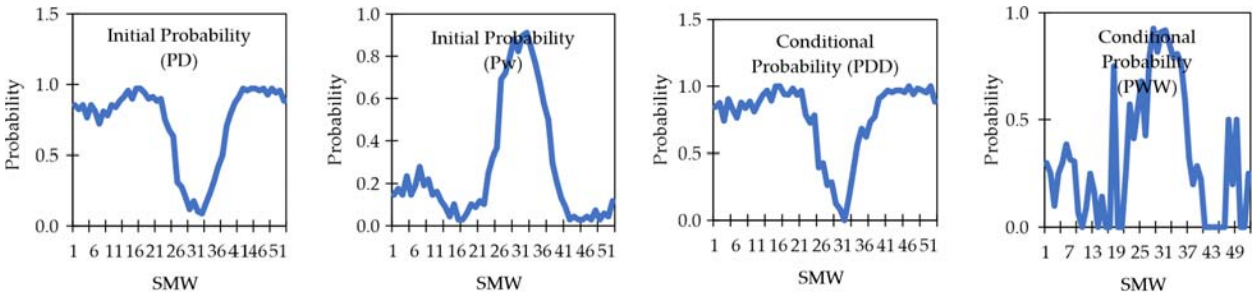

Fig. 3. Initial and conditional probability of rainfall at Hoshiarpur

11th to 13th, 16th to 20th, 42nd to 48th and during 50th SMW. Probability of dry spell preceded by dry spell was near about 80 per cent till 22nd SMW then it decreased to 14% in 32nd SMW which increased again up to 100% during 50th SMW (Fig. 4).

At SBS Nagar, probability of dry weeks was more than 80 per cent from 1st to 22nd SMW except 4th SMW (79%). Later, the probability of dry spells diminished and reached to 25% in 33rd SMW, it increased and stretched up to 100% in 43rd SMW. The probability of occurrence of wet spells was 75% during 27th, 31st and 33rd SMW. The conditional probability presented the chances of wet spells preceded by wet spells was maximum during 26th week (80%) followed by 32nd week (78%) and it was 0 per cent during 10th, 12th to 14th, 16th to18th and 41st to 50th SMW. The probability of dry spell preceded by dry spell was near 80 per cent till 21st SMW except 4th week which decreased up to 30% during 30th SMW and after that augmented to 100% during 42th SMW (Fig. 5).

At Rupnagar district the probability of dry weeks was more than 75 per cent from 1st to 22nd SMW. Far ahead, the possibility of dry spells decreased up to 7% in 33rd SMW and then it increased to 100% during 45th SMW. Possibility for the wet spells was calculated maximum during 31st week (92%) followed by 32nd SMW (80%). The conditional probability exhibited that possibility of dry spell preceded by dry spell was above 80 per cent till 22nd excluding 6th and 11th SMW and it declined to 0 per cent during 31st SMW and reached to 100% during 48th SMW, whereas, possibility of wet spells preceded by wet spells was maximum during 18th and 49th week (100%) followed by 30th week (92%) (Fig. 6).

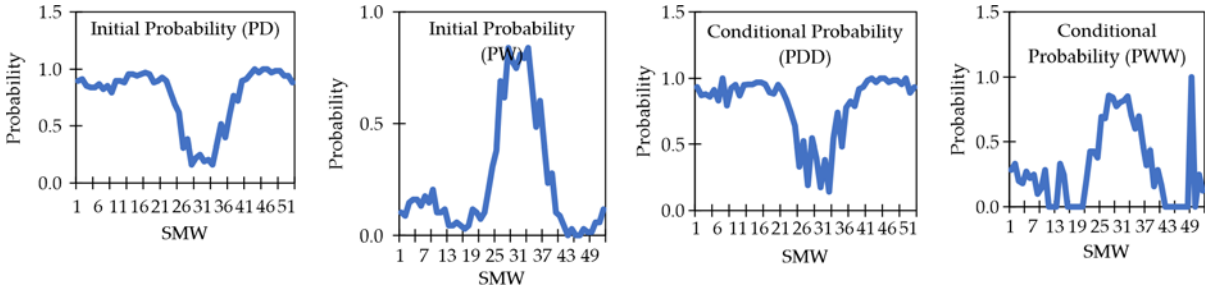

Fig. 4. Initial and conditional probability of rainfall at SAS Nagar

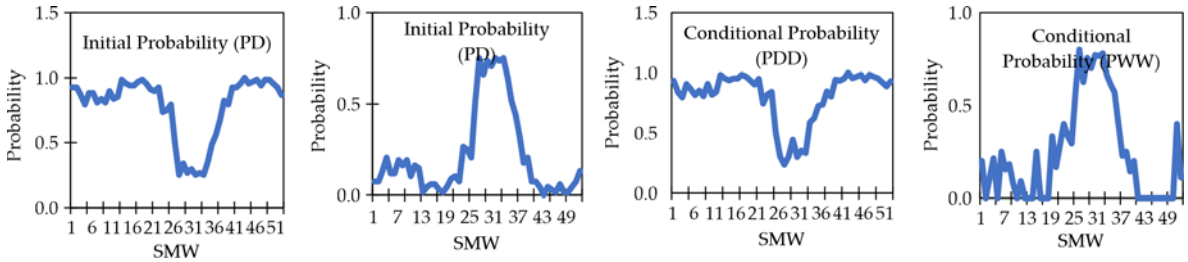

Fig. 5. Initial and conditional probability of rainfall at SBS Nagar

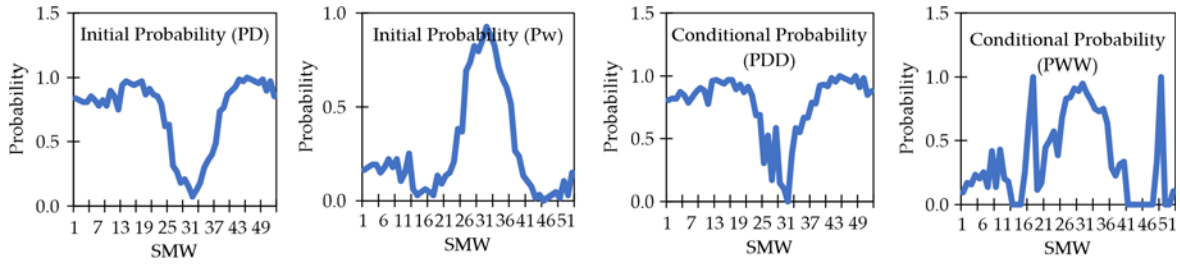

Fig. 6. Initial and conditional probability of rainfall at Rupnagar

Central plain zone

At Amritsar, probability of dry weeks were more than 80 per cent from 1st to 22nd SMW except 12th SMW (79%), the probability of dry spells diminished and reached to 25% during 29th SMW, then it increased and stretched up to 100% in 49th SMW. The probability of occurrence of wet spell was 75% during 29th SMW and 70% during 28th and 31st SMW. The conditional probability presented that, chances of wet spells preceded by wet spells was maximum during 28th week (79%) followed by 31st week (70%) and it was 0 per cent during 1st, 13th, 16th, 17th, 19th to 22nd, 40th to 51st SMW. The probability of dry spell preceded by dry spell was near 85 per cent up to 22nd SMW except 3rd (82%) and 11th (79%) SMW and decreased to 23% during 30th SMW and after that increased up to 100% during 50th SMW (Fig. 7).

At Fatehgarh sahib, the probability of dry weeks was more than 80 per cent from 1st to 22nd SMW. The possibility of dry spells decreased up to 23% during 32nd SMW which increased up to 100% during 47th SMW. Possibility for the wet spells was recorded to be maximum during 32nd week (76%) followed by 28th SMW (73%). The conditional probability exhibited that possibility of dry spell preceded by dry spell was above 85 per cent during 22nd SMW excluding 3rd (83%) and 6th SMW (80%), it declined to 22 per cent during 31st SMW and reached to 100% during 46th SMW. The possibility of wet spells preceded by wet spells was maximum during 20th and 30th SMW i.e., 100 and 79 per cent, respectively followed by 28th SMW (78%) and was 0 per cent during 1st, 13th-17th on or after 42nd-50th SMW (Fig. 8).

At Jalandhar the probability of dry weeks was recorded near to or above 80 per cent from 1st to 22nd SMW, next the occurrence of dry spells reduced to 29 per cent during 33rd SMW, then it increased to 100% during 46th SMW. Occurrence of the wet spells was maximum during 32nd week (76%) then followed by 30th SMW (75%). The conditional probability of the district displayed that, occurrence of dry spell preceded by dry spell was above 85% till 22nd SMW except 3rd (82%) and 6th (83%) SWM but later on, it declined to 29% in 31st SMW and then again it became 100 per cent on 45th SMW. Though, occurrence of wet spells preceded by wet spells was maximum during 31st (81%) and 29th week (75%) and it was 0% during 1st to 3rd, 13th, 14th, 17th to 19th, 21st to 23rd and 41st to 51st SMW (Fig. 9).

At Kapurthala, the Probability of dry weeks were noted above 80% till 22nd SMW excluding 7th SMW, afterwards the existence of dry spells reduced to 25% during 30th SMW, thereafter it increased to 100%

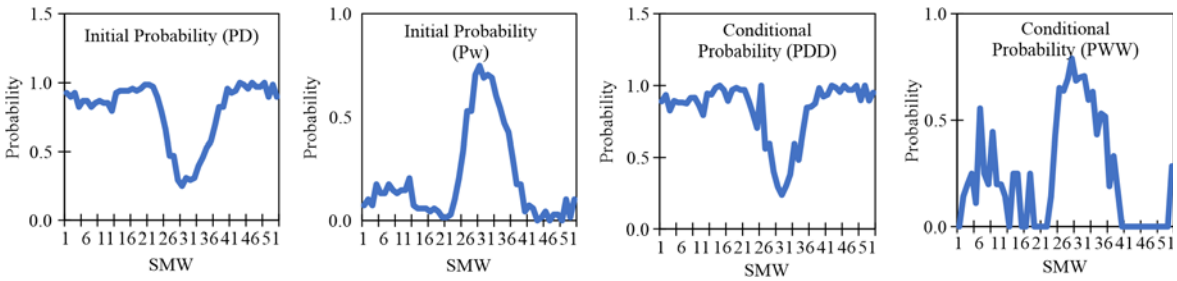

Fig. 7. Initial and conditional probability of rainfall at Amritsar

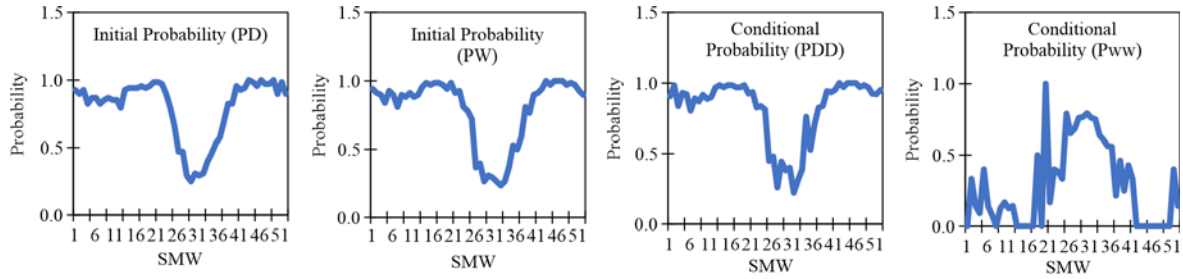

Fig. 8. Initial and conditional probability of rainfall at Fatehgarh sahib

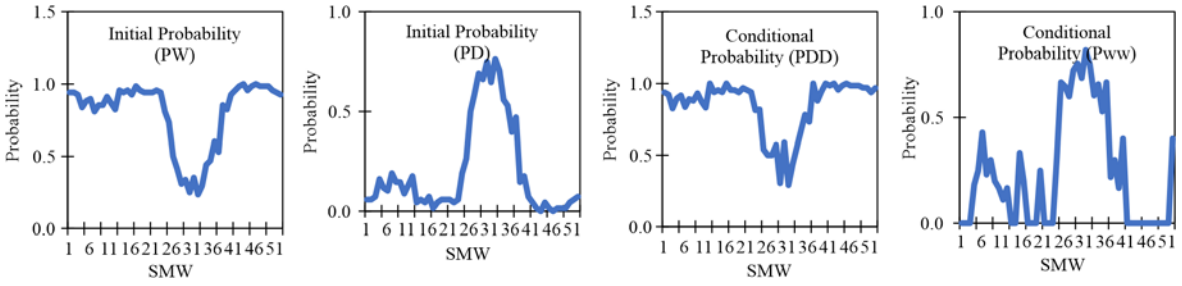

Fig. 9. Initial and conditional probability of rainfall at Jalandhar

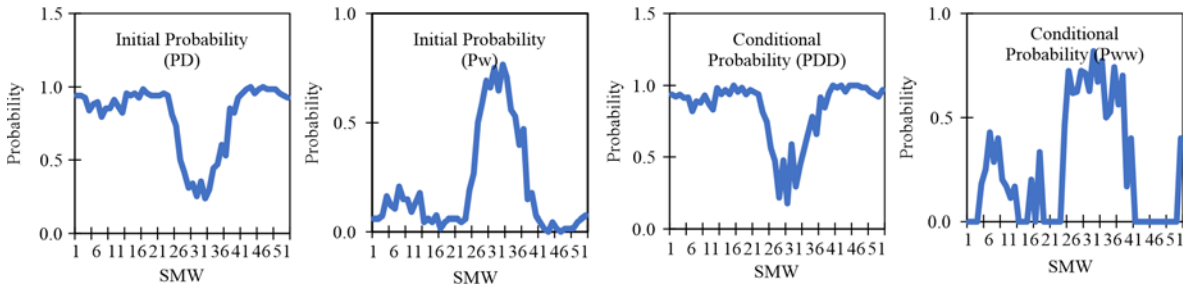

Fig. 10. Initial and conditional probability of rainfall at Kapurthala

during 32nd SMW. Probability of the wet spells were highest during 32nd SMW (76 per cent) followed by 30th SMW (75%). The conditional probability demonstrated that probability of dry spell preceded by dry spell was more than 85 per cent till 23rd SMW apart from 6th (81%) and 11th (83%) SMW then, it lessened to 17% in 29th SMW and after that it became 100 per cent on 46th SMW. However, Probability of wet spells preceded by wet spells was highest in 31st i.e., 81% followed by 33rd week (77%) and during 1st to 3rd, 13th to 15th, 19th to 23rd and 41st to 51st week the probability was 0% (Fig. 10).

Observations of probability in Ludhiana revealed that chances of dry weeks were experienced more than 80 per cent till 23rd SMW. Subsequently the chances of dry spells decreased to 30 per cent during 32nd SMW and probability improved to 100% during 48th SMW. Chances of the wet spells were highest during 29th and 32nd SMW, i.e., 69% followed by 33rd SMW (67%). The conditional probability confirmed that chances of dry spell preceded by dry spell were more than 85% up to 23rd SMW except 6th SMW. Later, it narrowed to 23% during 29th SMW and during 47th SMW it was maximum (100%). The chances of wet spells preceded by wet spells was at peak during 28th SMW (80%) followed by 27th SMW (70%) and then it became 0% during 1st, 3rd, 10th, 11th, 13th, 14th, 19th, 20th and from 41st-51st SMW (Fig. 11).

At Patiala, the possibility of dry weeks was 85% up to 22nd SMW which later reduced to 17% during 28th SMW. It enhanced to 100% during 46th SMW.

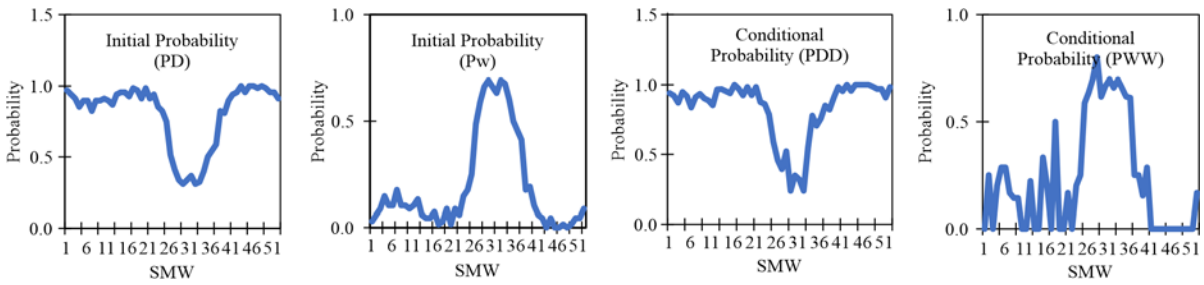

Fig. 11. Initial and conditional probability of rainfall at Ludhiana

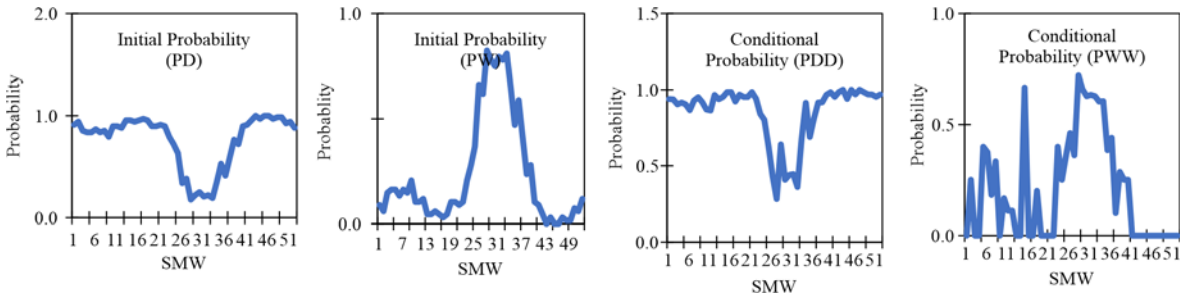

Fig. 12. Initial and conditional probability of rainfall at Patiala

The possibility of the wet spells was calculated maximum during 28th and 33rd SMW i.e., 82 and 80% respectively. The conditional probability exposed that possibility of dry spell preceded by dry spell was more than 80 per cent up to 22nd SMW. Far ahead, it lessened to 20% during 32nd SMW and then increased up to 100 per cent during 44th SMW. Similarly, the possibility of wet spells preceded by wet spells was highest during 49th (100%) followed by 28th SMW (85%) and faced 0% probability during 8th, 11th-13th, 16th, 17th, 19th and 42nd-48th SMW in wet week preceded by wet week (Fig. 12).

The probability of dry weeks in Tarn Taran was more than 85% from 1st to 23rd SMW which reduced to 36% during 33rd SMW. It increased to 100% during 48th SMW. Next, probability of the wet spells was extreme during the 28th, 30th and 32nd SMW which was 63 per cent. The conditional probability revealed that probability of dry spell preceded by dry spell was above 85% up to 22nd SMW, which reduced to 36% during 32nd SMW and improved to 100 per cent during 47th SMW. In the same way, probability of wet spells preceded by wet spells was maximum during 28th SMW (72%) followed by 15th SMW (66%). The district experienced 0% probability during 1st, 3rd, 4th, 13th, 14th, 16th, 17th, 19th-22nd SMW and 41st-52nd SMW (Fig. 13).

Western plain zone

At Faridkot, the probability of dry weeks were recorded near or above 85 per cent from 1st to 24th SMW which was reduced to 51 per cent during 29th SMW, then it increased up to 100% during 51st SMW. Occurrence of the wet spells was maximum during 29th SMW (48%) then followed by 33rd SMW (45%). The conditional probability of the district displayed that the occurrence of dry spell preceded by dry spell was above 90% till 22nd SMW but later it minimized up to 56% during 32nd SMW. It became 100 per cent during 51st SMW. The occurrence of wet spells preceded by wet spells was maximum during 2nd and 14th SMW (100%) which was followed by 26th SMW (60%) and it was 0% during 1st, 2nd-5th, 7th-13th 16th,17th, 19th-22nd and 41st-52nd SMW (Fig. 14).

At Ferozpur, the probability of dry weeks were noted above 90% till 22nd SMW, afterwards the existence of dry spells reduced to 48 per cent during 29th SMW, thereafter it increased up to 100% during 48th SMW. Probability of the wet spells were highest during 29th SMW (51%) followed by 30th SMW (48%). The conditional probability demonstrated that probability of dry spell preceded by dry spell was more than 90% till 23rd SMW which lessened to 55% during 27th SMW and it became 100 per cent during

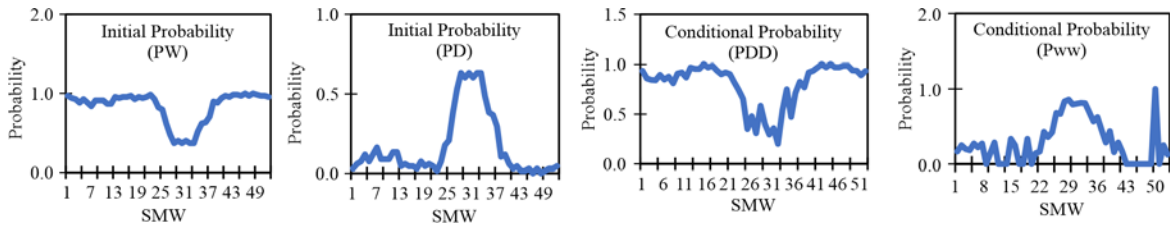

Fig. 13. Initial and conditional probability of rainfall at Tarn Taran

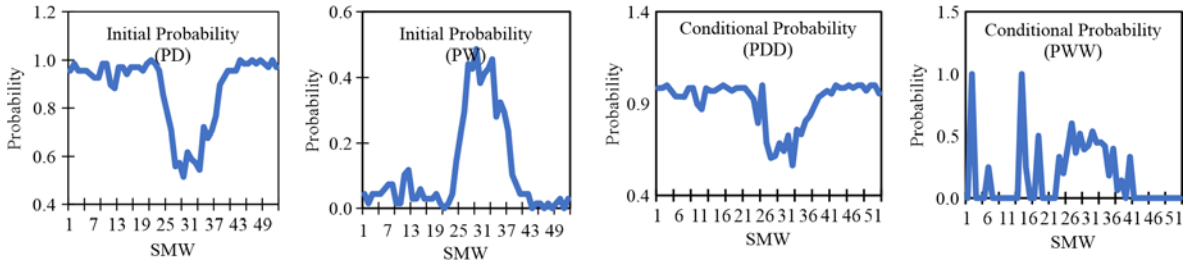

Fig. 14. Initial and conditional probability of rainfall at Faridkot

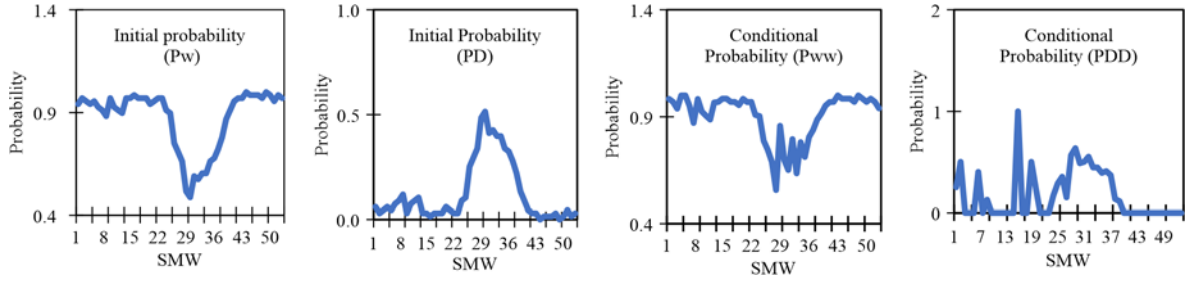

Fig. 15. Initial and conditional probability of rainfall at Ferozpur

47st SMW. However, probability of wet spells preceded by wet spells and was highest during 15th SMW (100%) followed by 28th SMW (63%) and from 3rd to 22nd SMW and 39th and 52nd week, the probability was 0% (Fig. 15).

Western zone

At Barnala, chances of dry weeks were experienced more than 90% up to 23rd SMW which decreased up to 51% during 31st SMW. Later it improved to 100% during 51th SMW. Chances of the wet spells were highest during 29th and 31st SMW (48%) followed by 28th SMW (47%). The conditional probability showed that chances of dry spell preceded by dry spell were more than 90% till 22nd SMW which narrowed to 58% during 30th SMW and next during 50th SMW it was 100 per cent. Likewise, chances of wet spells preceded by wet spells was at peak during 28th SMW (68%) followed by 31st SMW (60%) and then it becomes 0 during 1st to 5th, 7th, 8th, 10th to 14th, 20th and from 42nd to 52nd SMW (Fig. 16).

At Bhatinda, the possibility of dry weeks was observed more than 90 per cent till 24th SMW, afterward the possibility of dry spells reduced up to 56% during 31st SMW, then it enhanced to 100% during 50th SMW. The possibility of the wet spells was maximum throughout 30th and 31st SMW (44%) followed by 28th SMW (41%). The conditional probability showed that possibility of dry spell preceded by dry spell was more than 90% till 26th SMW. Far ahead, it lessened to 79 per cent during 37th SMW and then increased to 100 per cent during 52th SMW. Similarly, possibility of wet spells

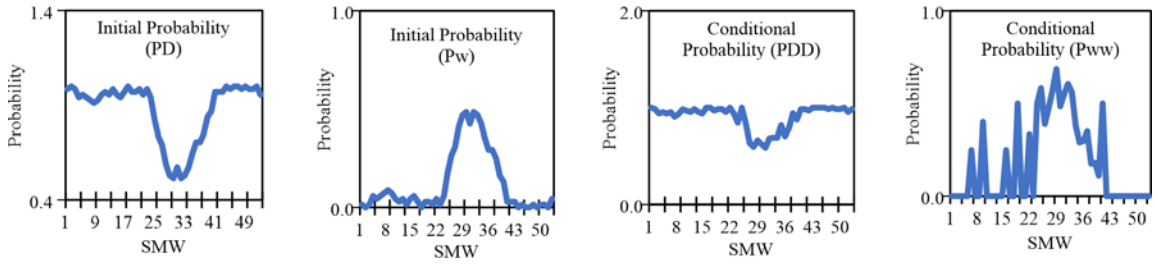

Fig. 16. Initial and conditional probability of rainfall at Barnala

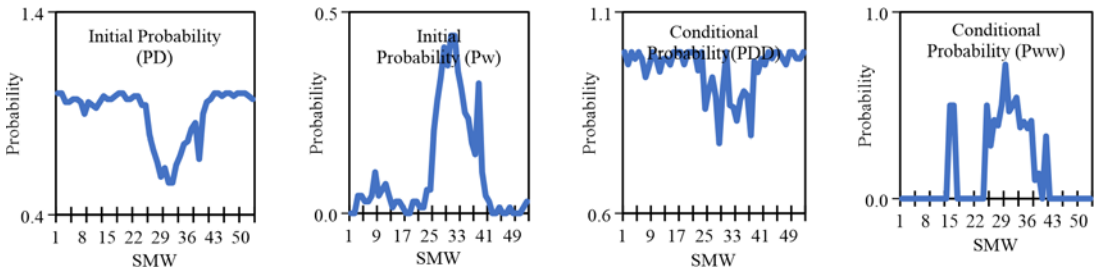

Fig. 17. Initial and conditional probability of rainfall at Bathinda

preceded by wet spells was highest during 29th SMW (72%) followed by 32nd SMW (52%) and faced 0% probability during 1st to 13th, 16th to 23rd 39th and 41st to 52nd SMW (Fig. 17).

Probability of dry weeks in Mansa was more than 90% from 1st to 23rd SMW which reduced up to 57% during 31st SMW and enhanced to 100% during 48th SMW. Probability of the wet spells was extreme during the 31st SMW (42%) followed by 28th SMW (36%). The conditional probability revealed that probability of dry spell preceded by dry spell was above 90% till 23th SMW. Later it diminished to 62% during 30th SMW and next improved to 100 per cent during 51st SMW. In the same way, possibility of wet spells preceded by wet spells was maximum during 32nd SMW (56%) followed by 30th SMW (52%) and experienced the 0% probability during 1st to 13th SMW and 42nd to 52nd SMW (Fig. 18).

At Moga occurrence of dry weeks was above 90% from 1st to 22nd SMW week but after 22nd SMW, the probability of dry spells decreased up to 44 per cent during 31st SMW, which again increased and reached 100% during 49th SMW. The probability of wet spells was highest during 31st SMW (55%) followed by 30th SWM (51%). The conditional probability of wet spells followed by wet spells was maximum during 5th SMW (100%) followed by 33rd SMW (62%) and it remains 0 per cent from 41st to 51st SMW. Probability of dry spell followed by dry spell was near or above 90 per cent till 22nd SMW except 11th SMW which decreased up to 39% during 30th SMW and then increased again up to 100 per cent during 52nd SMW (Fig. 19).

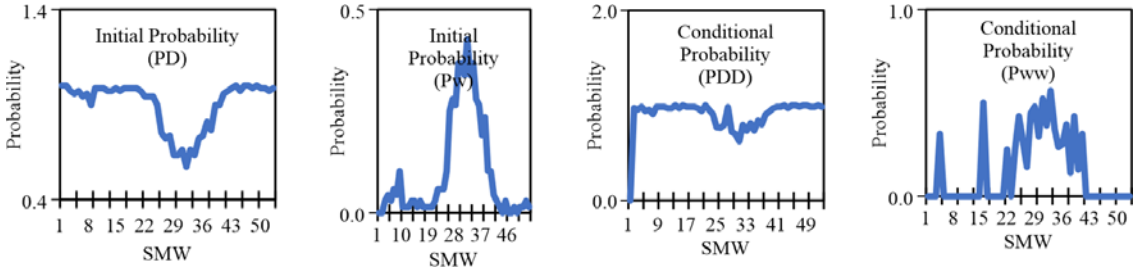

Fig. 18. Initial and conditional probability of rainfall at Mansa

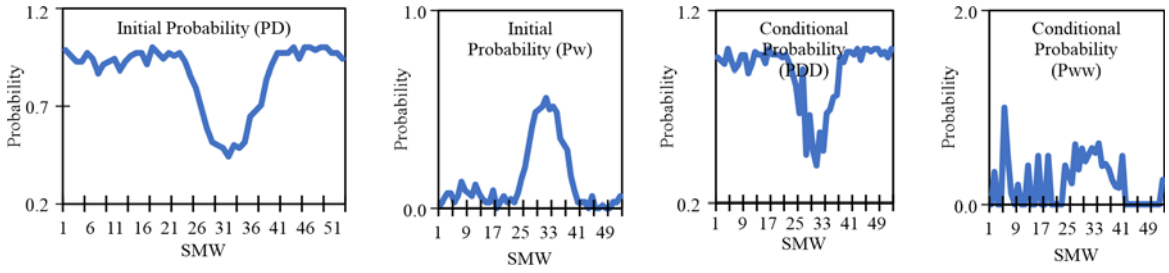

Fig. 19. Initial and conditional probability of rainfall at Moga

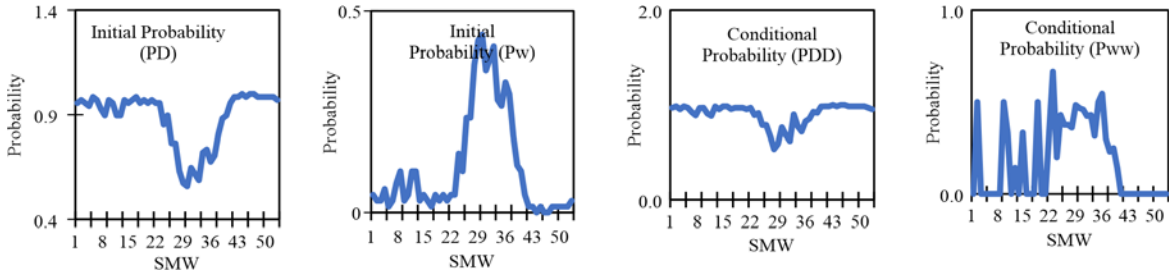

Fig. 20. Initial and conditional probability of rainfall at Muktsar

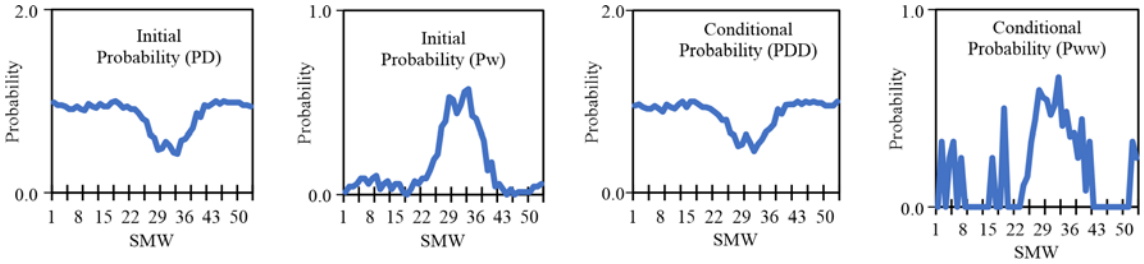

Fig. 21. Initial and conditional probability of rainfall at Sangrur

At Muktsar existence of dry weeks were above 85% from 1st to 24th SMW which touched 55% during 29th SMW, later reached up to 100% during 46th to 52nd SMW. The probability of occurrence of wet spells were highest during 29th SMW (44%) followed by 28th (42%) and 32nd SMW (41%). The conditional probability showed that probability of wet spells preceded by wet spells was maximum during 22nd SMW (66%) followed by 35th SMW (54%) which reduced to 0 per cent from 4th to 9th and 40th to 52nd SMW. Probability of dry spell preceded by dry spell was near 85% till 23rd SMW and reduced to 53 per cent during 27th SMW and increased again up to 100% during 45th to 52nd SMW (Fig. 20).

At Sangrur occurrence of dry weeks was above 85 per cent from 1st to 23rd SMW and decreased up to 42 per cent in 29th and 33rd SMW, but then again it enhanced and reached till 100 per cent during 45th to 52nd SMW. The probability of wet spells was highest during 32nd and 33rd SMW i.e., 57% and 55%, respectively followed by 28th SMW (52%). The conditional probability displayed that probability of wet spells preceded by wet spells was maximum during 32nd SMW (65%) followed by 59% during 27th SMW and reduced to 0 per cent from 47th to 49th SMW. Probability of dry spell preceded by dry spell was more than 85% up to 22nd SMW which decreased to 45% during 31st SMW and increased again up to 100% during 41st to 52th SMW (Fig. 21).

Conclusion

It has been concluded that, the initial probability of dry spells has been recorded more as compared to the wet spells in all the different districts and the probability of wet spells has been observed to be highest during 28th SMW to 33rd SMW. The conditional probability also showed that dry spell followed by dry spell occurred more as compared to wet spells followed by wet spells. This study can be useful for understanding the historical patterns of dry and wet spells, which can help farmers to improve crop planning. They can choose crops that are more resilient to adverse weather conditions. It can also be helpful in guiding the farmers for efficient water management and ensure adequate water availability during critical crop growth stages. The study can provide valuable insights into the changing patterns of rainfall in Punjab, including the frequency, duration, and intensity of dry and wet spells. This information can help researchers understand the impacts of climate change on the region and develop adaptation strategies.

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