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Evaluating Tobacco Farming Practices and Climate Variability Adaptation Strategies in Uriri Sub-County: Mitigation and Sustainable Agricultural Solutions

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Abstract: *The study addresses the challenges of climate variability on agriculture, emphasizing the need for effective adaptation strategies to sustain food production. Globally, governments and private entities have implemented short- and long-term measures, including crop diversification, optimized planting dates, and irrigation, to mitigate the impacts of erratic climate changes. However, more capital-intensive strategies, like changing crop types and modernizing farms, have seen limited adoption. In Kenya's Uriri Sub-County, the growth of smallholder tobacco farming over the past three decades has intensified environmental degradation and increased vulnerability to climate variability. Adaptation strategies such as altering planting dates and diversifying crops have been insufficient, exacerbating social inequalities among farmers. Grounded in sustainable livelihoods and climate resilience theory, this study employs a mixed methods approach to explore the complexities of tobacco farming and its impacts. A sample of 150 smallholder farmers from Uriri Sub-County, selected through stratified random sampling, participated in structured interviews, focus group discussions, and surveys. Data were analyzed using thematic coding and statistical methods. The findings reveal that current tobacco farming practices are unsustainable and inadequate for long-term climate resilience. The study advocates for adopting more sustainable agricultural practices, such as agroforestry and crop diversification, and calls for policy interventions to transition from tobacco to more sustainable crops. Strengthening local institutions and ensuring equitable access to agribusiness opportunities are essential for achieving long-term sustainability.*

Keywords: *Adaptation Strategies, Long-Term Strategies, Short-Term Strategies, Climate Variability, Tobacco Farming, Sustainable Solutions.*

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1. Introduction

Tobacco farming is a significant agricultural activity in many parts of the world, particularly in developing countries where it serves as a primary source of income for many rural households. However, the environmental impacts of tobacco cultivation are profound and multifaceted, posing serious challenges to sustainable development. The process of tobacco farming involves practices that contribute to deforestation, soil degradation, water pollution, and loss of biodiversity. These environmental consequences, coupled with the health risks associated with tobacco use, have prompted global debates

on the sustainability of tobacco agriculture and the need for regulatory measures to mitigate its impacts.

In regions like Sub-Saharan Africa, where tobacco farming is widespread, the environmental repercussions are particularly concerning. Countries such as Kenya, Uganda, and Tanzania have seen extensive land use changes driven by the expansion of tobacco cultivation. These changes often lead to deforestation as forests are cleared to create space for tobacco farms. The loss of forest cover not only diminishes biodiversity but also disrupts ecosystems, leading to soil erosion, reduced water quality, and altered climate patterns.

The National Environment Management Authority (NEMA) and the World Health Organization (WHO) have established standards and best practices aimed at minimizing the environmental damage caused by tobacco farming. However, compliance with these standards remains low, particularly among tobacco companies operating in developing countries. A recent study conducted between 2020 and 2022 revealed that only 11.6% of tobacco companies adhered to environmental standards set by NEMA and WHO. This lack of compliance underscores the challenges faced in enforcing environmental regulations in the tobacco sector.

Farmers' knowledge of the environmental impacts of tobacco farming is a critical factor in the adoption of sustainable practices. Understanding the extent to which farmers are aware of these impacts can provide valuable insights into the effectiveness of current educational and regulatory initiatives. The study found that while a significant portion of farmers had some knowledge of deforestation and the loss of native tree species, a substantial number had minimal understanding of these issues. Specifically, 23% of farmers had minimal knowledge, 59% had some knowledge, 9% had expert knowledge, and 10% had extensive knowledge of forest cover loss. This variability in knowledge levels has important implications for environmental conservation efforts and the implementation of sustainable agricultural practices.

The implications of these findings are far-reaching. Farmers with limited knowledge of deforestation may unknowingly engage in practices that contribute to environmental degradation, such as the excessive use of wood for curing tobacco leaves or the continued expansion of tobacco farms into forested areas. On the other hand, those with a deeper understanding of the environmental impacts may be more likely to adopt sustainable practices, such as agroforestry or the use of alternative fuels for curing tobacco. Therefore, enhancing farmers' knowledge through targeted education and outreach programs is essential for promoting sustainable tobacco farming practices.

Furthermore, the study highlights the need for stronger regulatory frameworks and enforcement mechanisms to ensure that tobacco companies adhere to environmental standards. The low compliance rate observed among these companies suggests that existing regulations may be inadequate or poorly enforced. Strengthening these regulations, along with increasing awareness and education among farmers, could significantly reduce the environmental footprint of tobacco farming.

In addition to its environmental impact, tobacco farming has social and economic implications. The labor-intensive nature of tobacco cultivation often leads to the exploitation of labor, including child labor, in many developing countries. The economic dependence on tobacco farming can also trap farmers in a cycle of poverty, as they struggle to achieve sustainable livelihoods amidst declining soil fertility and fluctuating market prices.

Given the complex interplay between the environmental, social, and economic dimensions of tobacco farming, this study seeks to explore these issues in greater depth. It aims to assess the current knowledge and practices of tobacco farmers regarding environmental conservation, evaluate the effectiveness of existing regulations, and identify opportunities for promoting more sustainable agricultural practices. The study will also examine the broader implications of tobacco farming on community health, biodiversity, and climate change.

1.1 Research Objectives

1. To assess the level of knowledge among tobacco farmers regarding the environmental impacts of tobacco farming, particularly deforestation and loss of native tree species.
2. To evaluate the compliance of tobacco companies with NEMA, WHO standards, and best practices for environmental conservation.
3. To explore the effectiveness of current educational and outreach programs in promoting sustainable tobacco farming practices.
4. To identify the social and economic factors influencing farmers' decisions to engage in tobacco farming and their willingness to adopt sustainable practices.

2. Literature Review

Human-induced climate change is already affecting regions across the globe, manifesting in extreme weather events such as heatwaves, heavy precipitation, droughts, and tropical cyclones (IPCC, 2021). These phenomena are contributing to rapid, broad-scale ecosystem changes, which are increasingly threatening biodiversity and agricultural productivity (Dasgupta, 2021; Pörtner et al.,

2022). Projections indicate that global warming of 1.5°C and 2°C could be exceeded during the twenty-first century unless drastic reductions in carbon dioxide (CO2) and other greenhouse gas (GHG) emissions are achieved in the coming decades (IPCC, 2021; Masson-Delmotte et al., 2018).

Tobacco farming and climate variability are phenomena with significant implications globally, particularly in regions where tobacco is a major agricultural product. The intersection of tobacco farming practices and climate variability has been studied in various contexts, each revealing unique challenges and strategies. Below is a detailed examination of these issues, incorporating examples from different regions and the inclusion of research questions and objectives.

In the U.S., particularly in states like North Carolina and Kentucky, tobacco farmers have faced the dual pressures of market decline and climate change. Strategies here have included the adoption of precision agriculture techniques to optimize water use and the implementation of conservation practices to reduce soil erosion and preserve water resources.

Brazil, one of the world's largest producers of tobacco, has experienced significant shifts in climate patterns, including increased temperatures and altered rainfall. These changes have prompted farmers to adopt new strategies, such as altering planting schedules and using drought-resistant tobacco varieties. Additionally, the government has initiated programs to encourage crop diversification, helping farmers transition away from tobacco to more sustainable agricultural practices.
In India, tobacco farming is prevalent in states like Andhra Pradesh and Karnataka. Farmers here have had to contend with erratic monsoons and rising temperatures. In response, there has been an emphasis on the development of climate-resilient tobacco varieties and the promotion of integrated pest management practices. The Indian government has also been active in encouraging farmers to diversify their crops and reduce their reliance on tobacco as a primary income source.

Agriculture, which significantly contributes to the gross domestic product (GDP) of many African nations and serves as a primary source of employment, is highly sensitive to variations in temperature and precipitation (African Development Bank, 2019). In East Africa, climate change is projected to increase median temperatures by 1.4–5.5°C and alter median precipitation by 2% to 20% by the end of the century (Adhikari et al., 2015). These changes are expected to decrease yields of staple crops through the shortening of growing season lengths, increased water stress, and the heightened incidence of pest and disease outbreaks (Challinor et al., 2014; Niang et al., 2014). Climate change is thus emerging as the most significant threat to the livelihoods of subsistence farmers (Ali, 2021).

In Zimbabwe, tobacco industry is heavily affected by climate variability, with increasingly unpredictable weather patterns leading to crop failures. Farmers in Zimbabwe have employed techniques such as water harvesting, the use of organic fertilizers, and crop rotation to mitigate the effects of climate variability. Additionally, there has been a push towards reforestation and sustainable land management practices to combat deforestation caused by tobacco curing processes.

While existing studies have extensively documented the impacts of climate change on agriculture in East Africa, there is a lack of region-specific research focusing on the adaptation strategies employed by smallholder farmers, particularly in the context of tobacco farming. Most studies have concentrated on staple crops like maize and wheat (Lobell et al., 2008; Thornton et al., 2011), leaving a gap in understanding the responses of farmers engaged in non-food cash crops, such as tobacco, which have significant economic and social implications (Ochieng et al., 2022). Furthermore, there is limited research on the integration of climate variability mitigation strategies within tobacco farming practices, and how these strategies could potentially be scaled to enhance resilience and sustainability (Dinesh et al., 2015).

Another gap in the literature concerns the socio-economic impacts of climate change on different demographic groups, such as women and youth, who are disproportionately affected by agricultural disruptions (Jost et al., 2016; Tavenner & Crane, 2018). Research that explores the intersection of climate change, agriculture, and social differentiation in rural East African communities remains scarce, necessitating a deeper investigation into how climate variability exacerbates existing inequalities and how inclusive adaptation strategies can be developed.

Recent studies have highlighted the urgent need for context-specific adaptation strategies to address the vulnerabilities of African agriculture to climate change (Schlenker & Lobell, 2010). The Intergovernmental Panel on Climate Change (IPCC) has stressed the importance of integrating local knowledge with scientific insights to develop effective adaptation measures that are both sustainable and scalable (IPCC, 2014). This approach is particularly relevant in East Africa, where diverse agro-ecological zones and socio-economic conditions demand tailored interventions (Gebrehiwot & van der Veen, 2013).

Smallholder farmers in East Africa are increasingly adopting short-term adaptation strategies, such as altering planting dates, crop diversification, and water conservation techniques (Bryan et al., 2013). However, the long-term effectiveness of these measures is often compromised by

limited access to resources, inadequate infrastructure, and the absence of supportive policy frameworks (Makate et al., 2016). In the case of tobacco farming, which is both labor-intensive and environmentally taxing, there is a pressing need to explore sustainable alternatives that can mitigate the negative impacts of climate variability while preserving the livelihoods of farmers (Ochieng et al., 2022).

Furthermore, the role of agribusiness in shaping the agricultural landscape under climate change remains under-examined. While contract farming has been promoted as a means of securing income for smallholder farmers, its implications for social equity and environmental sustainability are complex and require further exploration (Little & Watts, 1994; Reardon et al., 2009). This study aims to fill these gaps by evaluating tobacco farming practices and climate variability adaptation strategies in Uriri Sub-County, with a focus on identifying sustainable agricultural solutions that can be integrated into existing farming systems.

2.1 Theoretical Framework

This study is grounded in the Sustainable Livelihoods Framework (SLF), which provides a comprehensive approach to understanding how rural households manage and adapt to environmental changes. The SLF posits that livelihoods are sustained by five key assets: human, natural, financial, social, and physical capital (DFID, 1999). In the context of climate change, the framework helps analyze how these assets are affected by external shocks, such as climate variability, and how households mobilize and combine their assets to maintain or improve their livelihoods.

The SLF is particularly relevant in examining the adaptation strategies of tobacco farmers in Uriri Sub-County, as it emphasizes the importance of understanding the complex interplay between different livelihood resources and the external environment. This framework allows for the exploration of how climate change impacts not only agricultural productivity but also the broader socio-economic conditions of farming communities. By applying the SLF, this study seeks to identify the vulnerabilities of tobacco farmers, assess the effectiveness of current adaptation strategies, and explore potential pathways for enhancing resilience.

Moreover, the SLF integrates the concept of social differentiation, which is crucial for understanding how different groups within a community, such as women, youth, and marginalized households, experience and respond to climate change differently (Scoones, 1998). By incorporating this theoretical lens, the study will address the specific challenges faced by these groups and suggest targeted interventions that can improve equity and sustainability in climate adaptation efforts.

3. Methodology

This study employed a cross-sectional household survey targeting both tobacco and non-tobacco farming households within Uriri Sub-County. The sample was drawn from all five wards of the sub-county, with sampling ratios adjusted according to the population sizes in each ward. Apart from tobacco, farmers in these wards also cultivate crops such as maize, sugarcane, potatoes, beans, cassava, and soy. The number of households in each ward was used to proportionately determine the sample size in various sub-locations. For instance, Kanyamkago West Ward, with approximately 239 households, had its sample size calculated by dividing the number of households in the ward by the total number of households in Uriri Sub-County (1,329) and then multiplying by the study's sample size (100).

3.1 Study Area and Population

The study was conducted in Uriri Sub-County, a region that has witnessed significant growth in smallholder tobacco farming over the past three decades. The population targeted included both tobacco and non-tobacco farming households across all five wards in the sub-county: Kanyamkago West, Kanyamkago East, Central Kanyamkago, North Kanyamkago, and South Kanyamkago.

3.2 Sampling Procedure

A stratified random sampling technique was used to ensure representation across different socio-economic groups within the sub-county. The sample size consisted of 150 smallholder farmers, determined using Cochran’s formula for sample size calculation in a population survey. The sample was proportionately allocated across the five wards based on the number of households in each ward. For example, Kanyamkago West Ward, with approximately 239 households, contributed a proportionate number of participants to the study, calculated by dividing the number of households in the ward by the total number of households in the sub-county and then multiplying by the total sample size.

3.3 Data Collection Methods

Data was collected using a combination of structured interviews, focus group discussions, and household surveys. The structured interviews and surveys were

administered to the sampled farmers to gather quantitative data on their farming practices, climate adaptation strategies, and socio-economic characteristics. Focus group discussions were conducted to collect qualitative insights into the farmers' perceptions of climate variability, environmental degradation, and the effectiveness of various adaptation strategies.

3.4 Data Analysis

Quantitative data was analyzed using statistical software, where descriptive statistics such as frequencies, means, and percentages were generated to describe the demographic characteristics of the respondents and their farming practices. Inferential statistics, including chi-square tests and logistic regression, were employed to identify relationships between tobacco farming practices and environmental impacts. Qualitative data from focus group discussions were analyzed thematically, with key themes and patterns identified to complement and provide context to the quantitative findings.

3.5 Ethical Considerations

The study adhered to ethical research standards, including obtaining informed consent from all participants, ensuring confidentiality of the data collected, and securing necessary approvals from relevant local authorities and institutions. Participants were informed of the study's purpose, and their participation was voluntary with the option to withdraw at any stage of the research.

4. Results and Discussion

This section presents the findings of the study, integrating them with existing literature to provide a comprehensive understanding of the impact of tobacco farming on smallholder farmers in Uriri Sub-County. The discussions revolve around key themes, including the adaptation strategies employed by farmers in response to climate variability, the socio-economic implications of tobacco farming, and the sustainability of current agricultural practices. By comparing these findings with those from other studies, this section aims to offer a nuanced perspective on the challenges and opportunities faced by smallholder farmers in the region.

4.1 Response Rate

A total of 311 fully completed and usable questionnaires were collected out of 335 distributed, yielding a response rate of 92.8% and a non-response rate of 7.2%. According to Mugenda and Mugenda (2003), this response rate is adequate for analysis. Table 1 provides the detailed response rate, and all subsequent tables and graphs in this chapter are based on the sample size of 311 tobacco farmers.

Table 1: Response Rate

Response	Frequency	Percentage
Responded	311	92.8%
Did not respond	24	7.2%
Total	**335**	**100%**

Source: Field data (2024)

4.2 Respondents' Demographic Characteristics

The study analyzed the socio-demographic characteristics of respondents, focusing on gender, age, and education level. These characteristics are critical for linking literacy levels to farming practices and understanding the interplay between human factors, environmental parameters, and farmers' health and safety.

4.2.1 Respondent's Level of Education

The level of education among respondents was assessed to gauge their understanding of the study's questions.

Table 2: Gender and Education Level of Respondents

Variables \ Gender	Contracted Tobacco Farmers	Independent Tobacco Farmers	Former Tobacco Farmers	Non-Tobacco Farmers
	Male	Female	Male	Female
Education Level				
Non-formal	15%	-	06%	04%
Primary	42%	36%	40%	38%
Secondary	38%	48%	40%	50%
College/University	05%	16%	14%	08%
Total	**100%**	**100%**	**100%**	**100%**

Source: Authors' (2024)

The data reveals that the majority of tobacco farmers, 221 (71%), had completed primary and secondary education, while 72 (23.2%) had informal education. Only 18 (5.8%) had college diplomas or university degrees. This indicates that most respondents could comprehend the questions posed. For those with informal education, research assistants translated questions into vernacular to facilitate understanding.

4.2.2 Size of Land Under Tobacco Cultivation

Farmers provided information on the size of land allocated to tobacco cultivation. The average size of land under tobacco cultivation was 1.46 acres, with a minimum of 0.25 acres and a maximum of 4 acres.

Table 3: Size of Land Under Tobacco Cultivation in Acres

Descriptive Statistic	N	Minimum	Maximum	Mean	Std. Deviation
Land Under Tobacco Cultivation	311	0.25	4.00	1.4607	0.79533

Source: Field data, 2024

The findings suggest variability in land allocation among farmers. Contracted tobacco farmers typically allocated more land to tobacco compared to independent and non-tobacco farmers. This allocation trend is influenced by tobacco companies' predetermined requirements for tobacco quantity. Non-tobacco farmers allocated more land to other crops. The establishment of new tobacco companies may have led to an increase in land allocated to tobacco cultivation.

Table 4: Tobacco Farming and Land Use (Acres)

Farmers	Land Cultivated	Assigned to Tobacco	Percentage	Land Assigned to Other Crops
Contracted Tobacco Farmers	2.04	1.90	93.13%	0.14
Independent Tobacco Farmers	2.21	1.50	67.87%	0.71
Non-Tobacco Farmers	2.09	N/A	100%	2.09
Total	**6.34**	**3.40**		**2.94**

Source: Field data, 2024

4.3 Duration of Tobacco Farming

Respondents were asked about the duration of their tobacco farming experience, which provided insight into their familiarity with tobacco farming's impact on the environment and livelihoods. Available data shows that most farmers (40%) had been growing tobacco for between 10 and 20 years. A significant portion (28%) had been involved for 20 to 30 years, while 25.6% had less than 10 years of experience. This indicates that the majority of respondents had substantial experience with tobacco farming.

4.4 Knowledge of Tobacco Farming's Environmental Impact

The study assessed tobacco farmers' awareness of the environmental effects of tobacco farming between 2020 and 2022. Interviews and focus group discussions revealed a concerning lack of environmental compliance by tobacco companies, with a compliance rate of only 11.6% to NEMA, WHO standards, and best practices. Tobacco farming has several environmental impacts that are of significant concern, especially when farming practices do not comply with environmental standards and best practices. The potential impacts include:

Deforestation: Tobacco farming requires substantial land, leading to deforestation. In many regions, forests are cleared to make way for tobacco plantations, resulting in loss of biodiversity, disruption of ecosystems, and increased carbon emissions.

Soil Degradation: Tobacco plants are nutrient-intensive and can lead to soil degradation. Continuous tobacco cultivation depletes soil nutrients, leading to reduced soil fertility. The heavy use of chemical fertilizers and pesticides further exacerbates soil erosion and pollution.

Water Pollution: The use of agrochemicals such as fertilizers, pesticides, and herbicides in tobacco farming can lead to water pollution. Runoff from tobacco fields often carries these chemicals into nearby water bodies, contaminating drinking water sources and harming aquatic life.

Air Pollution: Tobacco curing, a process that involves drying tobacco leaves, often requires burning large amounts of wood or other fuel, contributing to air pollution. This process releases significant amounts of carbon dioxide and other greenhouse gases into the atmosphere, contributing to climate change.

Chemical Exposure: Farmers and local communities are at risk of exposure to hazardous chemicals used in tobacco farming. These chemicals can cause serious health issues, including respiratory problems, skin conditions, and other chronic diseases.

Impact on Food Security: Tobacco farming can reduce land available for food crops, negatively impacting food security. In regions where land is limited, the prioritization of tobacco over food crops can lead to a shortage of essential food resources for local populations.

Biodiversity Loss: The monoculture of tobacco farming reduces biodiversity. The intensive farming practices and the use of pesticides diminish the variety of plants and animals in the area, leading to an imbalance in the local ecosystem.

Climate Change: Deforestation and the use of wood for tobacco curing contribute to greenhouse gas emissions. Additionally, the environmental degradation associated with tobacco farming exacerbates climate change, further impacting agricultural practices and livelihoods.

Waste Generation: Tobacco farming generates significant amounts of waste, including plastic from mulch and packaging, pesticide containers, and unused plant material. Improper disposal of these materials can lead to pollution of the land and water.

These impacts underscore the importance of raising awareness among tobacco farmers and enforcing environmental compliance to mitigate the negative effects of tobacco farming on the environment. The low compliance rate of 11.6% to standards set by NEMA, WHO, and best practices is alarming, as it suggests that these potential impacts are not being adequately addressed or mitigated.

4.5 Knowledge of Large-Scale Deforestation

Farmers' knowledge of deforestation and loss of native tree species varied. It is evident that 71 (23%) had minimal knowledge, 182 (59%) had some knowledge, 27 (9%) had expert knowledge, and 31 (10%) had extensive knowledge of forest cover loss. The findings regarding farmers' knowledge of deforestation and loss of native tree species have several important implications:

4.5.1 Need for Increased Environmental Education and Awareness

The fact that only 9% of farmers had expert knowledge and 10% had extensive knowledge indicates a significant gap in understanding the full extent and impact of deforestation. This gap suggests a need for targeted educational programs to raise awareness about the importance of forest conservation and the consequences of large-scale deforestation on the environment.

4.5.2 Limited Understanding May Lead to Unsustainable Practices

With 23% of farmers having minimal knowledge of deforestation, there is a risk that these farmers may engage in practices that contribute to forest cover loss without understanding the long-term consequences. This could lead to unsustainable land use, further exacerbating environmental degradation and reducing the resilience of ecosystems.

4.5.3 Impact on Policy Implementation and Compliance

The variation in knowledge levels among farmers could affect the effectiveness of policy implementation related to forest conservation. Farmers with limited knowledge may be less likely to comply with environmental regulations and best practices, making it more challenging to enforce sustainable practices at the community level.

4.5.4 Potential for Targeted Interventions

The data suggests that 59% of farmers had some knowledge of deforestation. This group could be a key target for interventions aimed at deepening their understanding and equipping them with the tools and knowledge needed to adopt more sustainable practices. Targeted training and extension services could help move this group toward expert and extensive knowledge levels, fostering more sustainable land management practices.

4.5.5 Threat to Biodiversity and Ecosystem Services

Inadequate knowledge of deforestation and native tree species loss among a significant portion of farmers can lead to continued deforestation, further threatening biodiversity and the ecosystem services that forests provide. These include water regulation, soil fertility, and carbon sequestration, all of which are critical for both local livelihoods and broader environmental health.

4.5.6 Influence on Community Practices and Cultural Attitudes

The varying levels of knowledge can also influence community practices and cultural attitudes towards deforestation. Farmers with minimal knowledge may not fully appreciate the cultural and ecological value of native tree species, leading to practices that prioritize short-term economic gains over long-term environmental sustainability.

4.5.7 Challenges in Reforestation and Conservation Efforts

The lack of expert knowledge among the majority of farmers may pose challenges for reforestation and conservation initiatives. Without a deep understanding of the importance of native tree species and the impacts of deforestation, farmers may be less motivated to participate in or support reforestation efforts, undermining these initiatives.

4.5.8 Opportunity for Community-Led Conservation Initiatives

The presence of farmers with expert and extensive knowledge (19% combined) suggests a potential resource within the community to lead conservation efforts. These knowledgeable individuals could serve as champions or peer educators, helping to spread awareness and influence positive change among other farmers.

In summary, these findings highlight the critical need for enhanced environmental education, targeted interventions, and community engagement to improve farmers' understanding of deforestation and encourage more sustainable land use practices. Addressing these knowledge gaps is essential for the success of forest conservation efforts and the long-term health of the environment.

4.5 Pesticides Polluting Water Systems

Farmers use various pesticides, some of which may pollute water sources as shown in the table below:

Table 5: Common Pesticides Used in Tobacco Farming

Pesticide	Description
Aldicarb	Highly toxic, causing genetic damage and adverse effects on the environment.
Chlorpyrifos	Affects the nervous system, with residues contaminating air and water.
1,3-D	Causes respiratory problems and cancer, contaminating groundwater.

Source: Adapted from Campaign for Tobacco-Free Kids, 2001

Recommendations for mitigating pesticide impacts include implementing riparian strips to filter pollutants, controlling flowering weeds, and exploring alternative pest management methods.

5. Conclusion and Recommendations

5.1 Conclusion

Smallholder farmers in Uriri sub-county have demonstrated resilience and adaptability in the face of climate variability by incorporating several innovative and traditional agricultural practices. The use of manure as a soil amendment is one such practices, which not only enrich soil fertility but also enhance the soil's ability to retain moisture, making it more resilient to drought conditions. This practice is vital in stabilizing crop yields, ensuring food security, and improving the long-term sustainability of farming in the region. In addition to manure application, farmers are increasingly adopting local livestock breeds that are better suited to the changing climate and can thrive under less favorable conditions. By choosing these breeds, farmers can maintain livestock productivity while reducing the environmental impact and financial risks associated with raising non-native or high-maintenance breeds. Furthermore, the decision to reduce livestock numbers is a strategic response to the limitations posed by shrinking pasturelands and water resources, thereby preventing overgrazing and land degradation.

The increase in fertilizer application reflects an effort by farmers to boost crop productivity in soils that may have been depleted by continuous cultivation or affected by changing weather patterns. While this practice can lead to immediate gains in crop yields, it is crucial that it is managed carefully to avoid long-term negative impacts on soil health and the environment. Diversifying livelihoods is another critical adaptation strategy employed by these farmers. By engaging in various income-generating activities beyond traditional crop farming, such as small-scale trading, agroforestry, or artisanal crafts, farmers are reducing their dependence on a single source of income. This diversification helps to spread risk and provides a buffer against the economic shocks that might arise from crop failures or market fluctuations, particularly in an unpredictable climate.

These adaptive strategies collectively demonstrate the resourcefulness and agency of smallholder farmers in Uriri sub-county as they navigate the challenges posed by climate change. Their actions underscore the importance of integrating indigenous knowledge with modern agricultural techniques to build resilience. However, to sustain and scale these efforts, there is a need for continued support in the form of education, access to resources, and favorable policy frameworks. By fostering an environment that encourages innovation and sustainability, smallholder farmers can continue to thrive despite the ongoing challenges of climate variability.

5.2 Recommendations

This paper makes the following recommendations:

1. **Strengthen Educational Programs:** To enhance farmers' understanding of sustainable agricultural practices and their environmental impacts, it is crucial to develop and implement targeted educational programs. These programs should focus on key areas such as environmental sustainability, effective pesticide use, and soil management. Educational initiatives should be tailored to accommodate varying literacy levels and be accessible in local languages. Providing practical, hands-on training and resources will enable farmers to make informed decisions and adopt best practices in their farming activities.
2. **Promote Crop Diversification:** Reducing dependence on tobacco and fostering economic resilience can be achieved through crop diversification. Farmers should be encouraged to diversify their crops by offering incentives, such as subsidies or access to a variety of seed types. Educational efforts should emphasize the benefits of crop diversification, including its positive impact on soil health and income stability. Support programs can guide farmers in selecting

appropriate crops and managing diverse agricultural systems effectively.

3. **Enhance Environmental Compliance:** Improving adherence to environmental regulations and best practices in tobacco farming requires strengthening enforcement mechanisms. Tobacco companies should be held accountable for complying with environmental standards related to deforestation, pesticide use, and soil conservation. Regular environmental audits and training sessions can help ensure compliance and promote responsible farming practices. Collaboration between government agencies, tobacco companies, and local communities is essential for achieving these goals.
4. **Implement Integrated Pest Management (IPM):** To reduce reliance on harmful pesticides and mitigate environmental pollution, promoting Integrated Pest Management (IPM) practices is essential. IPM strategies include biological control, crop rotation, and the use of pest-resistant crop varieties. Training programs should be established to educate farmers on IPM techniques and provide resources for their effective implementation. By adopting IPM, farmers can manage pests more sustainably and minimize environmental and health risks.
5. **Improve Land Management Practices:** Enhancing soil health and reducing environmental degradation can be achieved through improved land management practices. Farmers should be encouraged to adopt conservation tillage, organic amendments, and riparian strips to manage soil erosion and nutrient runoff. Support for research and the development of innovative land management practices suited to local conditions will further aid in sustainable land use and agricultural productivity.
6. **Support Policy and Incentive Development:** A supportive policy environment is crucial for promoting sustainable agriculture. Advocacy efforts should focus on creating policies that support sustainable farming practices and provide financial incentives for adopting environmentally friendly technologies. Engaging with policymakers to ensure that agricultural policies align with long-term environmental and economic sustainability goals is vital for fostering a conducive environment for sustainable farming.
7. **Invest in Research and Technology:** Investing in research and technology is essential for developing and promoting sustainable agricultural practices. Support for research into alternatives to tobacco cultivation and technologies that improve crop yields while reducing environmental impacts is crucial. By advancing agricultural technologies and practices, farmers can achieve higher productivity and sustainability in their farming operations.
8. **Enhance Community Engagement:** Fostering community involvement in environmental conservation and sustainable practices can be achieved through community-based initiatives and participatory approaches. Engaging local communities in decision-making processes and encouraging collaborative efforts to address environmental challenges will enhance the effectiveness of sustainability measures. Community involvement is key to ensuring that environmental and agricultural practices are well-integrated and supported locally.

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