Climate change impact on forest and agrobiodiversity: A special reference to anuppur district, madhya Pradesh.

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Abstract

Kotma, located in the Anuppur district of Madhya Pradesh, India, occupies a pivotal position between latitude 22°15' to 20°58' N and longitude 81°25' to 20°5' E, affording it a unique and ecologically significant climate. This climatic setup sustains a diverse biological ecosystem that has, unfortunately, been substantially impacted by climate change in recent years. The alterations in the ecosystem and organisms due to climate change have led to significant biodiversity loss, posing a major challenge for Kotma and impacting its richness in various life forms. According to the 2021 India census, Kotma is home to a population of approximately 88,484, with males constituting 50.5% and females 44.5%. The town reports an average literacy rate of 67%, with male literacy at 75.5% and female literacy at 59.5%. Moreover, around 20% of the population is under the age of 6. Kotma is inhabited by several primitive tribal communities, including Baiga, Gonds, Panikas, Kol, and Dhanaur, whose livelihoods heavily rely on the region's forests and agriculture. In recent decades, climate change has led to a decrease in rainy days, significantly affecting crop production and the availability of non-timber forest products (NTFPs). The fisheries sector has also suffered due to these climate-related changes. Additionally, extreme forest fires and overexploitation have adversely impacted the availability of certain medicinal plants in the natural forest, further influencing the region's plant and animal diversity. Addressing and mitigating these climate change impacts is paramount to ensure the sustainable future of Kotma and the well-being of its inhabitants. Implementing strategies for sustainable agriculture, biodiversity conservation, disaster management, and the empowerment of tribal communities are crucial steps towards securing the region's ecological integrity and the livelihoods of its people.

Keywords: Climate change, Sustainability, Forest and Agriculture, Rainfall.

Introduction

In recent decades, climate change has significantly impacted both forested areas and agriculture. The decrease in average rainfall and the rise in extreme temperatures have adversely affected the production of crops as well as non-agricultural ones [1]. For a large portion of communities in India, particularly those dependent on land, forests, and agriculture, these sectors are critical for their livelihoods. On a global scale, forests cover approximately 33% of the Earth's surface and represent vital ecosystems, encompassing around 66% of all known terrestrial species [2]. Furthermore, forests serve as biodiversity hotspots, housing a rich array of plant and animal life. Unfortunately, up to now, about 50% of the world's forests have been cleared or significantly impacted due to various human activities.

Elevated levels of CO_2 in the atmosphere have stimulated the growth of specific forested areas. Additionally, a mere 1°C rise in temperature can lead to the migration of tree species, increased vulnerability to pest infestations, the expansion of invasive species, and a heightened risk of forest fires. Rural populations, in particular, rely significantly on a diverse range of forest products and engage in subsistence agriculture, underlining the pivotal role forests play in supporting their means of living [1].Changes in forest conditions directly impact these communities, bearing substantial socio-economic consequences. Furthermore, the significance of forest biodiversity is closely tied to the preservation of watersheds' hydrological cycles and the overall well-being of a myriad of ecosystems present worldwide [3].

When biological systems experience stress caused by deviations from their usual temperature and precipitation patterns,

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***Received:** 02-Oct -2023, Manuscript No. AAASCB-23- 118299; **Editor assigned:** 04 - Oct -2023, Pre QC No. AAASCB-23-118299 (PQ); **Reviewed:** 19-oct -2023, QC No. AAASCB-23-118299; **Revised:** 24 - Oct -2023, Manuscript No. AAASCB-23- 118299 (R); **Published:** 31- Oct -2023, DOI: 10.35841/2591-7366-7.5.196*

***Citation:** Harika A., Banavath NS. Climate change impact on forest and agrobiodiversity: A special reference to anuppur district, madhya pradesh. J AgricSci Bot. 2023; 7(5):196*

they become more susceptible to pests, diseases, and the encroachment of invasive species [4]. Changes in plant life and disruptions in hydrological systems are linked to phenomena like human migration, shifts in the geographic ranges of species, and alterations in land utilization practices. These factors contribute to an escalation in conflicts between humans and wildlife. As a result of droughts, floods, and natural disasters, in combination with changes in land use driven by deforestation, natural habitats and forests are often degraded [5]. This degradation forces both humans and other species to vie for territory and essential resources. The competition for land and resources intensifies, posing challenges to the coexistence of human and biological communities.

Climate stands as a pivotal determinant influencing global vegetation patterns, productivity, and the composition of both animal and plant species. Many plant species exhibit optimal growth and reproduction within specific temperature ranges, responding distinctly to varying precipitation levels. Alterations in climate, such as changes in temperature and precipitation, may displace certain plant species due to competition or result in their inability to survive . The third assessment report of the Intergovernmental Panel on Climate Change (IPCC) highlighted the potential severe impacts of climate change on forest ecosystems. This suggests that climate change can modify the structure and productivity of forest and agricultural ecosystems. The consequences of climate change on agriculture and agrobiodiversity are both direct and indirect. Across the globe, agriculture is being significantly impacted by changing climate patterns.

The fourth assessment report of the IPCC underscores that crop yield losses due to climate change will be more pronounced in tropical regions compared to temperate ones. Alarming projections suggest that climate change may subject 75–250 million people to water scarcity, underscoring the far-reaching effects of climate change on water resources. The adverse impacts of climate change disproportionately affect impoverished populations, exacerbating economic disparities. This renders them unable to access sufficient food and water, underscoring the urgency of addressing climate change to ensure equitable sustenance and well-being.

Current scientific research on climate change indicates an anticipated rise in mean annual temperatures, projecting an increase of approximately 1.5–1.8 °C. However, it's important to note that these temperature shifts may vary across different regions. Projections suggest that the most significant temperature increases will likely occur in tropical and subtropical regions. As a result of these changes, there is a predicted large-scale extinction of species, reduced agricultural yields, and substantial shifts in cropping patterns [6]. The primary influences on agricultural responses to climate change encompass both biophysical and socioeconomic factors. Meteorological elements, such as escalating temperatures, altering precipitation patterns, and heightened carbon dioxide levels, significantly impact crop production. Concurrently, socioeconomic determinants play a crucial role in shaping responses to alterations in crop productivity, including shifts in prices and changes in comparative advantage [7].

Crop yields are significantly impacted by various pollinator species, with the honeybee, Apis mellifera, being the most extensively managed and adaptable pollinator. It contributes to an increase in production for up to 96% of animal-pollinated crops [8] .Pollinators like bees and butterflies are highly sensitive to temperature shifts, including rising mean temperatures and extreme climatic conditions, potentially leading to the extinction of certain pollinator species [9]. Climate change also exerts multifaceted effects on soil nematodes. Elevated temperatures directly influence the life cycle of nematodes, affecting embryogenesis and growth rates in various species, a relationship demonstrated by several studies [10].

Climate change can distinctly impact livestock in two main ways: alterations in the quality and quantity of forage from grasslands, and direct effects on livestock due to increased temperatures. While research on the impact of climate change on livestock is relatively limited, available studies emphasize its significant consequences. Extinctions can disrupt fundamental ecological processes, and ongoing environmental changes have triggered biodiversity migration and extinction globally [11]. Projections suggest that significant ecological changes will unfold in the coming decades [12].

Climate change poses substantial threats to biodiversity, including habitat alteration and loss, overexploitation, chemical pollution, invasive species, and burgeoning populations. Forest ecosystems are also susceptible to climate change, resulting in shifts in vegetation patterns and alterations in the frequency, strength, duration, and timing of fire, drought, insect infestations, and pathogen outbreaks. Climate change and atmospheric CO_2 alterations can impact forest structure, function, and species composition. Notably, approximately 100 million people in and around Indian forests derive their livelihoods from the collection and sale of non-timber forest products (NTFPs). Changes in forestry practices can profoundly impact biodiversity, traditional livelihoods, industry, soil and water resources, and subsequently, agricultural productivity [13]. Thus, this study emphasizes the impact of climate change on the forest and agrobiodiversity of the Amarkantak region, shedding light on the relationship between rainfall and the production of agricultural and forest products.

Holistic Action Research and Development (HARD) is a grassroots community organization committed to uplifting the most disadvantaged sectors of society, with a primary focus on the Anuppur and Shahdol districts of Madhya Pradesh. With an outreach spanning over 1 lakh household, HARD envisions a society that is fair and just [14], providing equal opportunities for all individuals to pursue their development. At its core, HARD's mission is to empower marginalized communities, with a special emphasis on scheduled tribal and scheduled caste women. This empowerment is achieved through the mobilization of these communities into self-help groups, amplifying their capabilities and fostering self-sufficiency. The organization is dedicated to encouraging community engagement with local self-governance structures, empowering them to enhance their livelihoods, ensure food security, and ultimately break free from the clutches of poverty. HARD understands the importance of preserving the unique lifestyles of

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people in remote areas while working towards their social and political empowerment through collaboration with Panchayat Raj Institutions and local Community-Based Organizations (CBOs). A central pillar of HARD's objectives is to guarantee food security in tribal regions, striving for a more equitable and prosperous future for all.

Review of Literature

The literature review presented here offers a comprehensive exploration of the varied impacts of climate change on Kotma, a town situated in Madhya Pradesh, India. It delves into multiple dimensions of these impacts, encompassing biodiversity loss, alterations in agricultural productivity, socioeconomic implications, and specific effects on indigenous communities and vital ecosystems. One critical area discussed in the literature is the effect of climate change on biodiversity. The research underscores how shifts in temperature and precipitation patterns disrupt ecosystems, resulting in a loss of biodiversity (IPCC, 2014). This understanding is foundational in gauging the potential threats climate change poses to the abundant biodiversity in Kotma.

A significant focus is directed towards the impact of climate change on agriculture, a vital source of livelihood for Kotma's populace. Alterations in growing seasons, water availability, and extreme weather events are studied for their potential to adversely affect crop yields and food security [15]. These dynamics are pivotal in formulating strategies to ensure agricultural sustainability and address the challenges faced by the community. Furthermore, the review delves into the socioeconomic implications of climate change, particularly in rural areas. It underscores the vulnerability of Kotma's communities, heavily reliant on agriculture and forestry for their livelihoods. Socioeconomic factors, such as income disparities and resource accessibility, are shown to influence adaptive capacity and responses to climate- induced challenges .

The literature also emphasizes the profound connection between indigenous communities like Baiga, Gonds, Panikas, Kol, and Dhanaur, and the forests. Climate change is shown to exacerbate their vulnerabilities and disrupt their traditional ways of life .This underscores the necessity of integrating traditional knowledge and practices into climate change adaptation strategies. Additionally, the review highlights how climate change directly impacts specific elements such as medicinal plants, forest ecosystems, and the availability of non-timber forest products. These impacts are critical to comprehend the intricate relationship between the environment and the livelihoods of Kotma's inhabitants .

Lastly, the literature discusses adaptation and mitigation strategies, emphasizing the imperative of sustainable forest management, climate-resilient agricultural practices, and community-based initiatives. These strategies are viewed as essential for mitigating the adverse impacts of climate change on Kotma and promoting sustainable development [16]. In summary, this literature review provides a thorough understanding of the complex challenges that climate change poses to Kotma. It serves as a foundational platform for further research and the development of effective strategies to address these challenges, ensuring the region's resilience and sustainable development.

Climate and Its Influence on Crops of Madhya Pradesh

Madhya Pradesh, located in Central India, experiences a subtropical climate characterized by distinct seasons. The period from April to June constitutes the hot and dry summer, while July to September marks the monsoon season. The months from November to February are considered the winter months, characterized by cooler temperatures and relative dryness. However, research specific to the climate change impacts in the Kotma area remains limited. [17] conducted a study on the biodiversity impact of climate change in Central India, incorporating certain regions of Anuppur district.reported on the influence of climate change on major food crops in Madhya Pradesh, encompassing crops like rice, wheat, soybeans, maize, and sugarcane. explored the growth and yield response of soybeans to climate change in Madhya Pradesh. investigated the climate change impact on Eastern Madhya Pradesh. The anticipated impacts of climate change include increased water stress, reduced yields in rain-fed grain crops, and a rise in extreme weather events like droughts and floods. [18] focused their study on the climate change impact specifically on soybean production.

Direct Human Impact on Biodiversity Mechanisms

(Source: Adapted from [19, 20])

(a) Overexploitation of natural resources

(b) Expansion of agricultural land, forestry, and aquaculture

(c) Loss and fragmentation of habitats

(d) Indirect adverse effects through the introduction of new species by human activities

(e) Indirect positive effects through the introduction of new species by human activities

(f) Pollution of soil, water, and air

(g) Influence of global climate change

Indirect Mechanisms

(a) Socioeconomic organization of human societies

(b) Population growth

(c) Consumption patterns of natural resources

(d) Global trade and its patterns

(e) Economic systems and policies that lack comprehensive environmental assessment

(f) Inequality in the ownership, management, and equitable distribution of benefits derived from both the utilization and conservation of biological resources.

Forest and Agriculture in Madhya Pradesh

Madhya Pradesh (MP) boasts the highest forest cover in India, with approximately 27% of its geographical area comprising five distinct forest types: (a) southern dry mixed deciduous forest,(b) dry teak forest, (c) northern dry mixed deciduous forest, (d) moist peninsular sal forest, and (e) dry peninsular

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sal forest. The forests of MP are teeming with diverse flora and fauna. The state is divided into 11 agroclimatic zones, with agriculture serving as the backbone of its economy, supporting 71% of the population's income. Notably, about 72% of the cultivated area relies on rain-fed agriculture. Rural poor communities, highly dependent on natural resources such as agriculture and forestry, are significantly impacted by the changes in these sectors (Anonymous, 2017). A study by revealed a concerning decline in the availability of non-timber forest products (NTFPs) in the forests of Madhya Pradesh. This decline raises critical concerns about the sustainability and accessibility of these important resources, particularly for the rural communities that rely on them for their livelihoods. The decline in NTFPs further underscores the pressing need for sustainable management and conservation of forest resources in Madhya Pradesh.

Materials and Methods

The study employed a comprehensive approach to data collection, utilizing both primary and secondary sources to ensure a robust understanding of the impact of climate change on the forest and agrobiodiversity in the Kotma region. The primary data collection involved the use of a well- structured questionnaire specifically designed for this study. This questionnaire targeted farmers and forest dwellers from six distinct locations in the Kotma area, namely, Kotma, Kopra, Anuppur, Funga, Badahar, and Amarkantak. The questionnaire was meticulously crafted to address key aspects related to climate change impact, encompassing parameters such as rainfall patterns, temperature variations, crop production, forest productivity, availability of medicinal plants, and freshwater fishery. By focusing on these critical elements, the primary data collection aimed to capture the nuanced effects of climate change on the ecosystem and livelihoods of the local communities.

Table 1 displays the gender distribution of respondents. Out of the 79 survey participants, 15.18% identified as male (12 individuals), while 84.81% identified as female (67 individuals). There were no respondents in the "Others" category. The data underscores a predominant female representation in the survey.

In addition to the primary survey, secondary data was also harnessed to enrich the study. This included historical data on rainfall patterns and crop production spanning a decade, from 2012 to 2022, sourced from the Department of Land Record Anuppur. The integration of secondary data further augmented the depth of analysis and provided a longitudinal perspective on climate-related trends and their implications on the region. To augment the knowledge base, the research team visited Indira Gandhi National Tribal University (IGNTU) in Amarkantak. This visit was instrumental in gathering pertinent information concerning environmental data and the educational status of tribal communities in the region. The insights garnered from this visit contributed to a more holistic understanding of the social and educational dynamics intertwined with the climate impact.

Crop production in kg/hectare, ha hectare

Source: Department of Land Record Anuppur, Madhya Pradesh.

Study area

Kotma is a significant region situated in the Anuppur district of Madhya Pradesh, India. It is an area rich in natural resources and biodiversity. Located between latitude 22°15′ to 20° 58’ N and longitude 81° 25′ to 20°5′ E, Kotma is characterized by its geographical positioning and climatic conditions. The area is encompassed by dense forests, which are a vital part of the region's ecosystem. The residents of Kotma rely on both agriculture and forest resources for their livelihood. The major crops cultivated in this region include rice, maize, chickpea, wheat, and soya bean. The success of these crops is closely tied to the monsoon patterns, particularly the southwest monsoon. Kotma supports a range of flora and fauna, and the region is also home to various tribal communities, such as Baiga, Gonds, Panikas, Kol, and Dhanaur. These communities have a symbiotic relationship with the forest and agricultural land, depending on them for sustenance and various resources. The region boasts a diverse range of plant species, with a total of 1527 identified flora. Among them, 518 species hold significant value for food and medicinal purposes. Forest produce collection is a notable activity, with products like char (*Buchanania lanzan*), tendu (*Diospyros melanoxylon*), amla (*Phyllanthus emblica*), bel (*Aegle marmelos*), karonda (*Carissa spinarum*), sal leaf (*Shorea robusta*), mohlain leaf (*Bauhinia purpurea*), medicines, dry woods, and fodder being important.

In Table 2, a comprehensive analysis of the agricultural data spanning the last decade illuminates a noteworthy positive correlation between annual crop production and the region's annual rainfall. Particularly, rice (R^2 = 0.3477) emerges as the most rainfall-sensitive crop, showcasing a substantial reliance on adequate precipitation for optimal growth and yield. Following closely is kodo millet (R^2 = 0.2859), emphasizing its vulnerability to rainfall patterns, further emphasizing the critical role of weather in agriculture. Conversely, maize (R^2 = 0.0139) showcases the least sensitivity to rainfall fluctuations, signifying a comparatively lower dependency on this climatic variable. This underscores the fundamental significance of rainfall, a pivotal meteorological element, in governing agricultural productivity. The discernible impact of changing rainfall patterns on crop production underscores the necessity for adaptive agricultural strategies that can effectively navigate and mitigate the repercussions of these climatic shifts on the region's agricultural landscape. Adaptability and sustainable agricultural practices are pivotal in ensuring consistent and optimal crop yields amid evolving climate dynamics.

Result

Climate Change Impact on Agriculture

Climate change is exerting a profound impact on both agriculture and the environment in the Kotma region. The irregularity in rainfall patterns, a hallmark of changing climate, has resulted in direct consequences for both agricultural and forest production. Insufficient rainfall, in particular, has taken a toll on crop yields, affecting staple crops such as rice, wheat, and maize, as well as lac cultivation. The availability of water resources, including dams, rivers, and ponds, has been strained

Table 1. *Percentage of respondents in terms of gender (Gender distribution among farmers).*

S.No	Sex	No. of people responded	Percentage
1	Male	12	15.18%
2	Female	67	84.81%
3	Others	0	0%

Table 2. *Correlation between crop production and rainfall.*

S.No	Year	Rainfall(mm)	Rice	Maize	Kodo	Soyabean	Wheat
1	2012-2013	1518	2336	1246	402	1477	1141
2	2013-2014	1963	1974	1355	597	1244	953
3	2014-2015	1721	2244	1515	613	1368	1496
4	2015-2016	1031	668	1411	320	387	560
5	2016-2017	1139	2172	1398	253	1450	786
6	2017-2018	1349	1754	2893	277	744	3366
7	2018-2019	1210	1402	2343	547	1457	516
8	2019-2020	1477	1309	1145	415	1413	780
9	2020-2021	1100	1167	1237	510	866	617
10	2021-2022	1254	1675	1312	521	1417	717
		R^2 value	0.3477	0.0139	0.2859	0.1564	0.0486

by low rainfall. As a result, water stress has become a pressing concern, with these vital sources facing significant depletion. The effects of these climatic shifts were further illuminated through a comprehensive field survey and questionnaire conducted among the local population.

Figure 1 illustrates the varying responses to rice production over five years, spanning from 2018 to 2022. In 2018, more than half (56%) of the people said rice production was not good. About one- fifth (21%) thought it was okay, and a third (33%) said it was good. In 2019, rice production was so-so. Nearly a third (31%) were unhappy with it, more than half (54%) thought it was okay, and a small portion (15%) thought it was good. By 2020, rice production went down. Most people (77%) said it wasn't good. Only a few (15%) found it okay, and very few (8%) said it was good. In 2021, things were still tough. A lot of people (63%) were unhappy with rice production, some (18%) thought it was okay, and only a few (9%) said it was good. In 2022, it was still hard. Most (61%) said rice production wasn't good. A few (12%) found it okay, and a small group (11%) thought it was good.

Similar trends were seen in maize and wheat production. Figure 2 illustrates the varying responses to maize production over five years, spanning from 2018 to 2022. In 2018, most residents (77%) thought maize production was okay, while a small portion (8%) had a negative view, and 15% considered it good. In 2019, a large majority (80%) saw maize production as okay, 15% didn't think it was good, and only 5% found it good. By 2020, the pattern continued. A big portion (78%) said maize production was okay, 16% had a negative view, and 18% still thought it was good. In 2021, a good number (71%) believed maize production was okay, 18% thought it was not good, and 11% still found it good. In 2022, again, most people (72%) thought maize production was okay, 17% thought it wasn't good, and 12% still found it good.

Wheat production also faced challenges. Figure 3 illustrates the varying responses to wheat production over five years, spanning from 2018 to 2022. In 2018, almost half (46%) reported poor yields for wheat, a smaller portion (23%) saw it as okay, and 21% considered it good. In 2019, the situation worsened with a significant majority (62%) reporting poor wheat production. Only 8% found it okay, and 30% thought it was good. In 2020, a similar pattern continued with a majority (60%) reporting poor wheat production, 10% finding it okay, and 21% considering it good. In 2021, a majority (59%) still reported poor wheat production, 11% found it okay, and 25% considered it good. By 2022, there was a slight improvement. Less than half (41%) reported poor wheat production, 14% found it okay, and 29% considered it good.

Furthermore, traditional food crops like kodo and kutki are nearing extinction, with kodo millet production decreasing by 75% over the past 4-5 years. *Paspalum scrobiculatum* (kodo) cultivation has suffered, and it is no longer considered a primary food crop. Additionally, the freshwater fishery has become exceedingly challenging due to water stress in rivers, ponds, dams, and lakes. Local communities have been grappling with dwindling fish production in these water bodies in recent years.

These findings underscore the urgent need for climate adaptation strategies, sustainable agricultural practices, and conservation efforts aimed at preserving the vital resources of the Amarkantak region while mitigating the impacts of climate change on agriculture and the environment.

Impact on Forest and Forest Produces

The impact of climate change on the forests of Kotma has been profound, particularly on the availability of non-timber forest products (NTFPs). Over recent years, the region has experienced a noticeable decline in the availability of various NTFPs, significantly affecting forest dwellers and their traditional way of life. Wild edible fruits such as char (*Buchanania lanzan*), tendu (*Diospyros melanoxylon*), amla (*Phyllanthus emblica*), bel (*Aegle marmelos*), karonda (*Carissa spinarum*), and bhelwa (*Semecarpus anacardium*) have seen a sharp decrease in production.

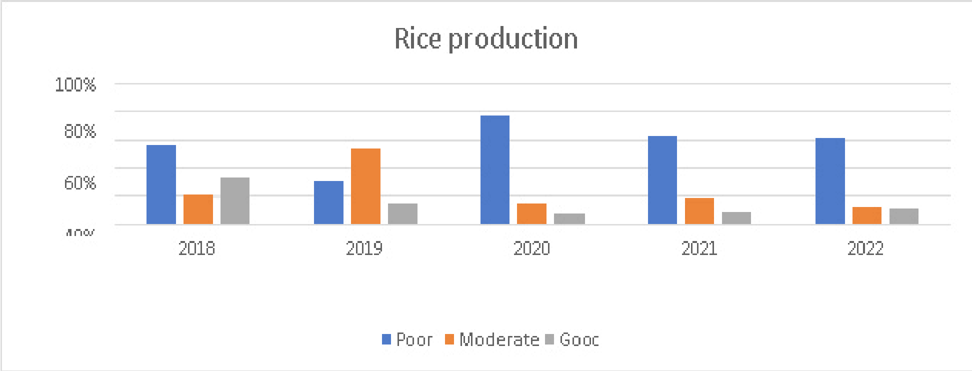

Figure 1. *Rice production response.*

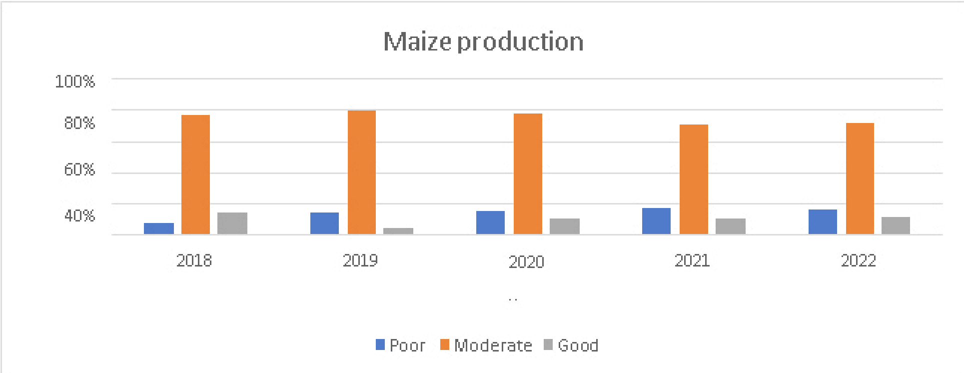

Figure 2. *Maize production response.*

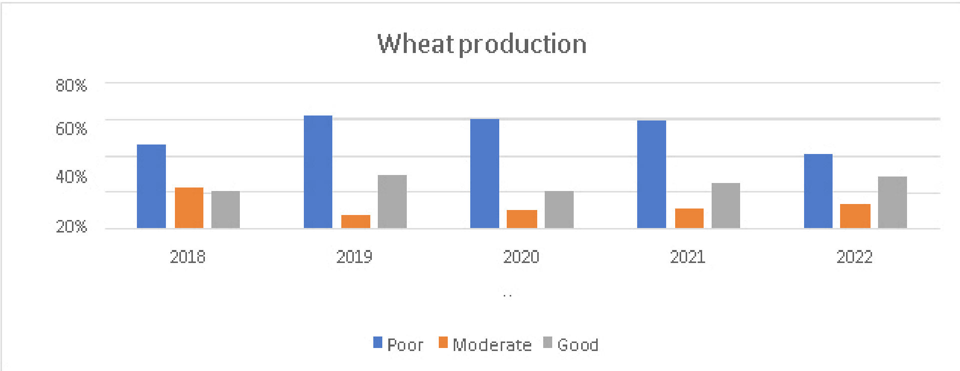

Figure 3. *Wheat production response.*

The forest ecosystem has been strained by multiple factors, including forest fires and overexploitation. The incidence of forest fires has not only caused direct damage but has also led to the depletion of important medicinal plants. For instance, Pterocarpus marsupium (beeja), a renowned medicinal plant has become scarce, primarily found in limited parts of the forest in Amarkantak.

Another critical concern is the dwindling water resources. Rainfall patterns have shifted, resulting in decreased water availability in the region. Water bodies such as rivers, dams, and wells are facing acute water shortages, impacting both the ecosystem and the communities relying on them. The groundwater table is steadily declining, necessitating deeper bore wells and hand pumps for access. Several water resources have become extinct, and others have transitioned into seasonal water sources.

The combined effects of these climate-induced changes are posing significant challenges to the forest ecosystem, the livelihoods of forest-dependent communities, and the overall sustainability of the region. Addressing these impacts requires urgent and concerted efforts, including sustainable forest management practices, forest fire prevention measures, water conservation initiatives, and community-led strategies aimed at adapting to the evolving climate while preserving invaluable forest resources.

Discussion

The study presented provides a comprehensive overview of the climate-induced challenges profoundly affecting the Kotma region. These challenges primarily manifest in the agriculture sector, water resources, and the forest ecosystem. Understanding the intricate details of these challenges is essential to formulate proactive strategies that effectively mitigate and adapt to the altering climate patterns.

Agricultural Resilience and Diversification: The irregular rainfall patterns have considerably impacted crop yields, endangering food security in the region. Staple crops like rice, maize, wheat, and millet have experienced a decline in production due to this irregularity. To bolster agricultural resilience, it is imperative to diversify crops and adopt climate-smart farming practices. Crop diversification can help mitigate the risks associated with heavy dependency on a few staple crops and make the agricultural sector more adaptable to varying climate conditions.

Water Resource Management and Soil Health: The decrease in rainfall has led to a severe strain on water resources, including dams, rivers, and ponds. Additionally, the issue of aluminium toxicity in soil due to water scarcity exacerbates the agricultural challenge. Implementing efficient water resource management practices and improving irrigation channels are critical steps to address this water stress. Furthermore, interventions to mitigate aluminium toxicity in soil, such as appropriate soil treatments and amendments, are essential to maintain soil health and crop productivity.

Sustainable Forest Management and Biodiversity Conservation: Climate change has emerged as a significant threat to the forest ecosystem and biodiversity in the Kotma region. The decline in non-timber forest products (NTFPs) availability and the occurrence of forest fires disrupt the delicate ecological balance. To ensure sustainability, forest management practices need to be in harmony with climate resilience goals. Preservation of medicinal plants and the overall biodiversity, alongside implementing measures to prevent forest fires, is vital for the region's ecological stability and the welfare of forest-dependent communities.

Community Involvement and Awareness: The active involvement of local communities is pivotal in driving sustainable practices and promoting climate-resilient strategies. Education and awareness programs can empower communities to adopt adaptive farming practices, reforestation initiatives, and water conservation efforts. Furthermore, fostering a sense of ownership and responsibility within communities will promote long-term sustainable practices that align with the climate adaptation goals.

Integrated Approach for Climate Mitigation: To combat the multifaceted challenges posed by climate change, an integrated approach is necessary. This entails combining conservation efforts, afforestation initiatives, and sustainable agricultural practices. The diversification of crops and the adoption of agroforestry models can mitigate the risks associated with mono-cropping, ensuring a more sustainable and climate-resilient agricultural landscape. Additionally, addressing water scarcity through a combination of water conservation strategies and improved irrigation channels will be fundamental for agricultural productivity and community well-being.

In conclusion, addressing the pressing challenges posed by climate change in the Kotma region necessitates a holistic approach. Sustainable practices, community engagement, and conservation efforts should be central components of any strategy aimed at enhancing resilience and ensuring a sustainable and secure future for the region amidst the changing climate. Continuous research, informed decision-making, and collaboration among stakeholders will be vital in refining and implementing effective mitigation and adaptation strategies.

Conclusion

Climate change presents a complex scenario in the Kotma region, showcasing a blend of detrimental and partially positive impacts. The study underscores the intricate relationship between climate shifts and various aspects of the environment and livelihoods. Agricultural productivity has suffered notably, with staple crops like rice, maize, wheat, and soya beans witnessing a decline in output due to erratic rainfall patterns and heightened temperatures. This directly threatens the livelihoods of communities dependent on agriculture. Additionally, the reduction in forest resources and the heightened vulnerability of the ecosystem due to forest fires highlight the vulnerability of the region's biodiversity. Water scarcity has emerged as a significant concern, affecting both surface and groundwater resources, and consequently impacting daily life. It is imperative to prioritize conservation efforts, sustainable practices, and community engagement to navigate the challenges posed by climate change effectively. Understanding the nuanced impacts of climate change is pivotal for developing targeted strategies that ensure resilience and a sustainable future for the region. Ongoing research and continuous monitoring will play a critical role in guiding adaptation and mitigation efforts**.**

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Citation: *Harika A., Banavath NS. Climate change impact on forest and agrobiodiversity: A special reference to anuppur district, madhya pradesh. J AgricSci Bot. 2023; 7(5):196*