**Original Research Article**

**Impact of Weather Aberrations and Farmers’ Perception of Climate Change on the Productivity of Major Crops in Haryana**

**Abstract:**

*Agriculture, a vital sector in Haryana’s economy, is highly vulnerable to climate variations, with changing rainfall patterns, rising temperatures, and depleting groundwater affecting crop yields. The study therefore, examines the impact of climate change and weather aberrations on the productivity of major crops in Haryana, alongside farmers' perceptions of these changes. The research, conducted in Hisar and Sonipat districts, employed a multi-stage random sampling method to survey 120 farmers, utilizing a structured interview schedule and 5 Point Likert scale to assess perceptions. Statistical analysis revealed that most farmers identified erratic rainfall and groundwater depletion as major concerns, followed by increased temperatures and altered crop productivity. The study further quantified the effects of weather aberrations, showing significant yield reductions due to extreme conditions such as high temperatures, excessive rainfall, and strong winds, particularly in paddy, wheat, and cotton crops. Findings indicated that climate variability affects crop maturity, irrigation requirements, pest infestations, and economic returns. While some farmers reported increased productivity under specific conditions, the overall trend pointed to declining yields and heightened risks. The study underscores the urgent need for climate-resilient farming strategies, improved water management, and enhanced farmer awareness to mitigate the adverse impacts of climate change. Strengthening extension services and integrating scientific knowledge with local farming practices can help farmers adapt to climate uncertainties and sustain agricultural productivity in Haryana.*

1. **Introduction:**

Climate change poses a significant challenge to agricultural systems worldwide, and its repercussions are particularly pronounced in regions dependent on agriculture for sustenance and economic stability. Agriculture sector has occupied almost 43 per cent of the geographical area, it contributed 18.3 per cent of GDP to the Indian economy in the year 2022-23. According to the Intergovernmental Panel on Climate Change (IPCC, 2007; Fusel, 2007), climate change is any change in climate over time caused by natural variability or human activity. Climate change poses a significant threat to rural people's livelihoods (Rakib *et al*. 2014). Crop productivity has also declined due to inadequate soil fertility and increased disease incidence (Rawat *et al*., 2013). In 19th century, the global average increase in temperature was 0.7°C and it is expected to increase around 1.4°C - 5.8°C by 2100 (IPCC, 2007). The CO2, CH4 and N2O concentrations are increasing during 19th to 21st century from 280 ppm to 395 ppm, 715 ppb to 1882 ppb and 227 ppb to 323 ppb respectively (Mahato, 2014). Due to rising in temperature, agriculture production is expected to decline by 2050 in Himalaya region and will lead food insecurity (Dahal, 2008). Changes in weather patterns also result in reduction in availability of fuel wood, grass for fodder, spring water (Gene, 2012). Even extension specialists have a low to moderate understanding of how climate change affects agriculture (Ghanghas *et al*., 2015). Farmers' understanding of the interaction of climate and agro-ecosystem must be bridged through the inclusion of farmers' communication networks in order to support farm-level decisions and minimize losses due to adverse climatic and weather conditions (Ravikumar *et al*., 2015). Climate change poses a significant threat to crop productivity, which is critical for food, feed, and fodder security in dryland agriculture (Chapke and Tonapi, 2018). Haryana, situated in the heart of India, is an agrarian state known for its pivotal role in the nation's food production. With a predominantly agrarian economy, Haryana's farmers are intricately connected to the natural environment, making them highly vulnerable to the impacts of climate change. The present study aims to delve into the nuanced perspectives of farmers in Haryana regarding the impact of climate change on their agricultural practices.

1. **Methodology:**

The present study was conducted in two districts of Haryana state: Hisar and Sonipat. Hisar and Sonipat districts were selected purposively in the study keeping in view of Haryana Agro Climatic zone. Sonipat district was selected for study from eastern Agro-Climatic Zone and Hisar district was selected from western Agro-Climatic Zone of Haryana.

Primary data were used for present study during the year 2023, which had impact on their agriculture. Required data for the study were collected using interview schedule method with the help of pretested, structured interview schedule. Multi-stage Random sampling technique was used for the selection of block, villages, Farmers. From each village 30 farmers were selected based on simple random sampling procedure. Thus, total of 120 farmers were selected for detailed study to draw the inference.

A 5-point Likert scale (1-strongly disagree to 5-strongly agree) were used to understand farmers’ perception on the impact of climate change. Each perception was tested statistically for its mean score to be significant. These perceptions were ranked according to their mean score.

1. **Results and Discussion:**

**3.1 Farmers’ perception related to climate change in Haryana**

Farmers’ perception on the impact of climate change using 5-point Likert scale (1-strongly disagree to 5-strongly agree) is presented in Table 1. Change in rainfall pattern occupied the 1st rank followed by depletion in groundwater levels. Drastic increase in temperature during summer and increase in productivity of crops were perceived 3rd and 4th rank respectively in the study area. This result was in line with the findings of Thornton *et al.* (2006) who reported that over the time rainy season has become shorter in duration. Also, Dhanya and Ramachandran, (2016), Amir *et al.* 2020 and Zakari *et al.* 2022 reported that farmers have the perception that rainy season was reducing and increasing temperature was getting excruciating.

Table 1: Farmers’ perception related to climate change in Haryana (n = 120)

|  |  |  |
| --- | --- | --- |
| Statements | Mean Score | Rank |
| Change in rainfall pattern | 4.42 | I |
| Depletion in ground water levels | 4.21 | II |
| Scarcity of water in surface water bodies | 3.98 | V |
| Increased occurrence of frost and frost injury | 3.85 | VII |
| Drastic risen in temperature during summer | 4.12 | III |
| No change in climate observed | 3.02 | X |
| Increased productivity of crops | 4.04 | IV |
| Reduced occurrence of dry spells | 3.62 | VIII |
| Drastic drop in temperature during winter | 3.87 | VI |
| Infestation of new pests and disease | 3.38 | IX |

Farmers identified key climate change concerns, with "Change in rainfall pattern" ranked highest, indicating shifts in timing, intensity, and distribution of rainfall, impacting agriculture and water availability. "Depletion of groundwater levels" followed, highlighting excessive extraction and declining irrigation resources.

A "drastic rise in summer temperature" ranked third, raising concerns about heat stress on crops, livestock, and farm operations. Interestingly, "increased crop productivity" ranked fourth, possibly linked to improved practices or favorable conditions. "Scarcity of surface water" was another major concern, affecting irrigation. Other notable perceptions included a drastic drop in winter temperatures, increased frost events, reduced dry spells, and rising pest infestations. Statistical analysis confirmed that rainfall pattern changes and groundwater depletion were the most significant concerns. The results corroborate the findings of Salman *et al.* (2018) who reported that …..

3.2 Perception of farmers on effect of climate change on productivity of wheat and paddy crops in Haryana

The cropping pattern of the sample farmers was dominated by paddy and wheat as presented in Table 2, the perceptions of Haryana farmers regarding the impact of climate change on paddy and wheat production. The data indicated that approximately 60 per cent of the respondents agreed that climate change affects the timing of paddy crop transplantation and causes delays in crop maturity, 67 per cent agreed with the statement that climate change affects the number of irrigations, while only a small percentage disagreed. Similar results were observed by Kumar and Sidana (2018) on paddy and wheat in Punjab agriculture.

Table 2: Perception of farmers on effect of climate change on productivity of wheat and paddy crops in Haryana (n = 120)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Statement | Agree | Per  cent | Neutral | Per  cent | Disagree | Per  cent | Mean Score | Rank |
| Whether climate change has led to a rise  in the usage of fertilisers in both crops | 81 | 67.50 | 37 | 30.83 | 2 | 1.67 | 1.34 | III |
| Higher incidence of diseases in paddy  and wheat crops | 86 | 71.67 | 32 | 26.66 | 2 | 1.67 | 1.30 | II |
| Whether climate variability has  affected transplantation of paddy crop | 69 | 57.50 | 42 | 35.00 | 9 | 7.50 | 1.50 | VIII |
| Delaying crop maturity of both crops | 78 | 65.00 | 35 | 29.17 | 7 | 5.83 | 1.41 | V |
| Whether the number of irrigations in  paddy or wheat crop has increased | 80 | 66.67 | 35 | 29.16 | 5 | 4.17 | 1.38 | IV |
| Quality of grain of paddy and wheat  has deteriorated | 66 | 55.00 | 49 | 40.83 | 5 | 4.17 | 1.49 | VII |
| Whether the paddy and wheat crop's net  returns have decreased | 90 | 75.00 | 26 | 21.67 | 4 | 3.33 | 1.28 | I |
| High infestation of insect pests | 79 | 65.83 | 33 | 27.50 | 8 | 6.67 | 1.41 | V |
| Leading to new weeds infestation | 41 | 34.17 | 61 | 50.83 | 18 | 15.0 | 1.81 | IX |

The cropping pattern of the sample farmers was dominated by paddy and wheat, Table 2 presents the perceptions of Haryana farmers regarding the impact of climate change on paddy and wheat production. The data indicates that approximately 60 per cent of the respondents agreed that climate change affects the timing of paddy crop transplantation and causes delays in crop maturity, 67 per cent agreed with the statement that climate change affects the number of irrigations, while only a small percentage disagreed. Similar results were observed by Kumar and Sidana (2018) on paddy and wheat in Punjab agriculture.

About 67.50 per cent of the respondents agreed that climate change led to an increase in the use of fertilizer application, while 1.67 per cent disagreed. Additionally, 71.67 per cent of the respondents perceived a higher incidence of diseases in paddy and wheat crops due to climate change, with a small percentage (1.67 per cent) disagreeing with this statement. Barlow *et al.* (2015) reported that heat stress affects the grain production and yield, cold stress result in sterility, and drought stress negatively influences the morpho-physiology of plants.

The primary impact of climate change was observed in the net returns from paddy and wheat crops, with 75.00 per cent of the respondents agreeing. Approximately one fifth of the respondents had a neutral response to the statement that weather variability affects the net returns of paddy and wheat crops.

**3.3 Effect of weather aberrations on productivity of paddy, cotton and wheat crops in Haryana**

The study analysed weather aberrations' impact on paddy, cotton, and wheat yields in Haryana, highlighting crop vulnerability (Table 3). It also assessed yield variations and gross returns based on MSP for the 2022-23 season. For paddy, it was observed that rainfall above normal during the Southwest (SW) monsoon (La Niña) resulted in an average yield of 5,401 kg/ha. compared to the average yield, which was higher by 346 kg/ha (6.84 per cent). The gross return based on the MSP for this yield was ₹ 110,180 per hectare. Similarly, Abbas and Mayo (2021) found that number of tillers and rice plant diet increase with the positive impact of rainfall at tillering stage. The average yearly rainfall was roughly 450 mm, with the average monthly rainfall during July and August being 133.4 and 116.2 mm, respectively. The average monthly rainfall was 54.5 mm in September and 49.8 mm in June. Deficit rainfall during the SW monsoon (El Niño) led to an average yield of 4,182 kg/ha, which was 873 kg/ha (17.27 per cent) lower than the average. Similar report by Grover and Upadhya (2014), found that rainfall positive impact on paddy. The gross return for this yield was ₹ 85,312 per hectare.

Pre-planting, germination, seedling and vegetative stage: during these stages, consistent and gentle rainfall is crucial. Sufficient moisture is required for seed germination and early seedling establishment. High wind velocity during the reproductive to maturity stage: The average yield under this condition was 3,523 kg/ha, resulting in a decrease of 1,532 kg/ha (30.31 per cent) compared to the average. The gross return for this yield was ₹ 71,869 per hectare. High winds can cause the plants to bend or even break, a phenomenon known as lodging. This can be particularly damaging during the reproductive to maturity stage when the plants are heavier and more susceptible to being pushed over. Lodging reduces the plant's ability to receive sunlight, affects nutrient uptake, and can lead to reduced yields.

**Table 3: Effect of weather aberrations on productivity of paddy, cotton and wheat crops in Haryana (n = 120)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Effect of weather aberration on selected crops | Average yield (kg/ha) | Yield (kg/ha) | Impact of particular on yield (kg/ha) | Gross return (MSP 2022-23) (₹/ha) |
| A. | **Paddy** | | | | |
| 1 | Rainfall above normal during SW monsoon (La Niña) | 5055 | 5401 | 346 (6.84) | 110180 |
| 2 | Deficit rainfall during SW monsoon (El Niño) | 4182 | -873 (-17.27) | 85312 |
| 3 | High wind velocity during reproductive to maturity stage | 3523 | -1532 (-30.31) | 71869 |
| 4 | High temperature during flowering to grain development stage | 4116 | -939 (-18.58) | 83966 |
| B. | **Cotton** | | | | |
| 1 | Insect-pest infestation due to high relative humidity | 1976 | 1580 | -396 (-20.04) | 96064 |
| 2 | Temperature fluctuations | 1440 | -536 (-27.13) | 87552 |
| 3 | High temperature | 1214 | -762 (-38.56) | 73811 |
| 4 | Rainfall at plucking stage | 1193 | -783 (-39.63) | 72534 |
| C. | **Wheat** | | | | |
| 1 | Low temperature, fog and drizzling during vegetative stage | 5219 | 5582 | 363 (6.95) | 112477 |
| 2 | Hailstorm | 2914 | -2305 (-44.16) | 58717 |
| 3 | High wind velocity along with rainfall | 4067 | -1152 (-22.07) | 81950 |
| 4 | Terminal heat stress | 3194 | -2025 (-38.80) | 64359 |

Note: Figure in parenthesis indicates percentage of change in yield

High temperature during the flowering to grain development stage: The average yield in this case was 4,116 kg/ha, which was 939 kg/ha (18.58per cent) lower than the average. The gross return for this yield was ₹ 83,966 per hectare. Similar findings by Grover and Upadhya (2014), found that high maximum temperature negative impact on paddy crop. Also, Abbas and Mayo (2021) found that maximum temperature has negative impact on rice crop at tillering and stem elongation stages.

A hot, humid atmosphere is needed for rice cultivation. It works best in areas with high humidity, lots of sunshine, and a reliable water supply. The typical temperature needed for the crop's life span is between 21 and 37 degrees Celsius. The highest temperature that the crop can withstand is between 40°C and 42°C. In Haryana, summertime air temperatures are relatively high. Wintertime temperatures below freezing (frost conditions) are not unusual. The area often experiences summer temperatures between 40 and 44°C and winter temperatures between 4 and 6°C. Haryana's average annual high and low temperatures are 31.5°C and 16.2°C, respectively. High temperatures can adversely affect the pollination process, leading to reduced seed set and lower grain yields. Heat stress during flowering can cause the abortion of flowers or developing grains and lead to the degradation of proteins in developing grains.

Regarding cotton, the study found that insect-pest infestation due to high relative humidity: This condition led to an average yield of 1,976 kg/ha, resulting in a decrease of 396 kg/ha (20.04 per cent) compared to the average. The gross return for this yield was ₹ 96,064 per hectare. High humidity creates favorable conditions for the proliferation of various insect pests that can feed on the leaves, stems, and reproductive structures of cotton plants. Singh *et al.* (2015) found that the whitefly population had a positive correlation morning and evening relative humidity.

Temperature fluctuations: The average yield under this condition was 1,440 kg/ha, which was 536 kg/ha (27.13 per cent) lower than the average. The gross return for this yield was ₹ 87,552 per hectare. Temperature fluctuations during the flowering stage can disrupt pollination, which was crucial for cotton production. Cotton fiber quality is influenced by temperature fluctuations during boll development. Rapid temperature changes can disrupt the biosynthesis and arrangement of cellulose, leading to shorter, weaker, and coarser fibers. High temperature: The average yield in this case was 1,214 kg/ha, resulting in a decrease of 762 kg/ha (38.56 per cent) compared to the average. The gross return for this yield was ₹ 73,811 per hectare.

High temperatures can affect the viability of pollen grains and reduce their germination, impairing successful fertilization. In extreme cases, excessive heat can cause flower drop, reducing the overall yield potential. Rainfall at the plucking stage: This condition led to an average yield of 1,193 kg/ha, which was 783 kg/ha (39.63 per cent) lower than the average. The gross return for this yield was ₹ 72,534 per hectare. Rainfall can cause the fibers leading to swelling and subsequent weakening at plucking stage. Similar revealed by Thakare *et al.* (2014) discovered that maximum and lowest temperatures were higher than normal throughout crop development (June-August) and blooming (October-December), disrupting crop physiology and indirectly impacting cotton yield. For wheat, the study identified various factors impacting the yield. Low temperature, fog, and drizzling during the vegetative stage: This condition resulted in an average yield of 5,219 kg/ha, which was 363 kg/ha (6.95 per cent) higher than the average. The gross return for this yield was ₹ 112,477 per hectare. This is optimum temperature and favorable weather for wheat growth. Liu *et al.* (2016) found that warmer regions were likely to suffer more yield loss with increasing temperature than cooler regions.

Hailstorm: The average yield under this condition was 2,914 kg/ha, resulting in a decrease of 2,305 kg/ha (44.16 per cent) compared to the average. The gross return for this yield was ₹ 58,717 per hectare. Hailstones have a high impact force when they fall, leading to physical damage to the wheat plants. They can break stems, leaves, and spikelets, which are vital for the wheat's growth and development. Elahi *et al* (2022) found that if thunderstorms and hailstorms were rated moderate or low in severity, a significant reduction in wheat yield. High wind velocity along with rainfall: This condition led to an average yield of 4,067 kg/ha, which was 1,152 kg/ha (22.07 per cent) lower than the average. The gross return for this yield was ₹ 81,950 per hectare. High wind velocity can cause the wheat plants to bend or break, a phenomenon known as lodging. Wind-driven rain can facilitate the spread of fungal and bacterial diseases in wheat crops.

Terminal heat stress: The average yield in this case was 3,194 kg/ha, resulting in a decrease of 2,025 kg/ha (38.80 per cent) compared to the average. The gross return for this yield was ₹ 64,359 per hectare. Terminal heat stress in wheat arises when the average temperature during the grain filling phase exceeds 31 °C. According to the IPCC (2014), temperatures in India are expected to rise by 0.7–2.0 °C by the 2030s and by 3.3–4.8 °C by the 2080s. Shew *et al*. (2020) reported that a 1 °C temperature increase could lead to an average wheat yield decline of 8.5%, escalating to 18.4% and 28.5% under 2 °C and 3 °C warming scenarios, respectively. These impacts are likely to be more severe in northern India and during the rabi season (November to March). A temperature rise of 0.5–1.56 °C between 2080 and 2100 is projected to negatively affect food production, potentially reducing India’s food grain output by 10–40% (Parry *et* *al*., 2004; IPCC, 2007). Heat stress disrupts the metabolic processes involved in grain filling, affecting the accumulation of starch and proteins in the grains. This leads to reduced grain weight and lower grain quality. During the Rabi season of 2021-22, significant yield losses were experienced in northern regions of India primarily due to the adverse impact of terminal heat stress.

**Conclusion**

The farmers perceive the impact of climate change on agriculture through various concerns. These include changes in rainfall patterns, depletion of groundwater levels, rise in summer temperatures, increased crop productivity, scarcity of water in surface water bodies, drops in winter temperatures, occurrences of frost and frost injury, reduced occurrence of dry spells, emergence of new pests and diseases, and some farmers reporting no observed change in climate. Overall, farmers' perceptions highlight the multiple ways in which climate change affects agriculture, encompassing both challenges and some potential opportunities.

The findings demonstrate that various weather factors have a significant impact oncrop yields, providing valuable insights into the vulnerability of these crops to specificweather conditions. Findings reveal that rainfall during the Southwest monsoon positivelyaffected paddy yields, while deficits and high winds reduced them. For cotton, insect-pestinfestation, temperature fluctuations, high temperatures, and rainfall at plucking stagedecreased yields. Wheat yields were positively influenced by low temperature, fog, anddrizzling, but hailstorms, high winds with rainfall, and terminal heat stress had negativeeffects. The study emphasizes the vulnerability of these crops to specific weather conditions.Overall, weather aberrations such as rainfall, wind velocity, temperature fluctuations, andhumidity have substantial impacts on crop productivity in Haryana.

**COMPETING INTERESTS DISCLAIMER:**

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

**Reference:**

Abbas, S., & Mayo, Z. A. (2021). Impact of temperature and rainfall on rice production in Punjab, Pakistan. *Environment, Development and Sustainability*, **23**(2), 1706-1728.

Amir, S., Saqib, Z., Khan, M. I., Ali, A., Khan, M. A., & Bokhari, S. A. (2020). Determinants of farmers’ adaptation to climate change in rain-fed agriculture of Pakistan. *Arabian Journal of Geosciences*, **13**, 1-19.

Barlow, K. M., Christy, B. P., O’leary, G. J., Riffkin, P. A., & Nuttall, J. G. (2015). Simulating the impact of extreme heat and frost events on wheat crop production: A review. *Field crops research*, **171**, 109-119.

Chapke, R. R., Tonapi, V. A., & Ahire, L. (2018). Enhancing farmers’ income through pulses in millets-based cropping in rainfed areas.

Dahal, B. M., Fuerhacker, M., Mentler, A., Karki, K. B., Shrestha, R. R., & Blum, W. E. H. (2008). Arsenic contamination of soils and agricultural plants through irrigation water in Nepal. *Environmental pollution*, **155**(1), 157-163.

Dhanya, P., & Ramachandran, A. (2016). Farmers’ perceptions of climate change and the proposed agriculture adaptation strategies in a semi-arid region of south India. *Journal of Integrative Environmental Sciences*, **13**(1), 1-18.

Elahi, E., Khalid, Z., Tauni, M. Z., Zhang, H., & Lirong, X. (2022). Extreme weather events risk to crop-production and the adaptation of innovative management strategies to mitigate the risk: A retrospective survey of rural Punjab, Pakistan. *Technovation*, **117**, 102255.

Fusel, H. (2007). A generally applicable conceptual framework for climate change research, *Journal of Agricultural Science,* **17**(2), 155-167.

Gene, C. (2012). Perception of climate change and community response adaptation: Survey in Uttarakhand, *Science Frontier* *Research: Agriculture & Veterinary,* **15**(4), 30-39.

Ghanghas, B. S., Shehrawat, P. S., & Nain, M. S. (2015). Knowledge of extension professionals regarding impact of climate change in agriculture. *Indian Journal of Extension Education*, ***51***(3and4), 125-129.

Grover, D.K. and Upadhya, D., (2014). Research Note: Changing Climate Pattern and Its Impact on Paddy Productivity in Ludhiana District of Punjab. *Indian Journal of Agricultural Economics*, **69**(902-2016-67962), pp.150-162.

IPCC (2007), “Impacts, Adaptation and Vulnerability”, The Intergovernmental Panel on Climate Change, Cambridge University Press, U.K., p. 976.

Kumar, S., & Sidana, B. K. (2018). Perception of Paddy and wheat growers towards climate change in Punjab agriculture. *Journal of Agricultural Development and Policy*, **28**(1), 54-63.

Kumar, S., & Sidana, B. K. (2018). Farmers’ perceptions and adaptation strategies to climate change in Punjab agriculture. *Indian Journal of Agricultural Sciences*, **88**(10), 1573-1581.

Liu, B., Asseng, S., Müller, C., Ewert, F., Elliott, J., Lobell, D. B., ... & Zhu, Y. (2016). Similar estimates of temperature impacts on global wheat yield by three independent methods. Nature Climate Change, **6**(12), 1130-1136.

Mahato, A. (2014). “Climate change and its impact on agriculture.” *International Journal of Scientific and Research Publications*, **4**(4), 1-6.

Parry, M. L., Rosenzweig, C., Iglesias, A., Livermore, M., & Fischer, G. (2004). Effects of climate change on global food production under SRES emissions and socio-economic scenarios. *Global environmental change*, ***14***(1), 53-67.

Rakib MA, M A Rahman, M S Akterand, MAH Bhuiyan, 2014. Climate change: Farmers Perception and Agricultural Activities. Herald Journal of Geography and Regional Planning, **3**: 115 - 123 June.

Ravikumar, A., Kijazi, M., Larson, A. M., & Kowler, L. (2015). *Project guide and methods training manual*. CIFOR.

Rawat, N., Neelam, K., Tiwari, V. K., & Dhaliwal, H. S. (2013). Biofortification of cereals to overcome hidden hunger. *Plant Breeding*, **132**(5), 437-445.

Salman, A., M.I. Hussain, I. Jan, M. Ashfaq, M. Rashid and U. Shakoor. (2018). Farmers’ adaptation to climate change in pakistan: perceptions, options and constraints. Sarhad Journal of Agriculture, **34**(4): 963-972.

Shew, A. M., Tack, J. B., Nalley, L. L., & Chaminuka, P. (2020). Yield reduction under climate warming varies among wheat cultivars in South Africa. *Nature communications*, **11**(1), 4408.

Singh, H., Kaur, P. and Mukherjee, J., (2015). Impact of weather parameters and plant spacing on population dynamics of sucking pests of cotton in south western Punjab. *Journal of Agricultural Physics*, **15**(2), pp.167-174.

Thakare, H. S., Shrivastava, P. K., & Bardhan, K. (2014). Impact of weather parameters on cotton productivity at Surat (Gujarat), India. *Journal of applied and Natural science*, **6**(2), 599-604.

Thornton, P.K., P.G. Jones, T.M. Owiyo, R.L. Kruska, M. Herrero and P. Kristjanson. (2006). Mapping climate vulnerability and poverty in Africa. In: Report to the department for international development. ILRI, PO Box 30709, Nairobi 00100, Kenya., 171. Kenya.

Zakari, S., Ibro, G., Moussa, B., & Abdoulaye, T. (2022). Adaptation strategies to climate change and impacts on household income and food security: Evidence from Sahelian region of Niger. *Sustainability*, **14**(5), 2847.