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AN ANALYSIS OF AGRICULTURAL VULNERABILITIES TO CLIMATE CHANGE IN SEMI-ARID AND DRY SUB HUMID REGIONS OF HARYANA

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Abstract

Climate change seems to be inevitable and as per IPCC, 2018 there is an increasing global temperature trend and variability in rainfall, which makes the phenomena more evident. These variations had very significant impacts on the ecosystem, livelihood, and overall human well-being. Being a managed ecosystem, agriculture is most vulnerable to these climatic variations and studies indicate that these extreme climatic events had an impact on yield, type of crops, crop duration, etc. However, such kinds of effects differ significantly in the different regions. Haryana, being one of the most agriculturally advanced states is a critical area to study the impacts of climate change on agriculture. This paper aims to understand the interaction between climate change and agricultural performance in semi-arid and dry subhumid parts of the Yamuna Nagar and Mahendragarh districts of Haryana. The study is based on 30 years of climatic data collected from IMD and agriculture data taken from Statistical abstracts of Haryana. Homogeneity index and Mann-Kendall's test have been used to understand climatic variations whilst multinomial logit and Weaver's crop combination methods have been used to understand crop response to climate. The results are very diverse, and both regions have responded differently to climate change. The dynamics between agriculture and climate change can be best understood when studied in specific physical conditions. Consistent changes in climatic conditions and changing demands for food have changed the face of agriculture in Haryana. Climatic variability is responsible for new adaptations and cropping patterns. In the context of agriculture, private adaptation actions (switching crops, using new methods, and delaying crops) have been a major change. Adaptation in the form of new methods, seeds, and technologies had further added to climate change in the form of a positive feedback loop.

Keywords

Climate Change, Agriculture, Adaptation, Dry-Sub Humid Regions, Semi-Arid Regions.

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Introduction

Climate change is commonly understood as significant changes in long-term weather conditions in any region, which can be temperature changes, increase in carbon dioxide, or uncertainty of rainfall. Globally climate change is considered the most important environmental challenge faced by humanity with implications for food, ecosystem, agriculture, water, health, etc. Extreme weather conditions, droughts, floods, and increasing temperatures affect agriculture directly or indirectly. According to IPCC (2001), climate change is mainly due to the accumulation of greenhouse gases and industrialization, which have changed the world climatic system by 0.74° C and impacted the environment by an increase in soil evaporation rates, droughts, and high temperature. High temperatures decreased yield eventually for the desired crop and encouraged weed and pest infestation. IPCC (2007) has further predicted and projected a temperature increase up to 4°C and significant changes in precipitation, due to which agriculture productivity could decline 10-25%.

In the Indian economy agriculture is a major sector and plays an important role in maintaining the economic and social wellbeing of people by contributing almost a quarter of the GDP and by providing livelihood to almost 54.4% population (census,2011) directly or indirectly. Post-green revolution most fertile lands of India like Punjab and Haryana became self-sufficient in agriculture production by using HYV seeds, mechanization, pesticides, and expensive irrigation facilities. However, in a few decades, it was impacted by soil erosion, a decline in water and soil quality, and resulted in a significant decline in yield. These results are discussed in many studies *(Sinha and Swaminathan 1991; Aggarwal and Sinha 1993; Hundal and Kaur 1996 Saseendran et al. 2000; Mall et al. 2006; Dash S.K. et al.2007; Aggarwal 2008, 2009)*

The climate in Haryana is extremely cold and hot in winters and summers respectively, as per these climatic conditions Haryana is divided into three major Agro-climatic zones Arid, Semi-Arid, and Dry Sub-humid. This paper will attempt a comparative study of Dry Sub-Humid and Semi-Arid regions by choosing Haryana and Mahendragarh districts by covering two major aspects. First, by drawing attention to the recent advancements in the climatic conditions and second by briefly analyzing the impact of climatic variability on agricultural productivity.

Literature Review

T N Rao, (2011) discussed the role of adoption by human beings in mitigating climate change, he also analyzed regional patterns of impacts on agriculture with potential changes in food production and its price. The study predicts a 20% decline in food production of developing countries by 2080, the main reason behind this drastic change is climate change. Similarly in industrial countries, it is expected to decrease by 6 percent and by 15 percent in developed countries. The study explains how climate is the main determinant of agriculture. The study also focuses on the role of the United Nations Framework Convention on Climate Change (UNFCC) in maintaining our social abilities of food production by reducing greenhouse gas emissions.

SK Sinha and MS Swaminathan (1991) mentioned in their research that the change of a 2°C increase in mean temperature will negatively impact the yield of rice by .75 ton/ hect in high-yielding areas and by .06 ton/hect in coastal areas of low productivity. He further explains that if there is a positive change of .5°C in winter temperature, it will decrease the productivity of wheat crop by 0.45 on/hect which can be considered as a total fall of 10% in the yield of wheat crop in states of Punjab, Haryana and Uttar Pradesh.

The paper by AKS Gosain and S Rao (2006) reveals that changing the proportion of GHGs may result in terms of drought conditions in some regions of the country and increase the intensity of floods in some parts. He also focuses on how the changing GHG conditions can reduce the total runoff. An important impact could be seen on the Luni, a west-flowing river that will face water scarcity and further impacts could be observed in the Kutch and Saurashtra regions of Gujarat and parts of Rajasthan, similarly other rivers like Pennar, Sabarmati, and Tapi are also assumed to face water shortage issues.

R Guitars (2007) analyzed the interrelationship between climate change and Agriculture. The study attempts to analyze the impact of changed weather conditions on agricultural production in 200 districts. The results explain and predict a major 9% reduction in crop production, he further correlated it with the socio-economic conditions and explained how long-term impacts could be seen on poverty.

Material and Methods

Description of data: the monthly observed rainfall and temperature data for 40 years (1970-2019) provided by the Indian Metrological Department is used to identify the trends of climatic conditions in both the selected districts. For agricultural-related information – the statical abstract of Haryana (2001-2019) is used, which provides data on the production of different crops in the regions. ‘

Methods: to analyze the climatic data some descriptive statistics like Mean and SD are used for the estimation of annual and seasonal and monthly time steps to get insight into precipitation and temperature. The study estimates the trend analysis and statistical significance with linear regression and non-parametric tests- Mann Kendall and Sen's slope method (Kumar et al, 2009).

To analyze the impact of climatic factors on agriculture first Weaver's (1954) Crop Combination method is used to identify the most preferred crop in both districts. Then Multi

Regression model is used between Rainfall, Temperature, and agricultural production (for the most preferred crop) of both districts to see the major impact.

Results and Discussions

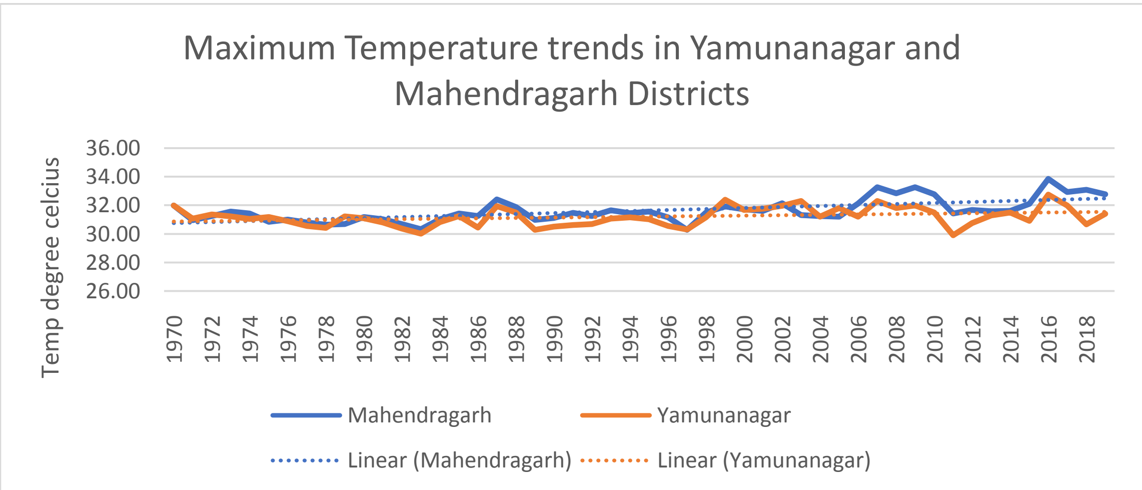
The state of Haryana, situated in the trans-Gangetic plains, is flanked by the Thar Desert's arid climate to its west and the sub-humid, cooler clime of the Himalayas to its north. The geographic position of the region endows it with moderate rainfall and also make it more vulnerable to climatic variability. This sensitivity to climatic shifts, as noted by Anurag et al. (2009), accentuates the necessity of a detailed examination of temporal and spatial weather patterns, which is critical for the optimization of resource management strategies within the state.

The research presented here delves into temperature fluctuations over a period of forty years, rangingfrom 1970 to 2019, in two differentagro-climatic zones of Haryana. showing data for the highest and lowest temperatures, respectively. The semi-arid and semi-humid regions represented by Yamuna Nagar region and the semiarid region represented by ahendragarh region are the focus of this analysis. The temperature indicators described in these figures help to understand the climate in the region and their impact on agriculture and water planning in this region. The study not only tracks historical temperature patterns but also forms a building block for predicting future climate and hence suggests sustainable development in different farms in prominent districts of Haryana.

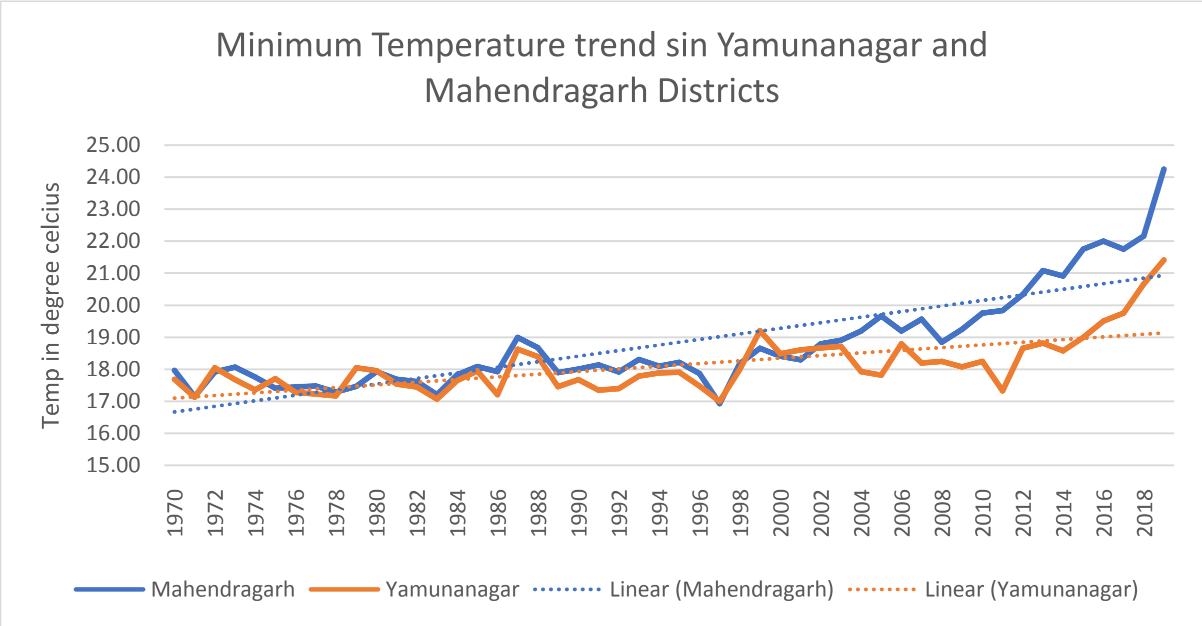
Empirical data collected from maximum and minimum temperatures in Yamuna Nagar a nd Mahendragarh districts, describing the weather pattern in the last four years and showing t he interaction between changes in the whole. In particular, the maximum temperature record d ecreased significantly around 2010, while the minimum temperature dropped between 2008 a nd 2011. In contrast, 2016 saw a sharp increase in average temperature; this represented all in cremental increases found in the temperature data for both regions.

These fluctuations may be symptomatic of broader atmospheric phenomena that transiently alter regional climate patterns, or they may reflect localized changes due to anthropogenic influences. The incremental trend, however, is indicative of a gradual warming, aligning with global patterns of climate change. The implications of such a warming trend are multifaceted, extending beyond the immediate alterations in humidity levels and vegetation growth dynamics.

Graph1: Trends of maximum temperature in Yamunanagar and Mahendragarh Districts



Graph2: Trends of minimum temperature in Yamunanagar and Mahendragarh Districts



Source: Indian metrological department

As posited by Quarehi and Hobbie in 1994, significant climatic perturbations, particularly in temperature, can precipitate a cascade of ecological consequences. In the context of agriculture, a sector fundamentally intertwined with the climatic conditions of these districts, the rising temperatures may exacerbate the vulnerability of crops to pests and diseases. The thermal increase could potentially disrupt the delicate balance of ecosystems, fostering conditions conducive to the proliferation of pathogenic agents and pest species.

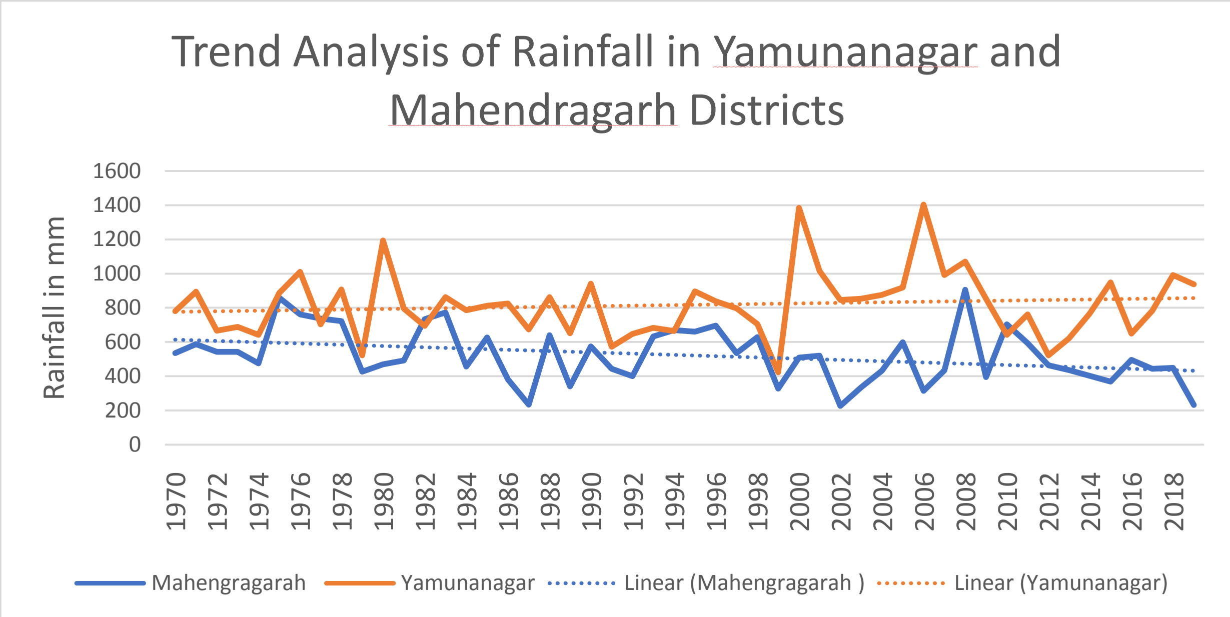
This study, therefore, not only charts the thermal trajectory of the Yamunanagar and Mahendragarh districts but also underscores the critical need for proactive measures in agricultural management. It compels a reevaluation of pest control and disease management strategies within the agrarian communities, anticipating the challenges posed by a warming climate. The data is a clarion call to integration of climatic considerations into agricultural planning and resource allocation, ensuring the sustainability and resilience of crop production in face of the inexorable march of climate change.

When the rainfall patterns in Yamuna Nagar and Mahendragarh regions are examined (Figure 3), the data show significant interannual variability. Seasonal distribution of rainfall in Yamuna Nagar district recorded a minimum of 233.5 mm in 1987 and a maximum of 1403 mm in 2006. Meanwhile, in Mahendragarh district, the lowest rainfall was recorded as 641 mm in 1976 and the maximum rainfall was 1383 mm in 2000. This rainfall dichotomy not only shows the difference between the two agroclimatic zones but also shows the heavy rainfall in Yamua Nagar, which is adjacent to Mahendragarh.

Annual rainfall analysis shows a decline in the climate of Mahendragarh, indicating that the climate in the region is becoming increasingly dry. In contrast, the rainfall trajectory over Y amuna Nagar shows an unclear pattern that defies clear classification. This erratic and decreasi ng rainfall indicates a rapid change in climatic conditions in Haryana and may herald a period o f drought and crop failure during the kharif season, as explained by Singh et al. (2006).

A combination of temperature and precipitation data shows extreme weather conditions and w eather extremes in the state; these show overall changes in response to climate change. This ag reement is based on the principles set out by the United Nations Framework Convention on Cli mate Change (UNFCCC), which defines climate change as an ongoing change in the weather pro duct. The evidence confirmed by Haryana thus confirms the concept of the United Nations Fra mework Convention on Climate Change and clarifies changes in climate in the region that go be yond natural variations into the realm of long-term change.

Graph3: Trends of Rainfall in Yamunanagar and Mahendragarh Districts



Source: Indian metrological department

Table 1: Mann Kendall and Sen's slope results for temperature

	Minimum temperature		Maximum Temperature	
	Yamunanagar	Mahendragarh	Yamunanagar	Mahendragarh
Kendall's Tau	0.510	0.680	.243	0.511
S	559	799	285	601
Var (s)	13457.667	13457.66	13453.667	13457.667
p-value (two-tailed)	< 0.0001	< 0.0001	.0104	< 0.0001
alpha	.05	.05	.05	.05
Sen's Slope	0.036	0.051	0.016	0.036

Source: Indian metrological department

In the non-parametric test Mann Kendall test analysis, the maximum and minimum temperatures in both districts have shown a positive trend. The Kendall's Tau value in both Yamunangar and Mahendragarh for minimum temperature suggests a moderate positive correlation between temperature and time. The test results also suggest that the p-value is less than the .05 alpha value so we reject the null hypothesis that there is no trend and accept the alternate hypothesis, which concludes that there is a significant trend in minimum temperature. Similarly the maximum temperature in both the districts of have shown a significant trend. The significant test results in the Mann-Kendall test and the fig1 and fig2 indicate a statically significant rise in temperature in the last 40 years.

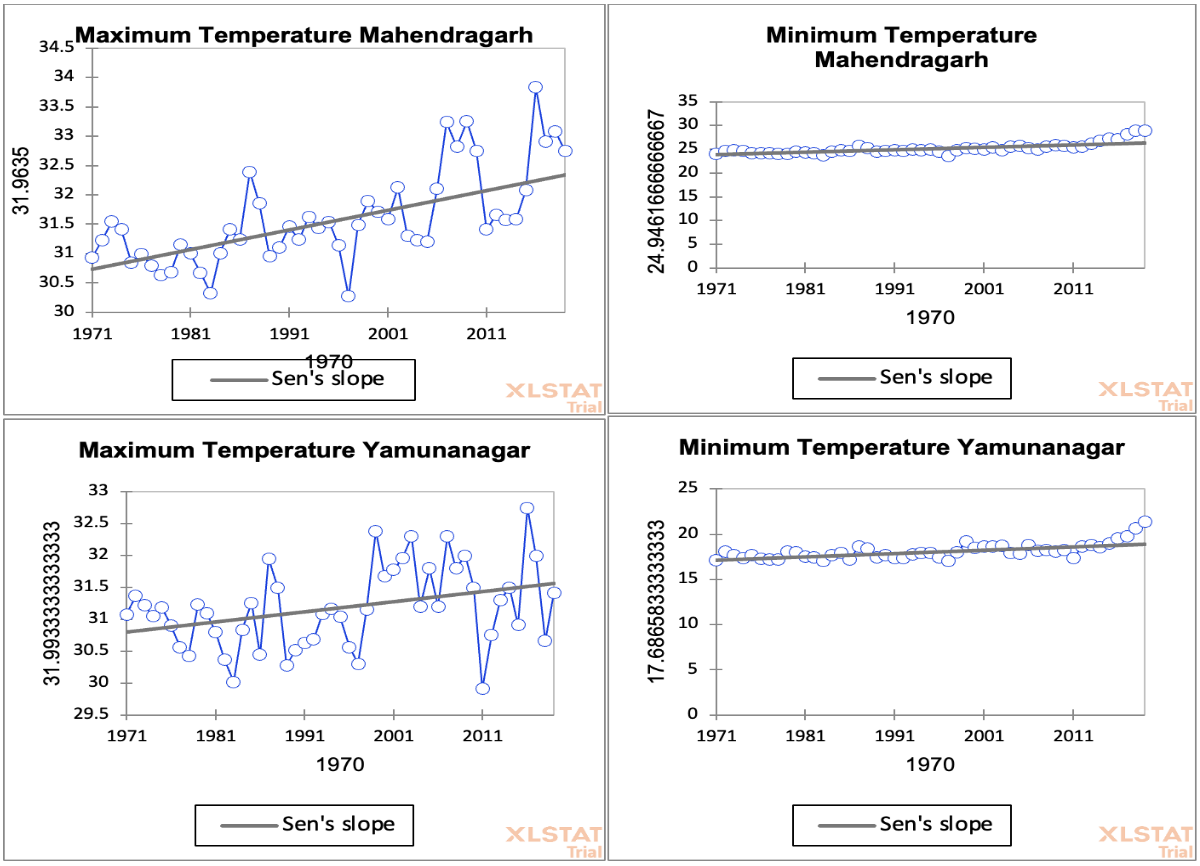
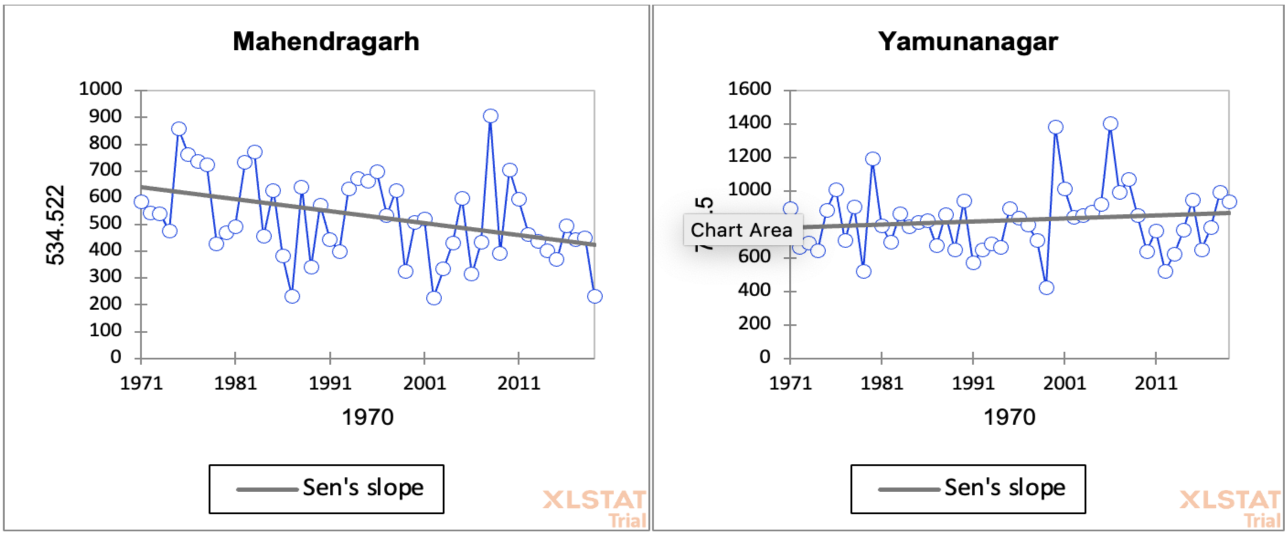


Table 2: Mann Kendall and Sen's slope results for Rainfall

Rainfall		
	Yamunanagar	Mahendragarh
Kendall's Tau	0.08	-0.260
S	95	-306
Var (s)	13457.667	13458
p-value (two-tailed)	.418	.009

alpha	.05	.05
Sen's Slope	1.814	-0.532

Source: Indian metrological department



The rainfall results show a very significant trend of rainfall in Mahendragarh where there is a negative relation between time and the rainfall data means that decreasing trends of rainfall in Mahendragarh are statically significant. While in Yamunanagar there is a positive Tau value which means that there is some increase in rainfall over time but at the same time it is also shown by the p-value that the trend is not significant. The amount of rainfall is either decreasing in one district or there are high variations with some extreme events of rainfall observed in another district of Yamunanagar. Though the concept of climate change is very subjective and seen differently by different scholars but going with the basic definition by UNFCC we can accept change in climatic conditions of both districts to a great extent.

In the study of geography, it is essential to study the patterns of crops because they play an important role in finding the transformation in agriculture and guide us to study the impact of climate change on those crops to conclude with more relevant results. Since the green revolution, there are many changes happened in the cropping patterns of Haryana (Kumar,2014). The changes in irrigation patterns and methods have shifted the trend toward the specialization of a few crops (Singh, 1976). In any region, the cropping pattern is the choice of a farmer in favor of one or preference over one competing crop (Siddiqui and Afzal, 2018). Cropping patterns can be considered successful when there is a possible increase in the production per unit area and time. The cropping pattern is the interaction between physical and socio-economic factors and there is a tendency that the cropping patterns to stabilize in time in different agro-climatic zones (Huaasin, 1996). Weaver's method of crop combination is used to identify the most favored crop in both the selected districts to evaluate the specific relation between climate change and agriculture.

Table 3: Analysis of crop diversity and crop ranking by Weaver's method, in Haryana

	First Rank					Second Rank					Third Rank				
Region/Year	1970-80	1981-90	1991-2000	2001-2010	2002011-19	1970-80	1981-90	1991-2000	2001-2010	2002011-19	1970-80	1981-90	1991-2000	2001-2010	2002011-19
Yamunanagar	Wheat	Wheat	Wheat	Wheat	Wheat	Rice	Rice	Rice	Rice	Rice	Sugarcane	Sugarcane	Sugarcane	Sugarcane	Sugarcane
Mahendragarh	Bajra	Bajra	Bajra	Bajra	Bajra	R&M	R&M	R&M	R&M	Bajra	Gram	Gram	Gram	Wheat	R&M
Haryana	Wheat	Wheat	Wheat	Wheat	Wheat	Rice	Rice	Rice	Rice	Rice	Bajra	Bajra	Bajra	Bajra	R&M

	Diversity				
Region/Year	1970-80	1981-90	1991-2000	2001-2010	2011-19
Haryana	0.75	0.72	0.67	0.65	0.78
Yamunanagar	0.73	0.77	0.71	0.65	0.54
Mahendragarh	0.67	0.65	0.71	0.65	0.77

Source: Statistical Abstract, Haryana

The tabulated data delineates the trajectory of agricultural diversity in Haryana, with a specific focus on the Yamunanagar and Mahendragarh districts, employing Weaver's index of diversity where a spectrum ranging from 0 to 1 serves as a measure, with 1 denoting maximal diversity. An examination of the temporal span from 1970 to 2019 reveals that Haryana, in its entirety, manifested a moderate diversity index from 1990 until the turn of the millennium. However, there is a discernible augmentation in diversity towards the end of the second decade of the 21st century, indicating a broader spectrum of crop cultivation within the state.

Intriguingly, the Yamunanagar district initially exhibited a diversity index superior to that of the aggregate state level for the first two decades; nevertheless, a subsequent decline is observed in the last decade under review. This downturn is emblematic of a contraction in crop variety, which may be attributable to the intensification of a monoculture system, primarily dominated by a select few crops. This phenomenon is congruent with the findings of Singh & Kalra (2002), who reported an expansive growth in rice production post-1970s, and VS Vyas (1996), who noted an ascendance of food crops, particularly wheat and rice, concomitant with a decline in other cereals.

Conversely, Mahendragarh showcases a relatively consistent and high level of diversity throughout the decades, a fact that may be correlated with its lesser water availability, propelling the cultivation of coarse cereals like Bajra, which are less water-intensive. The predilections in crop selection, with wheat, rice, and sugarcane ranking as primary, secondary, and tertiary crops in the more water-ample Yamunanagar, and Bajra taking precedence in the arid climes of Mahendragarh, underscore the adaptation strategies of local agriculture to prevailing climatic conditions.

Table 4: Regression analysis for favorable crop

Mahendragarh (Bajra)	*Coefficients*	R Square	*t Stat*	Obs
Mean Temp	128.368064	0.11694881	1.11229622	18
Rainfall	0.62186066		0.93199971	18
Yamunanagar (Wheat)				
Mean Temp	-247.46239	0.31054858	-1.6488811	18
Rainfall	-0.6979673		-1.5031457	18

The regression analysis described in Table 4 provides an analysis based on understanding the relationship between climatic conditions and crop production in Yamuna Nagar and Mahendragarh districts, comprising wheat and Bajra respectively. Data from Yamuna Nagar shows the relationship between climate change and crop yield: for every unit increase in temperature, crop yield will decrease by 247 units; this is a significant correlation indicated by a t-statistic of -1.64888. Similarly, the negative coefficient of rainfall is 0.697967, reinforcing the model that increased rainfall is associated with decreased rice production in the region.

On the contrary, data from Mahendragarh showed a positive correlation between weather and Bajra crop yield. It is well suited to the semi-arid conditions prevailing in the region. The average temperature coefficient is 128.368064, and the t-test is 1.11229622, indicating the positive effect of temperature on Bajra yield. Similarly, the positive value of rainfall is 0.62186066, indicating that the increase in rainfall is beneficial for Bajra agriculture.
The R-square value for the temperature in Yamunanagar is 0.31054858, corresponding to approximately 31% of the variance in wheat production, while the R-square for temperature in Mahendragarh is considerably lower at 0.11694881, accounting for roughly 12% of the variability in Bajra production. These statistics show that while climatic changes significantly influence agricultural output in Yamunanagar, their effect on Mahendragarh's primary crop, Bajra, is less pronounced.

Mehra (2018) states that Mahendragarh's agricultural land is undergoing a transformation by focusing on growing crops, optimizing the suitability of the land for such crops. Additionally, the introduction of new seeds and pearl millet varieties has also helped Bajra production. These factors, along with social studies, show that while agriculture in Yamuna Nagar, especially crops, is affected by climate change, Bajra in Mahendragarh is still robust and can recover by taking advantage of these changes. This dilemma highlights the importance of regional adaptation strategies to resist the effects of climate change in agriculture.

Conclusion and suggestions

After reviewing what we know about climate change and agriculture in developing countries, it is very clear that climate change has impacts on environmentally and economically vulnerable regions. The trend analysis of temperature indicates a increasing trend of temperature in both the agroclimatic zones, the rise in temperature can also be significantly explained with the M-K test results. Climate change assumptions become more realistic with the decreasing trends of the rainfall in both the regions. It's not only the decrease in rainfall but the episodes of heavy untimely rainfall are also observed. Both theagro-climatic regions show a clearly different preference for the production of crops. There are significant negative impacts of climate change on the production of wheat in Yamunanagar, however the impacts on Bajra (primary crop) in Mahendragarh are not negative while other crops have faced negative impacts. The paper makes a clear point that climate change is visible in both ethe regions which also has significant impact on the agriculture.

Following suggestions are recommended to overcome the issue of climate change and its impact on crops:

i. It is essential to have crop insurance for climate variability to reduce the losses due to climate change on agriculture.
ii. Use of climate resistant verities of seeds, to avoid impact of climate change.
iii. Early warning should give to the farmers so that they can use the other and alternative way to protect him from these types of changes.
iv. More focus on crops which are not much sensitive to climate and diversification of crops should be adopted as a solution to the problem.

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