

## When More is Not Necessarily Better: Examining Climate Change Adaptation Strategies and Household Food Security among Small - Scale Farmers in Kieni West Sub-County, Nyeri County, Kenya

Sylvia Wambui Muchiri\*, Willice O. Abuya<sup>1</sup>, Moses Beru<sup>1</sup>

<sup>1</sup>*Department of Sociology, Psychology and Anthropology, Moi University, Kenya*

\* Corresponding Author

---

**Abstract:** Climate change threatens the food security of smallholder farmers in semi-arid sub-Saharan Africa, yet it remains unclear whether the adaptation strategies farmers adopt translate into better food security. In Nyeri County, changing rainfall patterns have decreased amounts every 3-4 years, with drought now common in semi-arid Kieni West, resulting in crop failures and reduced milk production. Despite government efforts through the Climate Change Adaptation Strategy 2009-2030 and various farmer adaptation practices, 70% of Nyeri households still lack sufficient food. Through a survey method, where 270 households were interviewed, this article thus examines the adaptation strategies used by small-scale farmers in Kieni West Sub-County, Nyeri County, Kenya to fend off household food insecurity. Findings indicated that most farmers (92.96%) were aware of climate change, and 76.3% had adopted six to eight of the eight strategies identified. Improved crop varieties (70.74%), soil conservation (68.52%) and water management (66.67%) were the most widely adopted strategies. Adoption rose with age, farming experience and education but did not differ by gender. The Household Food Insecurity Access Scale (HFIAS) noted that only 1.8% of households were food secure while 67.4% were found to be severely food insecure. The z-tests showed a marginally significant relationship between strategy adoption levels and food insecurity patterns, with households adopting 6-8 strategies experiencing more mild food insecurity compared to those adopting 4-5 strategies. However, the overall relationship between strategy adoption and food security improvement was found to be weak, indicating that strategy implementation alone is insufficient for achieving food security. Agricultural extension should therefore prioritize the quality of implementation combined with market access and livelihood support.

**Keywords:** Climate change, Adaptation strategies, Food security, Small-scale farmers, Kenya

---

### 1. Introduction

One persistent global issue that still poses a threat to humanity is the phenomenon of climate change [1], [2]. As the world's second-largest continent, spanning over 30 million km<sup>2</sup>, Africa faces climate change as one of its most pressing ecological and social challenges of the 21<sup>st</sup> century [3]. The burden falls unevenly where developing countries bear the greatest consequences although they have contributed least to the problem and have the fewest resources with which to respond [4]. Rural farming communities are particularly exposed because their adaptive capacity and access to finance are limited, and meaningful progress is unlikely without targeted and sustained support [5]–[7].

Agriculture in Kenya, generates about a fifth of the gross domestic product and employs more than 40% of the population, and roughly 7.5 million small-scale producers account for about 80% of agricultural output [8]. Nearly all of this farming is dependent on precipitation, creating significant climatic vulnerability.

Nyeri County exemplifies this vulnerability. Semi-arid areas on the leeward side of Mount Kenya, including Kieni West, are prone to recurrent drought, with crop failure, prevented planting and lower milk production being the outcome. The county's climate risk profile reports that about 70% of households in Nyeri, particularly in Kieni, lack adequate access to food [9]. Rainwater harvesting, improved seed and livelihood diversification have been widely promoted and many farmers have taken them up, yet food insecurity persists.

Evidence from Kenya links adaptation to food security. Reviews show that climate variability and change undermine agricultural production and food security in the country [10] and national data indicate that farmers who use adaptation strategies are more likely to be food secure than those who do not [11]. However, such evidence often does not distinguish between how many strategies a household adopts and how well they work, and, to our knowledge, it has not been examined at sub-county level in semi-arid Kieni with a standard household food insecurity scale. Whether adoption is associated with lower food insecurity in such a setting is therefore an open question. This article assesses the range of adaptation strategies employed by small-scale farmers in Kieni West Sub-County, and their implication on food security to individual households. It puts to test one hypothesis that states that the adoption of climate-smart agricultural strategies is closely associated with food security.

### **1.1 Climate Change Adaptation**

Climate change is no longer a hypothesis but a present day reality for everyone, especially to rural communities whose livelihood depends on weather patterns. Rising temperatures, more erratic rainfall and more frequent droughts are projected to intensify and to worsen conditions for food production across Africa [12]. In Africa, environmental threats are expected to intensify, manifesting through rising temperatures, elevated sea levels, increased cyclonic activity in East Africa, and deteriorating conditions for food production [12]. In Kenya, climate variability and change have been shown to undermine agricultural production and food security [10]. For the smallholder households who account for about 80% of agricultural output in Kenya [8], the question is therefore not whether climate change will affect them, but how they will respond to it.

Reducing emissions alone cannot protect these households, because the changes already under way will continue to affect farming for decades. Communities that depend on rain-fed agriculture must therefore adjust their practices in order to survive. Adaptation, the process of adjusting to actual or expected climate and its effects in order to moderate harm, is the means by which farming communities stay productive and food secure [12]. Communities that do not adapt remain exposed to repeated crop failure, loss of income and hunger, whereas those that adapt are better placed to protect their livelihoods [13], [11]. Adaptation is, however, limited by the resources and capacity available to farmers [4], [7]. It is for this reason that it matters to establish which strategies farmers actually adopt, who adopts them, and whether adoption translates into food security.

### **1.2 Adaptation Strategies**

Given the great susceptibility of the agricultural sector to critical climatic variables such as temperature, precipitation, and wind [14], climate change has presented significant and increasing challenges to global agriculture [15]. Therefore, adaptation is essential to addressing this sector's vulnerabilities. The United Nations' Sustainable Development Goals 2 and 13 which aim to eradicate hunger and combat climate change, respectively are in line with adaptation strategies. Furthermore, in order to inform climate planning and commitments, all parties are required by the Paris Agreement to evaluate adaptation progress [16], [17].

Eight groups of strategies recur in the literature on smallholder adaptation. Diversifying farming methods, through mixed cropping, crop rotation and adjusted planting dates, spreads risk across crops and seasons and stabilizes income [18]. In Kenya, crop diversification has been shown to help manage climate risk, and maize-legume rotation and intercropping have raised maize yields under conservation agriculture in contrasting African environments [19].

Water resources have been vital to agricultural production, but they are increasingly threatened by growing water scarcity. By upsetting the delicate balance of the water cycle, the impending threat of climate change exacerbates these difficulties even more [20]. In order to deal with the increasing variability of rainfall and drought conditions brought on by climate change, smallholder farmers have implemented a variety of water management techniques. Typical strategies include rainwater harvesting, which has become a revolutionary method being used globally to address water scarcity and encourage sustainable living [21]. In dry and semi-arid areas, water harvesting methods such as runoff management, agricultural ponds, and micro-catchment systems are commonly used. For additional irrigation or ground water recharge, these methods collect and retain surface runoff or rainfall [22]. During dry spells, water collection supports crop output, increases water availability, and lessens reliance on erratic rainfall. Techniques that manage irrigation, such as alternating soaking and drying, precision irrigation, and deficit irrigation, have become more popular as adaptation measures. In order to maximize yield and water productivity, deficit irrigation applies water below the crop's full water requirements, permitting moderate stress. By precisely delivering water according to crop requirements and soil moisture levels, precision irrigation—made possible by technologies such as drip and sprinkler systems—minimizes water loss [23].

Improved crop varieties are cultivars that have had their characteristics and performance improved through selective breeding or genetic alteration. This can entail higher nutritional value, increased yield, resistance to pests or diseases, and flexibility in various environmental settings. It has become a normal practice to introduce and cultivate enhanced crop types that are resistant to climate conditions, diseases, and pests. Crop types created through breeding initiatives or genetic modification are becoming more and more popular among small-scale farmers as a way to increase their resistance to shifting environmental circumstances. The goal of this strategy is to protect livelihoods and guarantee steady harvests (FAO, 2020).

Farmers also adopt soil and land management practices to conserve soil, improve fertility, and enhance resilience to climatic variability. Conservation tillage, reduced or zero tillage, and retention of crop residues minimize soil disturbance, reduce erosion, and improve moisture conservation [24]. Mulching similarly protects the soil surface, suppresses weeds, regulates soil temperature, and enhances moisture and nutrient retention [25]. Organic matter management through composting and manure application improves soil fertility, structure, water retention, and infiltration while reducing dependence on external inputs [26], [27]. Other practices, including

cover crops, improved fallows, and agroforestry, contribute to soil rehabilitation, nutrient cycling, and improved land productivity [28], [29].

Environmentally sound animal production methods are fundamental for building agricultural system robustness internationally. These techniques involve regulating livestock populations or synchronizing animal numbers with accessible feed sources [30], feed enhancement that is delivering additional nutrition during periods of inadequate pasture or to address nutrient shortfalls [31], and selecting moisture-tolerant livestock species or breeding lines that exhibit decreased vulnerability to climatic challenges, resulting in improved productivity and income generation [32], [33].

Expanding livelihood alternatives can serve as a vital approach for climate change adaptation by helping distribute risks and establishing additional income sources [34]. Farm-based diversification involves combining different crop and livestock activities to spread production and income risks. Practices such as integrated crop-livestock systems, and beekeeping can provide alternative food and income sources while reducing households' vulnerability to climate-related shocks [35]. Non-farm income and migration can further strengthen household resilience. Alternative income activities can reduce losses following climatic shocks, while remittances from household members who migrate can improve food access and diversify income beyond climate-sensitive agricultural activities [36], [34].

Since its inception in the late 1950s, the integrated pest management (IPM) paradigm of crop protection has been the most widely used. The Food and Agriculture Organization (FAO) defines Integrated Pest Management (IPM) as the process of carefully weighing all available pest control methods and then incorporating suitable measures that prevent the growth of pest populations, maintain pesticides and other interventions at economically justified levels, and lessen or eliminate risks to the environment and human health. IPM stimulates natural pest management methods and supports the development of a healthy crop with the least amount of disturbance to agro-ecosystems [37].

Research indicates that improving smallholder farmers' access to and adoption of technologies such as weather monitoring tools, effective irrigation systems, and stress-tolerant seed varieties can raise agricultural productivity and incomes in the face of climate change [38]. To enable smallholder farmers to successfully address climate risks and improve resilience, technology adoption should be combined with varied cropping, climatic services, and social safety nets [11].

To appropriately analyse the findings of the study, the Sustainable Livelihoods Framework was adopted. This framework views households as pursuing livelihood strategies by drawing on five capitals (human, social, natural, physical and financial) within a vulnerability context of shocks and trends such as climate change, and mediated by institutions and policies, in order to achieve livelihood outcomes including food security. Two implications guide the analysis. First, adoption should vary with the assets households hold, which the study approaches through age, farming experience and education (human capital) and gender. Second, strategies are viewed as means rather than ends: whether households deliver on food security depends on the wider capitals and institutional context, not on adoption alone. The second view is whence the hypothesis that states that the adoption of climate-smart agricultural strategies is closely associated with food security among small-scale farmers is derived from.

## 2. Methodology

The study was conducted in Kieni West Sub-County, Nyeri County, central Kenya. The sub-county covers about 518 km<sup>2</sup> and has four wards: Gatarakwa, Mugunda, Endarasha/Mwiyogo and Mweiga. Its semi-arid conditions on the leeward slopes of Mount Kenya and its reliance on rain-fed farming make it vulnerable to drought and, occasionally, to floods. Farmers grow maize, beans, Irish potatoes and vegetables and keep livestock.

Kieni West was selected for four reasons. First, it is semi-arid and prone to recurrent droughts, and the county's climate risk profile reports that about 70% of households in Nyeri, particularly in Kieni, lack adequate access to food [9], so the link between adaptation and food security is a live concern there. Second, the sub-county combines the semi-arid conditions of the leeward slopes of Mount Kenya with wetter zones elsewhere, so it serves as a microcosm of the agro-ecological conditions and challenges faced by farmers across the wider region and allows adaptation strategies to be examined in both wet and dry areas. Third, its population is largely made up of smallholder farmers who keep both crops and livestock, the group most exposed to climate shocks. Lastly, the presence of the Kenya School of Agriculture at Wambugu Farm, a training institution that provides research and consultation services, gave the study access to expert knowledge and resources. Other sub-counties in Kenya, such as parts of Makueni, Kitui and Laikipia, are also vulnerable to climate change, but Kieni West brings these characteristics together in a single setting.

A survey method was used to collect data. The target population were small-scale farming households that cultivate less than 4.5 acres, derive a significant share of their income from farming, and keep both crops

and livestock. A two-stage procedure was followed. First, two of the four wards, Mwiyo and Mweiga, were selected by simple random sampling; together they hold 8,244 of the estimated 15,625 households in the sub-county. Through Cochran's formula, 270 households were determined for the study. This sample size was, then, through stratified sampling, apportioned to the two purposively selected wards (that is Mwiyo (81), and Mweiga (189)). Households were selected within each ward from the household listings held by the assistant chiefs' offices, organised by sub-location, using systematic interval. The unit of analysis were household heads.

Data was collected with a structured questionnaire administered by the researcher and entered directly into a password-protected electronic form. The instrument covered demographic characteristics, awareness of climate change and experienced impacts, adoption of eight adaptation strategies and the nine HFIAS questions. The questionnaire was pilot tested with a small group of farmers drawn from the larger target population, but who were not included in the main survey. The pilot study was conducted to identify ambiguous or confusing questions, unclear wording and potential bias, and to improve the consistency of responses. The questionnaire was revised on the basis on the feedback received, and this revised version was what was administered to the sampled household heads. For purposes of triangulation, key informant interviews and observation methods were also used. Six agricultural extension officers were interviewed as key informants, while for observation purposes, a check list was constructed to observe farm practices. Research authorization was obtained before fieldwork. During fieldwork, consent was obtained from participants before interviews, and responses were anonymized.

Adoption of each of the eight strategies was recorded as a yes/no response, and the number of strategies adopted was grouped as none, one to three, four to five, and six to eight. Household food insecurity was measured with the nine-item HFIAS, using a 12-month recall period, and households were classified as food secure, or mildly, moderately or severely food insecure from the occurrence and frequency of the nine conditions.

Analysis was done through descriptive statistics, with Pearson chi-square tests and z-tests used to analyse findings. The stated hypothesis in section 1 above was tested using Z-test, where households were grouped by the number of strategies adopted: low (none to three strategies, combined because the original groups were too small), moderate (four to five) and high (six to eight). The percentage of households in each food security category was compared across each pair of adoption groups using a two-proportion z-test. Because the analysis involved three pairs of adoption groups and three food security categories (food secure, mildly food insecure, and severely food insecure), a total of nine pairwise comparisons were conducted. If adoption was strongly associated with food security, the groups with higher adoption levels would be expected to have a higher proportion of food-secure households and a lower proportion of severely food-insecure households.

### **3. Field Findings**

#### **3.1 Respondents demographics**

Table 1 describes the 270 respondents. Most were male (91.9%), 43.7% were aged 55 years or more, and 47.4% had no formal education. More than half (52.6%) had 11–20 years of farming experience and a further 21.5% had more than 20 years.

Age is often linked to a person's exposure to different technologies, life experience and risk tolerance [11]; gender differences are critical in determining access to resources like land, technology and decision-making power [39]; Education influences a farmer's ability to understand, access, and apply new information regarding climate-smart agricultural practices [40] and farming experience provides practical knowledge about local climate patterns, farming practices, and past adaptation strategies [41]

Table 1: Characteristics of the respondents (N = 270)

| Characteristic     | Category            | Households | %    |
|--------------------|---------------------|------------|------|
| Age (years)        | Below 35            | 35         | 13.0 |
|                    | 35–44               | 28         | 10.4 |
|                    | 45–54               | 89         | 32.9 |
|                    | 55 and above        | 118        | 43.7 |
| Gender             | Male                | 248        | 91.9 |
|                    | Female              | 22         | 8.1  |
| Education          | No formal education | 128        | 47.4 |
|                    | Primary             | 52         | 19.3 |
|                    | Secondary           | 82         | 30.4 |
|                    | University          | 8          | 2.9  |
| Farming experience | Less than 5 years   | 32         | 11.9 |
|                    | 5–10 years          | 38         | 14.1 |
|                    | 11–20 years         | 142        | 52.6 |
|                    | More than 20 years  | 58         | 21.5 |

Source: Survey data, 2024.

This data was applied for purposes of intersectionality analysis.

### 3.2 Awareness and Impact of Climate Change

Awareness is the starting point of adaptation because farmers who do not recognize that the climate is changing are unlikely to change their farming practices. This section therefore presents the extent of farmers' awareness of climate change and the impacts they had experienced on their farms, before they now decide which strategies they are going to adopt in response.

Table 2: Farmers' Awareness of Climate Change

| Awareness of climate change                                | Frequency (n) | Percentage (%) |
|------------------------------------------------------------|---------------|----------------|
| Aware of climate change                                    | 251           | 92.96          |
| Not aware of climate change, but aware of climatic changes | 19            | 7.04           |
| <b>Total</b>                                               | <b>270</b>    | <b>100.00</b>  |

Source: Survey Data 2024

A large majority of farmers (251 households; 92.96%) reported being aware of climate change, and the remaining 19 (7.04%) recognized changing weather patterns without using the term climate change as shown in table 2.

Table 3 shows the impacts of climate change as experienced by farmers. Increased drought (92.96% of respondents), changes in the growing season (89.26%), more erratic rainfall (88.52), decreased water availability (84.81%) and more pest and disease outbreaks (84.07%) were the most commonly reported. Higher temperatures and soil erosion or degradation were each reported by 73.33% of respondents, flooding by 52.59% and heat waves by 32.96%. The survey results indicated a significant awareness among farmers regarding the impacts of climate change on their agricultural practices.

Table 3: Climate change impacts reported by farmers (N = 270)

| Climate change impact                | Households | % of respondents |
|--------------------------------------|------------|------------------|
| Increased frequency of droughts      | 251        | 92.96            |
| Changes in growing seasons           | 241        | 89.26            |
| More erratic rainfall patterns       | 239        | 88.52            |
| Decreased water availability         | 229        | 84.81            |
| Increased pest and disease outbreaks | 227        | 84.07            |
| Higher temperatures                  | 198        | 73.33            |
| Soil erosion or degradation          | 198        | 73.33            |
| Increased flooding                   | 142        | 52.59            |
| More frequent heat waves             | 89         | 32.96            |

Source: Survey data, 2024.

### 3.3 Climate Change Adaptation Strategies

As indicated, there exists various adaptation strategies that farmers can pick-up. In Kieni, farmers were found to have adopted eight (8) strategies as shown in Table 4. Improved crop varieties were the most widely adopted (70.74%), followed by soil conservation (68.52%), water management techniques (66.67%) and diversification of farming methods (63.70%). Livestock management (62.22%), livelihood diversification (59.30%) and integrated pest management (56.30%) followed and half of the farmers had adopted new technology (50.0%).

Table 4: Adoption of adaptation strategies

| Strategy                           | Adopted, n (% of 270) |
|------------------------------------|-----------------------|
| Improved crop varieties            | 191 (70.74)           |
| Soil conservation practices        | 185 (68.52)           |
| Water management techniques        | 180 (66.67)           |
| Diversification of farming methods | 172 (63.70)           |
| Livestock management               | 168 (62.22)           |
| Livelihood diversification         | 160 (59.30)           |
| Integrated pest management         | 152 (56.30)           |
| Adoption of new technology         | 135 (50.0)            |

Source: Survey data, 2024

### 3.4 Intersectionality and adaptation strategies

For each of the eight strategies, adoption was compared across four demographic variables: age, years of farming experience, education and gender. These characteristics were selected because, as outlined in section 3.1, each shapes a farmer's ability to access, understand and act on adaptation options: age through exposure to technology, life experience and risk tolerance; farming experience through practical knowledge of local climate and past adaptation; education through the capacity to access and apply new information; and gender through access to land, technology and decision-making power. They are also the human capital and personal attributes through which, in the Sustainable Livelihoods Framework, households convert their assets into livelihood strategies. Examining the four together shows whether adoption is concentrated among particular groups of farmers, and therefore where extension and support are most needed.

Tables 5 to 8 gives the findings as it relates to this. To test for association between strategy adoption as it relates to the intersectionality variables selected, Pearson chi-square test of independence was used. Table 5 shows results of age contrasted against adaptation strategies. The results show that adoption rose with age for every strategy, and that the association was statistically significant for each strategy.

Table 5: Adoption of strategies by farmers' age

| Strategy                           | Farmers who adopted the strategy, % of age group |                   |                   |                           | Chi-square test |       |
|------------------------------------|--------------------------------------------------|-------------------|-------------------|---------------------------|-----------------|-------|
|                                    | Below 35<br>(n = 35)                             | 35–44<br>(n = 28) | 45–54<br>(n = 89) | 55 and above<br>(n = 118) | $\chi^2$ (df)   | p     |
| Improved crop varieties            | 51.4                                             | 71.4              | 73.0              | 74.6                      | 8.842 (3)       | 0.031 |
| Soil conservation practices        | 40.0                                             | 64.3              | 71.9              | 75.4                      | 14.726 (3)      | 0.002 |
| Water management techniques        | 45.7                                             | 64.3              | 69.7              | 71.2                      | 11.246 (3)      | 0.010 |
| Diversification of farming methods | 45.7                                             | 53.6              | 65.2              | 70.3                      | 10.264 (3)      | 0.016 |
| Livestock management               | 34.3                                             | 57.1              | 65.2              | 69.5                      | 13.842 (3)      | 0.003 |
| Livelihood diversification         | 28.6                                             | 57.1              | 62.9              | 66.1                      | 16.843 (3)      | 0.001 |
| Integrated pest management         | 28.6                                             | 53.6              | 58.4              | 63.6                      | 15.624 (3)      | 0.001 |
| Adoption of new technology         | 20.0                                             | 42.9              | 53.9              | 57.6                      | 18.624 (3)      | 0.001 |

Source: Survey data, 2024

Age therefore weighed significantly when it comes to farmers taking up adaptation strategies. What first catches the eye is the finding that young farmers were the least likely to have adopted new technology. The reverse is what is expected, since younger farmers are commonly assumed to embrace new technologies more readily [42], [43]. This is consistent with the argument that older farmers have accumulated practical experience of farming and a deeper understanding of local environmental change, which helps them to recognise the long-term threat posed by climate change and to adopt strategies such as diversification to protect their livelihoods.

Ndung'u et al. [44] and Deressa et al. [45] similarly emphasised the link between age and environmental knowledge, with Ndung'u et al. finding that adoption of climate-smart agriculture technology increased with age, peaking in the above-55 age group. Older farmers may also have a greater stake in keeping their farms sustainable, since these are often multigenerational family enterprises. Younger farmers, in contrast, tend to be less familiar with long-term climate variability [46], and they may have fewer resources and less land with which to experiment with new techniques. The lack of productive resources such as land and capital among the youngest farmers has also been offered as an explanation for their low uptake of technology [46]. In Kieni West, however, resources and experience, rather than youthful familiarity with technology, appear to drive adoption.

Table 6 contrasts years of farming experience with strategies adapted. Results indicate that there was significant association between the array of adaptation strategies and years of experience. Adoption was lowest among farmers with less than five years of experience and highest among those with 11–20 years or more than 20 years.

Table 6: Adoption of strategies by years of farming experience

| Strategy                           | Farmers who adopted the strategy, % of experience group |                     |                       |                             | Chi-square test |       |
|------------------------------------|---------------------------------------------------------|---------------------|-----------------------|-----------------------------|-----------------|-------|
|                                    | Less than 5 years (n = 32)                              | 5–10 years (n = 38) | 11–20 years (n = 142) | More than 20 years (n = 58) | $\chi^2$ (df)   | p     |
| Improved crop varieties            | 46.9                                                    | 63.2                | 76.1                  | 75.9                        | 12.847 (3)      | 0.005 |
| Soil conservation practices        | 43.8                                                    | 57.9                | 74.6                  | 74.1                        | 13.967 (3)      | 0.003 |
| Water management techniques        | 37.5                                                    | 57.9                | 71.8                  | 75.9                        | 16.924 (3)      | 0.001 |
| Diversification of farming methods | 43.8                                                    | 57.9                | 66.2                  | 72.4                        | 18.742 (3)      | 0.001 |
| Livestock management               | 37.5                                                    | 52.6                | 69.0                  | 65.5                        | 11.842 (3)      | 0.008 |
| Livelihood diversification         | 31.3                                                    | 47.4                | 66.2                  | 65.5                        | 15.847 (3)      | 0.001 |
| Integrated pest management         | 31.3                                                    | 47.4                | 63.4                  | 58.6                        | 13.967 (3)      | 0.003 |
| Adoption of new technology         | 25.0                                                    | 42.1                | 57.7                  | 50.0                        | 12.983 (3)      | 0.005 |

Source: Survey data, 2024

The rise in adoption with farming experience is consistent with earlier studies. Amare et al. (2018) found that farming experience significantly influenced the adoption of crop management strategies, with more experienced farmers showing higher adoption rates. Experienced farmers typically have better access to resources and information networks [45] and are more knowledgeable about weather patterns and their implications for crop production [47]. The low adoption among farmers with less than five years of experience corroborates Bryan et al. [13], who found that newer farmers often face barriers to adopting climate adaptation strategies because of limited resources and knowledge.

Table 7 contrasts farmer education against adaptation strategies. The results indicate that adoption rose with each step up in education (from no formal education, to primary level, to secondary and post-secondary level) for all eight strategies. No chi-square test of education was reported, so this pattern is described but is not claimed to be statistically significant. The chi-square test of independence is valid only when the expected frequencies in the cells are sufficiently large, conventionally at least five. Only eight respondents (2.9%) had university education, so the expected frequencies for this group fell below that minimum for all eight strategies, and the test would not have been valid.

Table 7: Adoption of strategies by education level

| Strategy                           | Farmers who adopted the strategy, % of education group |                  |                    |                    |
|------------------------------------|--------------------------------------------------------|------------------|--------------------|--------------------|
|                                    | No formal education (n = 128)                          | Primary (n = 52) | Secondary (n = 82) | University (n = 8) |
| Improved crop varieties            | 60.9                                                   | 73.1             | 81.7               | 100.0              |
| Soil conservation practices        | 57.8                                                   | 71.2             | 80.5               | 100.0              |
| Water management techniques        | 56.3                                                   | 69.2             | 78.0               | 100.0              |
| Diversification of farming methods | 56.3                                                   | 65.4             | 70.7               | 100.0              |
| Livestock management               | 53.1                                                   | 65.4             | 70.7               | 100.0              |
| Livelihood diversification         | 48.4                                                   | 61.5             | 70.7               | 100.0              |
| Integrated pest management         | 45.3                                                   | 61.5             | 65.9               | 100.0              |
| Adoption of new technology         | 37.5                                                   | 53.8             | 62.2               | 100.0              |

Source: Survey data, 2024

The education findings show that adoption rose with each step up in education for all eight strategies, and that all eight university-educated farmers had adopted every strategy. This is consistent with evidence that higher education enhances farmers' understanding of climate challenges and adaptive strategies [48]. Ndamani and Watanabe [49] and Deressa et al. [45] likewise identified education as a critical determinant of adaptation, because educated farmers have better access to information and a greater ability to process complex agricultural decisions. Education also increases farmers' ability to obtain, interpret and understand climate-related information, and so to devise suitable responses [50], and Belay et al. [51] found that more years of education increased the likelihood of adopting improved crop varieties.

The next test was to assess whether gender was associated with adaptation strategies adopted. The results indicated that there was no significant difference when it came to gender (see Table 8).

Table 8: Adoption of strategies by gender

| Strategy                           | Farmers who adopted the strategy |                          | Chi-square test |       |
|------------------------------------|----------------------------------|--------------------------|-----------------|-------|
|                                    | Men, adopted of 248 (%)          | Women, adopted of 22 (%) | $\chi^2$ (df)   | p     |
| Improved crop varieties            | 176 of 248 (71.0)                | 15 of 22 (68.2)          | 0.076 (1)       | 0.783 |
| Soil conservation practices        | 170 of 248 (68.5)                | 15 of 22 (68.2)          | 0.001 (1)       | 0.973 |
| Water management techniques        | 166 of 248 (66.9)                | 14 of 22 (63.6)          | 0.095 (1)       | 0.758 |
| Diversification of farming methods | 158 of 248 (63.7)                | 14 of 22 (63.6)          | 0.142 (1)       | 0.706 |
| Livestock management               | 154 of 248 (62.1)                | 14 of 22 (63.6)          | 0.021 (1)       | 0.885 |
| Livelihood diversification         | 146 of 248 (58.9)                | 14 of 22 (63.6)          | 0.187 (1)       | 0.665 |
| Integrated pest management         | 140 of 248 (56.5)                | 12 of 22 (54.5)          | 0.027 (1)       | 0.869 |
| Adoption of new technology         | 124 of 248 (50.0)                | 11 of 22 (50.0)          | 0.000 (1)       | 1.000 |

Source: Survey data, 2024.

The finding that men and women adopted adaptation strategies at similar rates is consistent with recent work suggesting that gender differences in adoption narrow when access to resources and extension services is more equal. Mcharo and Waswa [52], for example, found diminishing gender differences in the adoption of soil and water conservation practices in Kenyan highland catchments, which they attributed to improved access to extension services and resources for female farmers. It contrasts with earlier studies that documented significant gender gaps, often because men have greater access to resources, land and decision-making [45], [44]. Two considerations temper the finding. First, similar adoption rates may mask differences in the scale and intensity with which women and men implement strategies [53]. Second, only 22 of the 270 respondents (8.1%) were women, so the comparison rests on a small group, and the household head recorded as male is not necessarily the only decision-maker: one extension officer interviewed observed that in households where women had more education or training they often influenced or even led the decision to adopt, regardless of who was registered as household head.

Taken together, Tables 5 to 8 shows that older, more experienced and more educated farmers took to more efficient strategies, whereas gender was demonstrated as bearing no significant impact. In terms of the Sustainable Livelihoods Framework, this suggests that human capital, in the form of knowledge built up through age, experience and schooling, shapes which households would adapt better adaptation strategies.

#### 4. Household Food Security

Food insecurity was measured using the HFIAS framework. Measurement of insecure and secure household was as described in section 2.

The findings showed that food insecurity was widespread. Worry about not having enough food was reported by 87.0% of households, and 85.2% reported being unable to eat preferred foods, eating a limited variety of foods, eating foods they did not want, or eating smaller or fewer meals. In addition, 68.5% of households reported having no food of any kind in the household, and 66.7% reported going to sleep hungry or going a whole day and night without eating. For every item, 27.8% of households reported that the condition occurred often. Only 1.8% of households (5) were food secure; 13% (35) were mildly, 17.8% (48) moderately and 67.4% (182) severely food insecure.

Table 9: Distribution of HFIAS Responses

| HFIAS Question                     | Yes, n (%) | Frequency among those who answered Yes                    | No, n (%) |
|------------------------------------|------------|-----------------------------------------------------------|-----------|
| 1. Worry about food                | 235 (87.0) | Rarely: 5 (1.9); Sometimes: 155 (57.4); Often: 75 (27.8)  | 35 (13.0) |
| 2. Unable to eat preferred foods   | 230 (85.2) | Rarely: 5 (1.9); Sometimes: 150 (55.6); Often: 75 (27.8)  | 40 (14.8) |
| 3. Eat limited variety of foods    | 230 (85.2) | Rarely: 5 (1.9); Sometimes: 150 (55.6); Often: 75 (27.8)  | 40 (14.8) |
| 4. Eat unwanted foods              | 230 (85.2) | Rarely: 15 (5.6); Sometimes: 140 (51.9); Often: 75 (27.8) | 40 (14.8) |
| 5. Eat smaller meals               | 230 (85.2) | Rarely: 5 (1.9); Sometimes: 150 (55.6); Often: 75 (27.8)  | 40 (14.8) |
| 6. Eat fewer meals in a day        | 230 (85.2) | Rarely: 5 (1.9); Sometimes: 150 (55.6); Often: 75 (27.8)  | 40 (14.8) |
| 7. No food of any kind             | 185 (68.5) | Rarely: 5 (1.9); Sometimes: 105 (38.9); Often: 75 (27.8)  | 85 (31.5) |
| 8. Go to sleep hungry              | 180 (66.7) | Rarely: 15 (5.6); Sometimes: 90 (33.3); Often: 75 (27.8)  | 90 (33.3) |
| 9. Go day and night without eating | 180 (66.7) | Rarely: 15 (5.6); Sometimes: 90 (33.3); Often: 75 (27.8)  | 90 (33.3) |

Source: Survey Data 2024

Of interest then was to assess whether adaptation of climate change strategies (as measured in section 3.3) had an impact on household food insecurity. This was done by testing the hypothesis formulated in section 1.

#### 4.1 Test of hypothesis

The hypothesis formulated postulated that the adoption of wide array of climate-smart agricultural strategies was closely associated with food security. The hypothesis contends that if this were true, then households that adopted more strategies should be more food secure. Table 10 shows food security for households grouped by the number of strategies adopted, and Table 11 presents the results of the two-proportion z-tests, which compare the percentage of households in each food security category (food secure, mildly food insecure and severely food insecure) between the three adoption groups: low (none to three strategies), moderate (four to five strategies) and high (six to eight strategies).

Each comparison in Table 11 uses a two-proportion z-test. It asks whether the percentage of households in a food security category (for example, severely food insecure) differs between two groups by more than chance would explain. The Z value expresses the size of the difference relative to the variation expected by chance, so values further from zero indicate larger differences; a positive Z means the first group had the higher percentage and a negative Z means it had the lower one.

Table 10: Household food security by number of strategies adopted, n (%)

| Strategies adopted     | Food secure     | Mildly insecure   | Moderately insecure | Severely insecure  | Total               |
|------------------------|-----------------|-------------------|---------------------|--------------------|---------------------|
| 0 strategies           | 0 (0.0%)        | 0 (0.0%)          | 1 (16.7%)           | 5 (83.3%)          | 6 (100.0%)          |
| 1-3 strategies         | 0 (0.0%)        | 0 (0.0%)          | 0 (0.0%)            | 2 (100.0%)         | 2 (100.0%)          |
| 4-5 strategies         | 0 (0.0%)        | 2 (3.6%)          | 12 (21.4%)          | 42 (75.0%)         | 56 (100.0%)         |
| 6-8 strategies         | 5 (2.4%)        | 33 (16.0%)        | 35 (17.0%)          | 133 (64.6%)        | 206 (100.0%)        |
| <b>Total (N = 270)</b> | <b>5 (1.8%)</b> | <b>35 (13.0%)</b> | <b>48 (17.8%)</b>   | <b>182 (67.4%)</b> | <b>270 (100.0%)</b> |

Source: Survey data, 2024.

The test indicated that severe food insecurity fell as the number of strategies adopted rose. However, none of these differences was statistically significant ( $p = 0.402, 0.148$  and  $0.143$ ). The proportion of food-secure households did not differ significantly between groups either ( $p = 1.000, 0.485$  and  $0.240$ ). Of the nine comparisons, only one was significant: mild food insecurity was more common among households adopting six to eight strategies than among those adopting four to five (16.0% against 3.6%;  $Z = -2.419, p = 0.016$ ). This points away from the hypothesised direction, and points that the single significant result among nine compari-

sons is not enough to support the hypothesis. The hypothesis was therefore rejected (with results signifying that adopting more strategies was not significantly associated with better food security).

Table 11: Two-proportion z-tests comparing groups by number of strategies adopted

| Comparison                | Outcome           | First group, % | Second group, % | Z             | p            |
|---------------------------|-------------------|----------------|-----------------|---------------|--------------|
| Low vs moderate adoption  | Food secure       | 0.0            | 0.0             | 0.000         | 1.000        |
| Low vs high adoption      | Food secure       | 0.0            | 2.4             | -0.698        | 0.485        |
| Moderate vs high adoption | Food secure       | 0.0            | 2.4             | -1.176        | 0.240        |
| Low vs moderate adoption  | Mildly insecure   | 0.0            | 3.6             | -0.548        | 0.584        |
| Low vs high adoption      | Mildly insecure   | 0.0            | 16.0            | -1.279        | 0.201        |
| Moderate vs high adoption | Mildly insecure   | 3.6            | 16.0            | <b>-2.419</b> | <b>0.016</b> |
| Low vs moderate adoption  | Severely insecure | 87.5           | 75.0            | 0.838         | 0.402        |
| Low vs high adoption      | Severely insecure | 87.5           | 64.6            | 1.447         | 0.148        |
| Moderate vs high adoption | Severely insecure | 75.0           | 64.6            | 1.466         | 0.143        |

Source: Survey data, 2024

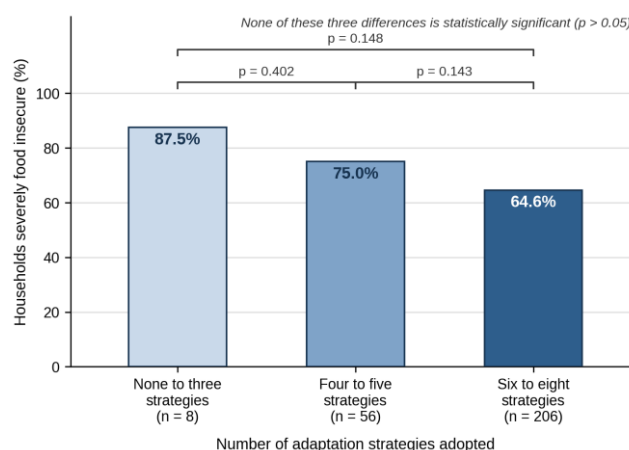


Figure 1: Severe food insecurity by number of strategies adopted

Source: Survey data, 2024

These results suggest that it is not the number of strategies a household adopts that determines its food security, but how efficiently those strategies work for that household. Adoption in this study was recorded simply as whether a farmer used a strategy, and the count of strategies gives every strategy the same weight, whether it is applied on the whole farm or on a corner of it, whether it is carried out on time and as recommended, and whether it suits local conditions. A household that has adopted six strategies in a token or partial way may therefore appear better adapted than a household that has adopted three and implements them well, yet it need not be more food secure.

This is consistent with the view that technology adoption has to be combined with varied cropping, climate services and social safety nets in order to build resilience [11], and with the observation that Kenyan farmers' capacity and resources to respond to climate change are limited [13]. The one significant result, more mild food insecurity among households adopting six to eight strategies than among those adopting four to five, points in the same direction: adopting many strategies did not by itself move households out of food insecurity. What matters, then, is the efficiency of the strategies adopted rather than their number. Extension and policy should therefore shift attention from encouraging farmers to adopt as many practices as possible towards ensuring that the practices they adopt are well matched to local conditions and to the resources of the households that adopt them.

## 5. Discussion

### 5.1 Intersectionality and Adoption Strategies

This article shows that farmers in Kieni West are aware of climate change and that they had responded in one way or another to this change. This they had done by adapting certain farming strategies. Low-cost, farm-based options such as improved seed, soil conservation and water management were the most common, and knowledge- and capital-intensive options such as new technology were the least common strategies adopted.

This fits the livelihoods framework's expectation that strategies are constrained by the capitals available to households [13], and the observation that Kenyan farmers' capacity to adapt is limited. The positive association of adoption with age and experience is consistent with human capital shaping adaptive capacity: accumulated experience of local climate and farming practice [44], and, as the descriptive education results suggest, formal education that helps farmers access and apply technical information [50], [40]. The finding that younger farmers were less likely to have adopted new technology differs from the expectation that they would be the age group more likely to be welcoming to new modern ways of doing things. The results may however reflect their limited access to land and capital, rather than reluctance.

The absence of gender differences should be treated with interest. Women were only 8.1% of the sampled respondents, which limits the power to detect differences and suggests that women are under-represented among the household heads surveyed. One extension officer interviewed observed that the most successful adopting households were those in which both spouses attended training and made joint decisions, a reminder that individual-level gender comparisons may miss how decisions are made within households.

### 5.2 Adoption and food insecurity

The central finding is the gap between adaptation and food security. Despite widespread adoption, with three quarters of households using six to eight strategies, two thirds of the sampled households (67.4%) were found to be severely food insecure (with only 1.8% found to be food secure.) Households adopting more strategies had lower rates of severe food insecurity (87.5%, 75.0% and 64.6%), but the difference between the three tested groups were found to be not statistically significant; hence the set hypothesis was rejected. This differs from other findings (i.e [11]) in which farmers with more adaptation strategies were found to be more food secure. This implies that we have to go beyond counting the array of strategies used to the efficiency of the strategies employed, however few.

This article opines that whereas age, experience and education do matter, farm-level adaptation cannot by itself offset other intermediate factors such as recurrent drought, constrained markets and limited national policies such as social protection. As already pointed out by Radeny et al. [54], crop failure in drought years has consistently impacted on food insecurity in Kenya's drylands, meaning that farmer effort has to be cushioned by government policies and practices. This explains why adaptation research increasingly argues for looking beyond production-side measures to broader vulnerability [7], and how governments can come in to mitigate farmers against these factors. In the terms of the livelihoods framework, the strategies studied act mainly on natural and human capital, whereas food security outcomes also depend on financial and physical capital and on institutions such as markets, credit, seed systems and extension.

## 6. Conclusion and implications

Small-scale farmers in Kieni West were found to be aware of climate change and to have adopted many adaptation strategies, with adoption rising with age and farming experience and education. Yet food insecurity is pervasive, and adopting more strategies was not significantly associated with better food security, as hypothesised. Four implications arise from this observation. First, the need for extension services should be given more particular attention, especially to the younger, less experienced and less educated farmers, who were found to adopted least. It ought to be pointed out that Kenya has progressively moved away from the earlier model in which agricultural extension services were provided free of charge by government. Reforms involving privatization, cost recovery and commercialization have resulted in a more pluralistic extension system involving public, cost-sharing and private-sector provision [55, p. 43], [56, p. ix] a policy that now ought to be reversed. Second, once extension services have been restored, climate-resilient seed distribution programme should be rolled out. It is well known that access to seed, conditions adoption [57]. Third, promoting adaptation alone should not be treated as sufficient for food security; rather, this should be combined with policy and practical measures that improve market access and livelihood diversification. Fourth, longitudinal research that follows same households across seasons, tracking production, market engagement and food security, is needed to clarify why perceived multiple adoption practices does not necessarily translate into food security. These new researchers should look into what other factors should be taken into consideration alongside these multiple adaptation strategies. These new research would provide evidence on this, evidence that would be crucial in tackling the next cycle of climate change impact across Africa.

## References

- [1]. Ogunyiola, A., Gardezi, M., & Vij, S. (2022). Smallholder farmers' engagement with climate smart agriculture in Africa: role of local knowledge and upscaling. *Climate Policy*, vol. 22(4), pp. 411–426. <https://doi.org/10.1080/14693062.2021.2023451>

- [2]. Malhi, G. S., Kaur, M., & Kaushik, P. (2021). Impact of Climate Change on Agriculture and Its Mitigation Strategies: A Review. *Sustainability*, vol. 13(3), 1318. <https://doi.org/10.3390/su13031318>
- [3]. Bedair, H., Alghariani, M., Omar, E., Anibaba, Q., Remon, M., Bornman, C., Kiboi, S., Rady, H., Salifu, A.-M., Ghosh, S., Guuroh, R., Sanou, L., & Alzain, H. (2023). Global warming status in the African continent: Sources, challenges, policies, and future direction. *International Journal of Environmental Research*. <https://doi.org/10.1007/s41742-023-00534-w>
- [4]. Filho, L. W., & Nalau, J. (2018). *Limits to climate change adaptation*. Springer International Publishing, Cham.
- [5]. Rahut, D. B., Aryal, J. P., & Marenja, P. (2021). Understanding climate-risk coping strategies among farm households: Evidence from five countries in Eastern and Southern Africa. *Science of the Total Environment*, vol. 769, 145236. <https://doi.org/10.1016/j.scitotenv.2021.145236>
- [6]. Trisos, C. H., Adelekan, I. O., Totin, E., Ayanlade, A., Efitre, J., Gameda, A., Kalaba, K., Lennard, C., Masao, C., Mgaya, Y., Ngaruiya, G., Olago, D., Simpson, N.P., & Zakiudeen, A. S. (2022). Africa. In H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegria, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (Eds.), *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press pp. 1285–1455
- [7]. Ayanlade, A., Smucker, T. A., Nyasimi, M., Sterly, H., Weldemariam, L. F., & Simpson, N. P. (2023). Complex climate change risk and emerging directions for vulnerability research in Africa. *Climate Risk Management*, vol. 40, 100497. <https://doi.org/10.1016/j.crm.2023.100497>
- [8]. Amwata DA. 2020. Situational analysis study for the agriculture sector in Kenya. CCAFS Report. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CAAFS).
- [9]. MoALF. (2016). *Climate Risk Profile for Nyeri*. Kenya County Climate Risk Profile Series. The Kenya Ministry of Agriculture, Livestock and Fisheries (MoALF), Nairobi, Kenya. <https://hdl.handle.net/10568/80459>
- [10]. Kogo, B. K., Kumar, L., & Koech, R. (2021). Climate change and variability in Kenya: A review of impacts on agriculture and food security. *Environment, Development and Sustainability*, vol. 23, 23–43. DOI: <https://doi.org/10.1007/s10668-020-00589-1>
- [11]. Gebre, G. G., Amekawa, Y., Fikadu, A. A., & Rahut, D. B. (2023). Farmers' use of climate change adaptation strategies and their impacts on food security in Kenya. *Climate Risk Management*, 40, 100495. <https://doi.org/10.1016/j.crm.2023.100495>
- [12]. IPCC. (2022). *Climate Change 2022: Impacts, adaptation and vulnerability: Summary for policymakers, technical summary and frequently asked questions*. Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Retrieved from <https://www.ipcc.ch/report/ar6/wg2/>
- [13]. Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., et al. (2013). Adapting agriculture to climate change in Kenya: household strategies and determinants. *Journal of Environmental Management*, vol. 114, pp. 26–35. <https://doi.org/10.1016/j.jenvman.2012.10.036>
- [14]. Antwi-Agyei, P., Stringer, L. C., & Dougill, A. J. (2014). Livelihood adaptations to climate variability: Insights from farming households in Ghana. *Regional Environmental Change*, vol. 14, pp. 1615–1626. <https://doi.org/10.1007/s10113-014-0597-9>
- [15]. Musafiri, C. M., Kiboi, M., Macharia, J., Ng'etich, O. K., Kosgei, D. K., Mulianga, B., Okoti, M., & Ngetich, F. K. (2021). Adoption of climate-smart agricultural practices among smallholder farmers in Western Kenya: Do socioeconomic, institutional, and biophysical factors matter? *Heliyon*, vol. 8(1), e08677. <https://doi.org/10.1016/j.heliyon.2021.e08677>
- [16]. Singh, C., Iyer, S., New, M. G., Few, R., Kuchimanchi, B., Segnon, A. C., et al. (2022). Interrogating "effectiveness" in climate change adaptation: 11 guiding principles for adaptation research and practice. *Climate and Development*, vol. 14(5), pp. 650–664. <https://doi.org/10.1080/17565529.2021.1964937>
- [17]. Berrang-Ford, L., Siders, A. R., Lesnikowski, A., Fischer, A. P., Callaghan, M. W., Haddaway, N. R., et al. (2021). A systematic global stocktake of evidence on human adaptation to climate change. *Nature Climate Change*, vol. 11, 989–1000. <https://doi.org/10.1038/s41558-021-01170-y>
- [18]. Mupangwa, W., Nyagumbo, I., Liben, F., Chipindu, L., Craufurd, P., & Mkuhlani, S. (2021). Maize yields from rotation and intercropping systems with different legumes under conservation agriculture in contrasting agro-ecologies. *Agriculture, Ecosystems & Environment*, vol. 306, 107170. <https://doi.org/10.1016/j.agee.2020.107170>
- [19]. Ochieng, J., Kirimi, L., Ochieng, D. O., Njagi, T., Mathenge, M., Gitau, R., & Ayieko, M. (2020). Managing climate risk through crop diversification in rural Kenya. *Climatic Change*, vol. 162, pp. 1107–1125. <https://doi.org/10.1007/s10584-020-02727-0>

- [20]. Oral, H. V., Radinja, M., Rizzo, A., Kearney, K., Andersen, T. R., Krzeminski, P., et al. (2021). Management of urban waters with nature-based solutions in circular cities – exemplified through seven urban circularity challenges. *Water*, vol. 13(23), 3334. <https://doi.org/10.3390/w13233334>
- [21]. Ruiz Martínez, H. G., & Cornejo Tueros, J. V. (2022). Rainwater harvesting system as a strategy for adaptation to climate change: A review. *IOP Conference Series: Earth and Environmental Science*, vol. 1121(1), 012007. <https://doi.org/10.1088/1755-1315/1121/1/012007>
- [22]. Kamuzora, A. N. (2023). Effects of Climate Change Adaptation Strategies on Maize Productivity among Smallholder Farmers in Dodoma, Tanzania. *East African Journal of Education and Social Sciences*, vol. 4(6), pp. 141-153. <https://doi.org/10.46606/eajess2023v04i06.0342>
- [23]. Wabela, K., Hammani, A., Abdelilah, T., Tekleab, S., & El-Ayachi, M. (2022). Optimization of irrigation scheduling for improved irrigation water management in Bilate Watershed, Rift Valley, Ethiopia. *Water*, vol. 14(23), 3960. <https://www.mdpi.com/2073-4441/14/23/3960>
- [24]. Calegari, A., Araujo, A., Tiecher, T., Bartz, M., Fuentes Llanillo, R., dos Santos, D., Capandeguy, F., Zamora, J., Jump, J., Moriya, K., Dabalá, L., Cubilla, L., Cubilla A., M., Carballal, M., Trujillo, R., Peiretti, R., Derpsch, R., Miguel, S., & Friedrich, T. (2020). No-till farming systems for sustainable agriculture: Challenges and opportunities. <https://doi.org/10.1007/978-3-030-46409-7>
- [25]. Iqbal, R., Raza, M. A. S., Valipour, M., et al. (2020). Potential agricultural and environmental benefits of mulches—a review. *Bulletin of the National Research Centre*, vol. 44, 75. <https://doi.org/10.1186/s42269-020-00290-3>
- [26]. Du, Y., Cui, B., Zhang, Q., Wang, Z., Sun, J., & Niu, W. (2020). Effects of manure fertilizer on crop yield and soil properties in China: A meta-analysis. *CATENA*, vol. 193, 104617. <https://doi.org/10.1016/j.catena.2020.104617>
- [27]. Kichamu-Wachira, E., Xu, Z., Reardon-Smith, K., Biggs, D., Wachira, G., & Omidvar, N. (2021). Effects of climate-smart agricultural practices on crop yields, soil carbon, and nitrogen pools in Africa: A meta-analysis. *Journal of Soils and Sediments*, vol. 21(4), 1587–1597. <https://doi.org/10.1007/s11368-021-02885-3>
- [28]. Paudel, P., Rimal, S., Ghimire, P., & Parajuli, K. (2019). Agro-forestry for enhancing adaptation of local community against drought in hilly region of Nepal. *International Journal of Agriculture Innovations and Research*, 7(4), 440-445.
- [29]. Walia, M 2020, Crop Diversification, Extension | University of Nevada, Reno, FS-20-28
- [30]. Gaughan, J. B., Sejian, V., Mader, T. L., & Dunshea, F. R. (2019). Adaptation strategies: ruminants. *Animal Frontiers*, vol. 9(4), pp. 47–53. <https://doi.org/10.1093/af/vfy029>
- [31]. Rojas-Downing, M. M., Nejadhashemi, A. P., Harrigan, T., & Woznicki, S. A. (2017). Climate change and livestock: Impacts, adaptation, and mitigation. *Climate Risk Management*, vol. 16, pp. 145–163. <https://doi.org/10.1016/j.crm.2017.02.001>
- [32]. Acosta, A., Nicolli, F., & Karfakis, P. (2021). Coping with climate shocks: The complex role of livestock portfolios. *World Development*, vol. 146, 105546. <https://doi.org/10.1016/j.worlddev.2021.105546>
- [33]. Ogada, M. J., Rao, E. J. O., Radeny, M., Recha, J. W., & Solomon, D. (2020). Climate-smart agriculture, household income and asset accumulation among smallholder farmers in the Nyando basin of Kenya. *World Development Perspectives*, vol. 18, 100203. <https://doi.org/10.1016/j.wdp.2020.100203>
- [34]. Rao, N., Singh, C., Solomon, D., Camfield, L., Sidiki, R., Angula, M., et al. (2020). Managing risk, changing aspirations and household dynamics: Implications for wellbeing and adaptation in semi-arid Africa and India. *World Development*, vol. 125, 104667. <https://doi.org/10.1016/j.worlddev.2019.104667>
- [35]. Makate, C., Wang, R., Makate, M., et al. (2016). Crop diversification and livelihoods of smallholder farmers in Zimbabwe: adaptive management for environmental change. *Springer Plus*, vol. 5, 1135. <https://doi.org/10.1186/s40064-016-2802-4>
- [36]. Sulemana, I., Bugri Anarfo, E., & Quartey, P. (2019). International remittances and household food security in Sub-Saharan Africa. *Migration and Development*, vol. 8(2), pp. 264–280. <https://doi.org/10.1080/21632324.2018.1560926>
- [37]. FAO, IFAD, UNICEF, WFP, & WHO. (2022). the State of Food Security and Nutrition in the World 2022. Repurposing food and agricultural policies to make healthy diets more affordable. The State of Food Security and Nutrition in the World 2022 p. 264. Food and Agriculture Organization of the United Nations.
- [38]. Kaczan, D., Arslan, A., & Lipper, L. (2013). Climate-Smart Agriculture: A review of current practice of agroforestry and conservation agriculture in Malawi and Zambia (ESA Working Paper No. 13-07). Agricultural Development Economics Division, Food and Agriculture Organization of the United Nations. Retrieved from <http://www.fao.org/economic/esa>

- [39]. Mishra, A. K., Pedde, V. O., & Barboza, G. A. (2018). Perception of climate change and impact on land allocation and income: Empirical evidence from Vietnam's Delta region. *Agricultural and Resource Economics Review*, 47(2), 311–335. <https://doi.org/10.1017/age.2018.11>
- [40]. Ziro, J. S., Kichamu-Wachira, E., Ross, H., & Palaniappan, G. (2023). Adoption of climate resilient agricultural practices among the Giriama community in South East Kenya: Implications for conceptual frameworks. *Frontiers in Climate*, 5, Article 1032780. <https://doi.org/10.3389/fclim.2023.1032780>
- [41]. Asrat, P., & Simane, B. (2018). Farmers' perception of climate change and adaptation strategies in the Dabus watershed, North-West Ethiopia. *Ecological Processes*, 7, Article 7. <https://doi.org/10.1186/s13717-018-0118-8>
- [42]. Moges, D. M., & Taye, A. A. (2017). Determinants of farmers' perception to invest in soil and water conservation technologies in the North-Western Highlands of Ethiopia. *International Soil and Water Conservation Research*, 5(1), 56-61.
- [43]. Tiamiyu, S. A., Akintola, J. O., & Rahji, M. A. Y. (2009). Technology adoption and productivity difference among growers of new rice for Africa in Savanna Zone of Nigeria. *Tropicultura*, 27(4), 193-197.
- [44]. Ndung'u, S., Ogemah, V., Thiga, M., & Wandahwa, P. (2023). Factors influencing the adoption of climate smart agriculture practices among smallholder farmers in Kakamega County, Kenya. *African Journal of Food, Agriculture, Nutrition and Development*, 23(10), 24759-24782. <https://doi.org/10.18697/ajfand.125.23400>
- [45]. Deressa, T., Hassan, R., Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change*, 19, 248–255. <https://doi.org/10.1016/j.gloenvcha.2009.01.002>
- [46]. Waaswa, A., Nkurumwa, A. O., Kibe, A. M., & Ng'eno, J. K. (2021). Understanding the socioeconomic determinants of adoption of climate-smart agricultural practices among smallholder potato farmers in Gilgil Sub-County, Kenya. *Discover Sustainability*, 2, 41. <https://doi.org/10.1007/s43621-021-00050-x>
- [47]. Israr, M., Faraz, M., & Ahmad, N. (2020). Perception for the sustainability of farming in Khyber Pakhtunkhwa-Pakistan. *Journal of Rural Development*, 8, 28-36. <https://doi.org/10.12691/ajrd-8-1-4>
- [48]. Mekonnen, A. B. (2024). Adoption of Climate-smart Agricultural Practices among Smallholder Farmers and Implications for Climate Change Adaptation in Southern Ethiopia (Doctoral dissertation, University of Nairobi).
- [49]. Ndamani, F., & Watanabe, T. (2017). Determinants of farmers' adaptation to climate change: A micro level analysis in Ghana. *Scientia Agricola*, 74(3), 201–208. <https://doi.org/10.1590/0103-9016-2015-0163>
- [50]. Walker, S. E., Bruyere, B. L., Zarestky, J., Yasin, A., Lenaiyasa, E., Lolemu, A., & Pickering, T. (2021). Education and adaptive capacity: The influence of formal education on climate change adaptation of pastoral women. *Climate and Development*, 14(5), 409-418. <https://doi.org/10.1080/17565529.2021.1930508>
- [51]. Belay, A., Oludhe, C., Mirzabaev, A., Recha, J. W., Berhane, Z., Osano, P. M., Demissie, T., Olaka, L. A., & Solomon, D. (2022). Knowledge of climate change and adaptation by smallholder farmers: Evidence from southern Ethiopia. *Heliyon*, vol. 8(12), e12089. <https://doi.org/10.1016/j.heliyon.2022.e12089>
- [52]. Mcharo, M., & Waswa, F. (2022). Gender Differentiated Adoption of Soil and Water Conservation Practices by Farmers in Kenyan Agricultural Highland Catchments. *Journal of Agricultural Extension and Rural Development*, 23(5), Article 30234. <https://doi.org/10.9734/JAERI/2022/v23i530234>
- [53]. Sonko, E., Florkowski, W. J., Agodzo, S., & Antwi-Agyei, P. (2020). Subsistence farmer knowledge of strategies alleviating food insecurity in the context of climate change in the lower river region of the Gambia. *Food Security*, vol. 12, pp. 607–624. <https://doi.org/10.1007/s12571-020-01024-z>
- [54]. Radeny, M., Desalegn, A., Mubiru, D., Kyazze, F., Mahoo, H., Recha, J., Kimeli, P., & Solomon, D. (2022). The relationship between climate change, variability, and food security: Understanding the impacts and building resilient food systems in West Pokot County, Kenya. *Sustainability*, 14(2), 765.
- [55]. Parliamentary Budget Office. (2021). *Budget options for 2022/2023 and the medium term*. Parliament of Kenya. [https://www.parliament.go.ke/sites/default/files/2021-12/Final%20Budget%20Options%202022\\_2023.pdf](https://www.parliament.go.ke/sites/default/files/2021-12/Final%20Budget%20Options%202022_2023.pdf)
- [56]. Ministry of Agriculture and Livestock Development. (2023). *Kenya agricultural sector extension policy 2023*. Government of Kenya. <https://kilimo.go.ke/wp-content/uploads/2024/10/KENYA-AGRICULTURAL-SECTOR-EXTENSION-POLICY-2023.pdf>
- [57]. Mwangi MN, Nyarindo WN, Ngigi MW, Isaboke HN (2026) Seeding food security: Overcoming barriers to quality potato seed adoption among smallholders in Kenya. *PLoS One* 21(5): e0346796. <https://doi.org/10.1371/journal.pone.0346796>