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Maize Production and Climate Variability: Evidences from Haryana

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Abstract— *This paper examines the influence of climatic factors—rainfall, temperature, and humidity—on maize production in Haryana, India. The study also explores how enhancing maize productivity can contribute to achieving several Sustainable Development Goals (SDGs), particularly those related to food security, sustainable agriculture, renewable energy, and water conservation. Using secondary data for the last ten years and applying multivariate regression and deviation analysis, the study assesses how variations in climatic conditions affect maize yield in Panchkula district, the major maize-producing region of Haryana. The results show that among the three climatic factors, rainfall had a relatively greater influence on maize yield, though none of the factors were found to have a statistically significant effect during the study period. These findings underline that while climate variability does not directly determine yield outcomes in every season, rainfall patterns remain a key driver of maize productivity. The study suggests that adopting climate-resilient farming practices, efficient water-use technologies, and improved maize varieties can help stabilise yields and enhance farmers' income. Such measures would also support India's broader developmental goals by promoting sustainable agriculture and strengthening rural livelihoods within the SDG framework.*

Keywords— ***Maize, Climate Variability, Rainfall, Sustainable Development Goals, Haryana***

I. INTRODUCTION

This paper looks at how climate factors affect maize production in Haryana. It also discusses how improving maize production can help achieve some Sustainable Development Goals (SDGs). In the race of economic development, mankind has exploited natural resources to a great extent (**Alex Acheampong and Evans Osei Opoku, 2023**). As a result, there has been a great increase in global warming and natural disasters over the last few decades (**Sarah S. Abdul-Nabo et al., 2025**). The earth's temperature has been higher than expected and projected (**Thomas C. et al., 2008**). This has become a threat to human existence (**Umair S., 2015**). Along with this, starvation and unavailability of basic needs are also becoming a threat to mankind. To keep all these challenges in high concern, UN Members have set some targets for 2030 known as SDGs-17 goals. The main objectives of these goals are to protect the environment as well as human lives. The current research paper is also affined to this series. The present research paper illuminates the importance of the maize crop in achieving SDG goals in possible manners. Further, in this context, the research also endeavours to know the effect of climate factors on maize production in Haryana. The basic intent behind this approach was to understand how maize production can be predicted and improved under different climatic conditions.

Maize is grown in almost every part of the world. From ancient times maize has been established as a rich source of human food. Maize contributes 20 percent of calories of human food (**Olaf Ehrenstein et al., 2022**). Maize is the staple food crop in many parts of the world. Due to its lower cost as compared to rice and wheat, maize is also a good source of nutrition for the poor (**Peter Ranwn et al., 2014**). Many studies proved that the production of maize is

economically cheaper than other important cereals (**John Baffies et al., 2024**). In this way, we can foreshow that increasing the production of maize can reduce the problem of hunger and fulfil every important nutrient regarding human growth at the world level (**A. Saritha et al., 2020**). It can be believed that increasing the production of maize will also be helpful in achieving SDG-17 Goals (2.1- Universal Access to safe and nutritious food and 2.2- End all forms of Malnutrition) (**Sherry A. Tanumihardjo et al., 2020**).

The Government of India has done commendable work in the last few years in the direction of increasing the production of ethanol for biofuel (**Ayush Saxena et al., 2024**). After experiencing positive results, the Government of India amended the National Policy of Biofuel-2018 in 2022 and set the target for 20 percent blending of ethanol in fuel (**Sarah Mark et al., 2025**). It will lead to reduced carbon emissions, strengthen the green fuel policy and reduce the oil import bill of the country (**Mahesh K. Saini et al., 2010**). Maize is a good source of ethanol (**Adewale Allen Sokan-Adeage et al., 2024**). Maize is being used as a major source of biofuel across the world; some states of India have also made remarkable progress in this direction (**Pranav Kumar, 2024**). In this way, it can be assumed that by increasing the production of maize, the supply of biofuel can be increased and that will help in achieving the SDG goals (7.1- Universal access to modern energy and 7.2- Increasing the global percentage of renewable energy).

The present research work has been conducted in Haryana. Maize is sown in the Kharif season in the state (**Dept. of Agriculture, Govt. of Haryana**). Rice is the main crop of this season, which is a very high water-intensive crop (**Report by Indian Council of Food and Agriculture (ICFA)**, **report by International Rice Research Institute (IRRI)**). In Haryana, the rice area has increased sharply in the last three decades; it was 661.2 (000 hectares) in 1990 which increased to 1525 (000 hectares) in 2020 according to **Haryana Statistical Abstract 2022-23**. The increasing area poses a threat to water resources, especially the groundwater of the state. As a result, 14 districts of the state were declared as red zones for groundwater (**Dharam Pal et al., 2022**). To deal with this problem, various options were explored to substitute the rice crop in the state. Maize is being seen as a valuable alternative to rice which has the chance of increasing farmers' income along with conserving water resources (**Mukta Nainwal et al., 2023**) and (**M. Uma Devi et al., 2020**). If the state succeeds in increasing the area under the maize crop, it will be a good effort to achieve SDG goals (2.4- Sustainable food production and 6.6- Protect and restore water-related ecosystems).

Along with this advantage, the maize pod stem is also a good source of food for animals. The fodder of maize includes valuable nutrients for cows and buffaloes (**D.P. Chaudhary et al., 2014**). Due to favourable climate and soil, there are a lot of possibilities for promoting maize cultivation in Haryana. According to various agricultural experts, the appropriate temperature required for maize is between 25-30 degrees Celsius and fertile alluvial or sandy loam soils are appropriate for the growth of the crop (**Muhammad Ahmed Waqas et al., 2021**, **M.A. Ansari et al., 2015**). On the other hand, production of maize also depends on different varieties. As a result of the sincere efforts of agricultural scientists, there are many variety options available for maize in Haryana (**Narender Singh et al., 2017**). Several research studies concluded strong evidence that maize production is highly correlated with climatic factors such as temperature, rainfall and humidity. Only an optimum condition of these factors can be beneficial for crop production, where less or more than the optimum level has an inverse impact on production (**Phrasia M. et al., 2020**, and **Usman Ahmad et al., 2024**).

To understand the impact of climatic factors on maize production in more depth, some selected research studies were analysed profoundly; the review of selected research work is as follows.

Mansoor M. et al., 2021 in their research work investigated the impact of climate on grain and silage in the Czech Republic during 2002-19. The study was based on secondary data and the data was processed with the help of T-Test and Pearson correlation. The study concluded that there was a low to moderate negative correlation between grain yield and average temperature. Moreover, a positive correlation was found between profit and grain yield rate and the precipitation and water deficit. Farmers' profit from maize was significantly associated with water deficit, precipitation and temperature. **Maiyo J.K. et al., 2024** in their research examined the effect of rainfall variability on maize production among small-scale farmers during 2008-18. The study was based on primary as well as secondary data. The study concluded that there was a positive relationship between rainfall and maize yield. Moreover, the study also highlighted that forests help reduce the amount of carbon gas in the atmosphere, which is the main cause of climate change that normally led to rainfall variability effects.

Suiven John P.T., 2024 in their research paper examined rainfall reliability and established the impact of rainfall reliability on maize production. The study was based on secondary data. For rainfall measurement, the author developed a standardised precipitation index (SPI) for measuring the difference from the standard value of rainfall.

Time series data on maize output were collected from annual reports. The study concluded that rainfall reliability ranged from 9.62 percent to 30.90 percent in the Bamenda highlands while maize production had been variable with decreasing trends. Finally, the study suggested that farmers need to engage in sustainable livelihood practices to ensure food security. **Emmanuel M.A. et al., 2013** in their research paper examined the impact of variability in rainfall characteristics on maize yield in a tropical setting. The study was based on secondary data; statistical tools like correlation and regression were used to find out the answers to the research questions. The study concluded that there was a high variability in rainfall characteristics which translated into a high yield of maize. The number of rainfall days and annual rainfall amount had a strong impact on maize yield per hectare in the study area. Finally, the study concluded that the study area and Benue state, in general, were found unsuitable for the optimum growth of maize. **Noah Eledi Kiguhi et al., 2025** in their research paper examined the impact of rainfall on maize production. The main objective of the study was to examine rainfall variability and its impacts on crops. The study was based on a mixed-method research design. Primary data was obtained by a scheduled questionnaire. The study concluded that rainfall variability was significantly linked with maize yield. The rainfall variability had the potential to affect future maize production. The study recommended that proper climate forecasts could be helpful in this regard. **K.M. Mehedi Adnam et al., 2021** in their study examined the responsible factors for profit in maize production. Multistage stratified random sampling techniques were used for the purpose of data collection. The study concluded that the maize crop is profitable for farmers. Factors such as age, education level, extension experiences and non-farm incomes were the main factors for profit inefficiency. There were several hybrid varieties of the crop that can lead to more profit. Finally, the study mentioned some significant measures for the betterment of the crop cycle and marketing facilities. **Phrasia M. et al., 2020** in their research explored the impact of rainfall variability on maize yield. The study found a weak negative correlation between rainfall and maize in Kwazulu-Natal and Free State Provinces; on the other hand, a weak positive correlation was found in the North-West province. Both the excess and deficit conditions of rainfall were not favourable for the productivity of maize.

After exploring the existing research work, the present research work is framed in the following research objectives.

Research Objectives of the Study:

1. To highlight the comparison of production and yield of maize
2. To examine the rainfall variability and its impact on the maize crop during the last ten years
3. To explore the deviation from optimum climatic conditions and actual climatic conditions from optimum production of maize

II. RESEARCH METHODOLOGY

As mentioned above, the maize crop is grown in Haryana during the Kharif season. Paddy is the main crop of the Kharif season in the state. During the basic observation of maize production data, it was found that the Panchkula district is the major producer of the maize crop. Considering this fact, Panchkula district was selected for the study.

The study is based on secondary data. Data for ten years for different variables were collected from various sources. Data regarding rainfall for ten years were collected from various sources of Haryana Statistical Abstracts. Data regarding temperature and humidity were collected from the website **www.aqi.com**. Data regarding the production and yield of maize in India and the world were collected from the website **ourworldindata.org**.

Statistical tools including multivariate regression and deviation methods were used.

Based on the objectives and methods, the study proposes the following hypotheses for testing.

Hypotheses of the Study:

- H1: Rainfall variation has a significant impact on maize yield in Haryana.
- H2: Temperature variation affects maize yield in Haryana.
- H3: Humidity variation affects maize yield in Haryana.
- H4: The impact of rainfall on maize yield is greater than that of temperature and humidity.

The data collected were analysed, and the results are given below.

2.1 Maize Yield in India and Haryana

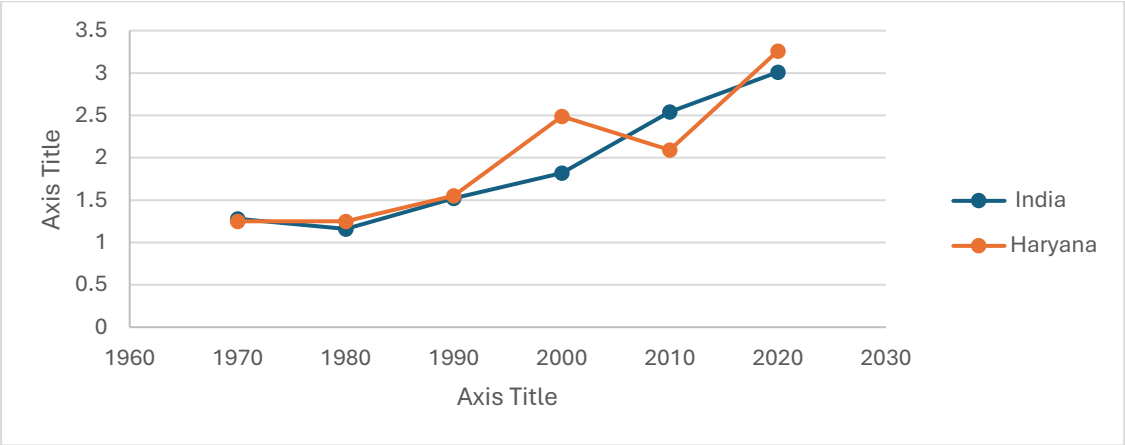
This part of the research paper presents a simple picture of maize productivity comparison on both horizontal and vertical bases. This part will help to understand the scope of increasing the productivity of maize in India as well as in Haryana.

Table-1: Maize Yield In India and Haryana-

Year	*Tonnes/Hec yield in India*	*Tonnes/Hec yield in Haryana*
1970	1.28	1.25
1980	1.16	1.25
1990	1.52	1.55
2000	1.82	2.49
2010	2.54	2.09
2020	3.01	3.26

Table 1 highlight the productivity comparison of maize in Haryana and India in last 70 years. Table shows that there was productivity difference in India and Haryana since 1970. The productive gap was maximum during 2000, it was 2.49 tonnes/Hec. In Haryana while it was 1.82 tonnes/Hec. Aggregate for India. On the other hand the productivity was high in aggregate level of India as compare to Haryana. Finally in 2020 the productivity level was high again in Haryana as compare to all India aggregate.

Chart-1: Maize Yield In India and Haryana-



Source- Our world in data (www.ourworldindata.org/maize-yiled

https://ourworldindata.org/grapher/maize-yields

Haryana Statistical Abstract- (2022-23)

This chart compare maize yield in India and Haryana from 1970 to 2020. Haryana started with slightly lower yields than India but later caught up. By 2020, Haryana's yield was higher than the national average, showing improvement in productivity over time. It reflects better farming practices and crop management in the state.

2.2 Yield of Maize in Different Countries

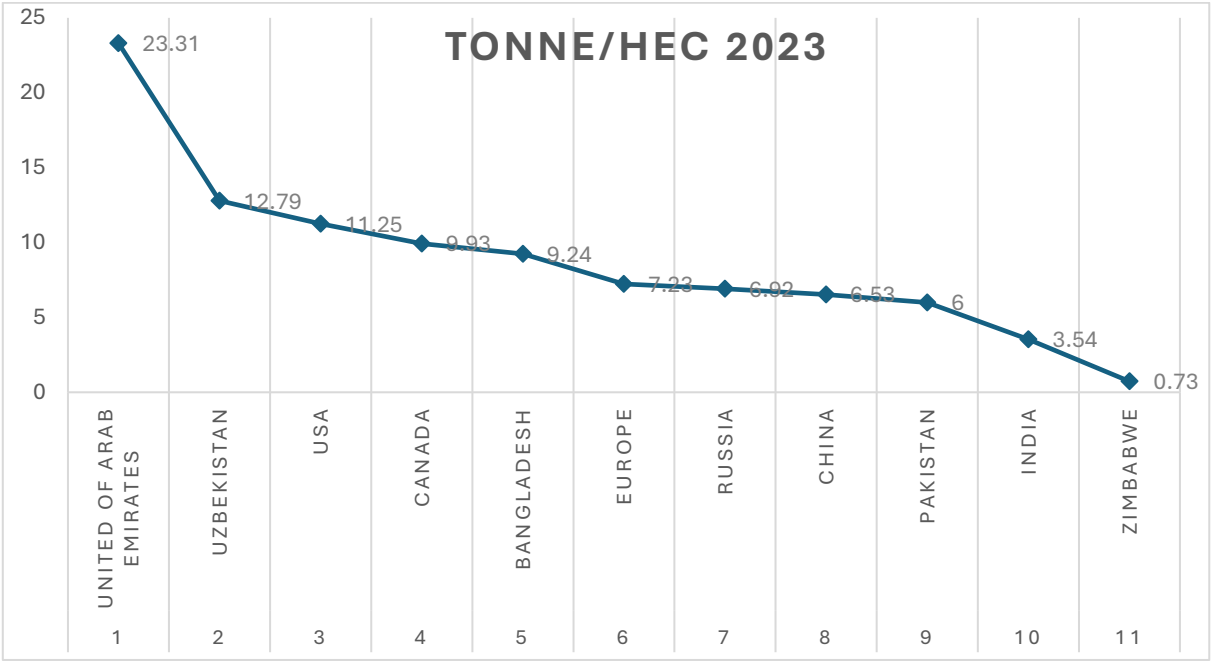
Table-2: Yield of Maize In Different Countries

Sr. No.	Name of Country	Tonne/Hectare
1.	United of Arab Emirates	23.31
2.	Uzbekistan	12.79
3.	USA	11.25
4.	Canada	9.93
5.	Bangladesh	9.24
6.	Europe	7.23
7.	Russia	6.92

8.	China	6.53
9.	Pakistan	6.00
10.	India	3.54
11.	Zimbabwe	0.73

Table 2 shows the productivity of maize across the world for the year of 2023. There were huge difference of yield among different countries. It was highest in UAE followed by Uzbekistan and USA. In case of India it was almost seven times low as compare to UAE and almost half as compare to neighbours Pakistan and China. It may be observed from the above results that there is a great potential and scope to expend the production of maize in India.

Chart-2: Yield of Maize In Different Countries



Source- Our world in data (www.ourworldindata.org/maize-yiled

https://ourworldindata.org/grapher/maize-yields

This chart compares maize yields across countries in 2023. UAE shows the highest yield, followed by Uzbekistan and the USA, while India's yield is far below many developed countries. The wide gap highlights the potential for India to adopt improved technology and practices to boost maize productivity.

The country-wise comparison shows the gap in maize productivity between India and other nations. Next, we look at how rainfall variation affects maize yield over the years in Haryana.

3.3 Percentage Difference from Optimum Yield and Rainfall

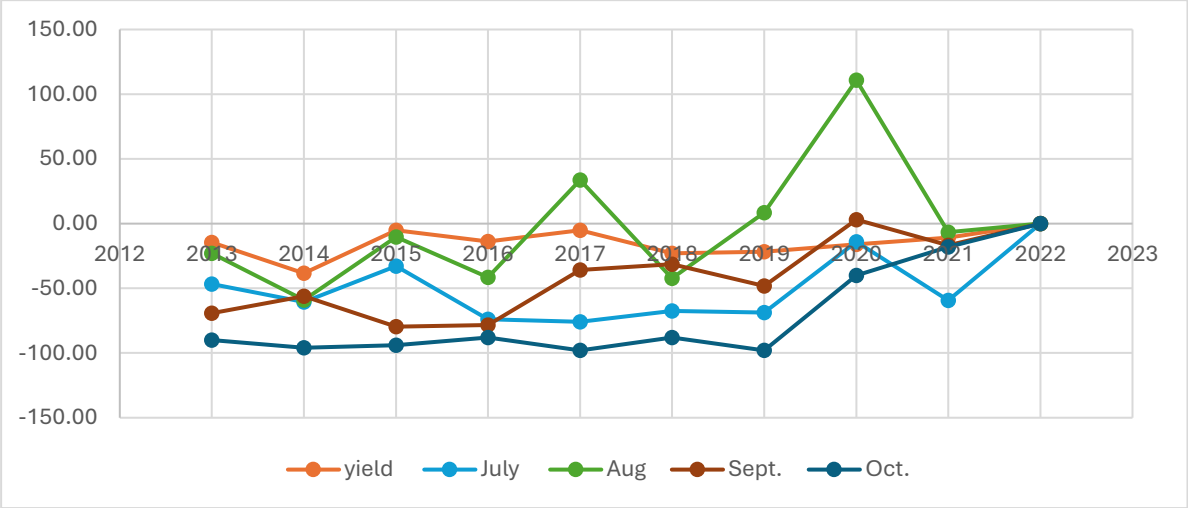
Table-3: Percentage Difference form Optimum Yield and Rain Fall of Maize

Year	*Yield*	*July*	*Aug*	*Sept.*	*Oct.*
2013	-14.64	-46.80	-22.89	-69.14	-90.00
2014	-38.38	-60.47	-59.04	-56.17	-96.00
2015	-5.14	-32.85	-10.24	-79.63	-94.00
2016	-13.80	-73.84	-41.57	-78.40	-88.00

2017	-5.05	-75.87	33.73	-35.80	-98.00
2018	-22.93	-67.44	-42.17	-31.48	-88.00
2019	-21.67	-68.60	8.43	-48.15	-98.00
2020	-15.99	-13.95	110.84	3.09	-40.00
2021	-10.94	-59.30	-6.63	-16.67	-18.00
2022	0.00	0.00	0.00	0.00	0.00

This table compares actual rainfall with optimum rainfall required for maize in different months and years. Positive and negative values show where rainfall was above or below the requirement. Such variations explain why yield fluctuates in different years, as rainfall shortage or excess directly affects maize growth.

Chart-3: Difference form Optimum Yield and Rain Fall of Maize



After rainfall variation, the next tables show how temperature and humidity influence maize yield.

3.4 Temperature impact on Maize yield

Table-4 Temperature impact on Maize yield Regression Statistics

Multiple R	0.53341491
R Square	0.2845
Adjusted R Square	-0.2878
Standard Error	416.3219135
Significance F	0.7409856
F	0.4971068

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	7289.199816	7075.27814	1.030235091	0.350133512
July	34.95148978	485.6085284	0.071974621	0.94541245
Aug	-513.9299398	586.6438029	-0.876051085	0.421088903
Sept.	302.0297938	413.0737161	0.7311765	0.49748235
Oct.	30.25185083	222.9661418	0.135679124	0.897368182

(Temperature data of Panchkula, Haryana) source- www.aqi.in

https://www.aqi.in/au/climate-change/india/haryana/panchkula

The regression table shows how temperature in different months affected maize yield. Coefficient values indicate whether higher temperatures increased or reduced yield. However, the p-values suggest that temperature alone did not have a strong or statistically significant impact on maize yield in the study period.

3.5 Humidity impact on Maize yield

Table-5 Humidity impact on Maize yield

Regression Statistics

Multiple R	0.70807
R Square	0.55015
Adjusted R Square	0.10280
Standard Error	347.485
F	1.2578
Significance F	0.3953

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	1952.925773	2187.90858	0.892599348	0.41296461
Hum. July	22.08205649	22.70305389	0.972646966	0.37540013
Hum. Aug	18.92792844	29.04552512	0.651664185	0.54337991
Hum. Sept.	-37.22239947	25.41334058	-1.46467952	0.20289479
Hum. Oct.	13.62877801	19.18671809	0.710323566	0.50925148

(Humidity data of Panchkula, Haryana) source- www.aqi.in

https://www.aqi.in/au/climate-change/india/haryana/panchkula

This table presents how humidity levels in July to October influenced maize yield. Some months show a positive effect while others negative, but none are statistically significant. It suggests that humidity alone cannot explain the changes in yield over the years.

3.6 Rainfall impact on Maize yield

Table-6: Rainfall impact on Maize yield

Regression Statistics

Multiple R	0.652652484
R Square	0.425955265
Adjusted R Square	-0.033280523
Standard Error	372.9087199
Significance F	0.515538234
F	0.927530642

	Coefficients	Standard Error	t Stat	P-value
Intercept	2789.040163	391.4800005	7.124349032	0.000845298
Rain July	-0.276461727	2.059902958	-0.134211044	0.898470678
Rain Aug	2.617630052	2.217774469	1.180295873	0.29096972
Rain Sept.	-6.352837649	5.137236035	-1.236625611	0.271141623
Rain Oct.	18.99275809	14.03052004	1.353674564	0.233813066

(Source- rainfall data of Panchkula, different vol. of Haryana Statistical abstract)

The table-6 shows that the independent variable (rainfall) did not have significant and equal impact on the yield. The rainfall of August and October had a positive correlation (2.61 and 18.99 respectively) with yield where the rainfall of July and September had a negative correlation (-0.27 and -6.35 respectively) with yield. rainfall of October had more impact full as compare to rainfall of other months. In case of R Square table shows that almost 42 percent of variation happens due to the rainfall but F value is less than 4 that means R-Square value is not significant. Since P value is greater than 0.05, which is our level of significance, therefore, we may conclude that the study did not enough evidence to claim any significant impact of independent variables on the dependent variables.

III. SUMMARY & CONCLUSION

The results from all three factors—rainfall, temperature, and humidity—are now combined to draw overall conclusions.

On the basis of tables, no 4, 5 and 6, it is concluded that among the three major climate factors, rainfall was more impactful as compare to temperature and humidity. The value of R-square for rainfall is 42 percent whereas for temperature it is 31 percent and for humidity it is 8 percent. In case of coefficient correlation, the tables show that in both positive and negative cases, the correlation of temperature with yield is higher than that with rainfall and humidity. The F-value of the three independent variables is less than 4, which shows that the value of P-square is not significant. Among the other three independent variables, rainfall has the least p value followed by temperature and humidity. But the p value of none of the variables is less than 5 percent which shows that none of the independent variables have any significant impact on the dependent variable. The p value of rainfall is less than that of humidity and temperature which shows that rainfall is more significant than humidity and temperature

The study finds that rainfall had more effect on maize yield than temperature or humidity, but none of the factors showed a strong impact in the data period. Even so, the results suggest that better water use, improved seeds, and climate-resilient farming can help increase maize production in Haryana. This will also support progress toward food security and environmental goals.

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