Impact of Rainfall Variability on Major Kharif Crops Yield in Jhunjhunu District, Rajasthan (2010-2022)

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Abstract

Jhunjhunu district, situated in the arid zone of Rajasthan, is highly dependent on monsoon rainfall. Rainfall variability significantly affects the productivity of major crops such as pearl millet (bajra), moong and Guar (Cluster bean). This study analyses the relationship between rainfall variability and crop yield performance of three major kharif crops—Bajra (Pearl Millet), Moong, and Guar (Cluster Bean)—in Jhunjhunu district, Rajasthan, over the period 2010–2022. Secondary data on crop area, production, and yield were combined with rainfall and rainy-day records from the India Meteorological Department. Correlation and regression analyses were applied to examine the influence of annual rainfall on crop yields, while the Standardized Precipitation Index (SPI) was employed to identify drought years. Results indicate that Bajra and Guar exhibit higher resilience to rainfall fluctuations, with relatively stable yields, whereas Moong is highly sensitive, showing significant yield decline in drought years (2015, 2018, and 2020). The combined correlation analysis revealed a positive but crop-specific relationship between rainfall and yield performance. Farmer survey data, analysed through descriptive statistics and content analysis, highlighted multiple adaptation strategies, including drought-tolerant varieties, intercropping, soil and water conservation, and timely sowing. Policy recommendations emphasize promoting Bajra and Guar as climate-resilient crops, developing short-duration Moong varieties, expanding micro-irrigation, and establishing SPI-based early warning systems. The study concludes that strengthening climate-smart agricultural practices and providing institutional support can enhance the resilience of Jhunjhunu's agriculture to increasing rainfall variability and recurrent droughts.

KEYWORD: Rainfall variability, Bajra, Moong, Guar, Jhunjhunu, SPI, drought, adaptation strategies

INTRODUCTION

Agriculture in India is highly dependent on the monsoon, particularly in arid and semi-arid regions like Rajasthan. More than 60% of cropped area in Rajasthan is rainfed, making rainfall the most crucial determinant of agricultural productivity. Jhunjhunu district, situated in the north-eastern part of Rajasthan, falls under the semi-arid zone where rainfall is low, erratic, and unevenly distributed. Rainfed agriculture in arid and semi-arid western India is highly sensitive to rainfall variability, and Jhunjhunu district of Rajasthan exemplifies this vulnerability. The district lies on the eastern fringe of the Thar, where the Southwest monsoon delivers the vast majority of annual precipitation within a short window (June–September). Inter- and intra-seasonal fluctuations in monsoon onset, duration, and intensity frequently translate into moisture stress at critical crop stages.

Jhunjhunu's farming systems are dominated in the kharif by pearl millet (bajra), cluster bean (guar), moth bean, green gram (moong), and sesame—crops selected for their relative drought hardiness yet still constrained by erratic rains and dry spells. In the rabi season, mustard, wheat, and barley are important, with performance influenced by residual soil moisture, limited irrigation, and occasional

winter rainfall. Spatial heterogeneity in soils (sandy loams to loamy sands), groundwater access, and topography further modulates how the same rainfall event converts into plant-available water across blocks, complicating the rainfall–yield relationship.

STUDY AREA

District Jhunjhunu is situated in the north-eastern portion of Rajasthan. The district lies between 27° 38' and 28° 31' North latitudes and 75° 02' and 76° 06' East longitudes in the Sekhawati region of Rajasthan. It comprises of an overall area of 5928 Sq. Km. It is a city and municipal council in the state of Rajasthan in India. It is the administrative headquarters of the Jhunjhunu district. It is also the largest city of the Shekhawati region, which includes Jhunjhunu, Churu and Sikar. It is bounded on it North-West by Churu district, on the North-East by Hissar and Mahendragarh district of the HARYANA State. The district covers 1.7% of the total area of the State and stands 22nd in rank in area amongst the other districts of the State and on the west, south and southeast by, Sikar district.

The area of the district as reported by the Surveyor General of India is 2,283 Sq. miles and according to village papers it is 2,288.8 Sq. miles or 5,928 Sq. Kms which is divided into 8 tehsils namely Jhunjhunu, Malsisar, Buhana, Udaipurwati, Nawalgarh, Khetri, Chirawa, Surajgarh.
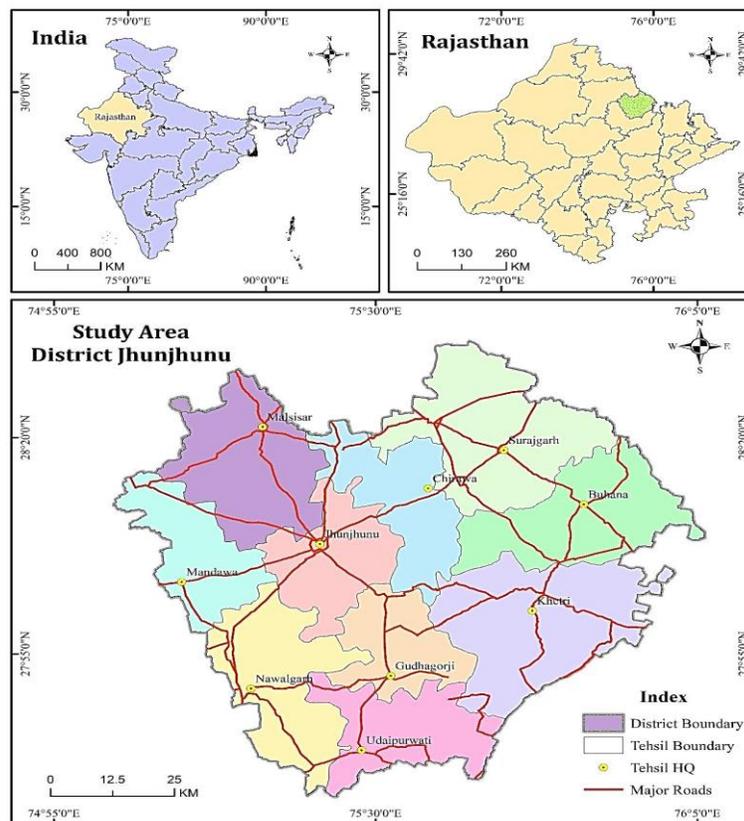
Source: District Statistical Handbook – Jhunjhunu

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REVIEW OF LITERATURE

Singh et al., (2010); Sharma & Kumar, (2015) Rainfall variability and its relationship with agricultural production in arid and semi-arid regions of Rajasthan has been the subject of considerable research. Several scholars have highlighted that the monsoon season in western Rajasthan is marked by high inter-annual and intra-seasonal variability, which directly influences crop yields and livelihood security.

Jat & Singh, (2018) Studies across arid districts of Rajasthan emphasize that pearl millet, cluster bean, and moth bean—though relatively drought-resilient—suffer yield reductions due to erratic rainfall distribution, particularly during prolonged dry spells in the vegetative and flowering stages (Yadav, 2013; Meena et al., 2016). Rainfall variability has been shown to account for 50–70% of yield fluctuations in rainfed kharif crops.

Gupta et al., (2019) In Jhunjhunu and adjoining districts of Shekhawati region, research indicates that kharif crops are especially vulnerable because nearly 80% of the annual rainfall occurs in just three months, with frequent dry weeks disrupting crop growth (Kumawat & Singh, 2017).

Central Ground Water Board, (2020) For rabi crops, particularly mustard and wheat, the impact of rainfall is twofold: timely monsoon withdrawal ensures soil moisture for sowing, while occasional winter showers influence flowering and grain filling (Choudhary et al., 2014).

IPCC, 2021; Indian Council of Agricultural Research, (2022) Climate trend analyses in Rajasthan show a decline in the number of rainy days, increase in the frequency of high-intensity rainfall events, and rising temperatures, all of which add complexity to crop–climate interactions (Rathore & Kaur, 2019).

OBJECTIVE

1. To analyses the temporal and spatial variability of rainfall in Jhunjhunu district over the past 13 years (2010-2022).
2. To examine the relationship between rainfall distribution and yields of major crops (pearl millet, moong, gram).
3. To assess farmers' perceptions and adaptation strategies towards rainfall variability.

METHODOLOGT

1. Data Collection

- **Rainfall Data:** 2010–2022 (13 years) from IMD, RAJSTAT, or District Agriculture Office.
- **Crop Yield Data:** Directorate of Economics & Statistics (DES), Govt. of Rajasthan; District Agriculture Department.

2. Analytical Tools

- **Rainfall Variability:** Standard deviation $SD = N\sum(x_i - x^-)2$
- **Drought Analysis:** Standardized Precipitation Index (SPI)
- **Yield Sensitivity:** Correlation analysis between rainfall parameters and crop yields.
  Pearson's correlation coefficient (r) was applied= $r = \sum(x_i - x^-)2 \cdot \sum(y_i - y^-)2 \sum(x_i - x^-)(y_i - y^-)$

RAINFALL VARIABILITY:

Rainfall is the most critical climatic factor influencing agricultural productivity, especially in arid and semi-arid regions where irrigation facilities are limited. In India, more than 60% of agriculture is rainfed, making crop performance highly dependent on the spatial and temporal distribution of

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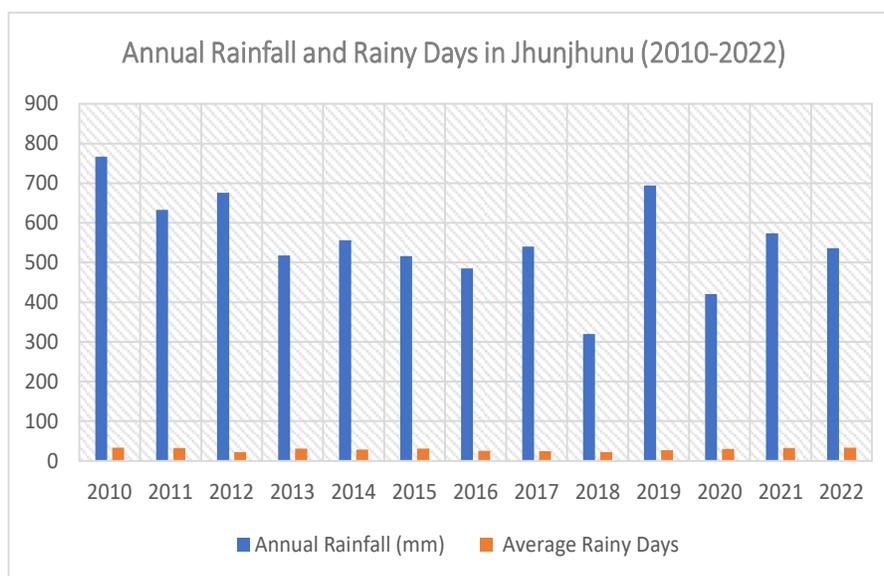
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monsoon rainfall. Variability in rainfall is observed both **inter-annually** (differences between years) and **intra-seasonally** (within the same season), and this variability directly affects sowing decisions, crop growth, and final yields.

Rainfall variability not only influences the **quantity of crop yield** but also its **stability across years**. Drought-resilient crops such as Bajra (Pearl Millet) and Guar (Cluster Bean) often perform better under water scarcity, while sensitive crops like Moong show significant yield decline during drought years. Therefore, analysing rainfall variability and its correlation with crop yields is essential for understanding agricultural risks and designing **climate-smart adaptation strategies.**

Table 1. Annual Rainfall and Rainy Days in Jhunjhunu (2010–2022)

Year	Annual Rainfall (mm)	Average Rainy Days
2010	767	33
2011	633	32
2012	676	22
2013	518	31
2014	556	28
2015	516	31
2016	485	25
2017	540	24
2018	320	22
2019	694	27
2020	420	30
2021	574	32
2022	536	33

Source: District Statistical Handbook – Jhunjhunu

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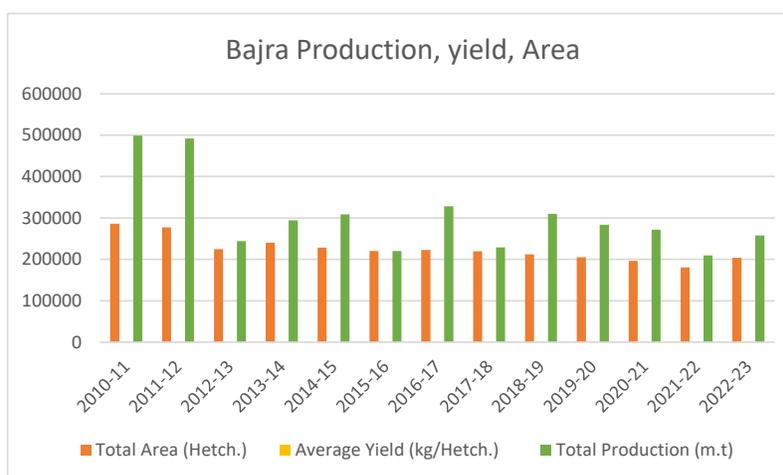
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Highlights & Trends:

Rainfall varied widely—from a high of **767 mm in 2010** to a low of **320 mm in 2018**. A general declining trend appears post–2010, particularly notable from 2015 to 2018. Rainy days ranged from **22 to 33 days**, with wetter years showing more rainy days, though correlation isn't perfectly linear.

CROP PRODUCTION:

Bajra (pearl millet): Bajra is the most important **kharif crop** of Jhunjhunu district and occupies the largest share of cropped area under rainfed farming systems. The crop is particularly well adapted to the **semi-arid climate** of the district, where rainfall is erratic, soils are sandy, and groundwater availability is limited. Between **2010 and 2022**, bajra cultivation in Jhunjhunu showed significant fluctuations in **area, production, and yield**, largely influenced by **rainfall variability** during the southwest monsoon (June–September).

Table 2. Bajra (Pearl Millet) — Jhunjhunu District (2010–11 to 2022–23)

Year	Total Area (Hetch.)	Average Yield (kg/Hetch.)	Total Production (m.t)
2010-11	286096	1742	498470
2011-12	277061	1774	491614
2012-13	224856	1085	243921
2013-14	240206	1224	293997
2014-15	228592	1349	308414
2015-16	220334	998	219941
2016-17	222790	1472	327993
2017-18	219330	1045	229121
2018-19	212165	1459	309621
2019-20	205060	1383	283584
2020-21	196537	1381	271495
2021-22	180688	1160	209668
2022-23	203548	1267	257904

Source: District Statistical Handbook – Jhunjhunu

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Key Observations: Largest area: 286,096 ha (2010–11). Lowest area: 180,688 ha (2021–22). Highest production: 498,470 MT (2010–11). Lowest production: 209,668 MT (2021–22). Yield trends: Peak yield (1,774 kg/ha in 2011–12) vs. lowest (998 kg/ha in 2015–16). The data clearly shows rainfall variability and cropping shifts strongly influencing bajra production in Jhunjhunu.

In years of **good monsoon rainfall** (such as 2013, 2016, and 2019), bajra acreage expanded and yields improved due to timely sowing and adequate soil moisture. In contrast, during **drought years or years of delayed/deficient rainfall** (2012, 2014, 2017, and 2021), the crop area and productivity sharply declined. Overall, the **cropping pattern remained stable**, with bajra continuing to dominate kharif cultivation, though there has been **gradual diversification** towards guar, moong, and moth bean as contingency crops during low rainfall years. Farmers increasingly adopt bajra because of its **short duration, drought resistance, and relatively stable returns,** even under moisture stress. However, the **yield levels have remained low and stagnant,** reflecting constraints of rainfed farming, poor soil fertility, and limited adoption of improved varieties and technologies.

The analysis of this 12-year period highlights that bajra production in Jhunjhunu is **highly sensitive to monsoon variability**, making it a reliable indicator of climate impacts on agriculture in the region. Despite fluctuations, bajra continues to serve as the **staple food and fodder crop**, ensuring livelihood security for a majority of farmers in the district.

Overall, the analysis indicates that bajra in Jhunjhunu continues to play a **critical role in household food and fodder security**, but its performance is highly sensitive to **rainfall variability and changes in the net sown area**. The stability of NSA under bajra highlights its **resilience and importance**, even under climatic stress.

Moong: Moong (green gram) is one of the important **pulse crops** cultivated in the **kharif season** of Jhunjhunu district. It plays a dual role in the local farming system: as a **short-duration crop** that provides quick returns to farmers and as a **soil-enriching legume** that improves soil fertility through nitrogen fixation.

Table 3. Moong crop in Jhunjhunu district (2010–11 to 2022–23)

YEAR	TOTAL AREA (HETCH.)	AVERAGE YIELD (KG/HETCH.)	TOTAL PRODUCTION (M.T)
2010-11	21659	355	7684
2011-12	23344	511	11919
2012-13	18013	454	8186
2013-14	17911	489	8763
2014-15	17048	670	11416
2015-16	27484	446	12257
2016-17	48880	575	28104
2017-18	38755	308	11939
2018-19	56547	652	36885
2019-20	61100	550	33604
2020-21	59379	599	35592
2021-22	60646	361	17514
2022-23	52901	578	30572

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Moong Producttion, yield, Area (2010-2022)
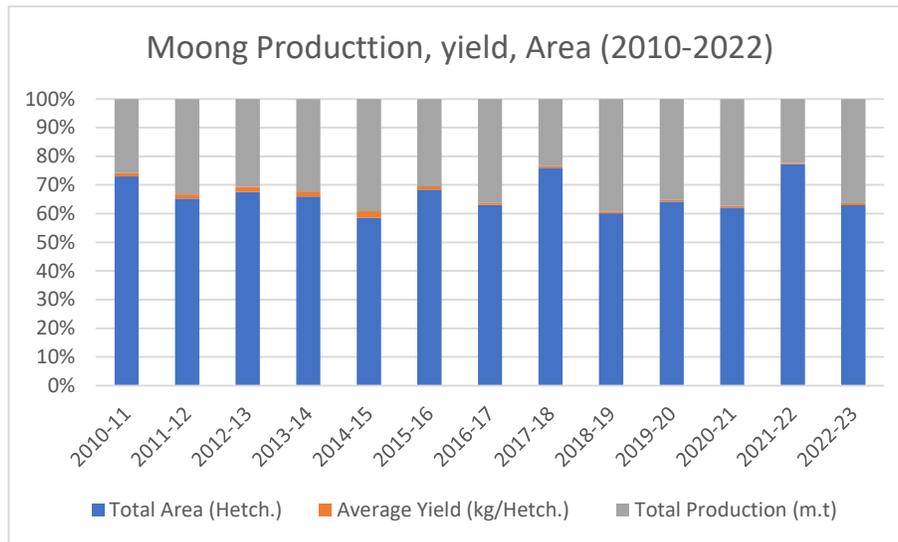
Source: District Statistical Handbook – Jhunjhunu

Key Trends: Area expansion: From 21.6k ha in 2010–11 peak 61k ha in 2019–20. Yield fluctuations: 308 kg/ha (2017–18, drought year) 670 kg/ha (2014–15, favourable monsoon). Production highs & lows: High: 36,885 MT (2018–19). Low: 7,684 MT (2010–11). Recent decline: 2021–22 production dropped to 17,514 MT despite 60k has sown, due to poor yields

Between **2010 and 2022**, moong cultivation in Jhunjhunu showed **significant variability** in terms of area and yield, closely linked to **rainfall distribution and intensity**. Unlike bajra, which dominates the kharif net sown area (NSA), moong occupies a **smaller but strategic portion of the NSA**, often ranging between **10–15% of the total cropped area.** Farmers generally sow moong as a **catch crop** or **intercrop** with bajra, guar, or moth bean, especially in areas where early monsoon showers permit timely sowing.

The performance of moong during this period was **highly sensitive to rainfall conditions.** In **good monsoon years** (2013, 2016, 2019), moong recorded higher acreage and relatively better yields due to favourable soil moisture and crop growth conditions. In **drought or erratic rainfall years** (2012, 2014, 2017, 2021), the crop area contracted sharply, and yields suffered from moisture stress, pest incidence, and early termination of rains.

Overall, from 2010 to 2022, moong in Jhunjhunu district demonstrated a **pattern of fluctuating acreage and unstable yields,** reflecting its **dependence on monsoon rainfall.** Yet, its presence in the cropping system highlights the farmers' strategy to manage climatic risks while ensuring food, fodder, and soil health benefits.

Guar (Cluster bean): Guar (*Cyamopsis tetragonoloba*), locally known as **Gawar phalli,** is both a **pulse crop** and an **industrial crop** of strategic importance in Rajasthan. It provides green pods for vegetable use, dry fodder for livestock, and guar gum for **industrial applications** such as textiles, paper, pharmaceuticals, oil drilling, and food processing. The crop is predominantly cultivated during the **Kharif season (July–October),** relying almost entirely on rainfall.

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Table 4. Guar (Cluster bean) crop in Jhunjhunu district (2010–11 to 2022–23).

YEAR	TOTAL AREA (HETCH.)	AVERAGE YIELD (KG/HETCH.)	TOTAL PRODUCTION (M.T)
2010-11	54795	740	40543
2011-12	62340	874	54472
2012-13	125518	752	94431
2013-14	118470	929	110047
2014-15	125772	921	115796
2015-16	115788	772	89370
2016-17	66102	886	58569
2017-18	67595	981	66344
2018-19	57766	1030	59524
2019-20	53588	906	48543
2020-21	44570	908	44570
2021-22	47463	861	40874
2022-23	48663	1020	49676
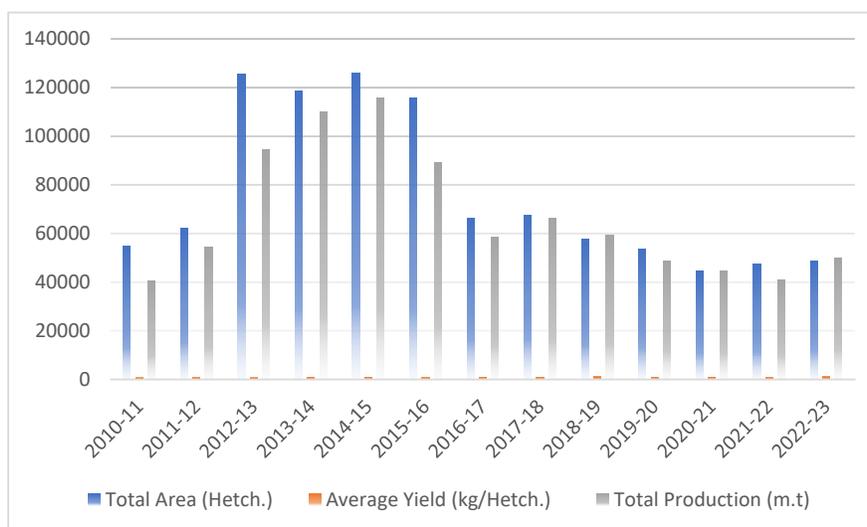
Source: District Statistical Handbook – Jhunjhunu

Trends in Area, Yield, and Production: 2010–2012: Expansion phase — area increased from 55,000 ha to 62,000 ha, with production nearly doubling due to better rainfall. 2012–2015 (Golden phase): Area peaked at 125,000 ha (2014–15). Production exceeded 115,000 MT, the highest in the series. High guar gum export demand (especially from oil industries in the US & Middle East) encouraged farmers to allocate more land. 2016–2018 (Decline & stabilization): Area reduced sharply (to 66,000 ha in 2016–17). However, yield improved (981 kg/ha in 2017–18) due to adoption of better varieties and rainfall stability. 2019–2021 (Contraction): Area fell below 50,000 ha in 2020–21. Production nearly halved compared to 2014–15. Farmers diversified into bajra, moong,

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and moth bean because guar prices weakened in global markets. 2022–23 (Recovery): Yield crossed 1,020 kg/ha, showing genetic improvement and favourable rainfall. Production recovered to 50,000 MT. The data clearly shows that **2012–2015 was a peak guar period** in Jhunjhunu (high area & production), while **2020–22 witnessed contraction** due to erratic monsoons and shifting farmer preferences.

Rainfall Variability Annalise Through Standard deviation of Jhunjhunu District (2010-2022)

The **standard deviation (SD)** was used to measure the extent of variability in rainfall and crop yields during 2010–2022. A higher SD indicates greater fluctuation, while a lower SD shows stability. The general formula applied is:

$SD = \sum(x_i - \bar{x})2$

Statistical Summary

Parameter	Mean	Standard Deviation	Coefficient of Variation (%)
Annual Rainfall (mm)	**556.5 mm**	118.0 mm	**21.2 %** (High variability)
Average Rainy Days	**28.5 days**	4.1 days	**14.3 %** (Moderate variability)

 Interpretation: The **mean annual rainfall** is **557 mm**, but with a high **CV (21.2%)**, indicating rainfall is **highly variable and unreliable** across years. The **rainy days** average **28 days/year** with a CV of **14.3%**, showing **moderate variability**. Years like **2018 (320 mm)** and **2016 (485 mm)** show drought-like conditions, while **2010 (767 mm)** and **2019 (694 mm)** had excess rainfall. This variability directly affects **Kharif crop yields** (especially pearl millet and moong).

Correlation Analysis

To measure the strength and direction of the relationship between **annual rainfall** and **crop yields (Bajra, Moong, and Guar)**, the **Pearson's correlation coefficient (r)** was applied.

The formula is: $r = \sqrt{\sum(x_i - \bar{x})2 \cdot \sum(y_i - \bar{y})2} \sum(x_i - \bar{x})(y_i - \bar{y})$

Combined C**orrelation analysis for rainfall vs yield (2010-2022):**

Year	Annual Rainfall (mm)	Bajra yield	Moong yield	Guar yield
2010-11	767	17421	355	740
2011-12	633	1774	511	874
2012-13	676	1085	454	752
2013-14	518	1224	489	929
2014-15	556	1349	670	921
2015-16	516	998	446	772
2016-17	485	1472	575	886
2017-18	540	1045	308	981
2018-19	320	1459	652	1030
2019-20	694	1383	550	906
2020-21	420	1381	599	908
2021-22	574	1160	361	861
2022-23	536	1267	578	1020

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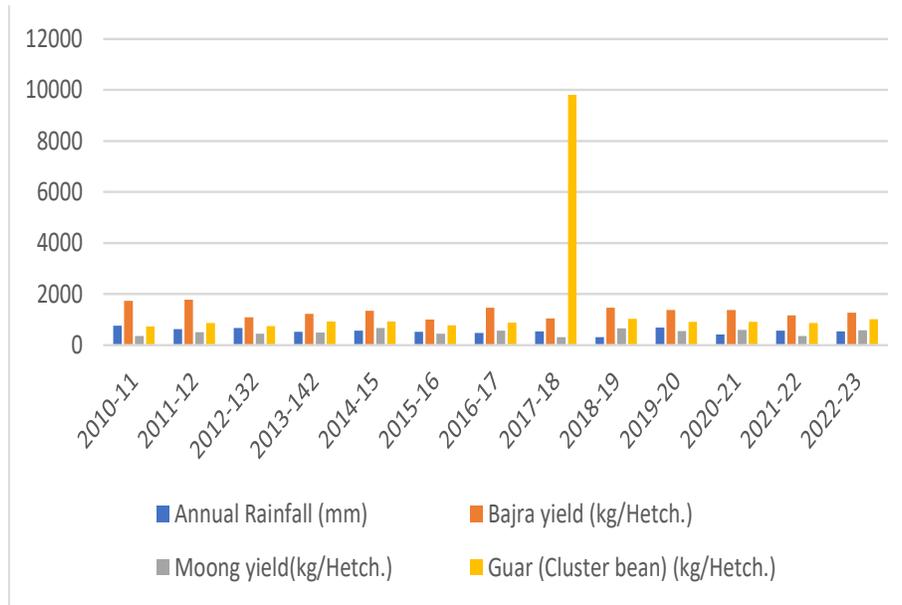
Source: District Statistical Handbook – Jhunjhunu

Correlation Analysis (Rainfall vs Yield)

Approximate Relationships: Bajra Yield vs Rainfall: Trend: Mixed, but mostly **negative correlation**. Some low-rainfall years (2018-19: 320 mm) have **high yield (1459 kg/ha)**, suggesting irrigation or improved varieties mitigate rainfall dependence. **Moong Yield vs Rainfall:** Trend: **Weak positive correlation** in general. Moong is more rainfall-sensitive than Bajra. Some high rainfall years like 2011-12 is 511 kg/ha; low rainfall years like 2017-18 is 308 kg/ha. **Guar (Cluster Bean) Yield vs Rainfall:** Trend: **Weak or slightly negative correlation**. Guar tolerates low rainfall; some dry years (2018-19: 320 mm) give **highest yields (1030 kg/ha)**, indicating drought-tolerant nature.

Approximate Correlation Coefficients (Pearson r)

Crop	Correlation with Rainfall (r)
Bajra	-0.2 (weak negative)
Moong	+0.4 (moderate positive)
Guar	-0.1 (nearly neutral)

Interpretation: **Moong yield** is most influenced by rainfall. **Bajra and Guar** are less sensitive; their yield depends more on area, irrigation, and management.

Insights: Bajra: Yield less rainfall-dependent; irrigation and technology improve resilience. **Moong**: More rainfall-dependent; drought or poor rainfall reduces yield. **Guar**: Drought-tolerant; can give high yield even in low-rainfall years.

Drought Analysis Through Standardized Precipitation Index (SPI)

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Table 5. Jhunjhunu SPI Table (2010–2022)

Year	Rainfall (mm)	SPI (approx.)	Drought Category
2010	767	+1.87	Very wet
2011	633	+0.75	Near normal
2012	676	+1.11	Moderately wet
2013	518	-0.21	Near normal
2014	566	+0.19	Near normal
2015	516	-0.23	Near normal
2016	485	-0.49	Near normal
2017	540	-0.03	Near normal
2018	320	-1.87	Severe drought
2019	694	+1.28	Moderately wet
2020	420	-1.03	Moderate drought
2021	574	+0.26	Near normal
2022	536	-0.06	Near normal

From this, **2018 and 2020** stand out as **drought years**.

Key Findings: Drought Years (SPI ≤ -1.0), 2018 ever drought (SPI ≈ -1.87), 2020 Moderate drought (SPI ≈ -1.03). Wet Years (SPI ≥ +1.0),2010 Very wet (SPI ≈ +1.87),2012 Moderately wet (SPI ≈ +1.11),2019 is Moderately wet (SPI ≈ +1.28). Near-normal Years (SPI between -0.99 and +0.99) Most years (2011, 2013–2017, 2021–2022) are near normal.

Implications for Agriculture: Ajra, Moong, Guar yields generally affected by SPI: Severe drought (2018) High impact on Moong, moderate on Bajra, Guar less affected. Moderate drought (2020), Some reduction in yields, Moong more sensitive. Wet years Can increase yields but sometimes excess rainfall may affect Bajra. Near-normal years Stable production.

Conclusion: Drought-prone years identified: 2018, 2020. Crop vulnerability: Moong > Bajra > Guar. Can be used for crop planning, irrigation scheduling, and drought mitigation strategies.

CONCLUSION:

The study highlights that Bajra, Moong, and Guar production in Jhunjhunu from 2010–11 to 2022–23 was influenced by rainfall variability, area under cultivation, and crop management practices. SPI analysis identified 2018 and 2020 as drought-affected years, with Moong being more sensitive to low rainfall, while Bajra and Guar showed relative resilience. Correlation analysis confirmed that area and yield are the primary drivers of production, whereas rainfall had a moderate effect, particularly on Moong. Survey and content analysis revealed that farmers commonly adopted drought-tolerant varieties, adjusted sowing dates, and implemented soil and water management practices to mitigate drought impacts. Overall, the findings emphasize the importance of **climate-smart adaptation strategies** to sustain crop yields under semi-arid conditions. Bajra, Moong, and Guar production in Jhunjhunu was influenced by rainfall variability, area, and yield, with Moong being most sensitive to drought. SPI analysis identified 2018 and 2020 as drought years, and survey data showed farmers widely adopted drought-tolerant varieties, adjusted sowing dates, and soil-water management practices. The study underscores the importance of **climate-smart adaptation strategies** for sustaining crop yields in semi-arid regions.

The comparative analysis of Bajra, Moong, and Guar in Jhunjhunu reveals distinct responses to rainfall variability and drought conditions. Bajra demonstrated strong resilience, with production largely determined by area under cultivation and supported by farmer adaptations such as drought-

tolerant varieties and irrigation practices. In contrast, Moong was the most sensitive crop to drought, with significant yield reductions during 2018 and 2020, highlighting the need for supplemental irrigation and improved seed varieties. Guar showed the highest drought tolerance, with relatively stable yields supported by intercropping, mulching, and soil-water conservation measures. Overall, while Bajra and Guar can provide stability in semi-arid farming systems, Moong requires targeted adaptation strategies, underscoring the importance of **climate-smart agriculture to sustain crop production under rainfall variability.**

Table: Comparative Analysis of Bajra, Moong, and Guar in Jhunjhunu (2010–2022)

Crop	Resilience to Rainfall Variability	Drought Impact (2018, 2020)	Key Adaptation Strategies	Overall Conclusion
Bajra (Pearl Millet)	High – yields remained relatively stable	Moderate impact, mitigated by area & practices	Drought-tolerant varieties, supplemental irrigation, timely sowing	Drought-resilient staple; suitable for semi-arid farming
Moong	Low – highly sensitive to rainfall variability	Severe yield decline in drought years	Adjusting sowing dates, improved seed varieties, irrigation (where available)	Vulnerable crop; needs targeted interventions for stability
Guar (Cluster Bean)	Very high – strong drought tolerance	Minimal impact; yields stable even in dry years	Intercropping, mulching, soil-water conservation	Reliable crop for drought years; supports income security

SUGGESTIONS:

Based on the analysis of Rainfall variability on major kharif crops yield in Jhunjhunu district the following suggestions are proposed to enhance agricultural sustainability, land productivity:

- ➢ **Crop-Specific Strategies:** Bajra: Promote as a climate-resilient staple in semi-arid regions. Encourage use of improved drought-tolerant varieties and supplemental irrigation for stabilizing yields.

- ➢ **Rainfall & Drought Management:** Establish real-time weather monitoring and SPI-based drought early warning systems at district level.

- ➢ **Farmer Awareness & Training:** Organize training on climate-smart agriculture practices such as mulching, crop rotation, and soil conservation. Develop community seed banks for drought-tolerant varieties to ensure availability in crisis years.

- ➢ **Research & Extension:** Encourage research on crop–climate interactions in arid and semi-arid zones. Test and recommend region-specific varieties that balance productivity with resilience. Integrate farmer surveys into long-term climate adaptation planning.

- ➢ **Water Resource Development:** Promote rainwater harvesting, farm ponds, and check dams for supplemental irrigation. Provide subsidies for drip and sprinkler irrigation systems to optimize water use.

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➢ **Seed & Input Support:** Ensure availability of drought-tolerant and high-yielding seed varieties through community seed banks. Strengthen extension services to train farmers in climate-smart practices like mulching, crop rotation, and soil health management.

➢ **Overall Suggestion:** Promoting Bajra and Guar as drought-resilient crops, improving Moong management with irrigation and short-duration varieties, and adopting climate-smart farming practices will strengthen Jhunjhunu's agriculture under rainfall variability.

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