P-ISSN: 2618-0723
E-ISSN: 2618-0731

NAAS Rating: 5.04
www.extensionjournal.com

International Journal of Agriculture Extension and Social Development

Volume 7; Issue 9; September 2024; Page No. 299-309

Received: 13-06-2024
Accepted: 14-07-2024

Indexed Journal
Peer Reviewed Journal

A study on climate change scenario in Haryana

Rahul[1], Ravi Prakash Mishra[2] and Bichitra Singh Negi[3]

[1, 3]Assistant Professor School of Engineering and Computing Dev Bhoomi Uttarakhand, University, Dehradun Uttarakhand, India

[2]Professor School of Agriculture, Dev Bhoomi Uttarakhand, University, Dehradun, Uttarakhand, India

DOI: https://doi.org/10.33545/26180723.2024.v7.i9e.1058

Corresponding Author: Rahul

Abstract

Over the past few decades, Haryana has witnessed a rise in average temperatures, leading to heatwaves that adversely affect both human health and agricultural productivity. Altered rainfall patterns, characterized by erratic monsoons and prolonged droughts, have exacerbated water scarcity, affecting crop yields and water resources management. The investigation of precipitation patterns is significant for a nation like India whose food security and economy rely upon the ideal accessibility of water. In this work, monthly, patterns of precipitation have been concentrated on utilizing a month-to-month information series of two years (2022-2023) for 22 locales in Haryana, India. Half of the districts showed an increasing trend in annual rainfall, but for only two (Yammunagar and Kurukshetra), this trend was statistically significant. Similarly, five districts (Jind, Fatehabad, Bhiwani, Hisar, and Rohtak) indicated a significant decreasing trend out of the 22 districts showing a decreasing trend in annual rainfall. In India, the rainstorms long periods of June to September represent over 80% of the yearly precipitation. During June and July, the quantity of sub-divisions showing expanding precipitation is practically equivalent to those showing diminishing precipitation. In August, the quantity of locale showing a rising pattern surpasses those showing a diminishing pattern, while in September, the circumstance is the inverse. Most of the sub-divisions showed next to no adjustment of precipitation in non-rainstorm months. The five principal locales of India showed no huge pattern in month-to-month precipitation in the vast majority of the months. For the entire of India, no critical pattern was recognized for yearly, occasional, or month-to-month precipitation. Precipitation in June, July, and September diminished, while in August and September showed an expanded pattern. This paper underscores the urgent need for comprehensive climate action plans to ensure the resilience and sustainability of Haryana's environment and economy.

Keywords: Climate change, rainfall, draught, flood

Introduction

Haryana is for the most part dry or semi-bone-dry with restricted precipitation going from 300 mm in the southwest to 1100 mm in the upper east. No enduring streams go through the State, and around 66% of the area is underlain by natural drainage. Before taking up the investigation, it is essential to understand the nature of parameters that are liable to change the climate and in the long run, affect the water resources. These effects can be seen in terms of groundwater level depletion, water quality variations, and less runoff. The environment, groundwater, and surface water arrangement of Haryana should be perceived specifically before connecting it to the issue of environmental change.

Study Area

Haryana is located in northwest India between 27 degrees 37' to 30 degrees 35' latitude and between 74 degrees 28' to 77 degrees 36' longitude with an altitude between 700-3600 ft. above sea level. Haryana shows a huge spatial variety in environmental viewpoints agroecological conditions, groundwater and surface water quality, and amount. Figure 1 shows the geographical area and rainfall analysis in different districts of Haryana. In addition, the surface water network is very wide and varied. The State is situated in the basins of the Indus and Yamuna rivers and receives water from the Sutlej and Yamuna rivers and its share of surplus water from the Ravi and Beas rivers. Haryana state mainly occupies the Indo-Gangetic water divide and forms a part of the Indo-Gangetic plain.

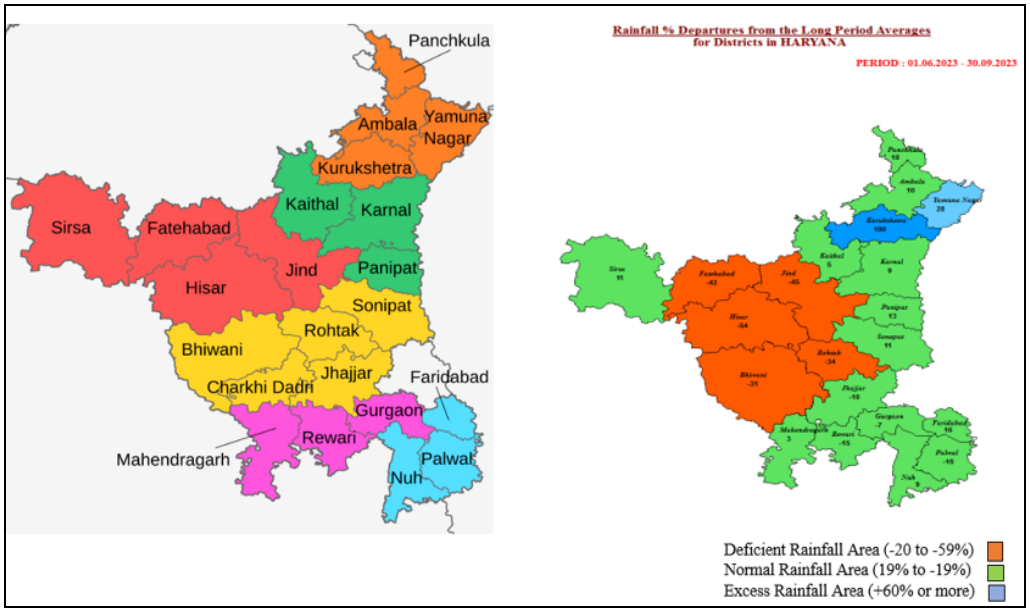

Fig 1: Rainfall pattern in Haryana during the year 2023 (IMD)

The Shiwaliks extend into its northeastern corner, which originates present-day seasonal rivers, viz., the Ghagger, Tangri, Markanda, and Chautang which flow taking a southwestern course. The few transient streams, viz. the Sahibi, Krishanawati, and Dohan from south to north. The Aeolian lots with sandunal exercises are normal in the south, northwest and western locale, in which outcrops of the Aravalli slopes happen discontinuously. Similarly, heavy rainfalls occur in many parts of the world. Typically, they are not cataclysmic events; however, a catastrophic event can result when the precipitation is heavier than expected and when safeguards have not been taken. (Malik and Setia 2020) [3]. All peripheral features have distinct relief and have higher elevations than the central structural basin, which represents a characteristically loose basin comprising a flat alluvial plain.

Methodology

Data source collection of necessary data and information through available reports, surveys, and field investigation is a prerequisite to determine the impact of climate change on water resources in Haryana. Discussion with the local inhabitants can provide many clues about the hydrological and geohydrological conditions in the study area. Such investigations are beneficial for the extraction of past information through questionnaires. Consequently, this investigation tries to extract maximum information through reports available from different sources, personal surveys, and field investigations. Although, there is no single model or approach appropriate for all socioeconomic assessments of climate impacts. In this investigation, primary data is collected from the personal surveys of sampled villages. This survey is conducted to collect information relating to the socio-economic aspects of the people. The survey shows that the biophysical factors such as temporal change in water quality, effect of water quality change on human being, slope, drainage pattern rock type, and their structure which control the surface runoff and percolation of surface water were evaluated and mapped.

Rainfall Analysis in Different Districts of Haryana (2022)

The rainfall distribution varies across Haryana, with the eastern and northern regions receiving more rainfall compared to the western and southern parts of the state. For instance, the areas around Ambala and Panchkula tend to get more rain, while the districts like Hisar and Jind receive less. Total annual precipitation is spread unevenly throughout the months, with substantial rain in July (220.4 mm) and August (70.0 mm), while January and December are relatively dry (69.0 mm and 0.0 mm respectively) as shown in Table 1.

Figure 2 reflects a range of Rainfall data across various locations, with notable variations in magnitude. At one end of the graph, Fatehabad and Bhiwani exhibit the lowest rainfall values, 32.1 mm, and 36.8 mm respectively, suggesting comparatively minimal quantities or occurrences. In contrast, Panchkula and Yamunanagar stand out with the highest values, 172.9 mm, and 169.3mm respectively, indicating significantly greater rainfall. Most other locations, such as Ambala (106.8), Gurgaon (96.8), and Kurukshetra (120.0), fall into the mid-to-high range, reflecting moderate to substantial measurements of rainfall values. The rainfall data reveals a general clustering around 50-100 mm for many areas, with a few outliers deviating considerably above or below this central tendency. This variation suggests a diverse distribution of the measured attribute across these locations, highlighting both prominent and minimal values in the dataset. Figure 3 shows that the rainfall data reflects various numerical values associated with different locations, likely representing some form of measurement. For instance, Yamuna Nagar has the highest rainfall value at 54.8 mm, suggesting it is a significant outlier compared to other locations. In contrast, Hisar shows the lowest rainfall value at 2.9 mm, indicating a lower measure relative to the other Districts. Kurukshetra and Panchkula also have notable values of rainfall, with 48.3mm and 37.2mm respectively, pointing to their considerable significance in the context of this dataset in a particular month. The values of cities i.e. Karnal (30.1 mm) and

Kaithal (21.5 mm) are also relatively high values of rainfall compared to others. Overall, rainfall data presents a range of values with noticeable variations, highlighting the diverse characteristics of rainfall across the different locations

Table 1: Rainfall analysis for the year 2022 (Indian Metrological Department)

Met Sub-Division/ State/UT/District	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Haryana	**69.0**	**15.3**	**0.2**	**0.5**	**34.5**	**36.0**	**220.4**	**70.0**	**138.3**	**35.9**	**0.3**	**0.0**
Ambala	106.8	17.9	0.0	0.2	19.6	47.1	203.7	39.7	180.5	30.7	0.1	0.0
Bhiwani	36.8	2.7	0.0	0.0	23.1	13.6	139.1	49.4	48.8	9.6	0.0	0.0
Charkhi Dadri	51.2	9.0	0.0	0.0	33.2	40.3	201.0	86.3	89.7	37.3	4.0	0.0
Faridabad	59.0	14.8	0.0	0.0	61.0	23.3	128.0	68.8	151.3	131.7	0.0	0.0
Fatehabad	32.1	10.5	0.0	0.0	30.7	41.6	249.9	61.1	206.1	15.5	0.0	0.0
Gurgaon	96.8	13.7	0.0	0.1	65.7	37.8	208.4	65.0	282.7	80.9	0.0	0.0
Hisar	44.3	2.9	0.1	3.2	30.0	30.9	216.3	74.7	128.4	4.6	0.5	0.0
Jhajjar	77.8	8.9	0.0	0.0	41.2	40.5	269.5	52.3	181.8	28.8	0.0	0.0
Jind	62.9	19.1	0.0	0.6	34.7	59.1	252.7	58.2	74.0	5.7	0.0	0.0
Kaithal	59.7	21.5	0.0	0.0	42.9	36.8	295.0	47.2	81.2	5.1	0.0	0.2
Karnal	80.9	30.1	0.0	0.0	58.9	40.5	312.1	96.8	231.8	8.4	0.0	0.2
Kurukshetra	120.0	48.3	0.0	0.0	71.8	50.2	262.3	29.9	175.5	20.0	0.0	0.0
Mahendragarh	58.7	4.0	0.0	0.8	11.0	38.0	202.7	85.2	158.9	57.1	1.3	0.0
Nuh	89.2	15.0	0.0	0.0	28.9	52.5	182.8	84.5	219.1	140.9	0.7	0.0
Palwal	64.3	12.5	0.0	0.0	20.0	38.0	207.3	90.5	125.5	132.0	0.0	0.0
Panchkula	172.9	37.2	0.0	0.6	37.7	60.1	374.2	173.1	157.7	45.6	0.0	0.0
Panipat	85.8	20.2	0.0	0.0	34.4	27.7	304.3	100.8	162.0	19.6	0.0	0.0
Rewari	72.1	11.3	0.0	1.2	23.1	37.2	181.8	45.7	136.5	51.6	0.1	0.0
Rohtak	57.2	12.1	0.0	0.4	30.4	24.6	282.4	39.4	167.1	12.8	0.0	0.0
Sirsa	35.6	6.6	1.7	1.0	15.8	28.5	167.9	66.9	36.4	1.0	0.1	0.0
Sonepat	86.1	14.6	0.0	0.0	35.0	24.1	189.9	90.2	127.1	18.9	0.0	0.0
Yamuna Nagar	169.3	54.8	0.0	0.3	42.4	43.6	259.7	116.8	216.6	38.1	0.0	0.0

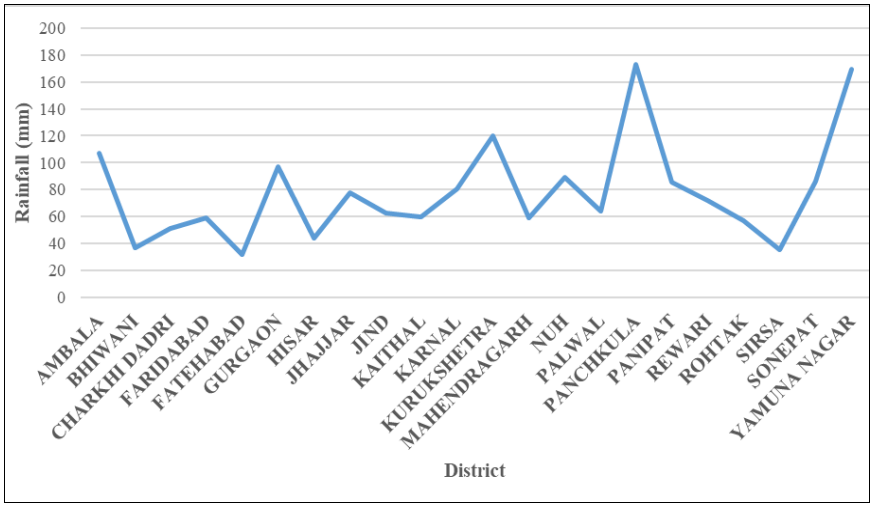

Fig 2: Shows the rainfall analysis in different districts of Haryana in January 2022

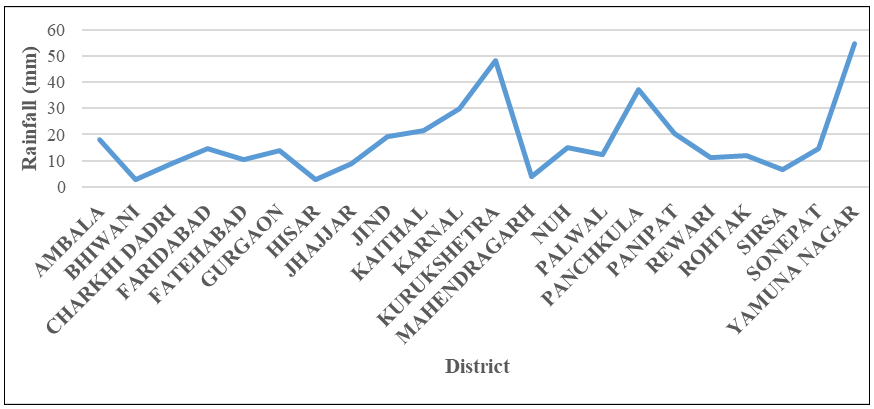

Fig 3: Shows the rainfall analysis in different districts of Haryana in February 2022

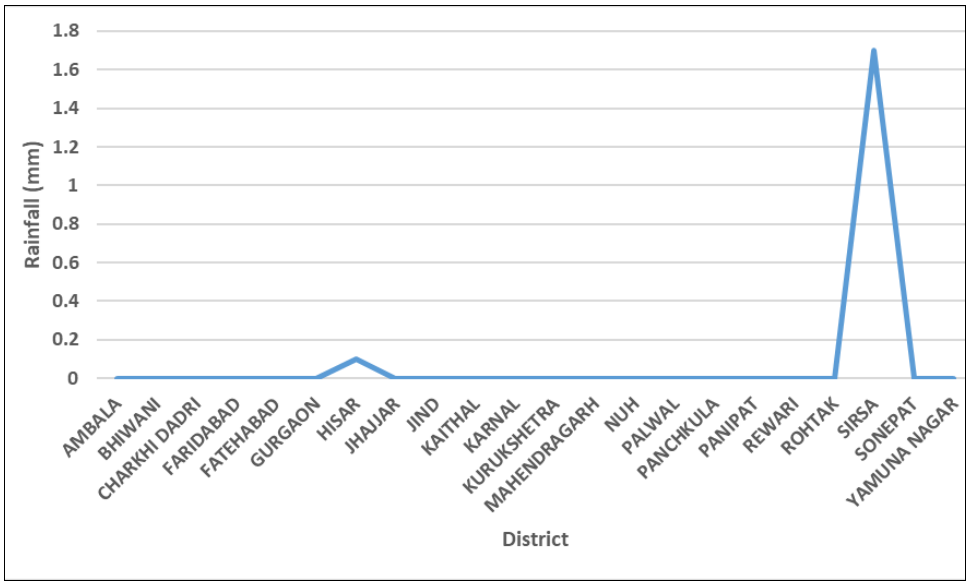

Fig 4: Shows the rainfall analysis in different districts of Haryana in March 2022

Figure 4 provided the rainfall data consisting mostly of zero values, with the notable exception of two distinct values 0.1mm and 1.7mm in Hisar and Sirsa. The predominance of zeros suggests that the majority of observations are negligible in this rainfall dataset in the month of March. A rainfall value of 0.1mm indicates a minor presence or occurrence, while 1.7mm stands out as a more significant value compared to the others. This disparity highlights that, aside from a few exceptions, the data reflects minimal or no activity in most cases, with only a couple of instances showing any substantial measure.

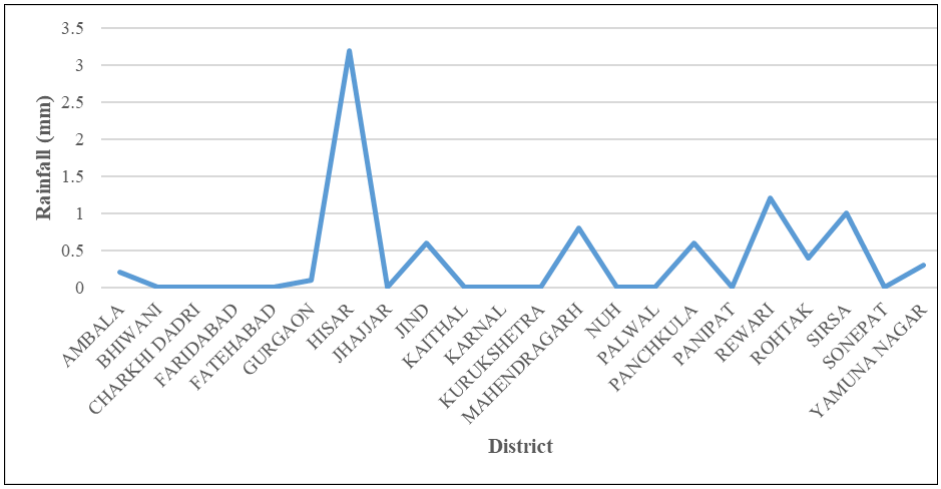

Fig 5: Shows the rainfall analysis in different districts of Haryana in April 2022

Figure 5 represents rainfall data across the multiple districts in Haryana. Ambala, Bhiwani, Charkhi Dadri, Faridabad, Fatehabad, Gurgaon, Hisar, Jhajjar, Jind, Kaithal, Karnal, Kurukshetra, Mahendragarh, Nuh, Palwal, Panchkula, Panipat, Rewari, Rohtak, Sirsa, Sonepat, and Yamuna Nagar each have recorded specific values. For instance, in April 2022, Ambala had a low value of 0.2mm, whereas Gurgaon showed a significantly higher value of 3.2mm, indicating a notable disparity across districts. Rewari also exhibits a higher value of rainfall with 1.2mm. Other districts like Faridabad, Jind, and Palwal have recorded zero values of rainfall. Rainfall data highlights the variations and unique attributes of each district, providing insights into regional differences and potential areas for further investigation.

Recent data on various cities in Haryana show a diverse range of metrics that illustrate the differing conditions across the region as shown in Figure 6. Ambala, with a rainfall of 19.6 mm, contrasts sharply with Charkhi Dadri at 33.2, indicating substantial variation. Different districts i.e. Faridabad and Gurgaon report significant values of rainfall 61mm and 65.7 mm, respectively. Meanwhile, some districts such as Nuh (11 mm) and Mahendragarh (28.9 mm) have relatively lower values of rainfall pointing to different local conditions. Some of the districts i.e. Hisar, Jhajjar, Jind, and Kaithal fall in the moderate rainfall regions. Karnal and Kurukshetra exhibit higher rainfall values of 58.9mm and 71.8mm. Some districts i.e. Palwal, Panchkula, and Rewari showed a variation in the rainfall with 20mm, 37.7mm, and 34.4mm. The last districts such as Rohtak (30.4mm), Sirsa (15.8mm), Sonepat (35.0mm), and Yamuna Nagar (42.4mm) showed a varying trend in May.

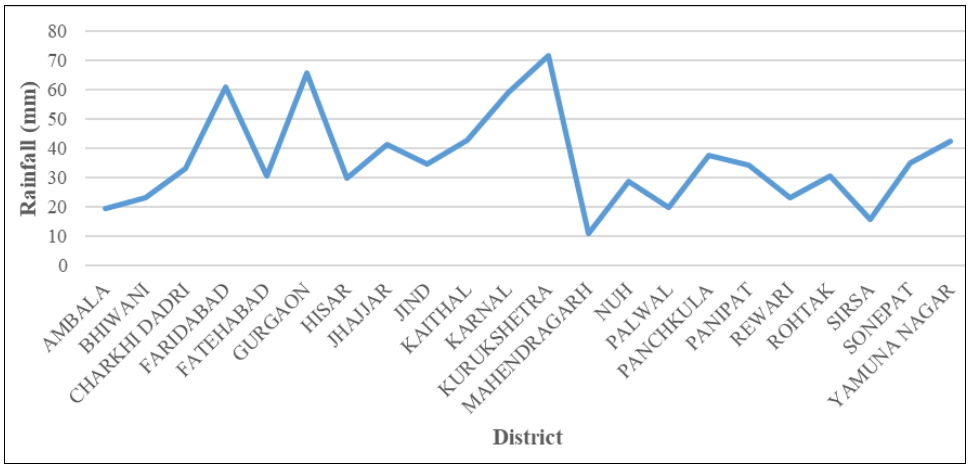

Fig 6: Shows the rainfall analysis in different districts of Haryana in May 2022

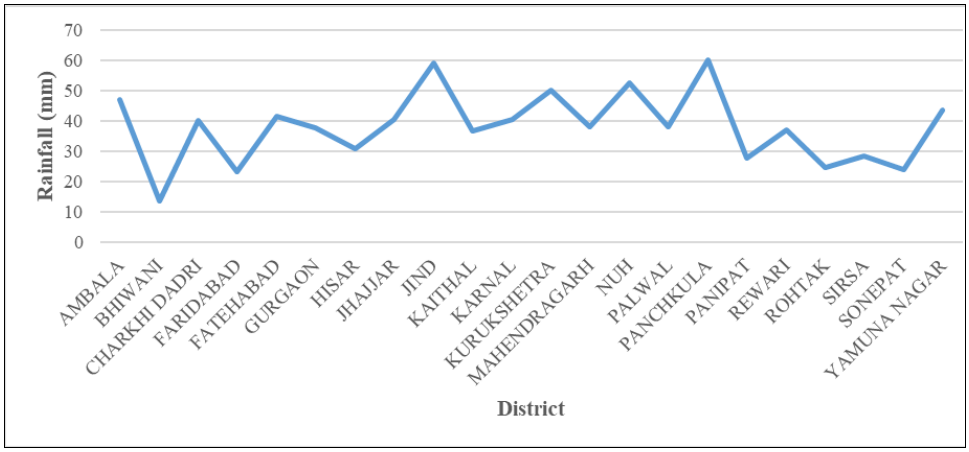

Fig 7: Shows the rainfall analysis in different districts of Haryana in June 2022

Ambala experienced the highest rainfall at 47.1 mm, while Bhiwani recorded the lowest at 13.6 mm as shown in Figure 7. Charkhi Dadri and Faridabad saw moderate rainfall of 40.3 mm and 23.3 mm, respectively. Fatehabad had substantial rainfall of 41.6 mm, and Gurgaon received 37.8 mm. Hisar and Jhajjar recorded 30.9 mm and 40.5 mm of rainfall, respectively. Jind experienced a significant downpour of 59.1 mm, and Kaithal received 36.8 mm. Karnal and Kurukshetra both recorded 40.5 mm of rainfall. Mahendragarh saw a heavy rainfall of 50.2 mm, while Nuh and Palwal each had 38.0 mm. Panchkula experienced a significant 52.5 mm of rainfall, while Panipat recorded the highest rainfall at 60.1 mm. Rewari received 27.7 mm, and Rohtak saw 37.2 mm. Sirsa and Sonepat recorded 24.6 mm and 28.5 mm of rainfall, respectively, while Yamuna Nagar received 24.1 mm. This data highlights the diverse rainfall patterns across Haryana's districts, emphasizing the regional climatic differences within the state.

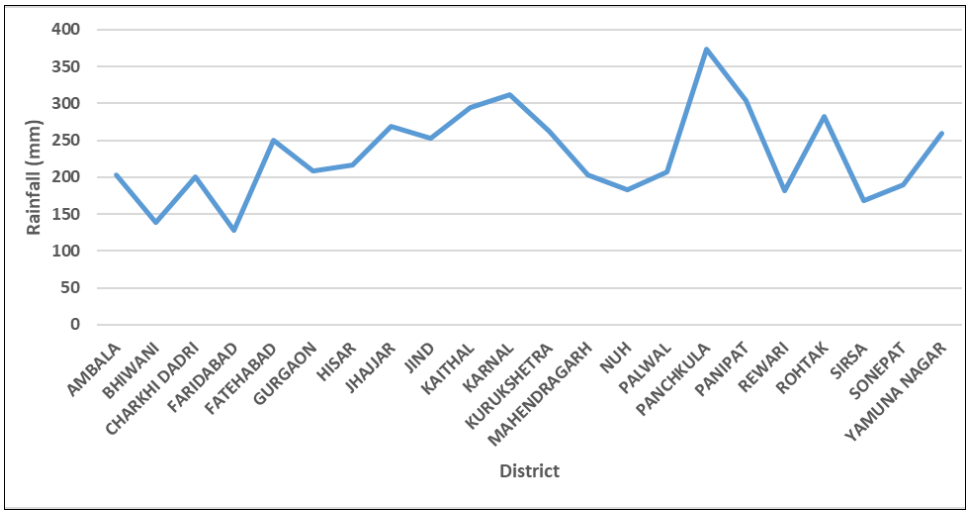

Fig 8: Shows the rainfall analysis in different districts of Haryana in July 2022

Figure 8 shows that Ambala shows a value of rainfall of 203.7mm in July, while Bhiwani has 139.1mm, and the rainfall data for other districts i.e. Faridabad, Gurgaon, and Hisar, reaching as high as 374.2mm in Panchkula.

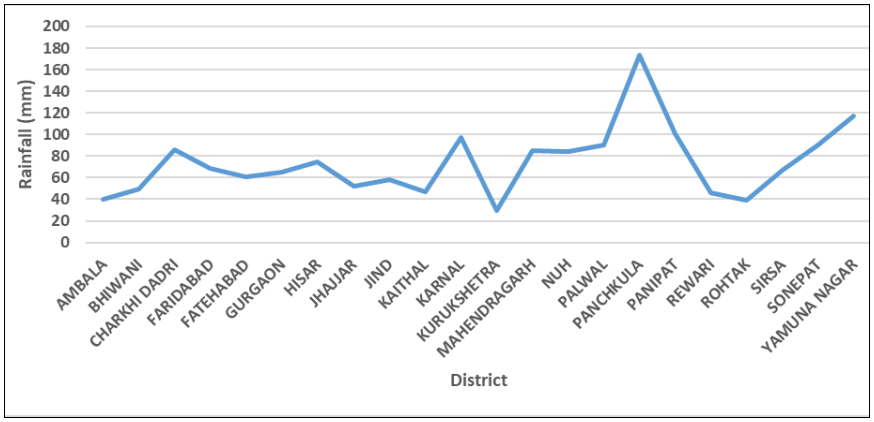

Fig 9: Shows the rainfall analysis in different districts of Haryana in August 2022

The data shows significant variation in rainfall across different districts. Panchkula recorded the highest rainfall at 173.1 mm, indicating a substantially higher level of precipitation compared to other districts as shown in Figure 9. On the other hand, Kurukshetra had the lowest rainfall, with only 29.9 mm recorded. Several districts, such as Faridabad (68.8 mm), Gurgaon (65.0 mm), and Hisar (74.7 mm), experienced moderate rainfall levels. Districts like Ambala (39.7 mm) and Rohtak (39.4 mm) had lower rainfall figures.

Understanding the distribution of rainfall across these districts is crucial for water resource management, agricultural planning, and disaster preparedness. The significant disparities in rainfall highlight the need for localized strategies to manage water resources effectively and mitigate potential flood or drought conditions.

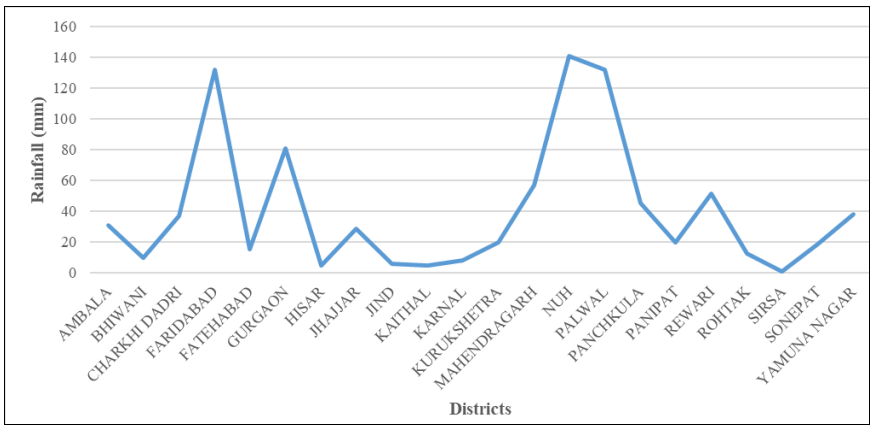

Fig 10: Shows the rainfall analysis in different districts of Haryana in September 2022

The rainfall data for the various districts provides an insightful look into the precipitation patterns in the region during September as shown in Figure 10. Gurgaon recorded the highest rainfall at 282.7 mm, indicating significant precipitation, possibly impacting local agriculture and water resources positively. Karnal, Nuh, and Yamuna Nagar also experienced substantial rainfall, with values of 231.8 mm, 219.1 mm, and 216.6 mm respectively, suggesting a generally wet season. Conversely, Sirsa received the least rainfall at 36.4 mm, which might lead to concerns about water scarcity and its effects on crops and daily life. Districts like Bhiwani and Jind also saw relatively low rainfall, with measurements of 48.8 mm and 74.0 mm, potentially indicating drier conditions. The distribution of rainfall across the districts is uneven, with some areas experiencing ample precipitation while others face significantly less, highlighting the variability in rainfall that can affect water management and agricultural planning.

The rainfall data provided appears to represent the rainfall measurements (in millimeters) for various districts in Haryana, India (Figure 11). Analyzing this data reveals significant variability in precipitation across the region. Ambala, for instance, records 30.7 mm of rainfall, whereas districts like Faridabad and Nuh receive substantially higher amounts at 131.7 mm and 140.9 mm, respectively. Conversely, Hisar and Rohtak experience much lower rainfall, with figures as low as 4.6 mm and 1.0 mm. This disparity in rainfall highlights the diverse climatic conditions within Haryana, which can have profound implications for agricultural practices, water resource management, and regional planning. Understanding these rainfall patterns is crucial for devising effective strategies to mitigate water scarcity, manage floods, and support the agricultural economy of the state.

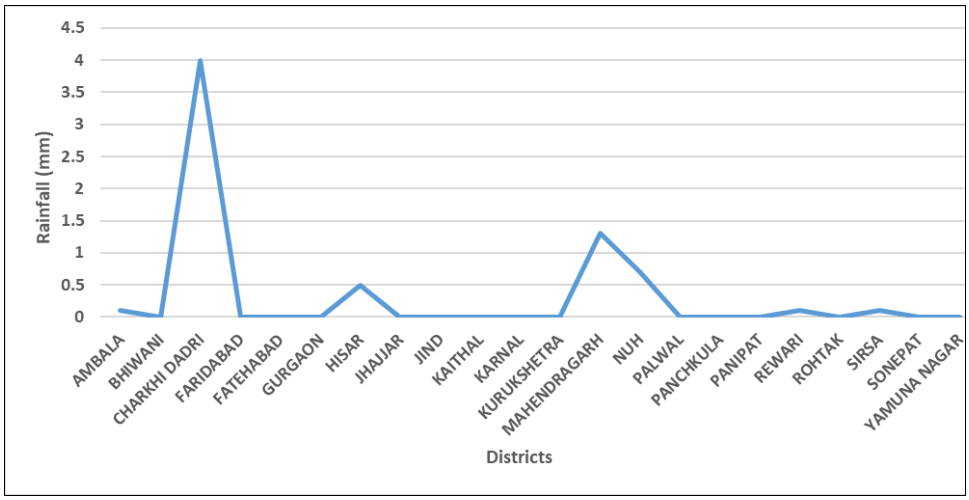

Fig 11: Shows the rainfall analysis in different districts of Haryana in October 2022

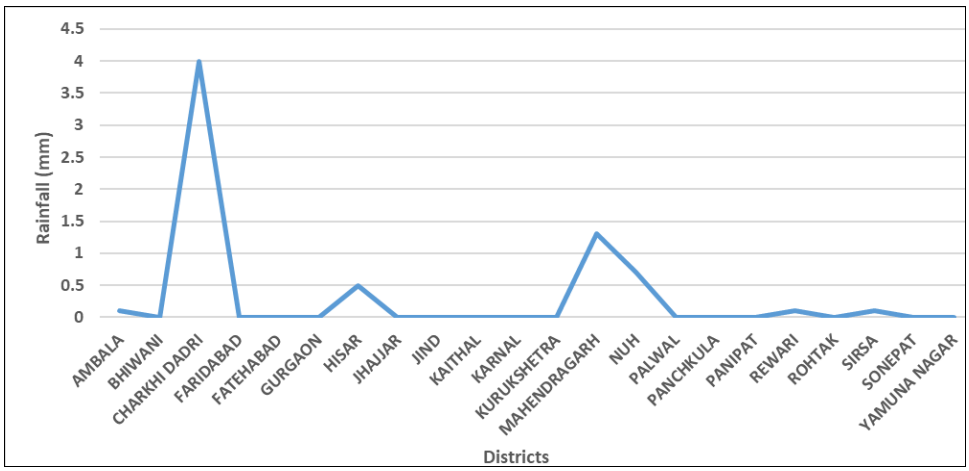

Fig 12: Shows the rainfall analysis in different districts of Haryana in November 2022

The rainfall data for various districts in Haryana shows significant variation, reflecting a diverse climatic pattern across the region. Ambala, Bhiwani, Faridabad, Fatehabad, Gurgaon, Jhajjar, Jind, Kaithal, Karnal, Kurukshetra, Palwal, Panchkula, Panipat, Rewari, Rohtak, Sonepat, and Yamuna Nagar reported no rainfall, indicating either a dry period or a lack of rainfall events during the observation period. In contrast, Charkhi Dadri, Hisar, Nuh, Sirsa, and Mahendragarh received some precipitation, with Charkhi Dadri experiencing the highest rainfall at 4.0 mm (Figure 12). Hisar and Rewari recorded minimal rainfall at 0.5 mm and 0.1 mm respectively, while Nuh and Sirsa also saw slight precipitation at 1.3 mm and 0.1 mm. This variability suggests localized weather phenomena influencing rainfall distribution, which could be attributed to factors such as topography, prevailing wind patterns, and regional climate variations. Effective water resource management and agricultural planning in Haryana would benefit from close monitoring and analysis of such rainfall data to mitigate the impacts of both drought and excessive rainfall.

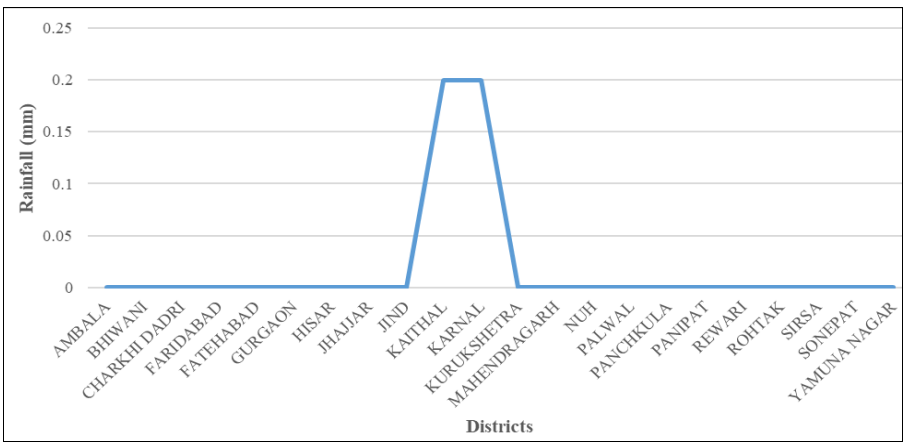

Fig 13: Shows the rainfall analysis in different districts of Haryana in December 2022

The rainfall data for the districts in Haryana reveals minimal precipitation across the region. Most districts, including Ambala, Bhiwani, Charkhi Dadri, Faridabad, Fatehabad, Gurgaon, Hisar, Jhajjar, Jind, Kaithal, Karnal, Kurukshetra, Mahendragarh, Nuh, Palwal, Panchkula, Panipat, Rewari, Rohtak, Sonepat, and Yamuna Nagar, recorded no rainfall during the observation period. Only Kaithal and Karnal received slight rainfall of 0.2 mm each, indicating very limited precipitation (Figure 13). This lack of significant rainfall may suggest a dry spell or a period of low atmospheric moisture in the region. Such conditions could impact water availability and agricultural productivity, underscoring the importance of water conservation strategies and preparedness for potential drought conditions. Monitoring and analysis of rainfall trends are crucial for effective resource management and to mitigate the effects of insufficient rainfall on local ecosystems and livelihoods.

Rainfall Analysis in Different Districts of Haryana (2023)

In June 2023, Haryana state received 80.7 mm (48%) of rainfall against 54.7 mm which was Excess rainfall departure than normal. The highest rainfall in Haryana during the last 121 (1901–2023) was 162.1 mm recorded in 1936 which was 230.8% above normal followed by years 2001 and 2008 with rainfall of 155.1 mm and 150.6 mm respectively.

Table 2: Rainfall Analysis of Haryana during the year 2023.

States	Rainfall Analysis		
	Actual	Normal	DEP
Ambala	899.8	819.9	10
Bhiwani	201.7	292.1	-31
Chandigarh	1227.1	844.8	45
Charkhi Dadri	316.3	400	-21
Faridabad	646.4	558.7	16
Fatehabad	151.5	261.6	-42
Gurugram	457.2	489.1	-7
Hisar	138	299.3	-54
Jhajjhar	343	380.5	-10
Jind	217.6	394	-45
Kaithal	384.1	365.1	5
KARNAL	568.7	521.9	9
Kurukshetra	826	413.6	100
Mahendragarh	406.4	394.4	3
Nuh	519.3	477.2	9
Palwal	334.8	399.3	-16
Panchkula	1018.1	859.6	18
Panipat	514.9	455.8	13
Rewari	366.8	431.4	-15
Rohtak	309.3	466	-34
Sirsa	235.1	210.8	12
Sonipat	533.5	479.1	11
Yamunanagar	1143.2	895.2	28
Subdivision	421.5	430.1	-2

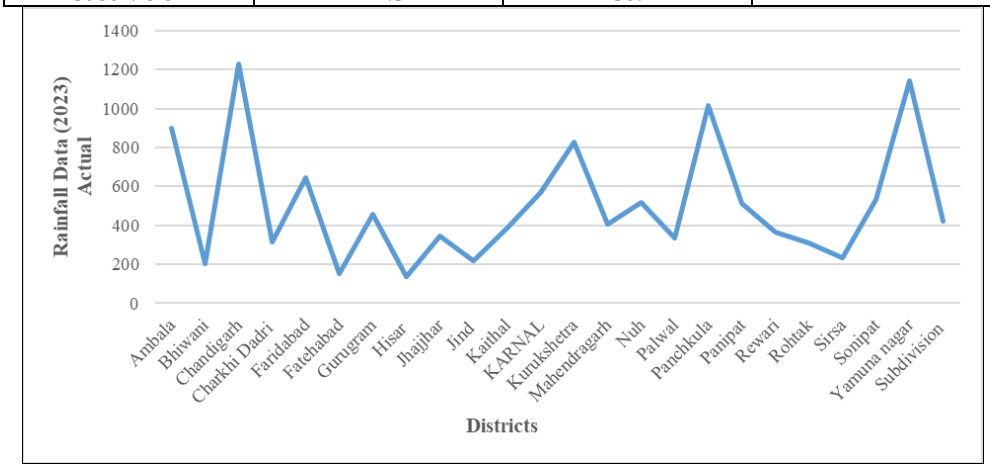

Fig 14: Shows actual rainfall analysis during 2023

During June 2023, 13 districts showed Large excess rainfall departures, one district showed excess rainfall departure, three districts Normal rainfall departures, and 05 districts showed deficient rainfall departures as shown in Figure 14.

In July 2023 Haryana state received 236.9 (59%) mm of rainfall against its normal rainfall of 149.1 mm which was Excess rainfall departure than normal. The most noteworthy precipitation got in Haryana during July month during

(1901-2023) was in the year 1964 was 390.8 mm of precipitation against its not unexpected precipitation of 150.3 followed by 1988 and 1994 when the state got 389.8 mm and 346.3 mm of precipitation separately. The most minimal precipitation in July (1901-2021) was in 1918 when the state got 19.8 mm of precipitation against 157.1 mm with a deficiency of 87.7% followed by years 2004 and 1911 when precipitation was 21.0 mm and 27.6 mm separately. During July 2023, 07 districts showed Normal rainfall departures, 05 districts showed Excess rainfall departures and 10 districts showed Large Excess rainfall departures. In August Haryana got 58.5 mm of precipitation against its ordinary of 146.1 mm which was 60% not exactly typical. The most noteworthy precipitation in Haryana during (1901-2023) was in 1995 when the state got 467.0 mm of precipitation against its typical of 179.0 mm with a general abundance of 161% followed continuously 1908 and 1960 when precipitation was 423.3 mm and 356.7 mm separately. During August 2023 04 districts showed Deficient rainfall departure, 16 districts showing Largely Deficient rainfall departure, and 02 districts showing Normal rainfall departures. In September state received 43.5 mm (-42%) of rainfall against its normal of 76.1 mm and was Deficient. The most noteworthy precipitation in Haryana during September month during (1901-2023) was in the year 1917 when the state got 343.0 mm of precipitation against its generally expected precipitation of 103.0 mm followed by 1933 and 1945 when the state got 316.2 mm and 293.7 mm of precipitation separately.

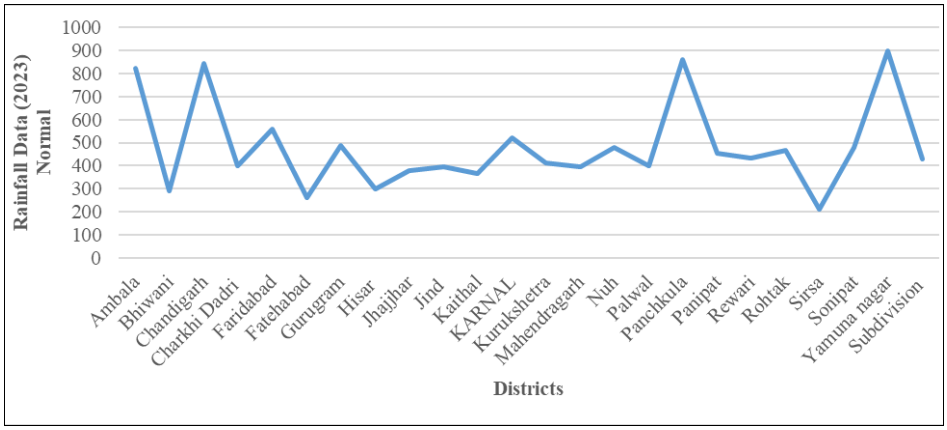

Fig 15: Shows normal rainfall analysis during 2023

During September 2023 02 districts showed Normal rainfall departures, 03 districts showed Excess rainfall departures, 06 districts showed Deficient rainfall departures and 11 districts showed Large deficient rainfall departures.

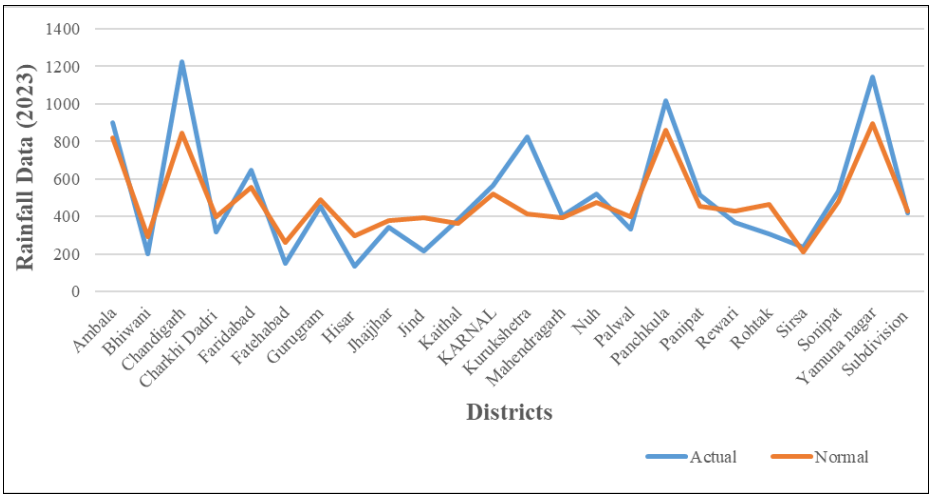

Fig 16: Shows a comparison between actual and normal rainfall during 2023

The comparison of normal and actual rainfall data for various regions reveals significant deviations as shown in Figure 16. Ambala, Chandigarh, Kurukshetra, Panchkula, and Yamuna Nagar received substantially more rainfall than normal, with actual rainfall figures exceeding the normal by a notable margin. For instance, Chandigarh had an actual rainfall of 1227.1 mm compared to the normal 844.8 mm. In contrast, regions like Bhiwani, Fatehabad, Hisar, and Sirsa experienced lower actual rainfall compared to the normal, indicating a shortfall. Hisar, for example, recorded only 138 mm of rainfall against the normal of 299.3 mm. This pattern indicates a varied distribution of rainfall across the regions, with some areas experiencing excessive rainfall while others faced deficits. The disparities suggest potential impacts on agricultural activities, water supply, and overall regional water management strategies.

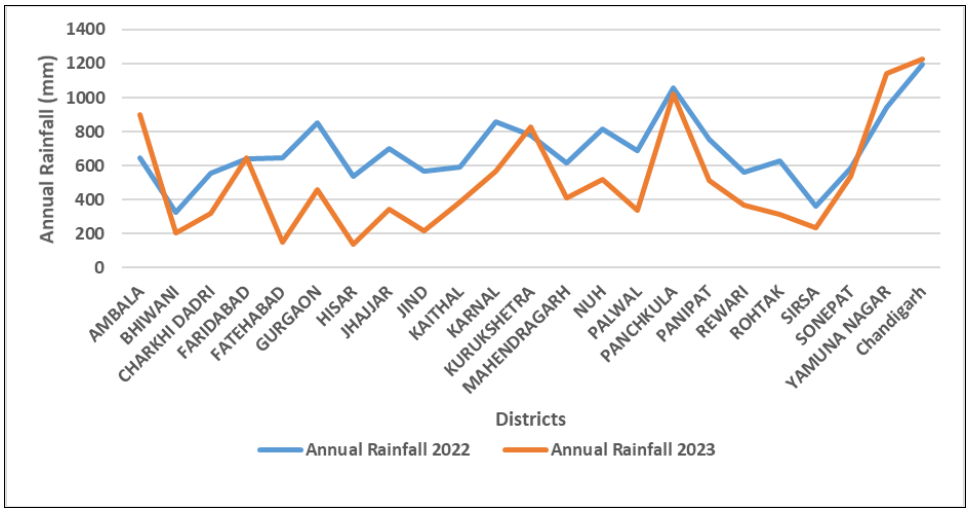

Fig17: Shows the comparison between annual rainfall for different districts of Haryana

The annual rainfall data for 2022 and 2023 across various districts indicate notable fluctuations, with significant decreases in most regions. Ambala, Kurukshetra, Yamuna Nagar, and Chandigarh experienced increases in rainfall, with Yamuna Nagar showing a substantial rise of 21.42% and Chandigarh a modest increase of 2.68%. Conversely, the majority of districts saw declines, with the most pronounced reductions observed in Fatehabad, Hisar, and Charkhi Dadri, registering decreases of 76.58%, 74.22%, and 42.69%, respectively. Bhiwani, Gurgaon, and Nuh also experienced considerable drops in rainfall, impacting regional water resources and agricultural activities. Faridabad showed a marginal increase of 1.32%, while Panchkula had a slight decrease of 3.85%. These variations highlight the challenges in predicting and managing water resources, emphasizing the need for adaptive strategies to cope with changing rainfall patterns.

Table 3: Annual rainfall data analysis for the years 2022 and 2023

District	Annual Rainfall 2022	Annual Rainfall 2023	Difference (mm)	Percentage Change (%)
Ambala	646.5	899.8	253	39.17
Bhiwani	323.0	201.7	-121.3	-37.56
Charkhi Dadri	551.9	316.3	-235.6	-42.69
Faridabad	638.0	646.4	+8.4	+1.32
Fatehabad	647.4	151.5	-495.9	-76.58
Gurgaon	851.1	457.2	393.9	-46.29
Hisar	535.9	138	-397.9	-74.22
Jhajjar	700.8	343	-357.8	-51.06
Jind	567.0	217.6	-349.4	-61.61
Kaithal	589.6	384.1	-205.5	-34.86
Karnal	859.7	568.7	-291	-33.86
Kurukshetra	777.9	826	48.1	6.18
Mahendragarh	617.7	406.4	-211.3	-34.22
Nuh	813.5	519.3	-294.2	-36.16
Palwal	690.0	334.8	-355.2	-51.45
Panchkula	1058.9	1018.1	-40.8	-3.85
Panipat	754.8	514.9	-239.9	-31.78
Rewari	560.6	366.8	-193.8	-34.57
Rohtak	626.4	309.3	-317.1	-50.62
Sirsa	361.4	235.1	-126.3	-34.94
Sonepat	585.8	533.5	-52.3	-8.93
Yamuna Nagar	941.5	1143.2	201.7	21.42
Chandigarh	1195.1	1227.1	32	2.68

Conclusion

The state of Haryana, situated in northern India, is experiencing profound effects of climate change that threaten its agricultural economy and overall development. The rise in average temperatures has led to frequent heatwaves, which adversely affect human health and agricultural productivity. Erratic rainfall patterns, characterized by inconsistent monsoons and extended droughts, have intensified water scarcity, impacting crop yields and water management. Additionally, the increased incidence of extreme weather events like floods and storms has disrupted livelihoods and damaged infrastructure.

Haryana's heavy reliance on agriculture, particularly water-intensive crops such as rice and wheat, the state is particularly vulnerable to climate-induced disruptions. To mitigate these adverse effects, it is essential to implement adaptation strategies that encompass sustainable agricultural practices, water conservation techniques, and robust policy frameworks. Comprehensive climate action plans are necessary to enhance the resilience and sustainability of Haryana's environment and economy. The varied rainfall distribution across the state further emphasizes the need for localized water resource management and agricultural planning to address the disparities and ensure effective utilization of water resources. The urgent need for such measures cannot be overstated if Haryana is to navigate the challenges posed by climate change and secure its future development.

References

1. Southwest Monsoon Report-2023 For the State of Haryana. Indian Meteorological Department; c2023.
2. Rainfall Statistics 2022. Indian Meteorological Department of India; c2022.
3. Malik R, Setia R. A comparative study on the floods in India due to heavy rainfall. Disaster Advances. 2020;13(1):17-28.
4. Nandy S, Latwal M, Pandey G, Chae KH. Synthesis of nanostructured ferrites and cation distribution studies by X-ray magnetic circular dichroism, Mössbauer spectroscopy, and X-ray absorption spectroscopy. Journal of Electronic Materials; c2022. DOI: 10.1007/s11664-022-09951-7.
5. Li YJ, Xu WQ, Zhu TY, Qi F, Xu TB, Wang Z. CO2 emissions from BF-BOF and EAF steelmaking based on material flow analysis. Advanced Materials Research; c2023. Available from: https://doi.org/10.4028/www.scientific.net/AMR.518-523.5012.
6. Murthy CS, Yadav M, Ahamed JM, Laxman B, Prawasi R, Sesha Sai MVR. A study on agricultural drought vulnerability at disaggregated level in a highly irrigated and intensely cropped state of India. Environmental Monitoring and Assessment. 2015, 187(3). DOI: 10.1007/s10661-015-4296-x.
7. Chauhan AS, Singh S, Singh RK, Maurya RKS, Danodia A. Spatio-temporal analysis of rainfall in relation to monsoon teleconnections and agriculture at regional scale in Haryana, India. Regional Environmental Change. 2023;30(55):116781-116803.