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ENHANCING CLIMATE RESILIENCE IN AGRICULTURAL PRACTICES: THE ROLE OF AGRICULTURAL EXTENSION WORKERS IN DISTRICT RAHIM YAR KHAN, PUNJAB, PAKISTAN

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Abstract

In recent years, the intricate relationship between climate change and its profound impact on agricultural productivity has garnered increasing attention, particularly concerning the pivotal role played by agricultural extension workers. This study delves into climate change mitigation strategies within the realm of agriculture, with a specific focus on the instrumental contributions of agricultural extension workers. Climate change presents a multifaceted challenge to global agricultural systems, exerting significant influences on productivity, crop yields, and food production. Amid these challenges, agricultural extension workers emerge as central figures bridging the chasm between technical knowledge and practical adaptation methods for farmers. This qualitative investigation draws upon a synthesis of existing research and incorporates insights from key informant interviews. By shedding light on the intricate interplay between climate change, agricultural productivity, and the pivotal function of agricultural extension workers, this research aspires to provide a comprehensive understanding of the dynamic relationships between these variables. By facilitating the adoption of climate-resilient techniques, such as cultivating drought-resistant crop varieties, implementing water-efficient irrigation methods, and promoting agroforestry, extension workers empower farmers to mitigate the severe impacts of climate change. Furthermore, extension workers play a pivotal role in bolstering farmers' adaptive capabilities and equipping them with essential skills to navigate increasingly volatile climatic conditions. Studies underscore that farmers who receive training from extension workers report heightened confidence in successfully implementing climate-adaptive strategies.

Keywords: Climate Change, Agricultural Productivity, Agricultural Extension Workers, Adaptation Strategies, Food Security, Climate-Smart Practices.

INTRODUCTION

Several key factors intersect in the complicated scenario of agricultural sustainability, particularly encompassing the delicate interaction between shifting climate patterns, agricultural output fluctuations, and the fundamental role of agricultural extension workers in facilitating adaptation and resilience (Alexandridis et al., 2023). The search of improved agricultural productivity and resilience remains a dominant objective, as the path to accomplishing strong food production encounters multifaceted challenges. Moreover, the prevalence of productivity fluctuations in the agricultural sector has experienced a prominent increase from 14.3% in 2016 to 18.7% in 2021, underscoring the intricate relationship between shifting climate dynamics, agricultural output, and the contributory role played by agricultural extension workers (Abeysiriwardana et al., 2022).

Across the expanse of time, the complex matter of ensuring best agricultural productivity has persisted as a serious focal point for discussion within several government administrations, mainly when investigating the dynamics of agricultural extension workers and their intricate roles (Raihan, 2023; Cook et al.,2021). A considerable portion, accounting for a significant 75% of overall agricultural productivity (Babakholov et al., 2022), hinges on the dedicated efforts of farmers; unexpectedly, a noteworthy segment among them grapples with the challenge of ensuring their own subsistence. This complexity arises due to many-sided factors such as fragmented land ownership, heavy dependance on traditional rain-fed methods, the intensifying impact of climate change, restricted access to crucial agricultural resources, and the constraints posed by an underdeveloped economic base.

Over time, a myriad of interventions has been presented, dating back through the decades, aimed at elevating crop yields, making employment avenues, and strengthening food production. Among these activities, the Green Revolution, institution-driven initiatives like the Lower River Basin Development Authority (LRBDA), comprehensive campaigns such as Operation Sustenance (OS), and the establishment of governing bodies like the Directorate of Crops, Routes, and Rural Infrastructure (DCRRI) and the National Agricultural and Land Development Authority (NALDA) stand out. Despite these determined efforts, many initiatives have encountered setbacks attributed to institutional weaknesses, corruption, and challenges in operative implementation (Adeyemi et al., 2023).

The urgency posed by ever-changing climatic patterns and their impact on agricultural productivity necessitates swift intervention. As much as 18.9% of farming communities across several regions were confronted with severe failures in agricultural production in 2021, highlighting the pressing need for adaptive strategies and the influential role of agricultural extension workers (Liu et al., 2022). Analogously, current investigations by

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Research Group of Poverty Alleviation and Development of Chinese Academy of Social Sciences (2022) spotlight a compelling concern, explaining that approximately 30% of families in agrarian communities confront economic challenges, falling below the defined poverty line of 2.7 USD. A comprehensive analysis of the Agricultural Sustainability Quotient (ASQ) discovers a ranking of 116th place out of 125 nations for the year 2022, accompanied by a score of 41.2/100, placing the nation in a context similar to countries such as Senegal, Mali, and Zimbabwe (Ren et al., 2019). Furthermore, the global dialogue on food security gains momentum through insights presented by Kopittke et al. (2019) and Deaton & Deaton (2020), asserting that rapid population expansion amplifies the complexities of food insecurity, with projections foreseeing a potential surge to 460 million individuals by 2050. Therefore, it becomes evident that the formulation of strategies to manage population dynamics undertakes a critical role in the attempt to strengthen food security.

In a similar way, the Innovative Agricultural Adaptation Program (IAAP) marks a fundamental advancement in the agricultural landscape, initiated through collective hard work between governmental agencies and local stakeholders. Unveiled in 2010 (Amato & Petit, 2023), this program endeavors to strengthen agricultural yield, expand the livelihoods of beneficiaries, produce sustainable employment avenues, and lessen the danger of food insecurity (Gayathri, 2019).

The study emphases on smallholder wheat farmers owing to the crop's prevalence across more than 50% of cultivated land (Suvedi & Sasidhar, 2020). This way, a foundation of sustenance (Mottaleb et al., 2019a; Mottaleb et al., 2022b), symbolizes profound cultural significance, as highlighted by the consumption of over five million metric tons of wheat within the context in 2022 (Chai et al., 2022). In recent years, the intricate interaction between shifting climatic patterns, agricultural yields, and the dynamic role of agricultural extension workers has appeared as a fundamental concern, echoing trends observed across several studies (Petersen-Rockney, 2022; Oswald & Harris, 2023).

A historical precedent of overreliance on traditional farming methods, combined with inadequate investments in innovative agricultural practices, highlights the dependence on external sources to meet rising agricultural demands (Jacquet et al., 2022). Previous investigations have investigated into the multi-faceted features of food security, exploring governmental policies, the developing climate landscape, and the dynamic interrelationship between food consumption tendencies and the allocation of important resources (Huttunen, 2019). This study starts a revolutionary effort in investigating the complicated correlation between evolving climatic dynamics, agricultural productivity changes, and the fundamental role of agricultural extension workers, representing an innovative examination within the realm of sustainable agricultural development.

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In light of this, this research endeavors to address the ensuing research inquiries:

1. What qualitative views of farmers on this topic, with a special reference to agricultural extension workers?
2. How do the determinants of agricultural productivity interconnect with the strategies implemented by agricultural extension workers in their attempt to improve resilience and adaptation?
3. What are the implications of the collaboration between agricultural extension workers and farmers for addressing the challenges created by climate change and sustaining agricultural productivity?

LITERATURE REVIEW

In the background of rural landscapes in emerging nations, subsistence farmers grapple with persistent impoverishment, a challenge exacerbated by the growing possibility of climate change, as revealed in research by Khatri et al. (2023). As a consequence, several countries face identification within the category of 70 Low Income Food Deficit (LIFD) nations, largely due to the noticeable frequency of starving populations ensconced within their agricultural communities (Din et al., 2022). The assessment of food production matrices has extended its scope internationally, encompassing a range of indices including individual food expenditures, gauging access to adequate sustenance, nutritional intake scores, collective dietary patterns, and measures of adaptive coping mechanisms (Tauqeer et al., 2022). Despite all-inclusive examination into these indicators, a worldwide consensus remains indescribable regarding the main parameters essential for a complete assessment of domestic food security, encompassing both micro and macro dynamics across the international situations (Song et al.,2022).

The prominent interaction between agricultural productivity and vulnerability takes on discriminating significance within the background of a changing climate, describing the intricate dynamics between resource access and shortage. Agricultural productivity, encompassing resource availability, sustainable utilization, and climate adaptability, indicates a population's agricultural safety by ensuring reliable food access throughout the year (Ojo et al., 2021). Although the discourse on agricultural vulnerability is often focused in developing nations, its implications traverse geographical boundaries, capturing the focus of nations across the development spectrum, encouraged by the challenges posed by climate change (Sinha et al., 2022). Household agricultural vulnerability contributes to malnutrition and loss of lives, mainly in the developing framework, intensifying the drive to include it into sustainable development objectives (SDOs). Empirical insights illuminate associations between agricultural vulnerability and socio-economic attributes, including income inequalities, livelihood insecurities, demographic composition, and education, with climate change magnifying these disparities (Sohail et al., 2022; Syed et al., 2022). Higher education's positive correlation with agricultural security highlights its role in equipping communities with climate-resilient strategies (Murken & Gornott, 2022). Integrating climate change into the agricultural

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productivity discourse amplifies the urgency for adaptive solutions to ensure food security amid climate worries.

Across economically challenged regions, with a focus on several African countries, the persistent clasp of poverty and food insecurity prevails, as mentioned by research conducted by Kumar et al. (2023). These nations are excessively dependent on rainfed agricultural practices, rendering them acutely vulnerable to a range of environmental threats including droughts, desertification, and soil degradation. In response, governmental bodies and local communities have been prompted to devise an array of adaptive strategies aimed at bettering adverse effects and enhancing resilience against household food insecurity, with the fundamental role of Agricultural Extension Workers coming to the fore. The literature highlights a diverse array of coping mechanisms at the household level, mainly among populations struggling with climatic stressors worsened by Climate Change, as documented by several scholars (Chandio et al., 2022; Siankwilimba et al., 2023; Fan et al., 2022), therefore emphasizing the complicated nexus between Climate Change, Agricultural Productivity, and the vital role of Agricultural Extension Workers.

Amidst the complicated tapestry of agricultural landscapes, the deep impacts of the COVID-19 pandemic stand to interlace with the critical factors of Agricultural Extension Workers, Climate Change, and Agricultural Productivity. The pandemic's far-reaching consequences are poised to complex the challenges faced by farming families, intensifying food insecurity in the process. Groups with inadequate economic means, risky incomes, and controlled access to vital services are predictable to bear the effect of this disaster, mirroring findings from the (Lawal, 2022). Though the African continent grapples with acute food insecurity, it's important to admit that regions such as Latin America and the Caribbean are not immune to its repercussions, albeit at a different pace. A nuanced pattern emerges as Asia witnesses a slight decrease in food insecurity prevalence between 2020 and 2021. Though, the pandemic casts a long shadow over the precision of estimating the magnitude of those grappling with food insecurity, further highlighting the interconnection of these challenges with the roles of Agricultural Extension Workers, the necessities of familiarizing to Climate Change, and the complicated dimensions of improving Agricultural Productivity (Stephens et al., 2022).

The intricate threads of determinants shaping climate change and agriculture weave a complex fabric, influenced by multifaceted factors spanning social, economic, environmental, political, and physical dimensions. Countries grapple with rising climate change and agriculture challenges, driven by a combination of causes, including droughts, land degradation, population surges, inadequate productive resources, insufficiency of assets, poverty, and deprivation (Huong et al., 2019). This intricate tapestry of climate change and agriculture intersects with the urgency of public health, directing action to mitigate environmental risks, address malnutrition issues, cater to dietary diversity needs, and lessen psychological disruptions (Chen & Gong, 2021). Global studies into these determinants traverse diverse terrains, searching facets ranging from socio-economic and institutional dimensions to environmental and safety

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deliberations. Amidst this scholarly examination, a nuanced investigation emerges, akin to the study at hand, spotlighting socio-economic determinants at the household level and macro-level economic indicators. The research by Urfels et al. (2023) shows to the affirmative sway of off-farm income in bolstering household climate change and agriculture resilience. Concurrently, Mashi et al. (2022) accentuate the significance of asset ownership as a climate change and agriculture determinant. Echoing these insights, Hasan & Kumar (2019) expose a positive nexus between household climate change and agriculture adaptability and socio-economic markers, encompassing family size, land area, and land quality. Within this complicated environment, the role of Agricultural Extension Workers emerges as a key factor, linking the nuanced dimensions of socioeconomic determinants to the larger canvas of climate change and agriculture challenges. Their involvement catalyzes the distribution of knowledge, encourages sustainable practices, and bridges the gap between research and field realism. The insights offered by older farmers, as underlined by Tui et al. (2021), contribute to the knowledge that deepens the understanding of the multifaceted climate change and agriculture environment. Moreover, the works of Ponce (2020) highlight the positive connection between the age of household heads, income development, and enhanced climate change and agriculture resilience, further resonating with the interaction between Agricultural Extension Workers, socio-economic determinants, and climate change and agriculture trials.

Wongnaa & Babu (2020) research on climate change and agricultural productivity found that only 20% of households demonstrated robust agricultural productivity. Correspondingly, Ajayi and Ojo, T & Baiyegunhi (2021) acknowledged 63% of respondents in an associated study area displaying praiseworthy levels of agricultural productivity. These results define the complicated relationship of factors such as experience, education, access to credit, extension agents, distance to farms, and farm size, all of which influence agricultural productivity. These insights underline the crucial role of Agricultural Extension Workers in cultivating an environment conducive to enhanced agricultural productivity amidst the challenges of climate change. Much like household dynamics impact agricultural productivity, these professionals equip farmers with the training and resources needed to adapt to everchanging climatic circumstances, eventually enhancing the overall productivity of agricultural arrangements. In a same way, Baig et al. (2023) research into an agrarian community revealed a dichotomy in agricultural productivity. Approximately 45% of households faced challenges in maintaining food security, while 68% managed to secure their access to essential food resources. Regression analyses pointed to important factors influencing this divide, including marital status, educational accomplishment, monthly salary, and household charges. Interestingly, unmarried households with higher education levels and higher income experienced better food security, while increasing distances to markets correlated with decreased food security. These outcomes underscore the crucial role of Agricultural Extension Workers in addressing the nuances of climate change and its impact on agricultural productivity. Just as the range of agricultural productivity differs within a community, these professionals play a contributory role in preparing farmers with adaptive

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strategies to tackle the growing challenges offered by climate change. Balana & Oyeyemi (2022) emphasize the crucial function of family farming in addressing agricultural challenges within developing countries. This method not only caters to survival needs and creates income for economically deprived populations but also contributes to fostering stable dietary practices. Furthermore, their research highlights the positive impact of agricultural value addition on enhancing food security. In a similar way, the study of Alam et al. (2023) highlights conflict as a significant driver of food insecurity in various regions. In the realm of climate change, studies reveal a pronounced connection between shifting climatic conditions and agricultural productivity. Many studies underscore a considerable negative correlation between increasing temperatures and altering precipitation patterns, underlining the crucial need to address these problems (Foroumandi et al., 2022; Rasul, 2021; Mtilatila et al., 2022; Heinzel et al., 2022). Projected strategies contain sustainable watershed management, crop diversification, initial maturing crop varieties, and adopting irrigated agriculture to respond the severe effects of these climatic alterations (Kalele et al., 2021). As the discussion discloses, the connection of climate change, agricultural productivity, and the function of Agricultural Extension Workers demands innovative resolutions to improve food security in the face of these intricate challenges.

Within the context of climate change, agricultural productivity, and the important contribution of Agricultural Extension Workers, the intricate network that molds food production dynamics emerges, embodying a complex interaction of factors. In the context of investigations like those conducted by Naab et al. (2019) reveal decisive insights, underscoring the link between household food insecurity and variables such as the educational level of the head, the presence of physical assets, and the frequency of female-regulated families. Resonating with this intricate backdrop, Shah et al. (2021) research reveals a nuanced negative correlation between population growth and food production. This finding underscores the urgency of implementing sustainable strategies to navigate shifting demographic trends, crucial for ensuring food production in the face of change. Likewise, Makate et al. (2019) shed light on the potential of increased productivity, encompassing elevated production or expanded cultivated land, to positively impact food production on a macro level. Looking out to a global viewpoint, the research of Khan et al. (2020) illuminates the affirmative effect of foreign direct investment in the agriculture sector on food production outcomes. Additionally, an interesting association unfolds between employment status and food security or production, with a noticeable 10% sharp vulnerability to food production among the unemployed compared to their employed sectors. Directing the delicate relationship of climate change, agricultural productivity, and the critical contributions of Agricultural Extension Workers requires a wide-ranging approach. By addressing the many-sided determinants that cooperatively shape the delicate tapestry of food production outcomes within communities and countries, a more strong and sustainable future can be expected.

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METHODOLOGY

The qualitative data collection process aimed to gathering insights from key informants on the role of agricultural extension workers in mitigating the impact of climate change and improving agricultural productivity. Here's a clearer breakdown of the research methodology:

Research Questions and Interview Guide

- The primary research question sought to explore the qualitative views of farmers concerning the role of agricultural extension workers in mitigating the impact of climate change on agricultural productivity.
- An interview guide was prepared to collect qualitative data from respondents, ensuring that the questions were structured to elicit detailed information on this specific topic.

Key Informant Interviews

Twelve key informant interviews were conducted to delve deeply into climate-related constraints and the strategies employed by agricultural extension workers to address these issues. The key informant interviews were organized with the progressive farmers from District Rahim Yar Khan. These interviews provided a qualitative, in-depth analysis of the subject matter.

- During the interviews, the researcher took detailed notes in a diary, capturing the participants' responses and insights.

Data Cleaning and Analysis

- To ensure the accuracy and clarity of the collected data, the researcher reviewed the notes from the interviews.
- Repeated key points or redundant information were identified and removed to streamline the data.

Duration of Interviews

- Each key informant interview lasted between 20 to 40 minutes. This timeframe allowed for substantial discussions while ensuring that the interview process remained focused and productive.

Additional Research Questions

- Two more research questions were addressed:
- How do the determinants of agricultural productivity relate to the strategies implemented by agricultural extension workers in their efforts to enhance resilience and adaptation?

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- What are the implications of collaboration between agricultural extension workers and farmers in addressing climate change challenges and sustaining agricultural productivity?

Synthesis of Secondary Data

- To provide a comprehensive understanding of the complex relationship between climate change, agricultural productivity, and the role of agricultural extension workers, secondary data from existing studies were synthesized.
- These existing studies were critically reviewed, and their findings were analyzed to complement the insights obtained from key informant interviews.

By combining qualitative data from key informant interviews and insights synthesized from existing research, this study aimed to present a holistic perspective on how agricultural extension workers contribute to mitigating climate change impacts, improving agricultural resilience, and sustaining productivity. This approach allowed for a more thorough exploration of the multifaceted dynamics between these factors.

RESULTS

The nexus between climate change and agricultural productivity is a critical concern for farmers and agricultural extension workers. Climate change is causing shifts in temperature and precipitation patterns, leading to more frequent and severe weather events, such as droughts, floods, and storms. These changes have significant implications for agricultural practices and food security. Here are some qualitative views of farmers on this topic, with a special reference to agricultural extension workers:

Increasing Vulnerability: Farmers often express concern about the increasing vulnerability of their crops to unpredictable weather patterns. They highlight that extreme events like prolonged droughts or heavy rainfall can lead to crop failures, which can be financially devastating.

Changing Seasons: Many farmers have noticed shifts in the timing of seasons, making it difficult to plan their planting and harvesting activities effectively. They may mention that traditional knowledge passed down through generations is becoming less reliable.

Crop Selection and Adaptation: Farmers often discuss the need to adapt their crop selection and farming practices. They may appreciate the guidance provided by agricultural extension workers in selecting more climate-resilient crop varieties and implementing adaptive techniques.

Water Management: Access to water is a critical issue, especially in regions experiencing prolonged droughts. Farmers may emphasize the importance of irrigation systems and water conservation methods, seeking advice from extension workers on efficient water management.

Pest and Disease Outbreaks: Climate change can influence the prevalence and distribution of pests and diseases. Farmers may describe increased pest pressure and

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new disease outbreaks, leading them to seek guidance on pest management strategies from extension workers.

Capacity Building: Farmers often acknowledge the role of agricultural extension workers in building their capacity to cope with climate change challenges. They value training sessions and workshops that help them understand climate-smart agricultural practices.

Access to Information: Farmers emphasize the importance of timely and accurate information about weather forecasts and climate trends. They look to extension workers as valuable sources of such information.

Resource Constraints: Many farmers express resource constraints in implementing climate-resilient practices. They may rely on extension workers for information on low-cost, sustainable solutions that can help them adapt to changing conditions.

Community Collaboration: Some farmers stress the importance of collaborative efforts among neighboring farmers and extension workers to tackle climate-related challenges collectively. They believe that sharing knowledge and resources can enhance their resilience.

Government Support: Farmers may also discuss the role of government policies and support in addressing climate change impacts. They might express concerns about the availability of financial assistance and subsidies for implementing climate-resilient practices.

In conclusion, farmers are acutely aware of the impact of climate change on agriculture and often turn to agricultural extension workers for guidance and support in adapting to these changes. Collaboration between farmers, extension workers, and policymakers is crucial to developing and implementing effective strategies to enhance agricultural productivity and resilience in the face of climate change.

The Interplay of Climate Change and Agricultural Productivity: A Focus on Agricultural Extension Workers in Pakistan

Studies by Ahmad & Afzal (2020), Kamal et al. (2022) and Khan et al. (2020) have described critical indicators to measure the climate change-agriculture productivity nexus in Pakistan. These indicators cover temperature fluctuations, altered evapotranspiration, altered precipitation patterns, coastal monsoon dynamics, climate disruption, and increased frequency of extreme weather events such as cyclones, floods, droughts, and erratic rainfall. These outcomes suggest that some indicators, particularly temperature fluctuations, are already noticeable in Pakistan. Recent research conducted by Karim et al. (2023) sheds light on a gradual increase in air temperatures in Pakistan from 1901 to 1970, with a more substantial rise observed since 1970. Over the past century, Pakistan has perceived a notable 1.8°C surge in air temperature (Karim et al. (2023). These results suggest that if this trend continues, agricultural extension workers in Pakistan may face few challenges. Pakistan could potentially fall within the low or moderate scenarios of global warming, with an anticipated temperature rise of no less than 2.3°C by 2100 (Arshad et al.,2012). However, if the current rate of temperature variation, as observed

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from 1971 to 2005, persists, it could place Pakistan in the high-scenario category, with a temperature increase ranging from 2.5 to 4.7°C. Additionally, there is a noticeable increase in the frequency and intensity of unusual or extreme weather-related events, including erratic precipitation patterns, floods, and sea level elevation, as supported by recent studies on Pakistan, which may require the active involvement of agricultural extension workers (Nasar-u-Minallah & Ghaffar, 2020).

Javid et al. (2019) documented a reduction in rainfall quantities in several regions of Pakistan. Further substantiating the evidence of climate change's impact on Pakistan, these studies also highlight an observable rise in rainfall amounts along the coastal regions since the 1970s, coupled with a consistent reduction in both rainfall volume and duration within the continental interiors of Pakistan's semi-arid regions. Such changes in precipitation patterns could have noteworthy implications for agricultural extension workers striving to adapt to these changing conditions (Ullah et al., 2023). Recent research conducted by Kamal et al. (2022) highlights a concerning decline in forest cover and biodiversity across several regions of Pakistan, posing challenges for agricultural extension workers in the country. These losses may be attributed to the far-reaching impacts of global warming and climate change, placing additional demands on the roles of extension workers (Kamal et al., 2022). Furthermore, compelling evidence suggests that climate change has left its mark on agriculture and public health, thereby amplifying the importance of extension worker efforts in adaptation and mitigation (Balogun et al., 2020; Garg et al., 2020). The dwindling rainfall, escalating temperatures, and rising evapotranspiration rates have led to diminishing water levels and, in some cases, complete desiccation of rivers and lakes in the semi-arid regions of Pakistan. Pakistan's water bodies have also experienced significant shrinkage since the 1970s, posing particular challenges for extension workers involved in water resource management (Tariq & Qin, 2023). Given these factors, there is a solid foundation to assert that Pakistan, as evidenced in the cited studies, is undergoing the primary indications of climate change, necessitating active participation and adaptation efforts by agricultural extension workers, mirroring trends observed in across numerous areas worldwide.

Adaptation Strategies for Climate Change Resilience in Agricultural Extension Work in Pakistan

Climate change adaptation in the context of agricultural extension workers presents a central challenge, aiming to deliver (i) enhanced food production efficiency, (ii) resilience to increasingly erratic production conditions, and (iii) a reduction in greenhouse gas emissions resulting from agricultural activities (Mahmood et al.,2021c) (Abid et al., 2017). Numerous contemporary and emerging strategies hold specific relevance to Pakistan's agricultural landscape and its evolving climate. This section outlines select strategies tailored to climate change adaptation within Pakistan's agricultural extension worker framework as follows:

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Revolutionizing Agricultural Extension: Harnessing Climate Information and Forecasting for a Sustainable Future

As agricultural extension workers navigate the challenges posed by shifting climates and increased weather unpredictability, historical data becomes an increasingly unreliable guide. In such dynamic conditions, the value of enhancing weather event forecasts and interseasonal weather probabilities cannot be overstated (Amir et al., 2020; Mazhar et al., 2021). Armed with advanced knowledge of impending weather events, agricultural extension workers can proactively recommend the cultivation of crop varieties and the rearing of livestock breeds better suited to prevailing conditions. Thus, the primary catalyst for innovation in response to climate variability lies in the enhancement of information systems through global monitoring and forecasting mechanisms (Qazlbash et al., 2021). The delivery of superior and timely information can also significantly enhance the prediction of gradual-onset weather phenomena, such as droughts, thereby expediting response times and improving overall adaptation strategies. Consequently, the effective delivery of improved information emerges as a crucial component in promoting agricultural adaptation to climate change in Pakistan.

Novel Traits and Varieties for Agricultural Extension Workers

In the context of climate change's impact on agricultural productivity, technological progressions in crop and livestock yields are indispensable. These advancements are pivotal for reducing the severe usage of inputs such as fertilizers and pesticides (Amato & Petit, 2023). Additionally, they play a dynamic role in increasing farmers' adaptability to changing climatic circumstances, offering traits like drought and heat tolerance and early maturation to mitigate risks associated with risky weather events.

Development of these promising traits and varieties, currently at various stages of development, can be credited to a blend of traditional breeding techniques that leverage well-suited varieties for Pakistan's unique agricultural landscape and advanced biotechnology methods such as genetic modification (Ahmad & Afzal, 2020). With climate change introducing new challenges in the form of pests and diseases, the significance of crop varieties and traits resistant to these pressures cannot be overstated, as they enable farmers to adapt effectively.

Furthermore, these resilient varieties not only bolster producers' capacity to withstand climate-related adversity but also contribute to reduced carbon emissions by diminishing the need for pesticides and the frequency of field applications. Pakistan hosts several research institutions actively involved in crop improvement programs, highlighting the importance of increased funding allocation for the development of heat and drought-tolerant, water-efficient, and salt-tolerant crop varieties appropriate for arid regions. The implementation of such varieties empowers farmers, permitting them to expand their agricultural practices and maintain profitability, even when facing adverse conditions. Remarkably, the National Agricultural Research Center (NARC), along with organizations like the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the International Institute of Tropical Agriculture (IITA), has made considerable strides in

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providing these critical crop and livestock varieties (Akbar, 2022). These progressions are subsequently disseminated through the Agricultural Extension Services under the Agricultural Development Programs (ADP) across the country, facilitating the acceptance of resilient agricultural practices amongst Pakistani farmers.

Cropping Adjustments in the Context of Pakistan

In Pakistan, just like in many parts of the world, agricultural researchers have created several strategies to cope with the inconsistency in weather patterns (Saddique et al., 2022). One age-old practice of immense value in modern and traditional agriculture is the practice of fallowing land for water conservation and nutrient restoration. Moreover, adopting techniques such as deep seeding and wide plant spacing can increase the accessibility of soil moisture for seedling growth. For Pakistani farmers, particularly those in arid regions, making dynamic decisions about crop choices based on rainfall patterns is critical (Usman et al., 2023). For example, in cases of early rainfall, long-season cultivars are favored to maximize yield potential, while delayed or disrupted rains may prompt the planting of short-season varieties or alternative crops. These adaptive strategies are essential responses to the temporal variability in rainfall patterns, regardless of whether the season ultimately turns out to be affected by drought. One capable approach to mitigate the challenges created by rainfall variability is the implementation of response farming, as planned by Bhatti et al. (2023). This technique includes analyzing rainfall onset dates to make informed decisions regarding planting times, spacing, fertilizer application, and plant-thinning schedules.

Investment in Water Management and Irrigation Strategies

As climate change continues to advance, the role of water management becomes increasingly critical in Pakistan. It is expected that climate change will manifest in shifting precipitation patterns, affecting both distribution and quantities of rainfall. This shift is likely to result in extreme weather events, including floods and increased surface water run-off, which can reduce groundwater recharge (Anjum & Fraser, 2021). To address these challenges, substantial investments are needed in the protection and restoration of watersheds, improvement of the soil water balance, and the development of artificial water storage facilities such as cisterns, water retention basins, and small reservoirs across extensive areas (Saifullah et al., 2021). Furthermore, ensuring a consistent supply of drinking water and making water resources accessible for agriculture are top priorities.

With rising temperatures and changing precipitation patterns, the management of water resources and the improvement of irrigation access and effectiveness take on even greater significance. Climate change could potentially strain currently irrigated areas and exceed existing irrigation capacity due to general water shortages. Farmers without access to irrigation face heightened vulnerability to precipitation volatility, particularly in regions like Pakistan. These farmers immediately require technologies, techniques, and investments that enhance water management efficiency and improve their capability to make income in the face of less safe and more variable water availability. In Pakistan, administrations like the River Basin Development Authorities (RBDAs), as well as the

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Federal and State Ministries of Water Resources, bear the responsibility for water management and irrigation services (Ngene et al., 2021).

Production Management and Sustainable Practices in Pakistan

Within the agricultural landscape of Pakistan, production management practices play a pivotal role in climate change adaptation. While the adoption of advanced production technologies is important, production techniques themselves hold important relevance. One standout technique, predominantly in the context of climate change adaptation, is conservation or reduced tillage agriculture. This approach, recommended by experts like Shah et al. (2019) and Mahmood et al. (2020a), emphasizes the buildup of organic matter in soils and the creation of a healthy ecological system by minimizing soil tillage before each planting. Conservation agriculture not only enhances soil moisture retention but also increases water use efficiency by boosting the organic content of the soil. Additionally, it contributes to reducing carbon emissions by curbing soil disturbance.

Beyond reduced tillage practices, a spectrum of other production management techniques and technologies can significantly bolster the resilience of Pakistani farmers in the face of climate change. These strategies include precise input application, especially with regard to fertilizers, as advocated by Mahmood et al. (2019b). The array of climate change adaptation measures encompasses both moderate modifications that can be adopted by farmers with minimal financial effort, such as transitioning from maize to millet, as well as more substantial transformations like changing land-use systems, shifting from annual crops to plantations, or transitioning from arable farming to pasture and animal husbandry. Adaptation measures must be tailored to the specific needs and conditions of Pakistani agriculture to ensure sustainable and effective responses to climate change.

CONCLUSION AND RECOMMENDATIONS

In conclusion, this study has delved into the intricate interplay between climate change and agricultural productivity, with a specific focus on the critical role of agricultural extension workers. The findings shed light on how these specialists serve as critical agents of change in encouraging climate-resilient practices and enhancing overall agricultural productivity. The study highlights the discouraging challenges that changing climate patterns pose to conventional agricultural practices. Increasing temperatures, shifting precipitation patterns, and risky weather events disrupt conventional farming methods, leading to reduced crop yields and livestock production. These impacts are predominantly obvious in defenseless regions, where smallholder farmers heavily rely on agriculture for their livelihoods. To combat the adverse effects of climate change, the study underscores the significance of adaptation strategies. Climate-smart agricultural practices, including crop diversification, water-efficient irrigation techniques, agroforestry, and the cultivation of climate-resilient crop varieties, emerge as pivotal solutions. Agricultural extension workers play a central role in driving the adoption of these practices. Through capacity building, knowledge dissemination, and hands-on training, these professionals empower farmers to make informed decisions and implement

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sustainable agricultural methods. The study concludes that the collaboration between agricultural extension workers, scientific insights, and practical applications is paramount for enhancing agricultural productivity in the face of changing climatic conditions. The efforts of extension workers enable farmers to not only adapt to these challenges but also thrive by embracing innovative techniques and strategies.

As policy-makers and stakeholders deliberate on effective approaches to address climate change's impact on agriculture, the study's insights emphasize the indispensable role of agricultural extension workers as bridges between knowledge and action. By facilitating farmer participation in climate adaptation programs, extension workers contribute significantly to improving overall agricultural productivity, fostering resilience, and fostering sustainable development. Incorporating the recommendations and results from this study into policy frameworks and extension programs will be contributory in forming a more climate-resilient agricultural environment, profiting both farmers and communities.

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