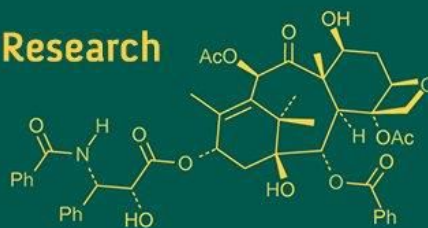
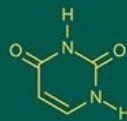
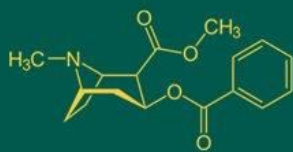


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Modeling the Impact of climate change on dryland crops for projected changes in temperature, precipitation patterns, and CO₂ levels

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Abstract

The shifting climate patterns, characterized by rising temperatures and altered precipitation, pose a significant threat to crop stability, underscoring the critical need to safeguard food security. Elevated CO₂ levels present a dual-edged impact on agriculture, offering potential yield enhancements through improved water use efficiency while exacerbating the adverse effects of climate change on crop quality and viability. Essential crops like maize and wheat face heightened vulnerability to climatic extremes like droughts and floods, leading to decreased productivity and jeopardizing agricultural output. Adaptation strategies, including the introduction of climate-resilient crop varieties, emerge as vital solutions to sustain agricultural productivity amid these challenges. Modeling environmental variables becomes imperative to inform adaptive agricultural practices capable of withstanding the evolving climate landscape and ensuring food security. Modeling studies have provided crucial insights into the influence of climate change on dryland crops, particularly regarding the effects of escalating CO₂ levels and shifting precipitation patterns. While elevated atmospheric CO₂ levels can potentially boost maize yield by enhancing water use efficiency and growth, counteracting some drought impacts, they also present challenges such as shifting farming practices and increased production costs to align with changing climatic conditions. The intricate relationship between the agricultural sector and climate dynamics complicates food security, with climate-induced productivity shocks leading to fluctuating crop prices. Adapting to these climate shifts is pivotal to sustainably secure food production, necessitating innovative strategies like integrated pest management and targeted support for smaller farmers facing increased vulnerability. Embracing holistic approaches and technological advancements is crucial for the agricultural sector to successfully navigate the complexities of climate change and ensure resilience in dryland agriculture through proactive policymaking, research investment in drought-resistant crop varieties, and sustainable land management practices. Collaboration among policymakers, agricultural experts, and local farming communities is essential to disseminate knowledge and resources effectively in addressing the challenges posed by climate change in agriculture.

Keywords: Dry land crops, climate change, modelling, temperature, precipitation, CO₂

1. Introduction

The increasing severity of climate change poses significant challenges for agricultural systems worldwide, particularly in dryland regions where water scarcity and temperature fluctuations can severely impact crop yields. As global temperatures rise and precipitation patterns become increasingly erratic, it is essential to understand how these changes will affect the cultivation of dryland crops. This essay will explore the intricate dynamics between projected climate variables, such as temperature increases, altered rainfall patterns, and rising CO₂ levels and their collective impact on agricultural outputs in arid environments. Utilizing advanced modeling techniques, the analysis will highlight potential vulnerabilities and adaptive strategies that farmers might employ to mitigate losses. By delving into these critical factors, the study aims to provide insights that are not only scientifically rigorous but also relevant for policy-making and sustainable agricultural practices, ultimately aiming to enhance food security in a rapidly changing climate.

2. Definition of dryland crops and their significance

Dryland crops, which are specifically cultivated in arid and semi-arid regions, play a vital role in global food security and agricultural sustainability. These crops, such as millet, sorghum, and certain varieties of legumes, have adapted to thrive in environments characterized by low and unpredictable rainfall, making them essential for maintaining agricultural production in challenging climates. Given the ongoing impacts of climate change, which threaten the viability of traditional crops through increased temperatures and altered precipitation patterns, the significance of dryland crops is becoming more pronounced. As demonstrated in studies, future climatic scenarios may simultaneously decrease agricultural yields while increasing competition for land due to urban expansion, leading to pronounced declines in production of vital crops, such as sugarcane, by a projected 24.94% to 34.93% between 2046 and 2055 (Attavanich *et al.* 2020) ^[9]. Thus, understanding and enhancing the resilience of dryland crops is critical in the face of these challenges. Moreover, the complex relationship between rising CO₂ levels and crop productivity raises important questions regarding adaptation and mitigation strategies needed for sustainable agricultural practices in dryland regions.

3. Overview of climate change and its global implications

The phenomenon of climate change has emerged as a pressing global crisis, fundamentally altering weather systems and agricultural viability across continents. As greenhouse gas emissions continue to rise, the resulting increase in atmospheric CO₂ concentrations has the dual effect of exacerbating temperature extremes while also enhancing plant growth in some contexts, particularly through CO₂ fertilization effects on crops like maize (Johnson *et al.* 2021) ^[16]. However, the synergistic impact of climate-related shifts in temperature and precipitation patterns poses significant challenges, especially in vulnerable regions where food security is already precarious. The global response, encapsulated by agreements such as the Paris Accord, aims to limit temperature increases and adapt agricultural processes to mitigate these adverse effects. Understanding the complex interactions between climate change parameters and crop yields will be crucial for formulating effective management strategies to sustain agricultural productivity in dryland environments facing imminent climatic adjustments (Johnson *et al.* 2021) ^[16].

4. Importance of modeling in agricultural research

Modeling plays a critical role in agricultural research, particularly in understanding the intricate relationships between climate change and crop productivity in dryland systems. Given the vulnerabilities of dryland agriculture to shifting temperature and precipitation patterns, effective modeling can help predict outcomes under various climatic scenarios. For instance, tools like the Decision Support System for Agrotechnology Transfer (DSSAT) have been utilized to simulate agricultural dynamics, revealing potential declines in crop yields and increased economic losses without adaptation measures. Additionally, simulation models assist in exploring how different environmental factors can influence plant growth and resilience, which is essential for developing adaptive strategies to climate change (Amanor-Boadu *et al.*, 2022) ^[8].

As climate impacts drive the need for sustainable practices, the integration of modeling in agricultural research not only enhances our understanding of these complex interactions but also informs policy decisions crucial for maintaining food security in the face of climate challenges (Grover *et al.*, 2023) ^[13].

5. Objectives of the review

The primary objectives of this review involve assessing the impacts of climate change on dryland crops by modeling projected changes in temperature, precipitation patterns, and CO₂ levels. Given the increasing concentrations of greenhouse gases, particularly CO₂, understanding its dual role is pivotal; while it enhances plant growth through CO₂ fertilization, it also exacerbates adverse climate conditions that can disrupt agricultural productivity. The essay further aims to analyze the economic implications for farmers, revealing the increasing production costs necessitated by climate adaptation strategies (Abbas *et al.*, 2020) ^[3]. Additionally, it seeks to align its findings with broader global climate policies, as articulated in frameworks such as the Paris Agreement, which aim to mitigate climate-related challenges for the agriculture sector. Ultimately, this exploration will contribute to better management practices for sustaining dryland agriculture in the face of ongoing climatic changes.

6. Understanding Climate Change and Its Drivers

The interconnectivity between climate change and its drivers is crucial for understanding its profound impacts on agriculture, particularly in drylands. As temperatures rise and precipitation patterns shift, aridity in these regions intensifies, posing significant threats to food security for vulnerable populations who depend on agriculture for their livelihoods (Adamo *et al.*, 2021) ^[4]. Climate variability, in conjunction with land-use practices and demographic changes, exacerbates existing stresses, underscoring the need for innovative adaptation strategies (Houmsi *et al.*, 2020) ^[13]. Current modeling efforts aim to quantify the impacts of projected climate scenarios on crop water demand and agricultural viability, utilizing tools such as the Decision Support System for Agrotechnology Transfer (DSSAT). This approach is essential not only for forecasting the effects of climatic changes on crop yields but also for informing policymakers and stakeholders in their efforts to mitigate the impending challenges associated with climate change.

6.1. Explanation of climate change and its causes

Climate change represents a profound shift in the Earth's climatic systems, primarily driven by the increased concentration of greenhouse gases, notably CO₂, in the atmosphere. The industrialization and urbanization of society have significantly escalated CO₂ emissions, contributing to a rise in global temperatures and altering precipitation patterns. These changes threaten agricultural productivity, particularly in dryland regions where crops are already susceptible to stress from drought and extreme temperatures. Studies indicate that while higher CO₂ levels can enhance certain crop yields through fertilization effects, the overall impact is complex and fraught with trade-offs; for example, maize may benefit, but wheat productivity diminishes under elevated temperatures and water scarcity (Amanor-Boadu *et al.*, 2022) ^[7]. Furthermore, regions

heavily reliant on agriculture experience severe food security challenges as rising temperatures disproportionately affect yields, especially in vulnerable areas. Understanding these dynamics is crucial for developing adaptive strategies to mitigate the adverse effects of climate change on crop production.

6.2. Role of greenhouse gases in climate change

The role of greenhouse gases, particularly carbon dioxide (CO₂), in climate change is pivotal in understanding the challenges faced by dryland crops. As CO₂ levels rise due to industrialization and land-use changes, this gas traps heat in the atmosphere, leading to increased global surface temperatures and altered precipitation patterns. Such conditions not only threaten crop productivity but also exacerbate stress factors like drought, which critically impact staple crops such as wheat (Abbas *et al.*, 2022) [2]. Furthermore, while elevated CO₂ can enhance photosynthesis and improve water use efficiency in some plants, it simultaneously disrupts the ecological balance necessary for sustainable crop production (Agnolucci *et al.*, 2020) [5]. This dual effect highlights the urgency for adaptation strategies among farmers. Effective management of CO₂ levels and climate adaptation is crucial to ensure food security and maintain the nutritional quality of crops, as changes in environmental factors can hinder seed health and yield (Bamel *et al.*, 2023) [9].

7. Historical trends in temperature and precipitation

Understanding historical trends in temperature and precipitation is essential for modeling the impact of climate change on dryland crops. Over the past century, average global temperatures have consistently risen due to human influence, with significant fluctuations in regional precipitation patterns that profoundly affect agricultural sustainability. These alterations have resulted in the shifting suitability of regions for staple crops, such as maize, rice, and wheat, which are vital for food security and economic stability in multiple countries, including China. Historical data indicate that increased greenhouse gas emissions have intensified these trends, leading to higher atmospheric CO₂ concentrations, which in turn can have a dual effect on crop yields by enhancing growth under certain conditions while simultaneously imposing stresses through elevated temperatures (Abbas *et al.*, 2022) [2]. Thus, grasping these historical patterns is crucial for predicting the future viability of dryland agriculture amid ongoing climatic changes.

8. Projected future climate scenarios

Projected future climate scenarios reveal significant implications for dryland crop production, particularly under the influence of increasing temperatures, shifting precipitation patterns, and rising CO₂ levels. These changes are expected to intensify drought conditions, which can adversely affect crop yields and overall agricultural productivity. However, elevated CO₂ concentrations may offer a paradoxical benefit through enhanced photosynthesis and water use efficiency. For instance, simulation experiments demonstrate that doubled CO₂ levels may reduce droughts negative impact on maize, suggesting a potential for higher yields under certain conditions. Additionally, economic analyses indicate that larger agricultural operations might adapt more effectively to

climate change, leveraging economies of scale, while smaller farms face increased production costs and market pressures. Therefore, understanding these projected climate scenarios is crucial for developing resilient agricultural practices that can sustain dryland crop systems amid global climate shifts (Niu *et al.*, 2022) [17].

8.1. Effects of Temperature Changes on Dryland Crops

The impact of temperature changes on dryland crops is a critical aspect of understanding agricultural resilience in the face of climate change. Elevated temperatures can disrupt growth cycles, leading to significant yield reductions, particularly among sensitive crops such as soybean and sunflower. Research indicates that while sunflowers tend to exhibit declines across various climate scenarios, groundnut crops may show potential for increased yield under certain conditions, particularly at specific sites like Ofcolaco and Syferkuil, as projected for the year 2050 under the RCP 4.5 scenario (Chemura *et al.*, 2024) [11]. Furthermore, rising temperatures exacerbate water scarcity, affecting the availability of essential resources for crop cultivation. While higher CO₂ levels might improve water use efficiency in some cases, the overall benefits must be weighed against the increasing likelihood of drought and heat stress, which could ultimately jeopardize the economic viability of dryland farming. Hence, adaptation strategies rooted in sustainable management are essential for mitigating these challenges.

8.2. Impact of rising temperatures on crop growth and yield

As global temperatures continue to rise, the impact on crop growth and yield becomes increasingly concerning, particularly for dryland crops that are already sensitive to climatic stressors. Elevated temperatures can disrupt critical growth processes, leading to reduced yields for major staples such as maize, wheat, and soybeans, as evidenced by studies showing significant declines under extreme weather conditions. Moreover, while increased CO₂ levels can enhance water use efficiency and yield potential through CO₂ fertilization, this benefit may be outweighed by the adverse effects of rising temperatures and altered precipitation patterns (Johnson *et al.*, 2021) [15]. Research indicates that these changes create significant variability in crop responses across different regions, thereby intensifying food insecurity in areas most vulnerable to climatic changes. Consequently, adaptation strategies, including the adoption of drought-resistant crops and improved agricultural practices, are essential to mitigate these challenges and ensure food security in an era of climate uncertainty (Johnson *et al.*, 2021) [15].

8.3. Heat stress and its physiological effects on plants

Heat stress poses a significant threat to plant health, particularly in dryland ecosystems where water availability is already compromised. As global temperatures rise due to climate change, plants experience increased physiological stress, which can lead to decreased photosynthetic efficiency and ultimately reduced crop yields. This phenomenon is particularly concerning for dryland agriculture, where crops must adapt to both temperature increases and erratic precipitation patterns. Studies indicate that rising temperatures disrupt leaf gas exchange and hydraulic processes in plants, making them more susceptible to

drought conditions, as demonstrated in various pasture species (Jacob *et al.*, 2021) ^[14]. Furthermore, heat stress negatively impacts the growth and productivity of specific plant functional groups, with significant implications for agricultural sustainability in these regions (Grover *et al.*, 2023) ^[12]. Addressing these challenges requires innovative strategies for crop selection and management to enhance resilience against the adverse effects of heat stress, thereby supporting global food security.

8.4. Adaptation strategies for temperature extremes

The agricultural landscape is increasingly characterized by temperature extremes attributable to climate change, which demands effective adaptation strategies to ensure food security in dryland regions. One approach involves selecting and cultivating crop varieties that exhibit heat tolerance and drought resistance, which aligns with rising temperature trends and altered precipitation patterns. Additionally, integrated pest management (IPM) strategies can mitigate the negative impacts of shifting pest dynamics driven by climatic changes, thereby safeguarding crop yields. Another significant adaptation strategy is the implementation of sustainable land-use practices that enhance soil health and water retention, crucial for crops affected by extreme weather (Adamo *et al.*, 2021) ^[3]. Moreover, diversifying cropping systems by introducing alternative drought-resistant crops can buffer the effects of climate extremes, reducing dependency on traditional staples that are increasingly susceptible to climate variability (Aguiar *et al.*, 2023) ^[6]. These strategies collectively pave the way for resilient food systems in the face of evolving climatic challenges.

8.5. Regional variations in temperature effects on dryland agriculture

The effects of temperature variations on dryland agriculture are not uniform, leading to significant regional disparities in crop viability and productivity. For instance, in areas experiencing increased temperatures, higher CO₂ levels can contribute positively to certain crops, enhancing their water use efficiency and potentially offsetting some negative outcomes associated with drought conditions, as evidenced in studies conducted in South Africa (Grover *et al.*, 2023) ^[12]. Conversely, climate projections indicate that staple crops like maize, rice, and wheat may see decreases in yield stability under extreme temperature conditions despite elevated CO₂ levels, particularly in regions undergoing dramatic shifts in precipitation patterns. Findings suggest that while some areas may benefit from a marginal northward shift in suitable planting zones, others might experience detrimental impacts from increased temperatures, underscoring the complex interplay between temperature rise and agricultural productivity. Thus, understanding these regional variations is essential for effective agricultural adaptation strategies in the face of climate change.

9. Changes in Precipitation Patterns and Their Consequences

The variability in precipitation patterns resulting from climate change is profoundly disrupting agricultural productivity, particularly in dryland regions where water scarcity is already a critical issue. This alteration in rainfall distribution not only affects crop yields but also exacerbates

pest populations and disease prevalence, posing further challenges to farmers operating under already strained conditions. The economic implications are significant; as illustrated in studies utilizing modeling tools such as FEWCalc, shifts in precipitation, alongside rising temperatures, could result in a substantial decline in agricultural outputs and increased financial losses if current farming practices are maintained. Moreover, while elevated CO₂ levels may enhance certain crop growth through CO₂ fertilization effects, the overall balance between these benefits and the adverse impacts of altered precipitation remains tenuous, necessitating immediate adaptation strategies to ensure sustainable agricultural practices in a changing climate (Niu *et al.* 2022) ^[17].

9.1. Analysis of altered precipitation patterns due to climate change

The influence of altered precipitation patterns due to climate change is critical in understanding the future of dryland agriculture. Research indicates that as the atmosphere warms, precipitation events are expected to become fewer but larger, challenging traditional agricultural practices in sensitive ecosystems, particularly drylands (Grover *et al.*, 2023) ^[12]. Increased precipitation intensity modifies soil water dynamics, potentially benefiting certain crop species, such as winter wheat, by leveraging deeper soil moisture even though total precipitation might remain constant (Amanor-Boadu *et al.*, 2022) ^[7]. Furthermore, in regions like Mediterranean vineyards, soil temperature and moisture interplay significantly impact crop performance, posing substantial risks to productivity amidst climate variability. Additionally, crops like pearl millet face heightened vulnerability to erratic rainfall patterns, exacerbating issues such as soil fertility decline and pest pressures, which underscores the necessity for adaptive management strategies focused on climate resilience. Understanding these interactions is essential for developing effective responses to ensure sustainable crop production in changing climates.

9.2. Effects of drought and water scarcity on crop production

Drought and water scarcity are critical factors adversely affecting crop production, particularly in arid and semi-arid regions where climate change is intensifying these challenges. The ongoing changes to precipitation patterns and rising temperatures directly compromise the viability of crops by reducing soil moisture and increasing evapotranspiration rates. As highlighted in the literature, dryland populations, which rely heavily on agriculture, are becoming increasingly vulnerable due to these stressors, with impacts on food security being profound and multidimensional. The urgency of understanding climate-induced changes in the water cycle reveals the significant risks faced by both natural ecosystems and human systems, underlining the necessity for effective adaptation strategies (A Gelfan *et al.*, 2022) ^[1]. Furthermore, pests and diseases proliferate under changing climatic conditions, complicating the agricultural landscape and necessitating innovative pest management approaches to mitigate these concerns (Grover *et al.*, 2023) ^[12]. Thus, understanding the intricate dynamics of drought and water scarcity is paramount for ensuring sustainable crop production in a rapidly changing environment.

9.3. Importance of irrigation and water management strategies

As climate change continues to disrupt traditional agricultural practices, effective irrigation and water management strategies are paramount for sustaining crop yields, particularly in dryland regions. The projected changes in temperature and precipitation patterns necessitate a shift towards modern irrigation techniques, which can significantly enhance water use efficiency and agricultural productivity. For instance, the introduction of pressurized irrigation systems has been shown to conserve water resources while boosting crop yields, thus reaching a delicate balance between supply and demand in water-scarce environments. Furthermore, studies indicate that crops such as maize can benefit from increased CO₂ levels, provided that water management systems are in place to offset the detrimental effects of drought. Such adaptive strategies not only mitigate the immediate consequences of climate change but also foster resilience among farming communities facing uncertain climatic conditions. Ultimately, prioritizing advanced irrigation methods will be critical in ensuring food security in a rapidly changing climate (Adamo *et al.*, 2021) ^[3].

9.4. Resilience of dryland crops to variable precipitation

The resilience of dryland crops to variable precipitation is a critical factor in maintaining food security amid climate change. Drylands, characterized by limited water resources, are particularly vulnerable to shifts in precipitation patterns, which can lead to significant agricultural challenges. Increasing climate variability necessitates that dryland crops develop adaptive mechanisms to withstand these changes, especially given that severe impacts on food production have already been documented in regions like Africa, where 95% of cropland relies on rainfed sources. Moreover, while elevated CO₂ levels may improve certain crop yields through better water use efficiency, adaptation strategies must be comprehensive to mitigate the interconnected risks posed by climate phenomena (Adamo *et al.*, 2021) ^[3]. Understanding these dynamics is vital, as effective resilience strategies can safeguard both livelihoods and crop viability in the face of ongoing climate disruptions.

10. Conclusion

In conclusion, the intricate relationship between climate change and dryland agriculture necessitates urgent attention and adaptive measures. As rising temperatures and altered precipitation patterns threaten crop stability, understanding these dynamics is essential for ensuring food security. The dual-edged nature of increased CO₂ levels reveals a complex interplay; while elevated CO₂ can enhance yields through improved water use efficiency, it simultaneously exacerbates the negative impacts of climate change on nutritional quality and crop viability (Adelekan *et al.*, 2022) ^[4]. Research highlights the vulnerability of essential crops like maize and wheat, which are losing productivity due to climatic extremes such as droughts and floods. Moreover, adaptation strategies, including the introduction of climate-resilient varieties, emerge as critical for sustaining agricultural output amidst these looming challenges. Therefore, the modeling of these environmental variables must be prioritized to inform effective agricultural practices that can withstand the evolving climate landscape (Johnson *et al.*, 2021) ^[15].

10.1. Summary of key findings from the modeling studies

Modeling studies have provided critical insights into the impacts of climate change on dryland crops, particularly in relation to rising CO₂ levels and changing precipitation patterns. Notably, elevated atmospheric CO₂ concentrations have the potential to enhance maize yield through improved water use efficiency and growth, effectively mitigating some drought effects attributed to climate change (Johnson *et al.*, 2021) ^[15]. However, this positive influence is accompanied by significant challenges, including shifts in farming practices and increased production costs as farmers adapt to new climatic realities (Johnson *et al.*, 2021) ^[15]. Furthermore, the broader context reveals that the agricultural sector is deeply intertwined with climate dynamics, complicating food security as climate-induced productivity shocks can lead to fluctuating crop prices. Overall, while model simulations indicate potential benefits under certain conditions, the overarching trend leans towards increasing vulnerability and economic disruption, especially for smaller farmers, highlighting the need for robust adaptation strategies.

10.2. Implications for future agricultural practices

The implications of climate change for future agricultural practices are profound, particularly for dryland crops. As temperature and precipitation patterns evolve, adapting to these changes becomes crucial to ensure food security and sustainable farming. Increased CO₂ levels present a duality of outcomes, while they may enhance crop yields through CO₂ fertilization, the negative impacts of drought and changing climate conditions threaten overall agricultural productivity. The disruption of traditional farming practices necessitates innovative methodologies, such as integrated pest management (IPM) strategies, to address the dynamic pest scenarios that arise from altered ecosystems (Lewis *et al.*, 2024) ^[16]. Moreover, larger farmers who can leverage economies of scale may adapt more successfully than smaller operators, underscoring the need for targeted support and resources (Johnson *et al.*, 2021) ^[15]. Ultimately, the agricultural sector must embrace holistic approaches and technological advancements to navigate the complexities of climate change effectively.

10.3. Importance of continued research and monitoring

The significance of continued research and monitoring cannot be overstated when addressing the effects of climate change on dryland crops. As shifting temperature and precipitation patterns lead to fluctuating agricultural yields, understanding these dynamics becomes critical for ensuring food security. Climate change models indicate that higher CO₂ concentrations may yield both positive and negative outcomes for crops, particularly maize, wheat, and rice, which are staples in many regions (Johnson *et al.*, 2021) ^[15]. Moreover, there is an inherent variability in climate-related agricultural performance; studies indicate that rising temperatures can compromise crop health through increased pest and disease prevalence, while extreme weather events disrupt established farming practices (Bojović *et al.*, 2020) ^[10]. Continuous research is essential for developing adaptive strategies and resilient crop varieties to mitigate adverse impacts and capitalize on beneficial conditions, as observed in projected yield improvements under certain scenarios (Niu *et al.*, 2022) ^[17]. Ultimately, systematic monitoring will

help forecast changes and inform policy decisions vital for safeguarding agricultural systems in vulnerable areas.

10.4. Call to action for policymakers and stakeholders

In light of the significant challenges posed by climate change, it is imperative for policymakers and stakeholders to adopt proactive measures that prioritize the resilience of dryland agriculture. The projected increases in temperature, erratic precipitation patterns, and elevated CO₂ levels necessitate a comprehensive approach to policy formulation that integrates scientific modeling with practical agricultural strategies. Policymakers should invest in research that explores drought-resistant crop varieties, innovative irrigation techniques, and sustainable land management practices. Furthermore, collaborative efforts between governmental agencies, agricultural experts, and local farming communities must be fostered to disseminate knowledge and resources effectively. By establishing clear guidelines and incentives that encourage adaptive practices, stakeholders can ensure the long-term viability of dryland crops, thereby safeguarding food security and rural livelihoods. This multifaceted response not only addresses immediate agricultural challenges but also paves the way for a sustainable future in the face of climate variability.

11. References

- Gelfan A, Mukherji S, Supratid A, Gain A, Lopez Gunn E, Liu J, Caretta MA, *et al.* Chapter 4: Water. Cambridge University Press. Available from: <https://core.ac.uk/download/535097538.pdf>. 2022.
- Abbas A, Elahi I, Jabbar S, Nawaz *et al.* Effect of Climate Change on Wheat Productivity. IntechOpen. Available from: <https://core.ac.uk/download/492703757.pdf>. 2022.
- Abbas G, Ahmad S, Ahmed M, Ahmed *et al.* The fingerprints of climate warming on cereal crops phenology and adaptation options. Available from: <https://core.ac.uk/download/342537437.pdf>. 2020.
- Adamo SB, Even T, Galvin KA, Heaviside *et al.* Food security among dryland pastoralists and agropastoralists: The climate, land-use change, and population dynamics nexus. SAGE Publications. Available from: <https://core.ac.uk/download/542327555.pdf>. 2021.
- Adelekan IO, Ayanlade A, Efitre J, Gemeda *et al.* Africa. Cambridge University Press. Available from: <https://core.ac.uk/download/580092229.pdf>. 2022.
- Agnolucci P, Alexander P, De Lipsis V, Eigenbrod *et al.* Impacts of rising temperatures and farm management practices on global yields of 18 crops. Springer Science and Business Media LLC. Available from: <https://core.ac.uk/download/391332526.pdf>. 2020.
- Aguiar FC, Costa JM, Egipto R, Madeira *et al.* The role of soil temperature in Mediterranean vineyards in a climate change context. Frontiers. Available from: <https://core.ac.uk/download/591454883.pdf>. 2023.
- Amanor-Boadu V, Barron RW, Hill MC, Kisekka *et al.* Consequences of climate change on food-energy-water systems in arid regions without agricultural adaptation, analyzed using FEWCalc and DSSAT. Elsevier BV. Available from: <https://core.ac.uk/download/543851129.pdf>. 2022.
- Attavanich W, Bejranonda S, Pipitpukdee S. Climate Change Impacts on Sugarcane Production in Thailand. Available from: <https://core.ac.uk/download/322380128.pdf>. 2020.
- Bamel K, Prabhavathi Talwar S. Impact of Elevated Temperature and Carbon Dioxide on Seed Physiology and Yield. Horizon E-Publishing Group. Available from: <https://core.ac.uk/download/553278668.pdf>. 2023.
- Bojović R, Jovović Z, Marjanović-Jeromela A, Mikić *et al.* Climatic change and agricultural production. Podgorica: University of Montenegro, Biotechnical Faculty. Available from: <https://core.ac.uk/download/481675886.pdf>. 2020.
- Chemura A, Kephe PN, Mkuhlani S, Rusere *et al.* Use of modelling tools to assess climate change impacts on smallholder oil seed yields in South Africa. Available from: <https://core.ac.uk/download/604657444.pdf>. 2024.
- Grover S, Kashyap R, Kaur B, Kaur *et al.* Insect and Pest Management for Sustaining Crop Production Under Changing Climatic Patterns of Drylands. DigitalCommons@University of Nebraska - Lincoln. Available from: <https://core.ac.uk/download/590237207.pdf>. 2023.
- Houmsi MR. Modeling impacts of climate change on aridity and crop water demand in Syria. Available from: <https://core.ac.uk/download/478813122.pdf>. 2020.
- Jacob VK. Gas exchange and hydraulic strategies of pasture species under climate change. American Psychological Association. Available from: <https://core.ac.uk/download/544084927.pdf>. 2021.
- Johnson RC. Economic impact of climate change on maize production in the Free State Province, South Africa. Faculty of Commerce, Department of Economics and Economic History. Available from: <https://core.ac.uk/download/534797247.pdf>. 2021.
- Johnson RC. Economic impact of climate change on maize production in the Free State Province, South Africa. Faculty of Commerce, Department of Economics and Economic History. Available from: <https://core.ac.uk/download/395091713.pdf>. 2021.
- Lewis A, Nguyen TH, Randall M. Factors Affecting Crop Prices in the Context of Climate Change—A Review. Available from: <https://core.ac.uk/download/604231048.pdf>. 2024.
- Niu H, Yu Q, Zhang Y. Impacts of climate change and increasing carbon dioxide levels on yield changes of major crops in suitable planting areas in China by the 2050s. Elsevier BV. Available from: <https://opus.lib.uts.edu.au/bitstream/10453/154227/2/1-s2.0-S1470160X21002533-main.pdf>. 2022.