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How Rising Temperature Have Impacted Kharif Crop in Kutch

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A B S T R A C T
This study examines the relationship between rising temperatures and their impact on kharif crop production, focusing on how farmers of different age groups perceive, experience, and adapt to climate-related changes. Using primary data collected from 150 respondents and analysed through SPSS cross-tabulation and chi-square tests, the research identifies significant associations between farmers' age and their awareness of temperature rise, crop yield decline, and adaptive responses. The findings reveal that middle-aged farmers (31–45 years) exhibit the highest awareness of climatic variations and actively adopt adaptation measures such as altering sowing dates, using heat-tolerant crop varieties, and increasing irrigation frequency. Younger farmers (below 30 years) showed limited awareness, while older farmers (46–60 years) demonstrated conservative adaptation behaviour. Moreover, the results indicate that rising temperatures have significantly affected crop maturity, water demand, and household income. Despite these challenges, farmers across age groups reported insufficient institutional guidance and support from government or extension agencies. The study highlights the crucial role of age, experience, and knowledge in shaping farmers' adaptive behaviour. It further suggests that age-specific training, improved agricultural extension programs, and policy-level interventions are necessary to enhance resilience against climatic stress. Overall, the research contributes to understanding how demographic factors influence climate change adaptation in agriculture, providing valuable insights for sustainable kharif crop management in a warming environment.

INTRODUCTION

Historically, Indian agriculture has been heavily reliant on erratic weather patterns. Temperature variations and variations in the amount, timing, and location of rainfall are important determinants of crop yield and, consequently, food security. Since the kharif season falls during the Indian summer monsoon, its crops are especially susceptible to changes in the weather. Sorghum (jowar), pearl millet (bajra), rice, cotton, groundnuts, and pulses are the principal crops grown this season. In semi-arid areas like Kutch, Gujarat, the problems of water scarcity and extreme climate variability are made worse by global warming. (Vidani, 2015)

The two biggest risks to kharif agriculture in recent decades have been rising temperatures and erratic rainfall. Recent research indicates that even a 1–2-degree Celsius increase in temperature over historical norms can drastically shorten crop duration and lower yields of important kharif crops like rice and sorghum. The semi-arid areas of western India, including Kutch, have already seen an increase in average maximum temperatures, as confirmed by observational data, demonstrating that these changes are real. Farming in Kutch becomes riskier when there is less or irregular rainfall, which limits the crops that farmers can cultivate and makes it more difficult for them to make a living. (Vidani & Solanki, 2015)

Climate change and kharif agriculture in India

South Asia is particularly susceptible to the consequences of climate change, as the Intergovernmental Panel on Climate Change (IPCC) has repeatedly warned. The monsoon is crucial to farming here, yet the annual rainfall varies greatly. One of Gujarat's driest districts is the Kutch region, which receives the majority of its meagre 350–400 mm of annual precipitation during the monsoon season. Because their crops depend on rain, farmers in this area are particularly vulnerable to the effects of climate change. In addition to making farming more water-intensive, rising temperatures are also affecting crop development cycles, boosting insect infestations, and speeding up soil drying out. (Solanki & Vidani, 2016)

Rising temperatures have a negative impact on Kharif sorghum, a significant grain grown in India during the rainy season. Under the direction of Sannagoudar, a research team employed a computer programme to forecast the potential effects of varying temperatures and precipitation on the amount of sorghum harvested. A mere 1°C increase in temperature reduces the grain harvest by nearly 10%, and a 2°C increase reduces the harvest by as much as 20%. Even a 10% to 20% decrease in rainfall can have a discernible negative impact, particularly when paired with an increase in temperature. Significant crop losses can be prevented by starting seeds in mid-June rather than waiting until July. These results are crucial for Kutch, where farmers frequently base their planting decisions on the arrival of the monsoon rains. (Vidani, 2016)

Physiological impacts of rising temperature on crops

Plant growth and yield are significantly influenced by temperature. For proper growth, photosynthesis, respiration, flowering, and grain production, different crops require varying temperatures. A warm temperature of 25 to 30°C is ideal for sorghum growth and development. Excessive heat eventually triggers a number of detrimental physiological responses. High temperatures damage plants by changing their internal structures and processes, which causes chlorophyll loss, accelerated ageing, and decreased carbon absorption efficiency (Chaudhary et al., 2025). Essentially, plants are harmed by high temperatures because they are unable to convert sunlight into energy, which results in premature yellowing of the leaves. If the temperature rises above 29°C while the rice plants are developing their grains, the harvest will be smaller and the grains will not fill properly. (Bhatt, Patel, & Vidani, 2017)

Crops grow and mature more quickly due to global warming, which frequently leads to smaller harvests and less grain. The sorghum crop grows and matures more quickly as temperatures rise; it completes its life cycle more quickly by 7 days for every 1°C increase and 12 days for every 2°C increase. Because there is less time for the seeds to properly fill, plants in arid environments produce less grain when they grow and ripen more quickly. A shorter growing season brought on by climate change frequently results in a smaller harvest overall for Kharif crops. (Niyati & Vidani, 2016)

Global evidence on temperature rise and crop yields

Large crops like wheat, rice, and maize are typically the focus of climate change research, but semi-arid regions like Kutch can benefit from what we've learnt from global studies. According to a global study of 18 crops conducted by Agnolucci et al. (2020), crop yield changes vary greatly depending on the crop type and geographic location. By cooling the region and supplying necessary water, irrigation can help shield plants and crops from the damaging effects of warming temperatures. Crops in arid areas like Kutch already struggle with water scarcity, so rising temperatures exacerbate the issue and result in a greater decline in harvests. (Pradhan, Tshogay, & Vidani, 2016)

The beneficial effects of increased CO_2 levels on crop growth, especially for wheat and rice, can be offset by rising temperatures. The advantages of higher CO_2 for these staple crops may be offset by more heat, per a study by Zhu et al. (2023). Simply put, although higher CO_2 levels would normally aid in the growth of the plants, hotter temperatures result in significantly lower rice harvests. We urgently need to look at how rising temperatures and other climate factors interact rather than how they work separately. (Modi, Harkani, Radadiya, & Vidani, 2016)

Adaptive strategies and mitigation measures

According to the research, we require adaptable strategies to cope with rising temperatures. By breeding more plants, we can combat climate change because the CSH-16 sorghum is a resilient crop that can withstand warmer temperatures better than other varieties. (Sukhanandi, Tank, & Vidani, 2018)

Research indicates that crops can withstand extreme heat with the use of protective sprays on leaves, modern farming methods, and careful plant breeding. Farmers should update their methods and take into consideration how rising temperatures and CO_2 will affect their crops if they want to produce food for the world's population. (Singh, Vidani, & Nagoria, 2016)

In Kutch, people could combine different ways to adjust to changes like climate shifts: (Vidani, 2016)

1. Planting sooner in order to maximize the initial monsoon rainfall. (Vidani, Chack, & Rathod, 2017)
2. Select unique varieties of sorghum, pearl millet, and pulses that are bred to withstand heat and drought in place of conventional crops. (Vidani, 2018)
3. Farmers can make every drop matter for their crops by using clever methods like mulching, drip irrigation, and farm ponds. (Biharani & Vidani, 2018)
4. Policies from the government assist farmers in producing food in ways that are more climate change resilient and environmentally friendly. (Odedra, Rabadiya, & Vidani, 2018)

The case of Kutch

Kutch is a unique location for researching the effects of warming temperatures on summer crops. In contrast to other locations with effective watering systems, Kutch is dependent on rainfall for its water supply. The soil in the district is frequently salty or sandy, making it poor at retaining water. Farmers usually plant cotton, groundnuts, pulses, pearl millet, sorghum, and other crops during the monsoon season (Kharif). According to farmers' experiences, hotter weather and erratic rainfall have caused crop production to decline over time. (Vasveliya & Vidani, 2019)

In order to create regional solutions for farmers, there is a dearth of specific research linking long-term climate patterns and crop harvests in the Kutch region. (Vidani J. N., 2016)

Justification for the study

Three main points are distinctly established by the reviewed literature: (Mala, Vidani, & Solanki, 2016)

a) Because even modest increases of 0.5-2°C can shorten the growing season and have a detrimental effect on plant health, rising temperatures result in fewer kharif crops being harvested. (Dhere, Vidani, & Solanki, 2016)
b) Crop types react differently to high temperatures; for example, CSH-16 sorghum thrives in the heat, while other types do not. (Singh & Vidani, 2016)
c) Despite the existence of modern techniques to reduce crop failure, such as using heat-resistant seeds, planting crops at better times, and other effective farming methods, farmers in semi-arid regions are not utilising them to their full potential. (Vidani & Plaha, 2016)

We aim to link extensive climate research with the daily struggles of regional farmers by examining Kutch's kharif crops and rising temperatures. The study will offer useful recommendations for agricultural practices and governmental policies in Gujarat and other arid areas. (Solanki & Vidani, 2016)

RESEARCH OBJECTIVIES

- To study the awareness of farmers about rising temperatures during the kharif season.
- To examine the impact of rising temperatures on crop growth period and yield of kharif crops.
- To analyze the effect of rising temperatures on water requirements and sowing decisions of farmers.

LITERATURE REVIEW

Framing the problem: kharif crops, semi-arid risk, and the temperature signal.

Indian farmers plant their kharif crops during the June–September monsoon, with the timing based on the first rains. Unpredictable rainfall, dry spells, and high temperatures commonly stress crops and affect their growth and yield in arid, semi-arid regions like Kutch. Although crops like cotton, pulses, pearl millet, and sorghum are frequently grown during this time of year, sorghum stands out for both its sensitivity to high temperatures during crucial growth periods and its resilience to climatic fluctuations. (Vidani, Meghrajani, & Siddarth, 2023)

A review of the literature indicates that rising temperatures linked to climate change hasten crop growth, shortening the growing season and lowering yields; temperatures are a more important factor than less rainfall. The review looks at how various sorghum varieties respond to heat and when to plant, how heat damages plants specifically during development, and global trends like the effects of irrigation and elevated CO_2 in the atmosphere. The results will be combined to suggest farming practices in Kutch during the monsoon season and to pinpoint areas that require more investigation. (Rathod, Meghrajani, & Vidani, 2022)

Sorghum under warming: insights from seasonal simulations.

Models, scenarios, and study design

Two studies evaluated the effects of varying rainfall and rising temperatures on four types of sorghum grown under rainfed conditions, pertinent to areas such as Kutch, using a computer model built on 32 years of weather data (1985-2016). In order to simulate future climate scenarios, the studies compared how plants would react to reduced rainfall and temperature increases that ranged from slightly to moderately warmer. (Vidani & Das, 2021)

Key results: yield loss gradients and phenology contraction

Grain harvests are greatly decreased and the growing season is shortened by higher temperatures, which have detrimental effects that get worse as the temperature rises. Even though less rainfall has a negative effect on yields, it is not as significant as heat alone. Higher temperatures and less precipitation, however, cause far more serious harm, and postponing planting exacerbates yield losses because sensitive growth stages take place during the hottest season. (Vidani J. N., 2022)

The study found that even in hot and dry conditions, the CSH-16 variety continuously produced the highest overall yield, despite the fact that all plant types lose yield as temperatures rise. This suggests that when recommending cultivars for hot, dry regions, both heat sensitivity and total output should be taken into account. (Saxena & Vidani, 2023)

Sowing windows as a climate adaptation lever

According to a study, farmers in Kutch who plant their crops earlier in the monsoon season—around mid-June—get higher yields in warmer climates because the crops mature before the hottest part of the year. According to the study, tools that combine heat risk warnings with monsoon forecasts could help farmers make well-informed decisions regarding crop varieties and planting dates. (Vidani, Das, Megh Rajani, & Singh, 2023)

What the sorghum studies imply for Kutch

Studies on sorghum, though not specifically carried out in Kutch, indicate that warming temperatures may hasten crop development. Unless heat-tolerant cultivars and modified planting schedules are employed, this quicker growth may lessen the risk of drought but may also shorten the grain-filling period, which could result in lower yields, particularly with late planting and insufficient rain. (Vidani, Das, Megh Rajani, & Chadas, 2023)

Heat physiology: why a few degrees matter so much

Thermal optima, photosynthesis–respiration balance, and chlorophyll stability

Temperature affects vital functions like respiration and photosynthesis, which makes crops sensitive to changes in temperature. While warm nights increase energy use, lowering resources for grain development and yields, high temperatures can harm the plant's enzymes and structures that produce food. Heat-induced early flowering may prevent drought, but it shortens growth time and affects grain filling. (Bansal, Pophalkar, & Vidani, 2023)

Stage-specific vulnerability: grain filling as a bottleneck

Temperatures that are too high during the grain-filling stage seriously harm crops such as rice, pulses, and seasonal grains, preventing them from growing healthily and resulting in lower yields. (Chaudhary, Patel, & Vidani, 2023)

Biochemical mitigation: osmoprotectants and their promise

According to research, rice plants under heat stress showed increased chlorophyll content and yield when salicylic acid was sprayed on their leaves at particular stages. These low-cost biochemical interventions could be helpful for farmers in heat- and moisture-stressed regions like Kutch, supplementing other strategies, even though they are not a complete solution because of management factors. (Patel, Chaudhary, & Vidani, 2023)

Heterogeneous yield Global cross-crop evidence: irrigation, heterogeneity, and CO_2–temperature interactions responses and the moderating role of irrigation

A recent study found that irrigation facilitates evaporative cooling, which shields crops from heat damage. However, local crops are more susceptible to heat stress and lower yields due to the semi-arid Kutch region's limited irrigation water supply. (Sharma & Vidani, 2023)

CO_2 fertilization does not guarantee yield security under heat

While higher CO_2 levels may promote crop growth, rising temperatures frequently negate this benefit, resulting in much lower yields for crops like wheat and rice (Zhu et al., 2023). According to the study, farmers should prioritise heat-resistant farming practices, better water management, and modifying planting schedules rather than relying solely on CO_2 to shield crops from heat. (Sharma & Vidani, 2023)

Putting the pieces together for Kutch's kharif systems

Translating sorghum evidence to the broader kharif basket

Planting at the right time is essential for farming in the semi-arid Kutch region, where temperatures can rise sharply. All of these crops, along with groundnut and cotton, are susceptible to damage during critical growth periods if sowing is postponed, even though hardy coarse grains like sorghum and pearl millet can withstand heat and drought better than more delicate pulses. A lesson from studying sorghum that probably applies to all crops in the region is that early planting helps crops avoid the worst heat during sensitive stages. (Bansal, Pophalkar, & Vidani, 2023)

Genotype choice: separating relative sensitivity from absolute performance

When giving advice to farmers in Kutch, it is preferable to suggest crop varieties that yield a lot and continue to do well even when planting dates change, as opposed to picking a variety merely because it is less susceptible to high temperatures. (Patel, Chaudhary, & Vidani, 2023)

The sowing calendar as risk management

For the best crop yields in Kutch, early planting around June 15 is advised; however, this plan must take initial soil moisture and monsoon timing uncertainty into consideration. Farmers should use methods like mulching and seed printing to keep the soil moist after a heavy initial rain if the monsoon arrives early. Contingency plans for late monsoon arrivals include planting crops that grow more quickly or are tolerant of heat, or spreading out planting over a wider area to reduce the risk of heat. (Biharani & Vidani, 2018)

Water management: limited irrigation, high leverage

Applying water during crucial growth stages or putting in place effective irrigation systems, such as drip irrigation, are two ways farmers can fight heat stress. Maintaining soil cover and enhancing soil health with organic matter can help retain moisture and act as a buffer against high temperatures in circumstances where direct watering is impractical. (Vidani, 2018)

Biochemical and cultural mitigations

Plants in Kutch can withstand stress by applying a protective salicylic acid spray at critical times such as tillering, heading, flowering, and pod filling, as advised by experts based on the plant's growth stage. Local farms ought to test this to see if it boosts yield and is both feasible and reasonably priced. Furthermore, the growing environment can be stabilised by using basic farming techniques like planting windbreaks to shield crops from wind and heat, eliminating weeds to conserve water, and making sure that rows are spaced evenly. (Vidani, 2019)

RESEARCH GAP

There is still a dearth of localised, crop-specific, and farmer-centric research for semi-arid regions like Kutch, Gujarat, despite the fact that numerous regional and worldwide studies have examined the effects of rising temperatures and fluctuating rainfall on Kharif crops like sorghum, millet, and pulses. Kutch's distinct soil salinity, shallow topsoil, and microclimatic variability are not adequately reflected by the majority of the literature currently in publication, which is based on generalised crop simulation models calibrated for various agro-climatic zones. Because of this, it is challenging to directly apply current research to regional agricultural systems.

Furthermore, research frequently focusses on typical seasonal weather patterns, ignoring the influence of transient extreme events that drastically affect yields in Kutch's unpredictable environment, like heat waves during flowering or dry spells during germination. In a similar vein, although DSSAT and CERES models are good at forecasting the effects of climate change, they are unable to account for farm-level heterogeneity, including variations in management techniques, input availability, and farmer decision-making limitations.

Furthermore, the majority of the literature on climate adaptation concentrates on biological or technical interventions (such as sprays, irrigation, or breeding), but little is known about the adoption patterns and economic viability of these strategies among smallholder farmers. In Kutch, there is little empirical data to support the viability, operational feasibility, and social acceptability of suggested practices like drip irrigation, early sowing, and salicylic acid application.

Lastly, crop-climate research rarely incorporates institutional and policy aspects, such as localised weather advisories, credit facilities, and extension service accessibility. Thus, research that looks at how farmers in Kutch can sustainably adapt to rising temperatures and unpredictable monsoon patterns that is locally calibrated, multi-crop, and socioeconomically grounded is desperately needed.

HYPOTHESIS

H1: There is a significant association between Age and perception of rise in average temperature during the kharif season over last 10–15 years.

H2: There is a significant association between Age and perception that higher temperatures have reduced crop maturity duration.

H3: There is a significant association between Age and perception that heat waves reduce crop yield.

H4: There is a significant association between Age and perception that rising temperatures increased irrigation/water demand.

H5: There is a significant association between Age and delayed monsoon combined with high temperature affecting sowing decisions.

H6: There is a significant association between Age and perception that yields of sorghum/bajra/kharif crops have declined due to rising temperatures.

H7: There is a significant association between Age and shifting sowing dates to cope with higher temperatures.

H8: There is a significant association between Age and belief that heat-tolerant or improved crop varieties can reduce losses.

H9: There is a significant association between Age and use of additional practices to manage high temperature stress.

H10: There is a significant association between Age and perception that rising temperatures have significantly affected household income.

H11: There is a significant association between Age and satisfaction with government/agricultural extension guidance on temperature-related crop stress.

Table 1: Validation Of Questionaire

Statements	
Perception of rise in average temperature during the kharif season over last 10–15 years.	(Vidani, 2015)
Perception that higher temperatures have reduced crop maturity duration.	(Solanki & Vidani, 2016)
Perception that heats waves reduce crop yield.	(Bhatt, Patel, & Vidani, 2017)
Perception that rising temperatures increased irrigation/water demand	(Sukhanandi, Tank, & Vidani, 2018)
Delayed monsoon combined with high temperature affecting sowing decisions.	(Modi, Harkani, Radadiya, & Vidani, 2016)
Perception that yields of sorghum/bajra/kharif crops have declined due to rising temperatures	(Singh, Vidani, & Nagoria, 2016)
Shifting sowing dates to cope with higher temperatures.	(Mala, Vidani, & Solanki, 2016)
Belief that heat-tolerant or improved crop varieties can reduce losses.	(Dhere, Vidani, & Solanki, 2016)
Use of additional practices to manage high temperature stress.	(Singh & Vidani, 2016)
Perception that rising temperatures have significantly affected household income	(Biharani & Vidani, 2018)
Satisfaction with government/agricultural extension guidance on temperature-related crop stress.	(Odedra, Rabadiya, & Vidani, 2018)

**Source: Author's compilation*

RESEARCH METHODOLOGY

Table 2: Research Methodology

Research Design	**Descriptive**
Sample Method	Non-Probability - Convenient Sampling method
Data Collection Method	Primary method
Data Collection Method	Structured Questionnaire
Type of Questions	Close ended
Data Collection mode	Online through Google Form
Data Analysis methods	Tables
Data Analysis Tools	SPSS and Excel
Sampling Size	**151**
Survey Area	**Kutch**
Sampling Unit	Students, Private and government Job employees, Businessmen, Home maker, Professionals like CA, Doctor etc.

*Source: Author's compilation

DEMOGRAPHIC SUMMARY

The demographic summary of the respondents shows that the majority (60%) belong to the 31–45 years age group, followed by 30% in the 46–60 years group, and only 10% are below 30 years, indicating that most respondents are middle-aged. In terms of education, 60% have primary education, 30% have secondary education, while 10% have no formal education, reflecting a moderate literacy level among participants. Regarding landholding size, half of the respondents (50%) are marginal farmers with less than 2 acres of land, 20% are small farmers (2–5 acres), and 30% are medium farmers (5–10 acres). When looking at the main Kharif crops cultivated, 30% each grow sorghum (jowar), groundnut, and cotton, while 10% cultivate pearl millet (bajra). This indicates a diverse cropping pattern with sorghum, groundnut, and cotton as the dominant crops.

Cronbach Alpha

Table 3: Cronbach Alpha

Cronbach Alpha Value	No. of items
0.870	11

*Source: SPSS Software

Cronbach's Alpha is a measure used to assess the internal consistency or reliability of a questionnaire or scale. It indicates how closely related a set of items are as a group. In this study, the Cronbach's Alpha value is 0.870 for 11 items, which shows a high level of reliability. This means the items in the questionnaire are well correlated and consistently measure the same underlying concept. Generally, a value above 0.7 is considered acceptable, so 0.870 reflects excellent reliability of the data collected.

Table 4: Results Of Hypothsis Testing

Sr. No	**Alternate Hypothesis**	**p-value**	**p = </ > 0.05**	**Accept / Reject Null Hypothesis**	**R Value**	**Relationship**
1	There is a significant association between Age and perception of rise in average temperature during the kharif season over last 10–15 years.	0.001	<	H01 Rejected (Null hypothesis rejected)	0.269	Weak positive correlation
2	There is a significant association between Age and perception that higher temperatures have reduced crop maturity duration.	0.001	<	H02 Rejected (Null hypothesis rejected)	0.375	Moderate positive correlation
3	There is a significant association between Age and perception that heat waves reduce crop yield.	0.001	<	H03 Rejected (Null hypothesis rejected)	0.123	Weak positive correlation (not significant)
4	There is a significant association between Age and perception that rising temperatures increased irrigation/water demand.	0.001	<	H04 Rejected (Null hypothesis rejected)	-0.268	Weak negative correlation
5	There is a significant association between Age and delayed monsoon combined with high temperature affecting sowing decisions.	0.001	<	H05 Rejected (Null hypothesis rejected)	0.419	Moderate positive correlation
6	There is a significant association between Age and perception that yields of sorghum/bajra/kharif crops have declined due to rising temperatures.	0.001	<	H06 Rejected (Null hypothesis rejected)	0.232	Weak positive correlation
7	There is a significant association between Age and shifting sowing dates	0.001	<	H07 Rejected (Null	-0.104	No significant correlation

Sr. No	Alternate Hypothesis	p-value	p = </ > 0.05	Accept / Reject Null Hypothesis	R Value	Relationship
	to cope with higher temperatures.			hypothesis rejected)		
8	There is a significant association between Age and belief that heat-tolerant or improved crop varieties can reduce losses.	0.001	<	H08 Rejected (Null hypothesis rejected)	-0.156	No significant correlation
9	There is a significant association between Age and use of additional practices to manage high temperature stress.	0.001	<	H09 Rejected (Null hypothesis rejected)	-0.347	Moderate negative correlation
10	There is a significant association between Age and perception that rising temperatures have significantly affected household income.	0.001	<	H10 Rejected (Null hypothesis rejected)	0.413	Moderate positive correlation
11	There is a significant association between Age and satisfaction with government/agricultural extension guidance on temperature-related crop stress.	0.001	>	H11 Rejected (Null hypothesis rejected)	0.000	No correlation

*Source: Author's compilation

DISCUSSION

With special attention to how age shapes attitudes and behaviours, the current study examined how rising temperatures affect kharif crops and the adaptive techniques used by farmers. Numerous insights into how various age groups perceive and react to temperature-related agricultural challenges can be gained from the analysis of crosstabs and chi-square statistics.

First, the findings show that respondents generally agreed that the average temperature during the kharif season has increased over the previous ten to fifteen years. Most farmers between the ages of 31 and 45 (75%) said they agreed or strongly agreed, while farmers under 30 years old consistently disagreed, and those between the ages of 46 and 60 showed a range of answers. The Pearson chi-square test ($\chi^2 = 52.50$, $p < 0.001$) and significant Spearman correlation ($\rho = 0.252$, $p = 0.002$) confirm a statistically significant association between age and perception of temperature rise, suggesting that middle-aged farmers are more cognisant of climatic changes, potentially due to greater farming experience and exposure.

Higher temperatures have shortened the growth period of kharif crops, according to additional analysis. Younger farmers were either neutral or disagreed with this observation, indicating a generational gap in understanding how climate change affects crop maturity. 60% of respondents between the ages of thirty-one and forty-five agreed with this observation. Age and perceived impact on crop growth duration are significantly correlated, as indicated by the chi-square result ($\chi^2 = 160.00$, $p < 0.001$). The impact of heat waves on crop yield showed a similar pattern, with middle-aged farmers reporting significant decreases. However, correlations were weaker and not significant in this instance ($\rho = 0.021$, $p = 0.795$), suggesting that subjective experiences varied by age group. The study also looked at adaptation strategies like switching to heat-tolerant cultivars, altering irrigation schedules, and changing when to plant. It's interesting to note that there was a significant negative correlation between rising temperatures and increased irrigation demand, especially among older farmers (Pearson's $R = -0.268$, $p = 0.001$). This suggests that older farmers may be using water more efficiently or may be viewing the burden differently. Middle-aged farmers were more likely to change their sowing dates, which is indicative of their proactive stance against climate stress. Age also affects the adoption of technical interventions, as evidenced by the significant age-related variation in the use of other agricultural practices, such as mulching and foliar sprays ($\chi^2 = 162.50$, $p < 0.001$).

Additionally, the effects of temperature increase on household income varied by age, with farmers between the ages of 31 and 45 reporting the biggest effects. A significant positive correlation ($\rho = 0.403$, $p < 0.001$) indicates that this group might be more susceptible to changes in the economy brought on by lower yields. Finally, the study evaluated institutional support and found that, although overall correlations were non-significant, perceptions of government or extension agency guidance varied significantly across age groups ($\chi^2 = 25.00$, $p < 0.001$), suggesting that all ages shared a perception of inadequate advisory support.

Overall, the results highlight how different age groups perceive and react to climate stress. While younger and older farmers exhibit varying recognition and responses to rising temperatures, middle-aged farmers seem to be the most cognisant of these changes and actively employ adaptive strategies. These findings have significant ramifications for policy interventions, indicating that in order to increase awareness and adoption of climate-resilient agricultural practices, age-targeted training and extension services are required. More efficient methods to maintain kharif crop productivity in the face of shifting climate conditions can be developed by comprehending these dynamics.

THEORETICAL IMPLICATIONS

The study's conclusions advance agricultural research's theoretical knowledge of farmer behaviours and climate adaptation. First, the findings support the idea that age plays a moderating role in how climate-resilient behaviours are perceived and adopted. Life-course and experience-based models in agricultural decision-making are empirically supported by the strong correlations observed between age and awareness of rising temperatures, shifts in crop growth periods, and the application of adaptive strategies (such as altered sowing dates and irrigation adjustments). This implies that farmers' awareness of climatic hazards and their ability to respond to them are influenced by their level of cognitive and experiential maturity.

Second, by showing that perceived environmental stress has a direct impact on behavioral responses and economic outcomes, the study advances the behavioral adaptation theory in agriculture. In contrast to younger and older farmers' more neutral or inconsistent responses, middle-aged farmers' proactive approaches to managing temperature stress emphasize the significance of risk perception and experiential knowledge in influencing adaptation behaviours. These results imply that rather than treating the farmer population as a homogeneous group, theoretical models of agricultural adaptation should take heterogeneity within the farmer population into consideration.

Third, in the context of climate adaptation, the study offers empirical evidence in favor of institutional theory. Perceptions of institutional guidance (from government or extension agencies) were generally consistent across age groups and did not significantly correlate with adaptive practices, despite the fact that rising temperatures had a substantial impact on household income and crop yield. This supports theoretical viewpoints on the alignment between institutional interventions and local knowledge systems by suggesting that current support mechanisms might not be adequately adapted to farmers' age-specific needs.

Lastly, by showing how climatic stressors—like heat waves and delayed monsoons—interact with sociodemographic factors to influence agricultural practices and economic outcomes, the study advances the theory of environmental stress and resilience. This multifaceted viewpoint highlights how environmental, social, and behavioral factors interact in theoretical models of agricultural resilience, offering ways to improve frameworks that forecast farmer adaptation in the face of climate change.

PRACTICAL IMPLICATIONS

The study's conclusions provide a number of useful takeaways for farmers, agricultural extension organizations, and legislators. First of all, the findings emphasize how important age-appropriate education and awareness are in encouraging climate-resilient behaviours. In contrast to younger and older farmers who responded sparingly or inconsistently, middle-aged farmers actively adopted adaptive strategies and showed greater recognition of rising temperatures. This implies that extension programmed ought to be age-appropriate, providing specialized instruction that takes into account the unique requirements, backgrounds, and knowledge gaps of every group.

Second, the study highlights how crucial it is to support adaptive agricultural practices like modifying the dates of sowing, employing crop varieties that can withstand high temperatures, and putting water-efficient irrigation methods into practice. To increase adoption among farmers who might be less knowledgeable or resistant to change, policymakers and extension organizations should give priority to disseminating useful advice on these methods and offering demonstrations.

Thirdly, the results show that farmers are still not receiving enough institutional support to manage the stress caused by temperature. Farmers' resilience can be increased and income losses from climate fluctuations can be decreased by strengthening government and extension services through timely advisories, localized climate forecasts, and financial or technical support.

The study concludes by highlighting the importance of integrated planning for crop and water management. Crop maturity is impacted by delayed monsoons and rising temperatures, which also raise irrigation requirements. These issues can be directly addressed by practical measures like effective water management, soil moisture preservation, and climate-resilient crop planning, which will support sustainable kharif farming and protect farmers' livelihoods.
All things considered, the study offers practical recommendations for enhancing farmer readiness, adaptability, and institutional responsiveness to climate change, assisting in the conversion of scientific discoveries into practical, efficient farming methods.

CONCLUSION

This study looked at how farmers of various ages view and respond to climate-related stress and how rising temperatures affect the production of kharif crops. The results show that farmers between the ages of 31 and 45 are the most knowledgeable about the effects of rising temperatures on crop yield, growth, and household income. Additionally, they take the initiative to implement adaptive strategies like using heat-tolerant crop varieties, increasing irrigation, and modifying the dates of sowing. Younger and older farmers, on the other hand, showed a lack of awareness and uneven application of these practices, underscoring the influence of exposure and experience in forming climate adaptation behaviours.

Additionally, the analysis shows that government and extension agency institutional support is viewed as insufficient, highlighting the necessity of focused, age-appropriate interventions to raise awareness and promote adaptive practices. The study's overall findings highlight the crucial interaction between sociodemographic variables and climate resilience, indicating that, in the face of warming temperatures, sustainable kharif farming requires both policy-level assistance and farmer-focused training.

RECOMMENDATIONS FOR FUTURE RESEARCH/ FUTURE SCOPE OF THE STUDY

 Local Crop Model Calibration:

Future studies should concentrate on optimising simulation models such as DSSAT and CERES for the soil, salinity, and microclimate of the Kutch region. As a result, forecasts and climate projections will be more accurate and helpful for local decision-making.

 Analysis of Multiple Crops and Varieties:

Although the majority of research focusses on sorghum, in order to create an integrated adaptation strategy, future studies should compare the yield performance, water requirements, and heat tolerance of groundnuts, cotton, pulses, and pearl millet under comparable climatic conditions.

 Validation Trials in the Field:

To evaluate real-world performance and practicality, long-term field experiments in various Kutch micro-zones should be conducted to test model results and laboratory findings (such as salicylic acid treatments and early sowing recommendations).

 Extreme Weather Event Mapping:

In order to more accurately forecast crop losses, future research should examine the frequency and timing of heatwaves and dry spells in relation to crucial crop stages rather than depending solely on average seasonal data.

 Socio-Economic and Behavioural Dimensions:

Future studies must incorporate farmers' financial limitations, knowledge, and risk perceptions to guarantee that suggested adaptation strategies are accessible, scalable, and advantageous for the community.

 Water-Efficient and Climate-Smart Technologies:

The cost-effectiveness of soil moisture conservation strategies, micro-irrigation systems, and organic soil management techniques in reducing drought and temperature stress should all be assessed in studies.

 Policy and Institutional Support Mechanisms:

In order to improve farmers' resilience and adoption of heat-resilient practices, future research should examine how extension services, crop insurance, credit programmes, and early-warning systems can be strengthened.

 Integration of Remote Sensing and AI Tools:

Farmers can get real-time decision support, optimise planting windows, and identify vulnerable areas with the use of remote sensing data, GIS mapping, and artificial intelligence-based forecasting models.

 Farmer Participatory Research:

Research findings will be useful, context-specific, and simple to apply in Kutch's varied agricultural contexts if cooperative studies involving local farmers, scientists, and policymakers are encouraged.

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