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Vulnerability of The Rice Milling Industry in Kenya: A Systematic Review

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Abstract

The vitality of rice as a food security and cash crop has grown over the past decades in Kenya. Rice is consumed by most households in Kenya and thus plays a strategic role in food security. This is evident in the 12 percent increase in its consumption annually. The rice milling industry acts as an engine for the entire rice value chain. However, its performance has been limited by various factors ranging from social, economic, environmental, policy, and technological. The industry's contribution to food security, poverty reduction, employment, and economic development has been greatly hampered by climate change and variability. Since the industry is dependent upon rice production, climate change impacts at the production node further affecting its value chain performance. Rice-related research in Kenya has mainly focused on climate-related effects on production and consumption nodes. Limited studies have widened their scope of climate change to demonstrate its impact on the rice milling industry. This systematic review maps the existing literature following the PRISMA protocol to synthesize the risks associated with climate change on the rice milling industry linking it with all nodes within the rice value chain. The paper further discusses possible implementable short-term solutions to under-utilization of rice mills as a result of climate change and recommends areas of future research that can provide lasting solutions to climate-related challenges in the rice value chain. Among the solutions include the need for increased investment in new irrigation infrastructure and technology, tolerant rice varieties as well as improved access to credit, inputs, and market information. Additionally, there is a need for stronger policy support to promote the growth and development of the rice milling industry,

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including measures to improve the regulatory environment, reduce taxation, and increase technical support and training for millers. Finally, promoting climate-smart agriculture practices can help mitigate the impacts of climate change on rice production and milling.

Keywords: Capacity utilization, climate change, installed capacity, milled rice, vulnerability

Introduction

The reality of climate change threatens agricultural production in Africa. The continent is particularly vulnerable to the impacts of climate change due to its reliance on rain-fed agriculture and limited access to irrigation (Terdoo & Teola, 2016). Climate change is already affecting crop yields, water availability, and food security in Africa, and these impacts are expected to intensify in the coming decades (Pereira, 2017). One of the main challenges facing agriculture in Africa is the increasing frequency and intensity of extreme weather events, such as droughts and floods (Bhargava, 2019). Kenya is not an exception to the challenges of climate change in Africa. This is exacerbated by the fact that the country's economy is heavily dependent on agriculture (Mutisya, 2022).

Rice is among the value chains that are greatly affected by climate change due to its high water-demanding nature. Irrigated rice dominates the Kenyan system consisting of 80 percent while 20 percent is rain-fed (MOA, 2008). Irrigated rice production is mainly concentrated in the Mwea Irrigation Scheme, which is the largest rice-growing area in the country (Mugalavai et al., 2018). Other rice-growing areas include Ahero and West Kano in the western region, and Bunyala in the eastern region (Mwongela et al., 2019).

As the third most significant cereal crop after maize and wheat (Obura et al., 2017), rice plays a critical role in the socioeconomic development of the Kenyan economy. Over 300,000 rice growers earn their living out of crop cultivation (Vishnu & Mukami, 2020). Rice is a staple food in Kenya, and increasing rice production helps to enhance food security in the country (Kadipo et al., 2021). In 2018, Kenya imported milled rice valued at 26 billion Kenya shillings (KNBS, 2019). Hypothetically, this is equivalent to approximately 40 percent of the 2022 national agriculture budget.

Rice milling is an important aspect of the rice value chain in Kenya (Uma, 2022a). The process involves removing the husk and bran from the rice grain to produce milled rice, which is the final product that is sold to consumers (Ndirangu & Oyange, 2019). Rice milling

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industry as used in the manuscript includes paddy drying, milling process, packaging and marketing. There are several rice mills in Kenya, with the largest milling capacity located in the Mwea Irrigation Scheme. However, the milling capacity is still relatively low compared to the country's production capacity. Rice milling in Kenya is primarily done using traditional methods (Ndirangu & Oyange, 2019). However, there is a growing trend towards the use of modern milling technologies (Watanabe et al., 2021). The vitality of the milling process is evidenced in its ability to transform paddy into nutritionally utilizable form while generating by-products husks and bran (Bodie et al., 2019). Unless irrigated and rain fed locally produced rice is milled, the efforts of those engaged in its production is rendered useless. However, it is worth noting that any hindrance to the production of rice equally impact on the activities of the rice milling.

Rice milling provides employment opportunities for thousands of Kenyans, particularly in rural areas where the industry is concentrated (Paman et al., 2016). This helps to reduce unemployment and poverty levels in these areas. Rice milling adds value to the raw rice grain by removing the husk and bran and producing milled rice that is ready for consumption. This increases the profitability of the rice value chain and benefits farmers, millers, and consumers.

Despite the efforts to increase rice production in Kenya, the sector still faces several challenges. Farmers in some areas have limited access to quality seeds, fertilizers, and pesticides, which impacts the productivity and quality of rice produced. Changing weather patterns, including droughts and floods, negatively impact on rice production. Rice pests and diseases which thrive due to climate change cause significant losses to farmers. Many smallholder farmers lack access to credit, which limit their ability to invest in their farms and cope with the impacts of climate change (Watanabe et al., 2021). These generally hamper the production volumes. Consequently, the vast majority of the installed capacity of the mills are underutilized chiefly because of absence of the paddy.

The rice milling industry in Kenya faces several challenges, including inadequate infrastructure, high production costs, and low-capacity utilization. Additionally, the industry is highly fragmented, with many small-scale millers operating with low efficiency. Due to the idleness and fast depreciation of the rice milling machines, high maintenance costs are incurred by the millers and mill owners (Ndirangu & Oyange, 2019). Other challenges facing

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rice milling industry include high foreign matter content due to poor quality milling equipment and poor storage and handling of paddy before actual milling (Atera et al., 2018). Additionally, high costs of labour, unreliable power supply, high costs of importation of raw material, inefficient transport facilities most especially within the lowland areas undermine rice production and milling efforts.

The challenges impacting rice production and milling industry in Kenya have been further compounded by climate variability. This has hampered the sector's contribution to food security, poverty reduction, employment, and economic development. Since the rice milling node is dependent upon rice production, climate change impacts at the production node which further influences the performance of rice milling activities.

Much as climate change has been fronted as a very serious contributor to agricultural related problems, research in relation to climate change has largely focused on its effects on the production node. Limited studies have widened their scope of climate change to demonstrate its impact on the rice milling industry. This systematic review is specifically designed to pinpoint the elements of climate change that directly and indirectly impact the rice milling node. The paper further discusses possible implementable short-term solutions to underutilization of rice mills as a result of climate change and recommends areas of future research that can provide lasting solutions to climate-related challenges in the rice value chain.

Theoretical Background

The vulnerability of agricultural value chains can be understood through a theoretical framework that takes into account the different factors that contribute to their instability and potential for disruption. One important framework for understanding the vulnerability of agricultural value chains is the systems theory approach. The theory was proposed by Ludwig Von Bertalanffy who fronted the idea that every system is part of a sub-system (Nicholz & Schwartz, 1998). According to Ludwig, studying individual parts of a system in isolation denies influence of the larger system thus limiting the understanding of the outside context which influences the individual part under study. Therefore, this approach recognizes that agricultural value chains are complex systems that are interconnected and interdependent. Disruptions in one part of the system can have ripple effects throughout the entire chain.

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Another framework that can be used to understand the vulnerability of agricultural value chains is the value chain analysis approach. The value chain concept was introduced to describe the full range of activities required to bring a product or service from conception through different phases from production to consumption (Porter, 1985). This approach tries to consider all economic activities within a value chain by understanding what is happening at different stages of the value chain as well as how the value chain operates as part of a system. Value chain analysis focuses on the build-up of costs and growth in value and distribution of returns along the value chain (Kaplinsky & Morris, 2000). This approach emphasizes the different stages of the value chain and the actors involved in each stage. It considers how changes in one part of the chain can affect the entire system.

A third theoretical framework that can be used to understand the vulnerability of agricultural value chains is the political ecology approach. The term political economy was first described by Wolf (1972) as a term that represents an explicit alternative to 'apolitical' ecology, which operates under common set of assumptions, and employs a reasonably consistent mode of explanation. This approach focuses on the political and social factors that influence the production and distribution of agricultural products. It considers issues such as power dynamics, social inequalities, and the impact of policies and regulations on the value chain. Overall, a comprehensive understanding of the vulnerability of agricultural value chains requires considering multiple theoretical frameworks and taking into account the diverse factors that can contribute to instability and disruption in the system.

The three theories fronted above are critical in understanding the relationship between climate change and rice milling node. However, they all have shortcomings. The systems theory approach does not offer specific tools or techniques for integration or understanding of the interdependence between an organization and its environment. This makes it difficult to use a specific methodology in applying the systems theory in understanding the relationship between rice milling node and climate change. The value chain approach largely focuses on the nitty-gritty details, and an organization may risk drifting from its overall mission and vision. Political ecology approach has a narrow definition of the environment and treats local and global environment as independent from one another which turns out to be unrealistic in climate change related studies.

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Materials and Methods

A systematic review can be conducted using **Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)** guidelines according to Briner and Denyer (2012). In the application of these guidelines, a guideline checklist was developed and followed to clearly indicate and describe the stages of article identification, selection, screening, eligibility criteria and inclusion. The study used rice value chain, climate change, rice milling and rice vulnerability as key words in various combinations. The results yielded by each database were as follows: Elsevier (101); Springer Link (116); Emerald Journals (29); Wiley Online Library (56); Taylor and Francis (112);and Science Direct (142). The search was limited to studies published between 2010 and 2023.

For an article to be included in the study, three parameters were to be met. The first was to examine rice vulnerability across all contexts in terms of geographical areas. Therefore, any study on the vulnerability of other crops were discarded at this point. Studies that included aspects related to vulnerability of rice production and milling with close focus on African context were considered. Studies that largely relied on marketing, consumption and use of rice by-products were excluded. Most importantly, studies that were found related to the objective of the study with reference to the Kenyan context were included and those that were far from the Kenyan context were relegated. Overall consideration was given to studies published in English language. The overall search generated a total of 556 results out of which 54 were regarded to be satisfactory in meeting the objectives of the study.

Results and Discussions

Characteristics of Studies Considered in the Study

According to Table 1, majority (44.4%) of the studies included in the study were published between 2016 and 2020, closely followed by 2011 to 2015, and lastly beyond 2020. This implies that climate change and its impacts on the rice value chain Kenya has gained significant attention as the years go by. The average percentage of studies considered beyond 2020 is 8 percent, this implies that by the end of 2025, the number of studies conducted in relation to climate change and rice milling node will surpass the previous years. This increasing attention can be attributed to the growing importance of the rice value chain in Kenya as a staple and driver of economic development.

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Table 1: Characteristics of Studies included in the Study

Criteria	Number of papers	Percentage (%)
Year		
Between 2011 to 2015	17	31.5
Between 2016 to 2020	24	44.4
Beyond 2020	13	24.1
Value chain node		
Production	19	35.1
Rice milling	6	11.1
Marketing	3	5.6
Entire value chain	24	44.4
Production & marketing	1	1.9
Milling & marketing	1	1.9
Area of concentration		
Climate change	17	31.5
Sustainability	18	33.3
Profitability and market analysis	14	25.9
Policy and others	5	9.3
Geographic area		
Kenya	34	63.0
East Africa	2	3.7
Africa	6	11.1
Global	6	11.1
Others	6	11.1

Majority (44.4%) of the studies reviewed analysed the entire rice value chain followed by 35 percent that focused on production and 11 percent that discussed rice milling node. It is still evident that most of the studies have given much attention to the production and to a larger extent neglected the rice milling node. This overrated attention can be attributed to the increasing challenges related to production node within Kenya. This is consistent with findings from Alila and Atieno (2006), who reported that agricultural policies and development initiatives in Kenya largely focus on improving productivity and the living standards of smallholder farmers. This further expounds on why studies focus on production node since most of the studies strive towards achieving national policies and agenda.

In relation to the reviewed literature, sustainability and climate change have received enormous attention at 33 and 31 percent respectively. Just like other African countries,

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agriculture still remains the driver of the Kenyan economy. This calls for actions and interventions towards mitigating any disturbance that threatens the flourishing of the agricultural sector in the country. Thus, the attention that has been given to climate change and sustainability studies, and the attention they are yet to receive is not by mistake, rather it is in relation to survival for the fittest. Profitability and market analysis has equally received attention (25%) in Kenya. This is as a result the promotion of agriculture as a business by the government and different development organizations by exposing smallholder farmers to marketing skills and financial literacy.

Vulnerability of Rice Production to Climate Change in Kenya

Climate change has come closer to us in the current times than never before. Previously, it used to appear as though it was foreign, mostly heard and read about from a far. With the current changes in rainfall patterns, rising temperatures and intensifying solar radiation that is felt in the deepest parts of our communities, it is evident that this unfortunate circumstance is fully part of us. According to Bhargava (2018), rainfall and temperature are the most important determinants of agricultural productivity.

Across Africa, over reliance on rain-fed agriculture and poorly developed infrastructure are dominant challenges (Pereira, 2017). Since there are evident changes in these two elements, potential and grave challenges to rice production and food security can be anticipated. Extreme temperatures were found to negatively affect rice yields across all varieties in Mwea and Western Kenya (Nyang'au et al., 2014). According to Kariuki (2016), climate change has affected rice production through reduced amounts of water for irrigation, increased incidences of pests and diseases, flooding of rice fields during the rainy seasons, increased incidences of pesticide and herbicide resistance.

Many rice farmers in Kenya rely on irrigation to grow their crops (Watanabe et al., 2021). Changes in rainfall patterns and increased evapotranspiration rates due to higher temperatures has led to water shortages, making it more difficult to irrigate crops. Extreme weather events, such as floods and storms, leads to soil erosion (Wawire et al., 2021), which further reduce soil fertility and bring about lower yields.

Climate change is expected to lead to extreme weather events (Terdoo & Feola, 2016), all of which can have a negative impact on rice production. Over 80 percent of rice growers

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in Kenya are smallholder farmers (Atera et al., 2018). Adhikari et al. (2015) notes that these smallholder farmers are the most vulnerable to climate change and variability since they possess minimal technical and financial resources to cope with the challenges associated with climate change.

According to FAO (2021), the rising temperature in Kenya is expected to make rainfall unpredictable and increase incidences of extreme events such as drought and floods. Extreme weather events, such as storms and floods, can also damage rice crops and infrastructure, such as irrigation systems and storage facilities which can further reduce yields and increase production costs. Oort and Zwart (2019) equally report that an increase in global annual temperatures is expected which does not exclude Kenya. They note that this will result to negative impacts on rice production and yields in tropical and hotter areas such as Kenya. The expected increase in drought instances in Kenya, according to FAO (2015) and Makokha et al. (2011), is likely to further reduce the areas under rice production and the total arable land in Kenya. This will imply reduction on the area under cultivation, consequently resulting to reduced annual production volumes.

Vulnerability of Rice Milling Subsector to Climate Change

As earlier noted, climate change and other social and economic factors affect rice production which generates the raw materials for rice milling, the rice processing node becomes affected as well. Among the factors that make rice milling node vulnerable include; inadequate roads and transportation systems (Mitullah et al., 2019) which make it difficult to transport rice from the mills to the markets thus resulting in high post-harvest losses and lowering quality and prices of milled rice received by millers. Rice milling requires significant inputs, including energy, water, and labour, which is costly for small-scale millers. The proposed increase in electricity tariffs by Kenya power from KES 3 to KES 5 which was effected from 1st April 2023 is expected to further dwindle the profitability of rice mills in Kenya.

Importation of superior quality rice significantly compete with locally produced rice and affect the demand and prices for locally milled rice. Rice pests and diseases, such as rice blast and stem borers, cause significant losses to rice producers (Kihoro et al., 2013) and reduce the quality of milled rice. According to Mey and Demontt (2013), birds can cause up to 100 percent losses of rice produced by farmers. This equally affects the volume of paddy

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sourced by rice millers leading to low level of utilization thus recurrent losses. The rice milling industry in Kenya lacks adequate policy support (Atera et al., 2018), which can limit its growth and development.

Rice requires a lot of water to grow (KALRO, 2015), and climate change has led to unpredictable rainfall patterns in Kenya, leading to water scarcity (Nzau, 2013). This makes it difficult to maintain the required water levels in the rice paddies, which affects the growth and yield of the crop. Increase in extreme weather events such as floods and droughts has been manifested in Kenya (IFRC, 2021). This has damaged rice paddies and milling infrastructure, leading to reduced yields and increased costs of production. Rice milling requires a significant amount of energy, mainly in the form of electricity or fuel (Goyal et al., 2014). Climate change leads to disruptions in energy supply due to factors such as extreme weather events, which affects the milling process and increase the cost of production.

Development Policies and Climate Change in Kenya

This subsection discusses development policies in relation to climate change in two different ways. It recognizes the fact that development policies exacerbate impacts of climate change while at the same time can mitigate impacts of climate change. Development policies in Kenya aim to eradicate poverty, reduce inequality and achieve sustainability (Uma, 2022b). However, there are unintended downsides that come along with development policies and Kenya is not in any way exempted from such circumstances.

Development Policies that Exacerbate Climate Change

Kenya has developed many policies related to economic growth, infrastructure development, and land use that contribute to greenhouse gas emissions, deforestation, and other activities that exacerbate climate change. Transforming Kenya into an industrializing middle income country is one of the key areas of concern of Kenya Vision 2030 (Republic of Kenya, 2013). Large-scale infrastructure projects, such as roads, railways, and airports that have accompanied this initiative, have a significant impact on greenhouse gas emissions. These projects often require the use of fossil fuels for construction and operation, and they also lead to increased land use change, deforestation, and soil degradation.

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Kenya Agricultural Policy of 2021 encourages large-scale commercial agriculture (MoALF&C, 2021), which indirectly incentivizes deforestation for other purposes. Kenya still relies heavily on fossil fuels, particularly for transportation which further worsens the climate change situation in the country. The National Urban Development Policy (NUDP) of Kenya aims at promoting rapid urbanization in Kenya (Ministry of Transport, Infrastructure, Housing and Urban Development, 2016). Rapid urbanization in Kenya has led to increased demand for housing, transportation, and energy.

Development Policies that Mitigate Climate Change

Kenya has implemented a range of climate change related development policies aimed at promoting sustainable development and reducing the country's greenhouse gas emissions. Kenya's National Climate Change Action Plan sets out the country's strategy for adapting to and mitigating the impacts of climate change (Ministry of Environment and Forestry, 2021). The plan includes sustainable land use management, renewable energy development, and promotion of energy efficiency. The Green Economy Strategy and Implementation Plan aims to promote economic growth while reducing greenhouse gas emissions and improving environmental sustainability (Government of Kenya, 2016). The plan includes policies and measures aimed at promoting sustainable agriculture, sustainable forestry, renewable energy, and green infrastructure.

The National Adaptation Plan outlines Kenya's strategy for adapting to the impacts of climate change (Ministry of Environment and Natural Resources, 2016). The plan includes policies and measures aimed at promoting climate-resilient agriculture, water resource management, and disaster risk reduction. Kenya's National Agriculture Policy includes policies and measures aimed at promoting sustainable agriculture and reducing greenhouse gas emissions from the agricultural sector (MoALF&C, 2021).

Kenya's National Energy Policy includes policies and measures aimed at promoting the development of renewable energy sources, such as wind, solar, and geothermal power (Ministry of Energy, 2020). Kenya's Forest Conservation and Management Policy purposes to promote sustainable forest management and reduce greenhouse gas emissions from deforestation and forest degradation (Republic of Kenya, 2016). The policy includes measures

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aimed at promoting reforestation and afforestation, as well as measures aimed at reducing illegal logging and promoting sustainable forest management practices.

Government Efforts to Mitigate Effects of Climate Change on Agriculture

The Kenyan government has implemented several measures to mitigate the impacts of climate change in agriculture. The Kenyan government has promoted the adoption of conservation agriculture practices, such as minimum tillage, crop rotation, and intercropping (Kinyumu et al., 2021). These practices help to reduce soil erosion, improve soil fertility, and increase the water-holding capacity of soils, thereby making agriculture more resilient to the impacts of climate change. The government has promoted the adoption of drought-tolerant crop varieties, such as maize and beans, which are better adapted to the changing climate conditions (Muinga et al., 2019). The government has invested in the development of irrigation infrastructure to help farmers cope with changing rainfall patterns and water scarcity (Mati, 2023). This includes the construction of small-scale irrigation systems, such as dams, ponds, and boreholes, as well as the promotion of water harvesting techniques.

Though to a limited extent, the Kenyan government has provided farmers with weather and climate information to help them make informed decisions about planting, harvesting, and crop management (Muema, 2018). This includes the use of mobile phone apps, radio broadcasts, and community-based weather monitoring systems. The use of renewable energy sources, such as solar and wind power, in rural areas is being promoted (Takase et al., 2021). This reduces the dependence on fossil fuels and helps to reduce greenhouse gas emissions. Overall, these measures demonstrate the Kenyan government's commitment to promoting climate-resilient agriculture and mitigating the impacts of climate change.

Conclusion and Recommendation

Rice milling in Kenya is vulnerable to climate change due to its reliance on consistent water availability and temperature conditions. The production of rice in Kenya is affected by climate change through unpredictable and extreme weather patterns, including prolonged droughts and floods. Droughts have reduced the availability of water for irrigation, leading to reduced rice production. On the other hand, floods most especially from River Nyando have damaged rice paddies and milling infrastructure in Ahero, causing significant losses in the industry.

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Climate change has led to the emergence of new pests and diseases that affect rice crops, reducing the quality and quantity of rice produced. Climate change has also affected the energy sector, which is crucial for rice milling operations, leading to frequent power outages and increased costs of energy. The government has tried to combat the situation through developmental policies, however, lack of effective implementation of the policies aimed at mitigating the impacts of climate change has instead worsened the situation in Kenya.

The vulnerability of rice milling to climate change in Kenya requires urgent measures to adapt to the changing climate. These measures include the adoption of new irrigation technologies, resilient rice varieties, pest and disease management, and the development of alternative sources of energy. Furthermore, the government and other stakeholders should implement policies that support climate resilience in the rice milling industry, including access to climate information and financial support for adaptation measures.

Additionally, there is a need for stronger policy support to promote the growth and development of the rice milling industry, including measures to improve the regulatory environment, reduce taxation, and increase technical support and training for millers. Flood control dam on River Nyando may be a bigger and expensive venture but certainly a long-term viable solution to challenges that it causes in the Ahero region. Finally, promoting climate-smart agriculture practices can help mitigate the impacts of climate change on rice production and milling. Overall, a combination of these solutions can help to mitigate the vulnerability of rice milling to climate change and ensure the long-term sustainability of the rice industry.

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