ASSESSING THE EFFECTS OF RISING TEMPERATURES ON CROP YIELDS IN MARATHWADA

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Keywords:

crop yields, Climate change, agricultural adaptation, climate-resilient agriculture.

Abstract

Due to climate change, the Marathwada region in Maharashtra has been experiencing rising temperatures and erratic weather patterns. This study assesses the effects of increasing temperatures on significant crops in the area, including wheat, jowar, and cotton.

The research analyses temperature trends over the past few decades, highlighting an increase in annual average temperatures and frequent heatwaves. These climatic shifts have led to several adverse effects on agriculture, including reduced soil moisture, shortened growing seasons, and increased pest and disease prevalence. Wheat, a winter crop, is particularly vulnerable, with high temperatures during the grain-filling stage leading to lower yields. Though drought-resistant, Jowar experiences biomass reduction and grain deterioration under prolonged heat stress. Cotton, another staple crop, suffers from premature flowering and boll shedding, reducing fibre quality and overall production.

The economic consequences of these changes are profound, as declining crop yields contribute to financial distress and migration among farming communities. This study explores adaptation strategies to address these challenges, including drought-resistant crop varieties, improved irrigation techniques, and precision farming technologies. Policy interventions such as climate insurance schemes, subsidies for resilient farming methods, and watershed management programs are also discussed as crucial measures to support farmers.

This study emphasises the urgent need for climate-resilient agricultural practices and long-term policy initiatives to safeguard crop production and farmer livelihoods in Marathwada. Addressing rising temperatures through sustainable strategies will be critical to ensuring the region's food security and economic stability.

Introduction

Climate change is one of the most pressing global challenges, affecting various sectors, including agriculture, which is highly sensitive to climatic variations. In India, agriculture forms the backbone of the economy, with millions of farmers dependent on seasonal rainfall and stable weather conditions for crop production. The Marathwada region in central

Maharashtra is known for its semi-arid climate, where temperature fluctuations and rainfall patterns significantly influence agricultural productivity.

Over the past few decades, the region has witnessed a steady rise in average temperatures, increased frequency of heatwaves, and erratic monsoon rainfall. These climatic changes have severely affected the agricultural sector, affecting crop yields, soil fertility, and water availability. Farmers in the region primarily cultivate wheat, jowar (sorghum), and cotton, all highly susceptible to temperature-induced stress. Rising temperatures accelerate evapotranspiration, leading to moisture stress, reduced photosynthesis, and crop failure in extreme cases.

Study Scope and Purpose

This study evaluates the impact of rising temperatures on crop yields in the Marathwada region of Maharashtra. Marathwada, a drought-prone region, has experienced increasing temperatures and erratic weather patterns in recent decades, significantly affecting agricultural productivity. This research focuses on major crops cultivated in the area, including wheat, jowar, and cotton, analysing how rising temperatures influence their growth cycles, yield, and quality.

The study utilises historical climate data, future projections, and farmer surveys to assess the extent of temperature-induced agricultural challenges. A stage-wise analysis of crop development highlights key risks such as heat stress during flowering, reduced soil moisture, and increased pest outbreaks. Additionally, this research investigates the socio-economic consequences of declining yields, including financial distress and migration among farming communities.

Temperature Trends in Marathwada

The Indian Meteorological Department (IMD) has recorded a rise in annual mean temperatures in Marathwada by approximately 0.5–1.2°C over the past three decades. Heatwaves have become more frequent during critical crop growth periods, further exacerbating yield losses. Additionally, the shift in monsoon patterns has led to unpredictable rainfall, causing droughts or excessive precipitation, negatively impacting crops.

According to climate models, the region is expected to experience further warming in the coming decades, with temperatures projected to rise by an additional 1.5–2°C by 2050. Such increases pose significant risks to agricultural sustainability, necessitating urgent mitigation and adaptation measures.

Study Area

The study focuses on the Marathwada region of Maharashtra, comprising eight districts:
Marathwada is a historically, culturally, and agriculturally significant region in Maharashtra, India. It comprises eight districts: Aurangabad (ChhatrapatiSambhajinagar), Beed, Jalna, Latur, Osmanabad (Dharashiv), Parbhani, Hingoli, and Nanded. The region forms a part of the Deccan Plateau, characterised by undulating topography, black soil, and a monsoon-dependent economy.Despite its rich cultural heritage and agrarian strength, Marathwada has faced significant socio-economic challenges, primarily due to frequent droughts, erratic rainfall, low irrigation coverage, and agricultural distress. The region has witnessed rural-to-urban migration, farmer suicides, and a growing need for technological and infrastructural advancements in agriculture.

Geographical and Climatic Overview

Geographical Location

Marathwada is located in central-eastern Maharashtra and spans 64,590 sq. km, making up 21% of Maharashtra's total area. The region is bordered by Vidarbha to the east, Western Maharashtra to the west, Telangana and Karnataka to the south, and Madhya Pradesh to the north (indirectly).The terrain is mainly plateau-based, with elevations ranging from 300 to 800 meters above sea level. The topography includes rolling plains, minor hill ranges, and scattered river valleys. The Deccan Plateau influences the region's geology, contributing to soil fertility and making it prone to erosion in some areas.

Assessing the Effects of Rising Temperatures on Crop Yields in Marathwada

Abstract Due to climate change, the Marathwada region in Maharashtra has been experiencing rising temperatures and erratic weather patterns. This study assesses the effects of increasing temperatures on significant crops in the area, including wheat, jowar, and cotton. The research analyses temperature trends over the past few decades, highlighting an increase in annual average temperatures and frequent heatwaves. These climatic shifts have led to several adverse effects on agriculture, including reduced soil moisture, shortened growing seasons, and increased pest and disease prevalence. Wheat, a winter crop, is particularly vulnerable, with high temperatures during the grain-filling stage leading to lower yields. Though drought-resistant, Jowar experiences biomass reduction and grain deterioration under prolonged heat stress. Cotton, another staple crop, suffers from premature flowering and boll shedding, reducing fibre quality and overall production. The economic consequences of these changes are profound, as declining crop yields contribute to financial distress and migration among farming communities. This study explores adaptation strategies to address these challenges, including drought-resistant crop varieties, improved irrigation techniques, and precision farming technologies. Policy interventions such as climate insurance schemes, subsidies for resilient farming methods, and watershed management programs are also discussed as crucial measures to support farmers. This study emphasises the urgent need for climate-resilient agricultural practices and long-term policy initiatives to safeguard crop production and farmer livelihoods in Marathwada. Addressing rising temperatures through sustainable strategies will be critical to ensuring the region's food security and economic stability.

Introduction Climate change poses a significant challenge to agriculture, particularly in drought-prone regions like Marathwada. The area, primarily dependent on monsoon rains, has witnessed an increase in average temperatures over the past few decades. Rising temperatures and erratic rainfall impact soil moisture, crop growth cycles, and yields. This paper examines the extent of temperature-induced changes in crop productivity and explores potential adaptive measures to sustain agricultural output in Marathwada.

Literature Review

Climate change has become a critical challenge for agriculture, particularly in semi-arid regions like Marathwada. Rising temperatures, erratic rainfall, and increased frequency of extreme weather events pose severe threats to crop productivity and farmer livelihoods. This literature review explores previous studies examining the relationship between climate change and agricultural performance, explicitly focusing on temperature impacts in Marathwada.

Several studies highlight Indian agriculture's vulnerability to climate change, particularly in regions with low adaptive capacity (Aggarwal & Mall, 2002; Rao et al., 2019). Research indicates that higher temperatures and shifting monsoon patterns adversely affect crop yields, water availability, and soil fertility, making agriculture increasingly unsustainable (Intergovernmental Panel on Climate Change [IPCC], 2021).

Research conducted by the Indian Council of Agricultural Research (ICAR, 2021) suggests that a 1°C increase in temperature can lead to a 4-5% decline in wheat yields, particularly during the grain-filling stage. Jowar, though relatively heat-resistant, suffers biomass reduction under prolonged heat stress (Pathak et al., 2018). Cotton productivity is also affected by temperature-induced boll shedding and increased pest infestations, as noted by Kranthi (2019).

Marathwada has witnessed increasing temperatures and declining annual rainfall, contributing to frequent droughts (Deshpande et al., 2017). Several district-level studies highlight the impact of climate variability on crop production, showing a decline in yields of wheat, jowar, and cotton over the past two decades (Patil et al., 2020). Reports from the Maharashtra Agricultural University indicate that wheat farmers in Marathwada face yield reductions due to shorter winter seasons, affecting the crop's vernalisation process.

A survey-based study by Kulkarni and Joshi (2016) found that farmers in Marathwadarecognise the impact of rising temperatures and have adopted measures such as shifting sowing dates, using heat-resistant crop varieties, and improving irrigation techniques. However, limited access to technological innovations and financial constraints hinder effective adaptation.

Several researchers emphasise the need for climate-resilient farming techniques, including drought-tolerant crop varieties, soil conservation, and precision agriculture (Singh et al., 2022). Improved irrigation systems, such as drip and sprinkler irrigation, are recommended to mitigate temperature stress in water-scarce regions (Sharma et al., 2019).

The National Adaptation Fund for Climate Change (NAFCC) and state-level initiatives have been introduced to support farmers in climate adaptation. Studies suggest that expanding crop insurance schemes and providing financial incentives for adopting climate-smart technologies can help mitigate risks (Reddy, 2021). However, gaps in policy implementation and lack of awareness among farmers remain significant challenges.

Temperature Variability and Its Effects on Agriculture

1. Increased Heat Stress: Prolonged exposure to high temperatures during crop flowering and grain-filling stages reduces pollination and seed setting.
2. Shortened Growing Seasons: Higher temperatures yield faster crop maturation, reducing grain size and yield.
3. Soil Degradation: High temperatures deplete soil moisture and organic matter, affecting soil fertility and productivity.
4. Increased Pest and Disease Incidence: Warmer temperatures create favourable conditions for pests and diseases, further reducing crop yields.

Impact on Major Crops in Marathwada

1. **Wheat (Triticumaestivum)** Wheat (Triticumaestivum) is susceptible to temperature fluctuations, particularly during its grain-filling stage. In Marathwada, the rising temperatures have significantly impacted wheat cultivation, as even a 1°C increase in temperature can lead to a 4-5% decline in yields (ICAR, 2021). The region has been experiencing shorter and warmer winters, adversely affecting wheat production by reducing the number of chilling hours required for optimal growth. The grain-filling period is crucial for yield formation, and excessive heat during this stage accelerates maturation, leading to shrivelled grains and reduced productivity. Additionally, higher temperatures cause faster evapotranspiration, decreasing soil moisture and further limiting wheat growth. These climatic changes have increased the vulnerability of wheat farmers in Marathwada, necessitating the adoption of heat-resistant wheat varieties, improved irrigation techniques, and modified sowing schedules to mitigate the adverse effects of rising temperatures.
2. **Jowar (Sorghum bicolor)**

   Jowar (Sorghum bicolour) is known for its drought resistance, making it a staple crop in the semi-arid regions of Marathwada. While moderate temperature increases have a relatively lower impact on jowarthan other crops, prolonged heatwaves and high nighttime temperatures pose significant challenges. Elevated night temperatures disrupt the plant's physiological processes, leading to reduced biomass accumulation and poor grain formation. Heat stress, especially during the reproductive stage, negatively affects pollination and grain filling, ultimately lowering yield and quality. Additionally, excessive temperatures accelerate moisture loss from the soil, further stressing the crop and reducing overall productivity. The impact of rising temperatures on jowar highlights the need for improved irrigation practices, heat-tolerant varieties, and adjustments in sowing schedules to ensure sustainable production in Marathwada's changing climate.
3. **Cotton (Gossypium spp.)**

   Cotton (Gossypium spp.) is a temperature-sensitive crop, thriving best within an optimal range of 25-30°C. However, the rising temperatures in Marathwada have disrupted its growth cycle, leading to early flowering and excessive boll shedding, significantly reducing both fibre quality and overall yield. Prolonged exposure to high temperatures accelerates the plant's physiological processes, often resulting in incomplete boll development and poor lint formation. Additionally, increased temperatures create favourable conditions for pest infestations, mainly pink bollworm (Pectinophoragossypiella) outbreaks, which have become more frequent and severe in recent years. These pests further deteriorate crop yields by damaging cotton bolls before they mature. Moreover, heat stress reduces soil moisture levels, weakening plant resilience and making cotton crops more susceptible to environmental fluctuations. To mitigate these challenges, farmers in Marathwada need to adopt integrated pest management (IPM), drought-resistant cotton varieties, improved irrigation techniques, and climate-adaptive farming practices to sustain productivity amidst rising temperatures.

Adaptation and Mitigation Strategies

1. Climate-Resilient Agricultural Practices

In the face of rising temperatures and erratic rainfall patterns in Marathwada, climate-resilient agricultural practices have become essential for sustaining crop productivity and ensuring farmer livelihoods. These strategies focus on enhancing crop adaptability, optimising water use, and improving soil health to counteract the adverse effects of climate change.

One of the most crucial approaches is developing and promoting drought-tolerant crop varieties. Scientists and agricultural research institutions have been working on breeding high-yield, heat-resistant varieties of staple crops such as wheat, jowar, and cotton to withstand extreme climatic conditions. These improved varieties have enhanced root systems that allow them to access deeper soil moisture, ensuring better resilience during prolonged dry spells. Additionally, early-maturing crop varieties help avoid the most intense heat stress periods, reducing the risk of yield loss. The Indian Council of Agricultural Research (ICAR) has introduced several such climate-resilient varieties, which have shown promising results in mitigating the impact of rising temperatures on agricultural productivity in drought-prone regions like Marathwada.

Another effective strategy is improved irrigation techniques, mainly micro-irrigation systems such as drip and sprinkler irrigation. SinceMarathwada frequently experiences water scarcity, these techniques are essential for optimising water use efficiency. Drip irrigation provides water directly to the root zone of the plants, minimising evaporation losses and ensuring that crops receive adequate moisture even during dry spells. On the other hand, Sprinkler irrigation helps cover larger areas with minimal water wastage, making it a viable option for farmers cultivating crops like wheat and cotton. The Government of Maharashtra has also introduced subsidy programs to encourage farmers to adopt micro-irrigation technologies, thus promoting sustainable water management in the region.

Soil health management plays a significant role in enhancing climate resilience in agriculture. Soil conservation methods, such as organic mulching, crop rotation, and cover crops, improve soil fertility, moisture retention, and microbial activity. Organic mulching—using crop residues, straw, or biodegradable materials—helps reduce soil temperature, prevent excessive moisture loss, and suppress weed growth. This practice is particularly beneficial for maintaining soil moisture in jowar and cotton fields vulnerable to extreme heat conditions.

Crop rotation is another vital soil conservation technique that involves alternating different crops in the same field across seasons. This method helps break pest and disease cycles, enhance soil fertility, and reduce the dependency on chemical fertilisers. For example, alternating legumes with cereals replenishes soil nitrogen levels, improving soil health naturally. Cover crops, such as green manure crops, help prevent soil erosion, enhance organic matter, and maintain soil structure, making the land more resilient to climatic stress.

2. Technological Interventions

Technological interventions have emerged as crucial solutions for enhancing agricultural resilience in response to the growing challenges of climate change in Marathwada. Advanced technologies such as weather forecasting systems, precision farming, and protected cultivation techniques help farmers mitigate risks, optimise resource use, and sustain productivity despite rising temperatures and erratic rainfall patterns.

One of the most effective technological solutions is the implementation of weather forecasting systems, which provide real-time climate advisories to farmers. These systems use satellite data, ground-based observations, and predictive analytics to generate accurate weather predictions, helping farmers make informed decisions about sowing, irrigation, and harvesting schedules. In regions like Marathwada, where unpredictable rainfall and temperature fluctuations impact agricultural cycles, timely weather information allows farmers to prepare for heatwaves, unseasonal rains, and drought conditions. The Indian Meteorological Department (IMD) and agricultural research institutions have been actively working to provide SMS-based alerts and mobile applications that deliver location-specific weather forecasts to farmers. By leveraging these technologies, farmers can adjust their farming practices, protect crops from climatic extremes, and reduce yield losses.

Another crucial intervention is precision farming, which uses remote sensing, Internet of Things (IoT)-based devices, and data analytics to monitor soil conditions, crop health, and resource utilisation. Precision farming technologies, such as GPS-enabled farm equipment, soil moisture sensors, and drone-based crop surveillance, enable farmers to apply fertilisers, pesticides, and water optimally. These techniques help reduce input costs, improve soil health, and enhance productivity, making farming more sustainable. For example, IoT-based soil sensors provide real-time data on soil moisture levels, allowing farmers to apply irrigation only when necessary, thereby conserving water—a critical resource in Marathwada's drought-prone environment. Similarly, drones equipped with multispectral cameras can detect early signs of pest infestations and nutrient deficiencies, allowing for targeted interventions rather than blanket pesticide applications.

Additionally, protected cultivation techniques, such as greenhouse farming and shade net farming, are proving to be highly effective in shielding crops from excessive heat and solar radiation. Greenhouses provide a controlled environment where temperature, humidity, and soil moisture can be regulated, ensuring optimal crop growth conditions. This method is particularly beneficial for cultivating high-value crops like vegetables, flowers, and exotic fruits, which are highly sensitive to temperature fluctuations. On the other hand, shade nets act as protective barriers that reduce the impact of direct sunlight, strong winds, and heat stress on crops. Farmers in Marathwada have started adopting shade net farming for vegetable and fruit cultivation, as it helps reduce water evaporation, prevent crop wilting, and maintain soil fertility.

3. Policy Recommendations

Intense policy interventions are essential to mitigate the adverse effects of rising temperatures on agriculture in the Marathwada region. Climate change has led to declining crop yields, financial distress, and increased vulnerability among farmers, necessitating the implementation of targeted policies that promote climate-resilient agriculture. Key policy recommendations include subsidies for climate-smart farming technologies, expanded crop insurance schemes, and comprehensive water resource management programs.

One of the most effective ways to support farmers adapting to climate change is through subsidies for climate-resilient farming. Adopting drought-tolerant crop varieties, micro-irrigation systems, precision farming technologies, and organic farming practices can significantly enhance productivity despite rising temperatures. However, many small and marginal farmers struggle to afford these advanced agricultural inputs. Government subsidies and financial incentives can bridge this gap by making climate-smart solutions more accessible. For instance, subsidies on drip irrigation and sprinkler systems can encourage water conservation, while financial assistance for solar-powered irrigation pumps can reduce dependence on erratic electricity supply. Additionally, subsidised seeds of heat-resistant crop varieties can help farmers maintain stable yields even under extreme weather conditions. The Maharashtra government, along with central agencies like the Indian Council of Agricultural Research (ICAR), should expand existing subsidy programs and introduce new incentives tailored to the specific climatic challenges of Marathwada.

Another critical policy intervention is the expansion of crop insurance schemes to protect farmers against climate-related risks. Rising temperatures, unpredictable rainfall, and frequent droughts expose farmers to significant financial losses, often leading to debt and distress migration. While the Pradhan MantriFasalBimaYojana (PMFBY) already provides insurance coverage for crop damage, its implementation must be strengthened in Marathwada. Many farmers are unaware of their insurance benefits, and delays in claim settlements reduce the scheme's effectiveness. Simplifying the insurance application process, increasing awareness campaigns, and ensuring timely claim disbursements will enhance the scheme's reach and impact. Furthermore, introducing region-specific climate insurance policies that compensate farmers for yield reductions due to heat stress, prolonged droughts, and pest outbreaks will provide better financial security. Private sector participation in weather-based crop insurance can supplement government initiatives, offering customised risk mitigation solutions for different crops and climatic conditions.

Lastly, water resource management is crucial to sustaining agriculture in the drought-prone Marathwada region. With rainfall becoming more erratic, enhancing watershed development programs can improve water availability for farming. Government agencies should prioritise the construction of check dams, percolation tanks, and farm ponds to enhance groundwater recharge. Encouraging community-led water conservation initiatives, such as the JalyuktShivarAbhiyan, can further strengthen local water security. Additionally, promoting wastewater recycling for irrigation, rainwater harvesting, and efficient water distribution systems can maximise the use of available resources. Integrating modern hydrological mapping technologies and remote sensing can also assist in identifying water-stressed areas and planning effective interventions.

Result and Data Interpretation

Gender Distribution of Farmers

The table below illustrates the gender distribution of farmers in Marathwada. The data reveals a significant disparity, with married males being the dominant group, numbering close to 370.

In contrast, the number of married female farmers is much lower, appearing to be under 50. This distribution suggests that farming in the region is primarily male-dominated, likely due to traditional gender roles, land ownership patterns, and agricultural decision-making authority.

Age Group of Farmers

Age Group	**Frequency**	**Percent**
Above 50	143	35.8%
35-50	118	29.5%
25-35	118	29.5%
Below 25	21	5.3%
Total	**400**	**100.0%**

The table above categorises respondents into four age groups. The largest group comprises farmers above 50 years (143 respondents), followed by the 25-35 and 35-50 age groups, with 118 respondents each. The smallest category is Below 25 years, with only 21 respondents. This distribution indicates that farming is primarily dominated by middle-aged and older individuals, suggesting possible challenges in youth participation. The low number of young farmers could stem from migration, lack of incentives, or limited interest in agriculture.

Land Holding

Land Size	Frequency	Percent
Less than 1 hectare	289	72.3%
2-4 hectares	100	25.0%
4-10 hectares	9	2.3%
Above 10 hectares	2	0.5%
Total	**400**	**100.0%**

The data indicates that the vast majority (72.3%) own less than 1 hectare, suggesting small-scale and subsistence farming as the dominant agricultural practice. Only 0.5% own more than 10 hectares, highlighting the rarity of large-scale farming in the region.

Main Water Source for Agriculture

The table below represents the primary water sources used by farmers in Marathwada. Most (76.8%) rely on rainwater, making them highly vulnerable to erratic rainfall. Only 5.0% of farmers use irrigation canals, while 18.3% rely on borewells, showing groundwater dependency.

Farmers' Strategies to Safeguard Crops from Climate Impacts

Strategy	Frequency	Percent
Use of advanced irrigation systems	165	41.3%
Switching to resilient crop varieties	116	29.0%
Diversification of crops	78	19.5%
None	41	10.3%
Total	**400**	**100.0%**

The table highlights that 41.3% of farmers have opted for advanced irrigation systems, while 29.0% have switched to resilient crop varieties. However, 10.3% of farmers have not taken any measures, emphasising the need for greater awareness and support for climate adaptation.

Climate Change Impacts on Farmers

Impact	Frequency	Percent
Less yielding Crop	182	45.5%
Less rainfall	115	28.8%
Crop destruction due to storms	35	8.8%
Multiple impacts (A & B)	56	14.0%
Untimely rainfall	12	3.0%
Total	**400**	**100.0%**

The data suggests that nearly half of the respondents (45.5%) reported a reduction in crop yield due to climate change, while 28.8% identified reduced rainfall as a major issue.

Conclusion

rising temperatures and erratic rainfall patterns in Marathwada have significantly affected agricultural productivity. Small land holdings, rain-fed agriculture, and financial constraints further exacerbate the challenges faced by farmers. Climate-resilient strategies, such as adopting drought-resistant crops and improving irrigation infrastructure, are crucial to sustaining agricultural livelihoods in the region

Rising temperatures significantly threaten agriculture in Marathwada, affecting significant crops like wheat, jowar, and cotton. Immediate adaptation measures, including improved irrigation, drought-resistant crop varieties, and policy support, are essential to safeguard agricultural productivity. Long-term climate mitigation strategies and sustainable farming practices must be prioritised to ensure the region's food security and farmer resilience.

References

1. Indian Meteorological Department (IMD). (2022). Annual Climate Report. Government of India.

2. ICAR. (2021). Impact of Climate Change on Crop Production in India. Indian Council of Agricultural Research.
3. Patil, R., &Deshmukh, A. (2020). Climate Variability and Its Impact on Agriculture in Maharashtra. Journal of Agricultural Science, 45(3), 112-124.
4. World Bank. (2019). Climate Adaptation Strategies for Drought-Prone Regions. Washington, D.C.
5. Kumar, V., & Sharma, P. (2018). Heat Stress Effects on Crop Yield and Adaptation Measures. International Journal of Agronomy, 30(2), 89-102.
6. Aggarwal, P. K., & Mall, R. K. (2002). Climate change and rice yields in diverse agro-environments of India. Climatic Change, 52(3), 331-343. https://doi.org/10.1023/A:1013700905864
7. Deshpande, R. S., Joshi, P. K., & Gupta, S. (2017). Climate change and agriculture in India: Emerging challenges and policy measures. Indian Journal of Agricultural Economics, 72(4), 536-549.
8. Indian Council of Agricultural Research (ICAR). (2021). Climate change impacts on Indian agriculture. ICAR Annual Report 2021.https://www.icar.org.in
9. Intergovernmental Panel on Climate Change (IPCC). (2021). Climate change 2021: The physical science basis. Sixth Assessment Report of the IPCC. https://www.ipcc.ch/report/ar6/wg1/
10. Kranthi, K. R. (2019). Temperature effects on cotton production and pest management in India. Journal of Cotton Research and Development, 33(2), 112-125.
11. Kulkarni, S., & Joshi, N. (2016). Farmers' perceptions and adaptation strategies to climate change in Marathwada. International Journal of Climate Change Strategies and Management, 8(3), 287-304.
12. Patil, A., More, S., &Deshmukh, P. (2020). Changing climate and its impact on agricultural productivity in Marathwada. Journal of Agricultural Science and Technology, 22(1), 45-60.
13. Pathak, H., Prasad, S., & Mishra, B. (2018). Climate change and its impact on sorghum productivity in semi-arid regions. Agricultural Systems, 162, 55-65.
14. Rao, C. H., Swain, D. K., & Sinha, S. (2019). Impact of climate change on Indian agriculture: A review. Climate and Agriculture, 15(4), 178-196.
15. Reddy, M. (2021). Policy approaches to mitigate climate risks in agriculture: An Indian perspective. Economic and Political Weekly, 56(12), 24-30.
16. Sharma, R., Gupta, S., & Yadav, K. (2019). Precision agriculture and irrigation management under climate change scenarios. Water Resources and Irrigation Journal, 14(3), 201-215.
17. Singh, R., Verma, S., & Kumar, P. (2022). Climate-smart agriculture: Adaptation strategies for Indian farmers. Sustainable Agriculture Reviews, 34, 121-139.