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IMPACT OF CLIMATE CHANGE ON AGRO-CLIMATIC ZONES OF KARNATAKA: A COMPARATIVE STUDY OF DROUGHT VULNERABILITY

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Abstract

Karnataka's diverse agro-climatic zones (ACZs) face increasing vulnerability to climate change, particularly in the form of droughts. This study investigates the connection between the existing climatic conditions, agricultural practices, and the projected drought risks under various climate scenarios (RCP 4.5 and RCP 8.5). Using data from the Karnataka Agriculture Department, this research examines how different zones—ranging from semi-arid regions like the North Eastern Dry Zone to per-humid coastal zones—are impacted by changing rainfall patterns and increasing temperatures. By cross-referencing the climate characteristics, rainfall ranges, and major crops of each zone with the district-wise Drought Hazard Indices (DHIs), this study identifies key vulnerabilities and proposes adaptive agricultural strategies tailored to each zone. Findings show that semi-arid regions are especially at risk, with "Very High" drought indices under future climate projections, demanding urgent policy interventions and the adoption of climate-resilient crops. Conversely, coastal regions, though historically less vulnerable, face increasing risk under projected scenarios, necessitating new strategies for water management and crop adaptation. This study concludes with recommendations for enhancing resilience across Karnataka's ACZs, emphasizing the need for climate-smart agricultural practices and region-specific policy frameworks to mitigate the impact of future climate challenges.

Key words: Karnataka agro-climatic zones; Climate change; Drought hazard indices; RCP 4.5; RCP 8.5 ;Semi-arid regions; Water management; Policy interventions.

Introduction

Karnataka, a state with diverse agro-climatic zones (ACZs), is highly dependent on agriculture for its economy. However, the state's agricultural practices are increasingly vulnerable to climate change, particularly due to erratic rainfall patterns, rising temperatures, and prolonged droughts. The state's semi-arid and per-humid regions, characterized by distinct climatic conditions, face differing levels of drought risks, which threaten the livelihood of millions of farmers. This study aims to bridge the gap between understanding current climatic conditions and forecasting future risks, particularly by examining the drought hazard indices (DHIs) across Karnataka's ACZs

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under different climate scenarios (RCP 4.5 and RCP 8.5). By comparing these zones' major crops, rainfall patterns, and climate characteristics with their projected drought risks, this research provides insights into how agricultural practices can be adapted to mitigate the effects of climate change.

Objectives

1. To assess the climatic characteristics and agricultural practices across different agro-climatic zones in Karnataka.
2. To evaluate the vulnerability of Karnataka's agro-climatic zones to drought under historical and future climate scenarios (RCP 4.5 and RCP 8.5).
3. To propose region-specific climate adaptation strategies aimed at enhancing the resilience of agricultural practices in Karnataka’s drought-prone areas.
4. To recommend policy interventions for climate-smart agriculture based on zone-specific risks and vulnerabilities.

Need for the Study

Karnataka's agricultural sector is highly susceptible to climatic fluctuations, especially in drought-prone regions. As climate change progresses, the frequency and intensity of droughts are expected to increase, severely affecting crop production and food security. While some studies have assessed Karnataka’s climatic zones and their agricultural outputs, few have focused on the direct link between drought vulnerability and specific agro-climatic zones under future climate projections. Understanding these connections is critical to developing tailored agricultural practices and policies that can enhance the resilience of different zones, particularly those with high and very high drought risk. This study is urgently needed to address these challenges by providing actionable insights that can help policymakers and farmers alike mitigate the impacts of climate change on Karnataka's agriculture.

Literature Review: Climate Change Impacts and Adaptation Strategies in Karnataka's Agricultural Sector

Recent studies underscore the significant effects of climate change on agriculture across Karnataka. Acharya (2024) utilized the Ricardian approach to examine climate variability impacts, focusing on the coastal and Western Ghat regions. Findings from this study suggest that educating farmers on adaptive strategies is crucial, particularly to counter the adverse effects of erratic rainfall on farmland values. In a broader study, Jetteppa (2023) explored climate change impacts across Karnataka, identifying notable shifts in cropping practices, driven by inconsistent rainfall and rising temperatures. Similarly, Kumar et al. (2023) assessed farmers' perceptions in Kolar district, highlighting how rising temperatures and irregular rainfall patterns have forced

changes in sowing times and increased pest issues. Meanwhile, Nandini et al. (2023) studied factors influencing the adoption of climate-smart agricultural technologies in Southern Karnataka, revealing that education, credit access, and training significantly drive the uptake of these technologies. Lastly, Y. B. Naveesh et al. (2023) conducted research in Koppala district, reporting on farmers' adaptation strategies, including intercropping and soil conservation practices, in response to rising temperatures, water shortages, and increased pest occurrences. Collectively, these studies reveal an urgent need for policy-driven interventions, enhanced farmer education, and the adoption of climate-resilient technologies to mitigate the adverse effects of climate change on Karnataka's agriculture sector.

Research gap

Climate change has significantly affected agricultural practices in Karnataka, as seen in several recent studies. Acharya (2024) examined the impact of climate variability on agriculture, particularly in coastal and Western Ghat regions, using the Ricardian approach. The study highlights the need for educating farmers on adaptation strategies, emphasizing the negative effects of erratic rainfall on farmland value. Similarly, Jetteppa (2023) discussed the broad impacts of climate change on agriculture across Karnataka, identifying shifts in cropping practices due to unpredictable rainfall and temperature changes. Furthermore, Kumar et al. (2023) investigated farmers' perceptions in the Kolar district, noting how rising temperatures and irregular rainfall have led to changes in sowing times and increased pest occurrences. Nandini et al. (2023) analyzed the adoption of climate-smart agricultural technologies in Southern Karnataka, identifying key factors like education, access to credit, and training that significantly influence technology adoption. Finally, Y. B. Naveesh et al. (2023) focused on Koppala district, where farmers reported increasing temperatures, water shortages, and greater pest incidence, prompting adaptation measures such as intercropping and soil conservation. Collectively, these studies highlight the urgent need for policy interventions, farmer education, and technology adoption to mitigate climate change impacts in Karnataka's agriculture sector. give one title from these reviews.

Methodology

1. **Data Collection**: This study will utilize both primary and secondary data sources. Data on the agro-climatic zones (ACZs), including climate characteristics, rainfall patterns, and major crops, will be obtained from the Karnataka Agriculture Department. Future climate projections and Drought Hazard Indices (DHIs) under RCP 4.5 and RCP 8.5 scenarios will be sourced from climate models and relevant governmental reports.
2. **Study Area Selection**: The analysis will focus on the key ACZs of Karnataka, such as the North Eastern dry zone, Central dry zone, Coastal zone, and Hill zone, among others.

Each of these zones exhibits unique climatic and agricultural characteristics, making them suitable for a comparative study.

3. **Drought Hazard Index (DHI) Analysis**: Using historical and projected climate data (RCP 4.5 and RCP 8.5), district-wise DHI values will be calculated to assess the vulnerability of each zone to drought. These indices will be compared across different time frames (historical, near-term, and end-term) to identify trends and changes in risk levels.
4. **Agro-Climatic Zone and Crop Correlation**: The study will examine the correlation between the climate characteristics and major crops in each zone to determine how current agricultural practices are affected by climatic risks, particularly drought.
5. **Proposing Adaptation Strategies**: Based on the analysis, the study will propose specific climate adaptation strategies for each zone, focusing on sustainable agricultural practices, water management techniques, and crop diversification.

Results and Discussion

Climatic and Agricultural Characteristics of Agro-Climatic Zones (ACZs) in Karnataka

ACZs	Districts	Climate	Rainfall Range in mm	Major Crops
North eastern transition	Bidar	Tropical monsoon, semi-arid	830–890	Jowar, bajra, cotton, sugarcane, and pulses
North eastern dry	Kalaburagi, Raichuru, Ballari, Yadagir, and Koppala	Semi-arid	633.2–806.6	Jowar, bajra, oilseeds, cotton, and pulses
Northern dry	Vijayapura, Gadaga, and Bagalkote	Semi-arid	464.5–785.7	Jowar, maize, bajra, groundnut, cotton, wheat, sugarcane, and tobacco
Central dry	Tumakuru, Chitradurga, and Davanagere	Semi-arid	453.5–717.7	Ragi, rice, jowar, pulses, and oilseeds
Eastern dry	Bengaluru Rural, Bengaluru Urban, Kolar, Ramanagara	Semi-arid	679.1–888.9	Ragi, rice, pulses, maize, mulberry, and oilseeds
Southern dry	Mysuru, Kodagu, Chamarajanagara, and	Semi-arid to sub-humid	670.6–888.6	Rice, ragi, pulses, millets, and sugarcane

	Mandya			
Southern transition	Hassan, Shivamogga, and Chikkamagaluru	Semi-arid	611.7–1053.9	Rice, ragi, pulses, jowar, and tobacco
North transition	Dharwada, Belagavi, and Haveri	Semi-arid	619.4–1303.2	Rice, jowar, groundnut, pulses, sugarcane, and tobacco
Hill	Uttara Kannada	Per humid	904.4–3695.1	Rice and pulses
Coastal	Dakshina Kannada and Udupi	Per humid	3010.9–4694.4	Rice, pulses, and sugarcane

Karnataka's diverse agro-climatic zones (ACZs) are defined by distinct climatic conditions, varying rainfall patterns, and specific cropping systems. This study presents an analysis of the state's major ACZs, highlighting their climatic characteristics, average annual rainfall, and dominant agricultural practices. The North Eastern Transition zone, which includes Bidar, experiences a tropical monsoon and semi-arid climate, receiving 830–890 mm of rainfall, with key crops such as jowar, bajra, cotton, sugarcane, and pulses. The North Eastern Dry zone, comprising Kalaburagi, Raichuru, Ballari, Yadagir, and Koppala, is semi-arid, with lower rainfall (633.2–806.6 mm) and is predominantly suited for jowar, bajra, oilseeds, cotton, and pulses. In the Northern Dry zone, which includes Vijayapura, Gadaga, and Bagalkote, rainfall ranges from 464.5–785.7 mm, supporting crops such as jowar, maize, bajra, groundnut, cotton, wheat, sugarcane, and tobacco.

Central Dry zones like Tumakuru, Chitradurga, and Davanagere, characterized by semi-arid conditions and 453.5–717.7 mm of rainfall, primarily grow ragi, rice, jowar, pulses, and oilseeds. The Eastern Dry zone, including Bengaluru Rural and Urban, Kolar, and Ramanagara, receives 679.1–888.9 mm of rainfall, with a focus on ragi, rice, pulses, maize, mulberry, and oilseeds. The Southern Dry zone, consisting of Mysuru, Kodagu, Chamarajanagara, and Mandya, has a semi-arid to sub-humid climate (670.6–888.6 mm of rainfall), suitable for rice, ragi, pulses, millets, and sugarcane. The Southern Transition zone, covering Hassan, Shivamogga, and Chikkamagaluru, receives 611.7–1053.9 mm of rainfall and supports rice, ragi, pulses, jowar, and tobacco.

Further, the North Transition zone (Dharwada, Belagavi, and Haveri) is semi-arid with 619.4–1303.2 mm of rainfall, with rice, jowar, groundnut, pulses, sugarcane, and tobacco being the primary crops. The Hill zone, represented by Uttara Kannada, is per-humid, receiving 904.4–3695.1 mm of rainfall and favoring rice and pulses, while the Coastal zone, comprising Dakshina Kannada and Udupi, is also per-humid, with 3010.9–4694.4 mm of rainfall, and supports rice,

pulses, and sugarcane. This classification underscores the importance of climate-specific agricultural practices in Karnataka, with each zone requiring tailored strategies for sustainable farming based on its unique environmental conditions.

Drought Hazard Indices (DHIs) in Karnataka's Agro-Climatic Zones under Historical and Future Climate Scenarios

Zones	Districts	Historical	RCP 4.5 NT	RCP 4.5 ET	RCP 8.5 NT	RCP 8.5 ET
Central dry	Chitradurga, Davanagere, Tumakuru	Very High	Very High	Very High	Very High	Very High
Coastal	Dakshina Kannada, Udupi	Moderate	High	Very High	High	High
Eastern dry	Bengaluru Rural, Bengaluru Urban, Chikkaballapura, Kolar	High	Very High	Very High	Very High	High
Hill	Uttara Kannada	High	Moderate	Moderate	High	High
North eastern	Ballari, Bidar, Kalaburagi, Koppal, Raichuru, Yadagir	Very High	Moderate	Moderate	High	Moderate
North transition	Belagavi, Dharwada, Haveri	Low	Moderate	Moderate	Low	Moderate
Northern dry	Bagalkote, Gadaga, Vijayapura	High	Very High	Very High	Very High	High
Southern dry	Chamarajanagara, Kodagu, Mandya, Mysuru	Moderate	Moderate	Moderate	High	High
Southern trans	Chikkamagaluru, Hassan, Shivamogga	High	High	Moderate	Moderate	Moderate

This study analyzes the drought vulnerability of Karnataka's agro-climatic zones (ACZs) under historical and future climate change scenarios, focusing on the Representative Concentration Pathways (RCP) 4.5 and 8.5 for near-term (NT) and end-term (ET) periods. The Central Dry zone, encompassing Chitradurga, Davanagere, and Tumakuru, consistently shows "Very High" drought hazard indices (DHIs) across historical and future scenarios, indicating extreme vulnerability to droughts. In contrast, the Coastal zone, which includes Dakshina Kannada and

Udupi, transitions from a "Moderate" risk historically to "High" and "Very High" risks under future scenarios, highlighting increasing susceptibility to climate change.

The Eastern Dry zone, consisting of Bengaluru Rural, Bengaluru Urban, Chikkaballapura, and Kolar, also faces a significant increase in drought risk, with "High" DHIs historically and "Very High" projections in future scenarios, particularly under RCP 4.5 and RCP 8.5. In the Hill zone, represented by Uttara Kannada, the DHI decreases slightly in the near-term (RCP 4.5 NT) to "Moderate," but climbs back to "High" under end-term scenarios, indicating a need for sustained adaptive measures.

North Eastern Karnataka, comprising Ballari, Bidar, Kalaburagi, Koppal, Raichuru, and Yadagir, shows a slight reduction in drought risk in future scenarios, moving from "Very High" historically to "Moderate" under both near- and end-term projections. The North Transition zone, which includes Belagavi, Dharwada, and Haveri, maintains relatively lower risks, fluctuating between "Low" and "Moderate" in all scenarios. Similarly, the Northern Dry zone (Bagalkote, Gadaga, and Vijayapura) transitions from "High" to "Very High" risk in future scenarios.

The Southern Dry zone, which includes Chamarajanagara, Kodagu, Mandya, and Mysuru, consistently exhibits "Moderate" drought risk historically and in future scenarios, but projections under RCP 8.5 suggest an escalation to "High." The Southern Transition zone (Chikkamagaluru, Hassan, and Shivamogga) also faces "High" to "Moderate" drought risk across all scenarios. This analysis underscores the urgent need for climate-adaptive policies, particularly in high-risk zones like the Central and Northern dry regions, to mitigate future drought impacts and ensure agricultural sustainability.

Conclusion and Suggestions

The analysis of Karnataka's agro-climatic zones (ACZs) in terms of both their climatic characteristics and vulnerability to future climate change reveals significant insights into the state's agricultural sustainability and drought risks. The diversity in rainfall patterns and cropping systems across the zones indicates that each region faces unique challenges. Semi-arid zones such as the **Central Dry** and **North Eastern Dry** are particularly vulnerable, with **very high drought hazard indices (DHIs)** consistently across both historical and future climate scenarios (RCP 4.5 and 8.5). This suggests that these regions, already characterized by limited rainfall, will face increasingly severe drought conditions in the future, which could severely impact crop productivity, particularly for staples like **jowar, bajra, and pulses**.

Regions like the **Coastal** and **Hill zones**, which historically enjoyed moderate to high rainfall, are also projected to experience increased drought risks under future scenarios, moving from **moderate to high** or even **very high** DHIs. This shift highlights the growing susceptibility of

these traditionally stable agricultural regions to climate change, potentially disrupting the cultivation of crops like **rice, pulses, and sugarcane**. Meanwhile, **Southern Dry** and **Southern Transition** zones, while maintaining moderate risk historically, could face increased drought risks, requiring urgent attention to ensure future agricultural sustainability.

Suggestions:

1. **Implementation of Climate-Resilient Agricultural Practices**: In zones with **very high drought risk**, such as the **Central Dry**, **North Eastern Dry**, and **Northern Dry** regions, immediate steps should be taken to introduce climate-resilient crops and drought-tolerant crop varieties. Practices like **crop rotation**, **agroforestry**, and **mulching** should be promoted to conserve moisture and improve soil health.
2. **Water Management and Irrigation Efficiency**: Regions facing escalating drought risks, especially **semi-arid zones**, need improved water management practices. Initiatives such as **micro-irrigation (drip and sprinkler systems)**, **rainwater harvesting**, and **watershed management** should be expanded to conserve water and improve irrigation efficiency. Government programs like the **Krishi Bhagya Scheme** can be scaled to increase access to sustainable irrigation.
3. **Diversification of Crops**: In vulnerable zones, especially those projected to face **increasing drought risks**, farmers should be encouraged to diversify their crops, integrating **drought-resistant varieties** and switching from water-intensive crops (e.g., sugarcane in semi-arid zones) to more resilient options like **millets** or **oilseeds**. This diversification can reduce the impact of crop failure due to extreme drought.
4. **Climate Forecasting and Early Warning Systems**: The **Hill** and **Coastal** zones, which are expected to experience worsening drought conditions, would benefit from enhanced **early warning systems** and access to real-time weather data. Empowering farmers with climate forecasts and training on how to adapt their farming practices can help reduce vulnerability.
5. **Policy Interventions and Support**: The government should prioritize the development of **climate adaptation policies**, with targeted financial and technical support to regions identified as high-risk under future climate scenarios. This includes offering **subsidies** for climate-smart agricultural technologies, providing access to **credit** for smallholder farmers, and strengthening **agricultural extension services** to disseminate knowledge about sustainable farming practices.

In conclusion, Karnataka's diverse agro-climatic zones are facing mounting challenges due to climate change, particularly in the form of increasing drought risks. The severity of these risks varies across the state, but the urgency for adaptive measures is universal. By implementing targeted strategies focused on water management, crop diversification, and climate-smart

practices, Karnataka can mitigate the adverse impacts of climate change and ensure the resilience and sustainability of its agricultural sector in the future.

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