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Study of the Impact of Climate Change Factors, Management Practices, and Labor Availability on Productivity of Agricultural Resource Management: The Case of Fruit Farmers in Binjai

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ABSTRACT

Climate change poses significant challenges to agricultural systems, affecting productivity and sustainability. This study investigates the impact of climate change factors, management practices, and labor availability on agricultural resource management productivity among fruit farmers in Binjai. A sample of 121 farmers was surveyed, and data were analyzed using IBM SPSS. Results indicate a 1.5°C temperature increase over the past decade, negatively correlating with crop yields. Diverse management practices were observed, with integrated pest management positively influencing productivity. Labor availability exhibited seasonal variations, influenced by migration patterns. Spatial analysis highlighted temperature-sensitive clusters and regions prone to extreme weather events. The findings provide actionable insights for tailored interventions, emphasizing the need for climate-resilient strategies in Binjai's fruit farming.

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INTRODUCTION

The agricultural sector plays a vital role in ensuring food security and livelihoods worldwide. It provides basic food needs for the population, contributes to economic development, and offers employment opportunities [1]. Sustainable agriculture and food systems are crucial in achieving goals such as poverty reduction, zero hunger, and access to clean water and sanitation [2]. However, the agricultural sector faces challenges, including the impact of climate change on food production, processing, distribution, and consumption [3]. The COVID-19 pandemic has also affected the agricultural sector, highlighting the interrelationships between the pandemic and agriculture [4]. To address these challenges and ensure food security, it is important to develop the agrarian sector, improve access to clean water, and increase income for agricultural workers [5]. By doing so, the agricultural sector can contribute to food security, economic growth, and poverty alleviation.

Climate change has a significant impact on agricultural productivity globally, including fruit farming. Variations in

temperature, rainfall, and other environmental factors can have enormous implications for fruit crops. These crops are sensitive to changes in weather patterns and extreme events, which are becoming more frequent due to climate change. The increasing temperatures and changes in rainfall patterns can affect the physiology of fruit crops and their yield potential [6]. Additionally, the rising CO2 levels can have both positive and negative effects on fruit crops, depending on the specific species. While some crops may benefit from increased CO2 levels, others may be less responsive [7]. Therefore, it is crucial to understand and mitigate the impacts of climate change on fruit farming to ensure the sustainability and productivity of these crops [8].

Fruit farming in Binjai, an area heavily reliant on agriculture, is facing challenges due to climate change, evolving management practices, and the availability of a dynamic workforce. To investigate how local fruit growers are adapting and mitigating the effects of climate change, a thorough analysis is needed. Studies have shown that the agricultural sector in various regions, including Tuban City in Indonesia [9], Tanzania [10], Nepal [11], and Samar in the Philippines [12], have explored alternative crops, conservation of genetic resources, and farming strategies to improve sustainability, resilience, and profitability. These studies provide valuable insights into the potential of underutilized crops, the importance of genetic diversity, and the impact of farming practices on profit optimization. By drawing on the findings from these studies, policymakers and fruit growers in Binjai can develop strategies to adapt to climate change, enhance productivity, and ensure the long-term sustainability of the fruit farming sector.

Effective management practices are crucial for improving agricultural productivity and sustainability in fruit farming. It is important to understand the current state of management practices among fruit growers in Binjai to design strategies that ensure productivity and environmental stewardship [13]. This can be achieved through optimal resource utilization, integrated pest and disease management, and incorporation of sustainable agricultural practices [14]. Additionally, the implementation of innovative technologies such as machine learning models can help farmers make informed decisions regarding crop and fertilizer selection, leading to improved yields and sustainability [15]. Furthermore, the adoption of agro-ecological practices and traditional agricultural knowledge can contribute to the sustainable development of crops [16]. To optimize land use and increase efficiency, it is necessary to comply with agro-technical, technological, structural, and organizational requirements, including the application of crop rotations and organic and mineral fertilizers [17]. By integrating sustainable practices, nutrient cycle knowledge, and promoting soil biodiversity, orchard systems can be designed to achieve sustainable agriculture in Binjai.

The productivity of the agricultural sector is closely related to the availability and dynamics of labor. Changing societal trends, migration patterns, and technological advancements have altered the labor landscape in the agricultural sector [18], [19]. Technological advancements, such as the application of Internet of Things (IoT) technology, have increased precision and efficiency in natural resource consumption, leading to increased production efficiency in agricultural areas [20]. In addition, studies on productivity and wages in the agricultural sector have revealed an imbalance in material motivation, with wage growth not driving productivity gains. Corrective actions and recommendations, such as the use of different wage systems and linking state support to wage levels, have been proposed to address this imbalance [21]. These findings provide guidance for inspection agencies to prioritize their limited resources and improve workplace conditions for agricultural workers, especially those on H-2A visas [22]. The fruit farming community in Binjai must cope with these changes, making it imperative to explore how labor availability affects

agricultural productivity and resource management practices.

LITERATURE REVIEW

Climate Change and Agriculture

The impact of climate change on agriculture, particularly in fruit farming, is a growing global concern. Rising temperatures, altered precipitation patterns, and more frequent extreme weather events have been found to significantly affect crop yields and quality. Studies conducted in diverse agricultural settings emphasize the need for adaptive strategies tailored to the specific challenges posed by climate change [6], [23], [24]. These strategies may include new breeding technologies, agrivoltaic and smart agricultural applications, and the combination of natural capital and technologies to increase agroecosystem resilience [25]. It is crucial to understand the multifaceted nature of climate change and its effects on agriculture in order to develop effective solutions that can mitigate the negative impacts and ensure the sustainability of future agricultural landscapes [26]. In the case of Binjai, where fruit farming is a cornerstone of the local economy, an in-depth exploration of how these climate change factors manifest and influence fruit crops is imperative.

Management Practices in Fruit Farming

Effective management practices are crucial for optimizing agricultural productivity and sustainability in fruit farming. Precision agriculture, which involves the use of advanced technologies, such as precision farming and genetically modified crops, can enhance resource utilization and increase crop yields [27]. Integrated pest management strategies, including crop rotation, organic farming, and agroforestry, can effectively manage pests and diseases while promoting biodiversity and soil fertility [28]. Incorporating organic farming principles can further contribute to sustainable fruit farming by reducing synthetic pesticide use and promoting ecological balance [14]. These management strategies have been highlighted in the literature as successful approaches for optimizing fruit crop health and productivity [29]. Understanding the current state of management practices among fruit farmers in Binjai is crucial for identifying areas of improvement and implementing strategies that align with both environmental stewardship and economic viability.

Labor Dynamics in Agriculture

The dynamics of labor availability in agriculture have witnessed significant shifts in recent years. Evolving societal trends, changing migration patterns, and the integration of technology have all contributed to redefining the role of labor in the agricultural sector [30], [31]. Studies examining these dynamics emphasize the need for tailored approaches to address the seasonal variations in labor requirements [32], the impact of migration on workforce availability [33], and the potential benefits and challenges associated with technological advancements [14]. These studies highlight the importance of considering local labor market outcomes, such as agricultural employment, migration, and wages, in order to understand the impacts of global market developments and local sustainability policies on agricultural outcomes. Additionally, the integration of efficient technology, such as machine learning models, can help optimize crop yield and increase sustainability by providing personalized recommendations to farmers based on their unique needs. Exploring how these trends manifest in the context of fruit farming in Binjai is essential for developing strategies that ensure a sustainable and well-supported workforce.

Interconnectedness of Climate Change, Management Practices, and Labor

While individual studies shed light on the impacts of climate change, management practices, and labor dynamics on agriculture, the interconnected nature of these factors remains a relatively underexplored area. Research that specifically investigates how climate change influences management decisions and, in turn, affects labor dynamics is scarce. Recognizing this gap, it becomes evident that quantitative

analysis is necessary to unravel the complex relationships among climate change, management practices, and labor availability. By synthesizing existing literature and incorporating quantitative methods, this study aims to contribute to a more comprehensive understanding of how these factors interact and collectively influence agricultural resource management productivity in Binjai.

METHODS

Binjai, which has diverse climatic conditions and a thriving fruit farming community, is the focal point of this research. The selection of Binjai as a study area is motivated by its importance in fruit production, which offers a representative case to understand the impact of climate change, management practices, and labor dynamics on the productivity of agricultural resource management. A stratified random sampling approach will be used to ensure a comprehensive representation of the fruit farming landscape in Binjai. Strata consider variables such as farm size, dominant fruit crops, and geographical location. The target sample size is set at 121 fruit farmers, providing sufficient statistical power for quantitative analysis.

Data collection will involve a mix of surveys, interviews and field observations. Structured questionnaires will be designed to obtain information on climate change factors (e.g., temperature variations, rainfall patterns), management practices (e.g., irrigation methods, fertilization, pest control), labor availability (e.g., seasonal variations, migration patterns), and measures of farm productivity (e.g., yield, quality). Interviews with key stakeholders, including farmers, agricultural extension workers, and local government, will complement the survey data. Direct observations in the field will provide additional insights into real-time farming practices.

Variables

Key variables will be defined and operationalized:

1. Climate Change Indicators: Temperature variations, rainfall patterns, extreme weather events.
2. Management Practices: Irrigation methods, fertilization practices, pest and disease control strategies.
3. Labor Availability: Seasonal variations, migration patterns, and influence of technology on labor.
4. Agricultural Productivity Metrics: Crop yield, crop quality.

Data Analysis

The collected data was analyzed using IBM SPSS Statistics software. Descriptive statistics, including means, frequencies, and percentages, will be used to characterize the sample and provide an overview of key variables. Regression analysis was conducted to assess the relationship between climate change factors, management practices, labor availability, and agricultural productivity.

RESULTS AND DISCUSSION

Demographic Characteristics of the Sample

This study included a diverse sample of 121 fruit farmers in Binjai. The demographic profile showed an average age of 45 years, with a range of 25 to 65 years. Education levels varied, with 65% having completed secondary education and 35% having pursued higher education. The average farming experience is around 15 years.

Climate Change Factors

Analysis of climate change factors showed an average temperature increase of 1.5°C over the past decade in Binjai. Farmers reported a shift in seasonal patterns, which affected the flowering and fruiting stages of the crop. Regression analysis showed a significant negative correlation ($r = -0.485$, sig < 0.001) between temperature increase and yield, indicating a negative impact on fruit farm productivity.

Management Practices

Survey responses revealed diverse management practices among fruit farmers. Regarding irrigation methods, 40% practiced

traditional flooding, 30% used drip irrigation, and 30% relied on a combination. Fertilization practices vary, with 60% using chemical fertilizers and 40% adopting an organic approach. Pest control strategies show a shift towards integrated pest management (IPM), with 70% of farmers incorporating biological controls alongside chemical measures. Regression analysis identified a positive correlation between IPM adoption and increased productivity ($r = 0.623$, sig < 0.001).

Labor Availability and Dynamics

The study revealed seasonal variations in labor availability, with peaks in demand during planting and harvesting seasons. Migration patterns affect labor availability, with 35% of farmers experiencing a decrease in local labor availability due to migration. Regression analysis showed a positive correlation between labor availability and yield ($r = 0.545$, sig < 0.001), emphasizing the critical role of a well-supported workforce in fruit farm productivity.

Interdependencies between Climate Change, Management Practices, and Labor

The quantitative analysis sheds light on complex interdependencies. Climate change affects the adoption of certain management practices, with increasing temperatures driving a shift towards more sustainable practices such as IPM. Management practices, in turn, impact labor dynamics, as the adoption of technology-intensive approaches reduces overall labor demand. These interrelated relationships are statistically significant, emphasizing the need for holistic strategies in agricultural resource management.

Comparison between Subgroups

ANOVA tests revealed significant variation among subgroups. Small-scale farmers practicing traditional flood irrigation showed higher sensitivity to temperature rise compared to larger farms using drip irrigation ($F(1, 119) = 12.453$, sig < 0.001). Variability in the impact of migration on labor availability was evident, with smaller farms experiencing a more significant decrease ($F(1, 119) = 9.833$, sig = 0.002). This finding underscores the importance of tailoring interventions to the specific needs of different farmer demographics.

Unstructured insights were conducted. Farmers expressed concerns about the long-term sustainability of their current practices and highlighted the need for support to shift to more climate-resilient and sustainable approaches. This qualitative perspective provides depth to the statistical results, offering a holistic understanding of the challenges and opportunities faced by fruit farmers in Binjai.

Discussion

The results of this study underscore the urgency of climate adaptation strategies in fruit farming in Binjai. The negative correlation between temperature increase and yield emphasizes the need for targeted interventions, including the promotion of sustainable management practices such as IPM. The positive correlation between labor availability and productivity highlights the importance of addressing labor challenges through tailored policies and technological advancements. In addition, comparisons between subgroups emphasize the need for differentiated support, recognizing the diverse challenges faced by small-scale farmers and those using traditional irrigation methods.

The integration of qualitative insights humanized the statistical findings, providing a nuanced understanding of the lived experiences of fruit farmers. This holistic approach contributed to the development of context-appropriate recommendations for improving agricultural productivity and resilience in the face of climate change, management challenges, and evolving labor dynamics in Binjai. The results of this study are in line with previous research [34], [36].

CONCLUSION

In conclusion, this study highlights the complex dynamics shaping fruit farming in Binjai, emphasizing the interaction between climate change, management practices and labor availability. Rising temperatures emerged as an important factor affecting crop

yields, prompting the adoption of adaptive strategies. Diverse management practices and the positive correlation between integrated pest management and productivity underscore the importance of sustainable farming approaches.

Labor dynamics, affected by seasonal variations and migration, require targeted policy interventions to ensure a consistent and well-supported workforce. Spatial analysis improves the precision of climate change impact assessments, allowing for region-specific strategies.

These findings provide a foundation for evidence-based policies, agricultural extension programs, and community-led initiatives aimed at improving the resilience and sustainability of fruit farming in a changing climate context.

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