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TOWARDS FOOD SOVEREIGNTY: THE ROLE OF SMALLHOLDER FARMERS' SEED SECURITY IN IMPROVING CLIMATE CHANGE RESILIENCE IN NORTHERN MALAWI

DANIEL AMOAK, ESTHER LUPAFYA, LAIFOLO DAKISHONI and ISAAC LUGINAAH

ABSTRACT. With climate extreme events increasing in frequency and intensity in Malawi, the future of local food production faces serious threats, necessitating renewed efforts to build the adaptive capabilities of the majority poor smallholder farmers. In this context, seed security is critical to improving rural livelihoods and agrobiodiversity; however, knowledge of its role in climate change resilience is sparse. Drawing insights from vulnerability and resilience literature, this paper examines the role of seed security in enhancing climate change resilience in northern Malawi. Using a cross-sectional survey of 1,090 smallholder farmers and applying logistic regression analysis, the study found that households that are seed-secure were significantly more likely to report stronger resilience to climate change than those that were not seed-secure, even after controlling for theoretically relevant variables (OR = 1.89; $p < .01$). Other noteworthy predictors of climate change resilience included level of education, wealth, agroecological practice, and seed sources. Based on the findings, we advocate for promoting seed security as part of broader localized and place-specific action plans to foster resilience to climate change in agricultural regions. *Keywords: seed security, food systems, seed systems, resilience, social network, climate-resilient communities.*

There is overwhelming evidence that climate change will continue to have far-reaching repercussions for agricultural-driven livelihoods and will disproportionately impact poor and smallholder farmers (IPCC 2022). These repercussions will manifest in many forms, including making food production extremely challenging, now and well into the future (Zougmoré and others 2016; Mbow and others 2019). For instance, projected climates will stir latitudinal changes in the breeding and spread of different pests, diseases and pathogens that affect crop growth and development (Kumar 2021). It is also expected that prices of essential food commodities such as cereals will increase by up to 29 percent by 2050 (IPCC 2022). A global report further underscores the anticipated ramifications of climate change, wherein agricultural productivity is projected to diminish, giving rise to concerns pertaining to food safety, distribution networks, income reduction, diminished nutrient concentrations in select crops, and substantial alterations in diet quality (Bezner Kerr and others 2022). These multifaceted

Daniel Amoak, Department of Geography and Environment, Western University, Canada, London; [damoak@uwo.ca]. Esther Lupafya, Community outreach, Soils Food and Healthy Communities, Malawi; [elupafya@gmail.com]. Laifolo Dakishoni, Community outreach, Soils Food and Healthy Communities, Malawi; [dakishoni@gmail.com]. Isaac Luginaah, Department of Geography and Environment, Western University, Canada, London; [iluginaa@uwo.ca].

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consequences collectively bear implications for the domains of food security and nutrition (Bezner Kerr and others 2022).

Malawi's present and future food production could be in peril if urgent steps are not taken. According to the Global Climate Risk Index (IFAD 2022), Malawi is a highly vulnerable region where current climatic stressors outpace adaptation and mitigation efforts (Asfaw and others 2013; Dickerson and others 2022). With nearly 85 percent of livelihoods hinging on rain-fed agriculture, Malawi is expected to lose about US$1.6 billion between 2020 and 2050 under prevailing climatic conditions (Cacho 2020). A recent report highlighted that Malawi is grappling with substantial challenges in food production and health issues linked to climate change, and is not on track to meet key sustainable development goals (SDGs), such as food security, ending hunger, and reducing poverty (Government of Malawi 2020). The report further underscored the urgent need to implement strategies to build resilience to climate change to safeguard and enhance present and future food production (Government of Malawi 2020).

Climate change resilience is the "capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation" (IPCC 2018, 557). Empirical research has explored the factors associated with climate change resilience among smallholder farmers. In Tanzania, it was revealed that crop adaptation—the process by which crops undergo genetic, physiological, or morphological changes to better suit the environmental conditions in which they are grown—is a crucial livelihood strategy that enables farmers to adjust to the changing environmental conditions, and farmers with greater socioeconomic opportunities are more likely to initiate strategies to improve their resilience to climatic stresses (Westengen and Brysting 2014). Other studies have highlighted that adapting climate-smart agricultural strategies such as high-yielding varieties, climate insurance, agroforestry, and integrated soil fertility management practices can improve the climate change resilience of smallholder farmers (Zougmoré 2018; Bezner Kerr 2021; Kansanga 2021). In Malawi, empirical research shows that harnessing indigenous knowledge and expertise in response to limited agricultural extension services provision through farmer-to-farmer knowledge transfer systems is linked to improved health and climate change resilience among smallholder farmers (Amoak, Oluwaseyi, and others 2023; Kansanga and others 2023). In addition, some scholars highlighted livelihood diversification (Makate and others 2019; Mohammed and others 2021), income diversification (Wan 2016), and stronger social capital (Aldrich 2012) as response mechanisms to improve farmers' adaptive capacities and resilience to climate change.

Despite the adaptation strategies discussed in the literature, the frequency and intensity of climate stressors outpace resilience building in many rain-fed agricultural regions, including Malawi. Specifically, climate change stressors such as droughts, high temperatures, and erratic rainfall are reshaping agroecological conditions (Wheeler and Von Braun 2013; Hamel 2016; Ministry of Agriculture Irrigation and Water Development 2016; Amoak, Kwao, and others 2023). This shift is causing increased seed germination failures and poor plant growth, posing a significant challenge to seed availability and suitability, thereby heightening inaccessibility to seeds within their regions and networks (Sperling and Remington 2006; McGuire and Sperling 2016; Warnatzsch and Reay 2019). In this context, farmers' seed security—defined as when they "have sufficient access to quantities of available good quality seed and planting materials of preferred crop varieties at all times in both good and bad cropping seasons" (Food and Agriculture Organization [FAO] 2016, 6)—can help to mitigate adverse impacts of the changing climate for the majority population depending on rain-fed agriculture, and relying on a few crops that can pose threats to their food security and nutrition (Massawe and others 2016).

In the face of multiple climatic stressors, seed security can provide adequate protective buffers that better position farmers to adopt proactive agricultural practices, reduce risks, and ultimately bounce back (Sperling and others 2008; McGuire and Sperling 2013). Furthermore, evidence suggests that timely access to quality seeds can prevent seed germination failure, improve yield, and decrease food insecurity among smallholder farmers (Westengen and others 2019; Mulesa and others 2021; Amoak and others 2022). Researchers in Malawi further opine that seed security promotes crop diversification, which is useful for dietary diversity and reducing food insecurity in the context of climate change (Bezner Kerr and others 2019; Vernooy 2022). Despite such evidence, Malawi's policy on seeds aligns with the prevailing narrative and practices associated with the "African Green Revolution." A central tenet of this movement is the widespread adoption of improved seed from the commercial sector as the key driver for increased food production (Moseley 2016; Kpienbaareh and Ahmed 2023). However, a capitalist seed market tends to offer only a limited range of seeds (of commercial value) and alienates poor households from accessing quality seeds. Farmers' low ability to access diverse seeds, in turn, bolsters monocultures that have caused significant environmental degradation and reduce farmers' adaptive responses in the context of climate change (Altieri and others 2015; Springmann and others 2018).

The sparse research on the role of seed security on farming communities' resilience in the face of climate change is problematic for two reasons. There is growing evidence that the enduring impact of the rise of the commercial seed industry has led to the reduction in plant genetic diversity, the attrition of traditional seed use, and the destruction of traditional seed breeding (Scoones and Thompson 2011; Bezner Kerr 2014). Secondly, at the policy level, seed security has not been considered part of the arsenals for improving smallholder farmers' resilience to climate change in Malawi. Farmers in Malawi thus may be deprived of the advantages associated with accessing a diverse repertoire of seeds and plant genetic resources, which can potentially mitigate the adverse impacts arising from climate change-induced stressors.

To address this void in the literature, we examine the association between farmers' seed security status and perceived climate change resilience using data from a cross-sectional survey and theoretical insights from vulnerability and resilience literature. The study contributes nuanced and disaggregated data on seed security in Malawi. It provides critical policy pointers to achieve the targets of national policies such as the Malawi Growth and Development Strategy III and the Country Strategic Opportunities Programme 2023–2030 of improving farmers' seed security and seed sector development to alleviate hunger, undernutrition, and child stunting and to build a productive and resilient nation (Government of Malawi 2017; Ministry of Agriculture Irrigation and Water Development 2018; IFAD 2022). Finally, our findings also contribute toward achieving the sustainable development goals 1 (no poverty), 2 (zero hunger), 3 (good health and well-being), and 11 (sustainable communities).

Changing Geographies of the Seed Landscape in Africa: A Need for Seed Sovereignty

For centuries, smallholder farmers' seed culture has thrived through informal networks and sharing practices deeply embedded in the informal seed system. Drawing from long-standing knowledge, farmers engage in the production, selection, and preservation of seeds, fostering a culture of sharing through barter, gifting, or local market transactions (Nabuuma and others 2022). This seed culture has demonstrated resilience in the face of challenges, ensuring a diverse range of seeds are exchanged and cultivated. A notable attribute of the informal seed system lies in its facilitation of easy seed diffusion, adaptation to local environmental conditions, and the preservation of greater genetic diversity (Westengen and others 2023). These qualities are increasingly recognized as essential for building resilient food systems, particularly in the context of climate change challenges.

In the last three decades, however, under the guise of a new green revolution, there have been significant transformations in the seed sector of SSA, with notable shifts observed in terms of accessibility and governance. While studies point to a range of factors driving this change, including climate change, and the shifting global food demands (Godfray and others 2010; Prosekov and Ivanova 2018), the rise of transnational seed corporations, and their strict seed control apparatus, have reduced the array of seeds available and accessible to smallholder farmers (Kloppenburg 2004).

Multinational corporations' quest for the commodification and privatization of global food production has been spearheaded through monopolistic approaches to seed production, such as intellectual property laws, plant variety protection, and trade and investment agreements (Kloppenburg 2014; La Via Campesina and GRAIN 2015). Additionally, seed corporations have resorted to subtle forms of economic and political pressure (as examples: trade agreements, regional integration initiatives, and bilateral investment treaties) to gain exclusive ownership of seeds and, ultimately, the entire crop and food production process (Kloppenburg 2004; La Via Campesina and GRAIN 2015; Peschard and Randeria 2020). In light of this development, Kloppenburg (2004, 201) stressed that "the seed, as embodied information, becomes the nexus of control over the determination and shape of the entire crop production process," highlighting that the future geography of food is ultimately defined by who controls seeds and other plant genetic materials.

The gradual takeover and strict control of seeds raise critical questions about the types of seeds that are available to smallholder farmers now and into the future. In Malawi, for instance, as of 2018, there were about 25 multinational seed companies and over 700 agro-input dealers compared to only the National Seed Company of Malawi in 1980, working with farmers to save seeds (Ministry of Agriculture Irrigation and Water Development 2018). The more commodified seeds have become, the more they are subjected to "various forms and degrees of management, regulation, manipulation and control" (Pionetti 2011, 153). Controlling the means of seed production and provision creates power asymmetry, placing the survival of smallholder farmers in the hands of corporations and threatening their positions as stewards of agrobiodiversity (Demeulenaere 2018).

Smallholder farmers' seed culture is not the seed industry's own to erase; yet, these restrictions are taking shape despite seed treaties negotiated by FAO (for example, the International Treaty on Plant Genetic Resources for Food and Agriculture) legitimizing farmers' seed sovereignty and their inclusion in seed management processes (Cooper 2002; Peschard and Randeria 2020). These restrictions raise fundamental questions, such as whether farmers, irrespective of their socioeconomic status, can access seeds at the right time and of their preferred varieties. Available evidence suggests that attrition of traditional seed availability has been reported (Bezner Kerr 2014) and that poor farmers and those in remote areas are unable to secure seeds of their preferred variety (Snapp and others 2019; Kramer and Galiè 2020). Left unchecked, vulnerable smallholder farmers, including women and those farming on marginal lands, may face unique food and seed security barriers. Additionally, the growth of the commercial seed sector and the reduction in informal seed-sharing practices in regions like Malawi raises questions about sustainable food production, considering the region's high levels of poverty and vulnerability to climate change.

Reflecting on this trajectory of the seed system, seed sovereignty—"farmers' control over the seeds (germplasm) they use and they have developed in addition to community and public provisioning of seeds in their diversity and quality to maintain the culturally, economically and ecologically sustainable farming system" (Adhikari 2014, 36)—is fundamental to the realization of present and future food and seed security, and will ultimately define the future geography of food on the African continent. The future geography of seeds will be the net of the enduring grip of the commercial seed industry and the local seed sovereignty movement's resolve to protect their sovereignty and to redraw the lines regarding the variety of seeds they can access, store, and reproduce. Amidst climate variability and change, seed security could be one of the ways to safeguard indigenous foods for future generations. Through farmer's ability to select, preserve and store seeds, farmers exercise autonomy and circumvent the economic challenges associated with procuring seeds as well as other restrictions that may be imposed by seed corporations (Kloppenburg 2014). This empowerment enables smallholder farmers to use indigenous knowledge to preserve well-adapted seeds to address present and future hunger and food insecurity concerns.

Theoretical Framework: Geographies of Vulnerability and Resilience

Our study draws from two strands of geographical scholarship—the vulnerability and resilience perspectives—to generate contextual insights about the link between seed security and climate change resilience. Vulnerability and resilience perspectives converge around a common pillar. Environmental hazards interact with existing structural weaknesses (vulnerability context) to constitute differentiated risks to people. As Fiona Miller and others (2010) argue, collectively, these perspectives provide a more nuanced and all-encompassing picture of environmental change as it pertains to ecosystem management and climate change adaptation.

Vulnerability, as defined by Watts and Bohle (1993, 45), refers to a person's "exposure, capacity and potentiality." According to the authors, to be vulnerable means that one must be exposed to risk and have limited capacity to cope with the risk, and the consequences of this risk on the individual must be severe (in relation to others). A fundamental tenet in the vulnerability perspective is the critical role that demographic and socioeconomic factors, including gender, level of education, and wealth differences, play in determining people's risk levels to adverse environmental conditions (Hewitt 2014; Ayantunde and others 2015; 2019; Rao and others 2019). It further highlights that the differences in vulnerability context observed in communities are socially mediated, particularly on the basis of decision-making power and access to resources (Watts and Bohle 1993; Rao and others 2019).

On the other hand, geographies of resilience is an analytical lens that traces its roots to ecology (Folke 2006). While Miller and others (2010) consider vulnerability and resilience thinking to be comparatively similar and like "two sides to a coin" and call for more interaction between the two paradigms, some scholars consider resilience thinking to be "more positive and promising" than vulnerability thinking (Sakdapolrak and Etzold 2016, 229). Resilience refers to the ability of a system to not only bounce back but also thrive after exposure to a disturbance (Folke 2006). Resilience thinking studies multiple scales. However, there has been greater emphasis on the household unit in recent resilience literature, owing to the lens' strength in exploring the nuances inherent in microlevel efforts to mitigate risks. At the household level, the lens interrogates how power imbalances affect household members' exposure to environmental hazards. For instance, women farmers are more marginalized than male farmers in regions where embedded cultural practices incentivize male farm production over women through access to production resources like land and seeds (Momsen 2009; Oriangi and others 2020). Accordingly, when interrogating environmental hazards from a vulnerability and resilience perspective, despite the ontological and methodological diversity, one point of convergence has been the recognition that marginalized people are the most vulnerable to natural and human-induced disasters (Hewitt 2014; Ayantunde and others 2015; Rao and others 2019) and that the most effective way to help is to develop policies targeting, and in consultation with them.

Based on these perspectives, we contend that the seed security status of farmers may contribute to their vulnerability context. When farmers have less access to diverse seeds, they are placed in a position that reduces their capacity to be resilient to climate change stressors. Indeed, many countries around the globe are strengthening access to quality seeds to boost agricultural productivity and resilience to climate change (Otieno and others 2022; Louwaars and Manicad 2022). At the household level, seed security is mediated through decision-making dynamics, gender and social networks (Bezner Kerr 2013). In Malawi, evidence also points to the fact that the seeds made available to farmers are wrapped in various types of power relations and influenced by a complex set of macro- and microforces that determine access and use of seeds and other plant genetic materials (Scoones and Thompson 2011; Andersen and others 2022). For instance, seed breeding programs, government-backed seed aid and the seeds sold by agro-input dealers have been criticized for the lack of gender sensitivity which can result in suboptimal seed choices for women farmers, reducing productivity and increasing vulnerability to climate change and other biotic and abiotic stresses (Amoak and others 2022; Bryan 2024). We, therefore, propose that farmers who are seed-secure will have more opportunities to be resilient than those who are not seed-secure.

Material and Methods

study area

The Mzimba District is in northern Malawi, with a total land size of 10,430 km^2, making it the largest district in the country. With approximately 940,184 people representing 13 percent of the nation's population, Mzimba is one of the least populated districts in northern Malawi (Malawi Statistical Office 2019). The region is characterized by subtropical climatic conditions and an unimodal rainfall pattern with total annual rainfall ranging between 600–1100 mm/year and lasting about six months or 195 days (Bezner Kerr 2014; Snapp and others 2019). Like the rest of the country, HIV/AIDS has been a significant problem facing the region. Despite the recent progress made, it is estimated that 10.6 per 100 adults aged 15–64 live with HIV/AIDS, adversely impacting household food production (Niehof and Rugalema 2019; Mandiwa and others 2021). Mzimba district is a patriarchal society with clearly defined gender roles. The gendered nature of the district, like other regions, manifests in their farming practices. Men primarily produce cash crops like tobacco and maize, while women cultivate vegetables and other common crops like sorghum, pumpkin, and cassava. As a result, men primarily concentrate on cash crops while women manage the food crop seeds when it comes to seed management and saving.

Economically, agriculture is the most predominant livelihood activity, employing over 80 percent of the population with an average farm size of about two hectares (Kansanga and others 2021; Malawi Statistical Office 2019). Most of the land is used to cultivate maize, the region's main staple, and other crops like beans and groundnuts (Malawi Statistical Office 2019). In terms of the state of crop diversity, Kankwamba and others (2012) estimated that 2.3 crops are planted on average and are typically maize, cassava, and sweet potatoes. In addition to farming, farmers also practice on-farm casual labor, called "ganyu," as a supplementary livelihood strategy (Bezner Kerr 2005). Forests are essential resources here. Most households use firewood from the forest for their fuel needs, raising significant environmental degradation concerns (Zulu 2010).

The Mzimba District, like most of northern Malawi, is susceptible to climate change impacts. Historical and recent meteorological records indicate the experience of droughts (Bezner 2018), and a relatively higher record of erratic rainfalls, floods, dry spells, and temperature variations (UNICEF 2022). The district is also characterized by high poverty levels and limited environmental resources, all of which impact household resilience (Government of Malawi 2017; Malawi Statistical Office 2019). Also, as the district is a frequent target for foreign and domestic agricultural interventions, this creates a good mix of diverse agricultural households.

DATA COLLECTION

This paper draws data from the FARMS4Biodiversity[1] cross-sectional survey conducted in Mzimba District from July to August 2019. A multiple-staged technique was employed to select smallholder farmers ($n = 1090$). Purposive sampling was used to select 30 village areas[2] in the Mzimba district for this study (Figure 1). The village areas were selected based on a gradient of semi-natural habitats within a 1 km radius surrounding the study site. The rationale was to keep the sample locations about 2 km apart to prevent spatial autocorrelation. We then employed systematic sampling to select households. Specifically, each fifth house was sampled from where the research team entered the village. The questions primarily focused on household seed availability, access, utilization and varietal suitability, and climate change. Other thematic areas include household demographic characteristics, socioeconomic conditions, gender relations, dietary diversity, health conditions, adaptive capacity, and on-farm activities. Western University, Canada's nonmedical research ethics board, provided ethical clearance for this study.

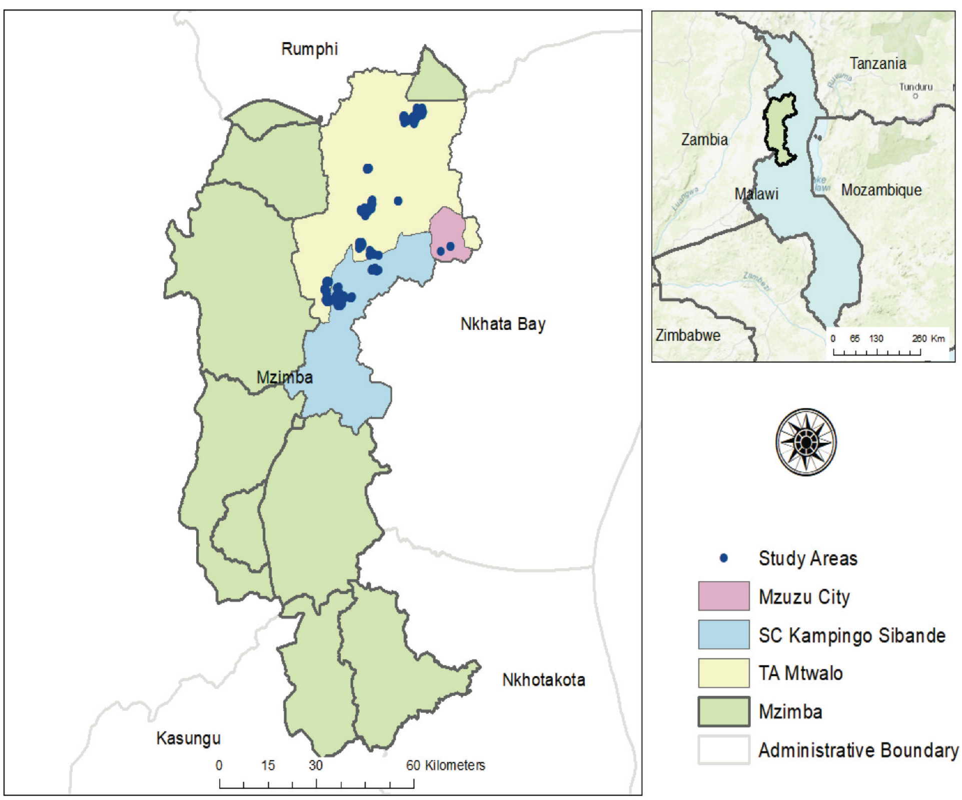

FIG. 1.—Map of the study area.

MEASURES

The dependent variable is "climate change resilience." Consistent with other studies (Mohammed and others 2021; Amoak and others 2023), respondents were asked to rate their capacity to anticipate, adapt, and recover from climate-related disturbances, including droughts, storm surges, rainfall variability, and floods in the past growing season. Based on these questions, smallholder farmers were asked to rate their level of resilience as either "poor," "satisfactory," or "good." This was coded as 1 = poor, 2 = satisfactory, and 3 = good. By using a self-reported scale to measure household resilience, we align with Jones and Tanner's (2015) subjectivist resilience lens, which argues that smallholder farmers not only are capable of reporting their resilience levels, but also have a better understanding of the disturbances they experienced and the systematic approaches that resulted in their recovery. The use of self-rated measures also circumvents the data challenges associated with secondary-data acquisition in SSA and the limiting nature of standardized resilience measures in communities characterized by multidimensional variabilities (Jones and Tanner 2015).

Independent variables

The key independent variable is seed security, derived from the FAO's 2016) seed security assessment toolkit. This measure is based on four indicators—availability, access, quality, and varietal suitability—and is used to evaluate seed security. To create the scale, respondents answered 12 questions (listed in Table 1) with either a yes or no. Based on the responses, seed security status is coded as (0 = seed-secure, 1–4 = moderate seed insecurity, 5+ = seed-insecure).

We also controlled for theoretically relevant factors (covariates) associated with climate change resilience that were included in the analysis based on the literature. Demographic variables include the age of respondent (coded as 0 = 15–25, 1 = 26–35, 2 = 36–45, 3 = 66–55, 4 = 55+); gender (0 = Female, 1 = male), marital status (0 = single, 1 = married, 2 = divorced, 3 = widowed); and household size (0 = 1–4, 1 = 5–8, 2 = >8). We also included socioeconomic factors, such as level of education (0 = no formal education, 1 = primary, 2 = secondary and 3 = tertiary), and wealth, calculated using a composite wealth index of valuable household assets, including household construction materials, possessions (such as car ownership, fridge, television, and motorcycles) and other dwelling characteristics. Results from the wealth index computations were coded as (0 = poorest, 1 = poorer, 2 = middle, 3 = richer, and 4 = richest). Lastly, we accounted for contextual (cultural and farm-level) factors; such as agriculture-related decision-making dynamics (0 = man-only, 1 = woman-only; and 2 = joint decision making), social capital (1 = very poor, 2 = poor, 3 = moderate, 4 = high, 5 = very high), MAFFA member/agroecological practices (0 = yes, 1 = no); and seed sources (1 = own stock, 2 = local market, 3 = social network, 4 = agro-input dealers, 5 = seed aid (NGOs), and 6 = seed aid (government)). The Malawi Farmer-to-Farmer Agroecology (MAFFA) intervention was a five-year project that trained farmers on agroecological practices (Kangmennaang and others 2017; Kansanga and others 2021). The initiative leveraged local assets and employed a peer-to-peer knowledge exchange strategy to educate smallholder farmers in the implementation of agroecological techniques, to enhance both agricultural productivity and household nutrition. Addressing prevalent issues like micronutrient deficiencies and soil infertility, the project advocated for the diversification of farming practices. This involved integrating legumes such as pigeon peas, groundnuts, and cowpeas, along with other tuber crops like cassava and sweet potato. These farmers continue to practice agroecology on their farms, including crop diversification, intercropping, agroforestry, and residue management, which is consistent with prior studies (Kansanga and others 2021). MAFFA membership is thus used as a proxy for agroecology practice in this study. We recorded 10 missing variables, which we dropped since the number was insufficient to change the dynamics of the results.

Data Analysis

We computed the descriptive statistics for each variable to describe the sample's basic characteristics, such as mean and percentages. Descriptive statistics are essential because they condense the data for easy comprehension. In addition to descriptive statistics, we employed ordered logistic regression analyses to understand the association between covariates and climate change resilience. Ordered logistic regression analysis is a technique for examining the relationship between an ordinal dependent variable and a set of categorical independent or explanatory variables. First, we run a bivariate ordered logistic model to compute the association between the covariates and the outcome variable (food security). Second, we run multiple ordered logistic models controlling for demographic, economic, sociocultural, and agricultural factors. After checking for multicollinearity in the regression model using variable inflation factor (VIF), we determined that the variables were not highly correlated as the VIF values recorded were less than 2.0 for the variables in the multivariate regression model. The ordered logistic regression equation is adopted from Hedeker and others (2000) and given as:

$$\log\frac{P(Yij \leq 1)}{(1 - P(Yij \leq 1)} = a0 + \sum_{k=1}^{p-1}\left(a_{jk}X_{ijk} + V_{ij,}C = 1, \ldots .\Omega - 1\right)$$

where P(Yij ≤1) is the probability that a household reports good resilience as opposed to satisfactory or poor), while α_{jk} is the coefficient term. The explanatory variables are represented by X_{ijk}, while (k = 1) is the first and *p*–1 is the last explanatory variable. α_o and $\Omega - 1$ are the 'intercept terms, and V_{ij} is the error term. All data analyses were implemented in STATA version 17.

Findings

descriptive analysis

Table 2 presents the findings of the descriptive analysis. The results indicate less than a fifth (18 percent) of respondents reported good resilience to climate change, while the majority (71 percent) reported their resilience as poor. In terms of seed security status, 37 percent were secure, 39 percent were moderately seed-insecure, and 24 percent were seed-insecure. The majority of respondents were female (65 percent) and married (81 percent). Also, the largest age group is 55+ (24 percent), followed by 36–45 (23 percent) and 26–35 (22 percent). Most households had between 5–8 members. Most respondents had primary education (77 percent), while 22 percent and 17 percent belonged to the poorest and poorer wealth quintiles, respectively. The results further highlight that decisions on agriculture were predominantly taken solely by the men in the household (48 percent). Also, about 24 percent and 30 percent of farmers rated their social capital as high and very high, respectively. The data also shows that 46 percent of the sample were MAFFA members. Sourcing seeds from the farmers' stock constituted the primary seed source (57 percent) among the respondents, 14 percent from the local market, 11 percent from agro-input dealers, and 9 percent from seed aid by Government and NGOs.

We conducted additional sensitivity analyses to test the robustness of the relationship between farmers' perceptions and experience of climate change and seed security. The hypothesis (Ho) for this analysis is that there is no significant association between the experience of climate change stressors and seed security among farmers in the Mzimba District. Table 3 shows the relationship between smallholder farmers' experiences of climate change and variability and household seed security. The results reveal that most of the farmers who experienced floods, droughts, and erratic rainfall in the previous 12 months reported moderate seed insecurity or seed security. For example, of the farmers who reported experiencing erratic rainfall in the 2018 cropping season, 52 percent (51.70 percent, $\chi 2 = p < .001$) were seed-secure in the 2019 cropping season. Additionally, the majority of farmers who prioritized and perceived climate change as a severe threat in relation to other socio-ecological vulnerabilities in the previous cropping season reported moderate seed-insecure (37.41 percent, $\chi 2 = p < .001$) and seed-secure (35.97 percent, $\chi 2 = p < .001$) in the 2019 cropping season. A further crosstabulation and chi square test analysis (Table A1) indicated that 49 percent of households that reported good resilience were seed-secure. These results indicate that the relationship between experiencing climatic stressors and seed security is not due to random chance and we, therefore, reject the null hypothesis. The results from Table 3 are consistent with growing studies (Elum and others 2017; Cacho and others 2020) reporting that farmers' experience and perception of climate change is strongly associated with seed security and greater attention to their seed needs.

BIVARIATE ANALYSIS

Table 4 reports the independent relationship between all predictors and perceived climate change resilience. We find that respondents who were moderately seed-insecure and seed-secure were 1.75 times ($p < .01$) and 3.62 times ($p < .001$) more likely to report good resilience to climate change, respectively, compared to their seed-insecure counterparts.

MULTIPLE REGRESSION ANALYSIS

Table 5 shows the results of the multiple regression analysis. Overall, we found a positive and statistically significant association between seed security and good climate change resilience. However, the magnitude of the odd ratios reduced after controlling for theoretically relevant factors. For instance, in Model 1, seed-secure households were 2.69 times ($p < .001$) more likely to report their resilience as good than seed-insecure ones, after controlling for demographic and socioeconomic factors. This relationship remained robust with slight attenuation after controlling for all theoretically relevant factors in Model 2. Specifically, in Model 2, the results reveal that seed-secure households were 1.89 times ($p < .01$) more likely to report good resilience to climate change than seed-insecure households, as demonstrated in Table A2. The relationship between seed security and self-reported resilience to climate change and their corresponding probabilities are shown diagrammatically in Figure 2. The figure shows that the predicted probabilities of reporting good resilience increase as one becomes seed-secure.

In addition to our key independent variable, some demographic, socioeconomic, and contextual (on-farm) factors were significantly associated with good climate resilience. For instance, we found that married, divorced, or widowed households were more likely to report good resilience compared to never-married households. We also noted that respondents with higher education were 12 times more likely to report good resilience than those without formal education. In terms of socioeconomic status, respondents whose households belonged to the richest wealth quintiles were 1.75 times more likely to be resilient than those in the poorest quintile. Results from Model 2 further indicate that those who were not MAFFA members were 57 percent less likely to report good resilience, compared to MAFFA members. Similarly, households whose primary source of seeds was through seed aid from NGOs (OR = 8.05; $p < .001$) and social networks (OR = 2.26; $p < .001$) were more likely to report good resilience than those who used farm-saved seeds.

Discussion

In the context of increasing climatic stressors and their associated fallouts, including food insecurity, widespread micronutrient deficiencies, and exposure to adverse health outcomes, improving farmers' resilience is crucial to achieving sustainable livelihoods (McGuire and Sperling 2016; Cacho and others 2020). In

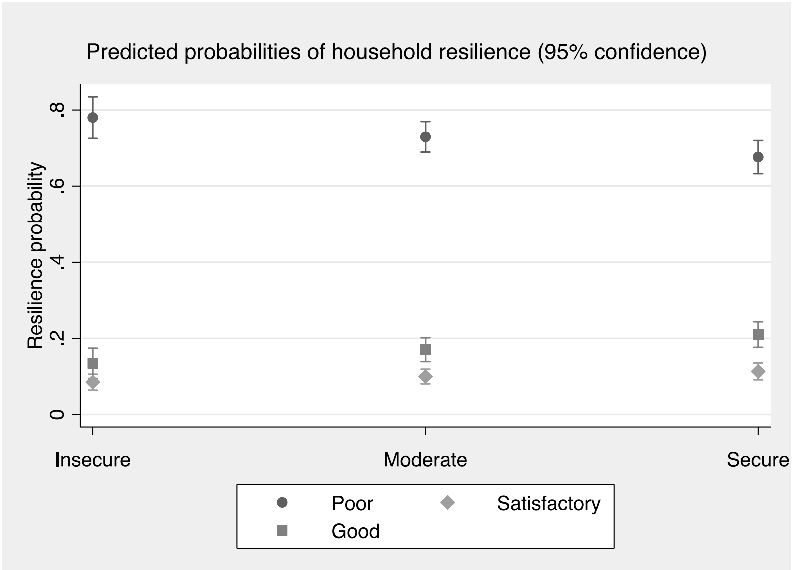

Fig. 2.—Predictive margins of household seed security status on perceived climate change resilience.

the predominantly rural context of northern Malawi, access to quality seeds is a fundamental priority, making smallholder farmers' seed security a crucial facet of any agricultural-based development strategy. Yet, the link between seed security and climate change resilience outcomes is a key gap in the literature. This study adopts the FAO's seed security assessment toolkit to examine the association between seed security and perceived climate change resilience.

Overall, the study revealed that about a third of farming households (36 percent) were seed-insecure, most of them being affected across all four pillars of seed security. In a high climate stress context like northern Malawi, seed insecurity introduces an additional layer of vulnerability to farmers and complicates efforts to build climate resilience. In this region, the predominant channels for acquiring seeds are through farm-saved seeds and kinship networks. While these channels mitigate financial barriers to seed acquisition, scholars contend that it is important to strengthen and expand seed sourcing channels, including seedbanks, local markets, and agro-input dealers, to provide farmers with a repertoire of seed-source options (De Falcis and others 2022; Westengen and others 2023). Improving the variety of channels through which farmers acquire seed is seen as a mitigation strategy to withstand climate emergency situations and to foster sustainable seed security. For example, empirical research from the 2016/17 season by Mazvimavi and others (2017) highlighted that a significant portion of Malawian farmers (38 – 51 percent) grappled with seed insecurity of groundnuts, an important food and cash crop which commands considerable market value and demand. The seed insecurity of groundnut can partly be attributed to poor harvests caused by El Niño in the previous season, which subsequently depleted individual stock reserves and reduced farmers' willingness to share within their social networks. In line with our theoretical construct, we contend that adopting a pluralistic approach that hinges on the inclusion of farmers in seed-sector development is not merely advantageous but imperative. A pluralistic pathway for seed sourcing is vital for enhancing seed security in Malawi as this approach advocates for the complementarity between formal and informal seed systems, integrating their activities rather than focusing solely on the development of one system (Mulesa and others 2021). In addition, researchers have noted that seed insecurity in northern Malawi is also partly driven by rising costs of seed, inadequate knowledge and adaptation of seeds, poor relationships with local seed traders, as well as low government investment in farm inputs, including seeds (FAO 2017; Quarshie and others 2021). Hunga (2023) also noted that the present seed insecurity farmers face is influenced indirectly by poor seed policies pushed by some "external forces" that often do not take into consideration the local environmental context, farmer's knowledge, and preference. These policies, in addition to the low government investments in farmer's seed security, may hamper Malawi's multisectoral National Resilience Strategy 2018–2030 of crop diversification for food security and climate resilience for smallholder farmers (IFAD 2022). The low rate of seed security poses severe concerns for the future geographies of food in Malawi given the rising intensity of climatic stressors in the past decade which is projected to increase under prevailing conditions.

Furthermore, our findings highlight that seed-secure farmers are more likely to report good climate change resilience than their counterparts who are seed-insecure. This finding is consistent with Nordhagen and Pascual (2013), who argued that seed-secure farmers with access to a diversity of cultivars report higher levels of resilience in the advent of climatic shocks. Being seed-secure allows farmers to adjust alongside the changing climate, be it modifications to the type or variety of seed sown or time of planting to achieve optimal yields. Cacho and others (2020) explain that when farmers are seed-secure, they are better positioned to address setbacks such as crop loss due to adverse climatic stressors—for instance, erratic rains and flooding—as they have the ability to replant promptly. This ability to bounce back stems from their access to adequate seed reserves. Additionally, against the backdrop that government-backed hybrid seeds introduced in some African markets, including Malawi, have been found to be less resistant to the environmental context (Nyantakyi-Frimpong and Bezner Kerr 2015), farmers' ability to select seeds of their preference is more compelling at a time of heightened climatic stressors. Seed security ensures that farmers can access a wide range of high-quality seeds that are specifically adapted to the local condition (Westengen and others 2018). Access to this genetic diversity enhances smallholder farmers' ability to withstand climate impacts. It has also been argued that seed security promotes on-farm seed saving and breeding, including open pollination, allowing farmers to continually adapt their seed stock to the changing climatic conditions (Bezner Kerr 2013; Vansant and others 2022). Seed security of leguminous crops in Malawi is especially useful in climate change resilience because of the crop's ability to improve soil fertility through nitrogen fixation and soil erosion reduction. The cultivation of leguminous also provides the added benefit of overcoming nutritional deficiencies as they contain proteins, oils and Vitamin A (Sichal and others 2013; Nyantakyi-Frimpong and others 2017; Jensen and others 2020).

Consistent with our theoretical lens, we found a range of demographic, socioeconomic and on-farm practices associated with farmers' resilience to climate change. As is corroborated by other studies on agroecology (Altieri and others 2015; Nyantakyi-Frimpong and others 2017; Bezner Kerr and others 2019; High Level Panel of Experts 2019; Wanger and others 2020), we found that the practice of agroecology makes a household more resilient to climate change and variability. Studies have demonstrated that the integration of agroforestry, crop diversity, residue management, mixed farming, and organic soil management practices work to bend the curve of ecological destruction, ensure sustainable food production, and improve ecosystem service provision (Kansanga and others 2020; Wanger and others 2020). The participatory agroecology approach used by the MAFFA project was hinged on "horizontal learning." This approach involved lead farmers using field days, farm-level experimentations, and social settings to teach other farmers in the local community about sound agroecological practices. Farmers were trained on low-cost options such as legume integration, intercropping, and agroecological pest management (Kpienbaareh and others 2022; Kansanga and others 2023). Members of the MAFFA initiative received training in seed selection and multiplication best practices for open-pollinated local seeds, ensuring the reliable recycling of seeds without compromising valuable traits. Additionally, farmer exchanges facilitated practical knowledge transfer of proper seed storage techniques, establishing miniseed banks at home. These practices contribute significantly to enhancing seed availability and accessibility among smallholder farmers in our study context. Training farmers in these diverse farm sustainable land management practices that are tailored to their local context using peer-to-peer approaches not only fosters peer solidarity and honest reflection but also foster trust and community belonging, which are necessary for adapting climate-smart agricultural practices in rural Malawi. Indeed, findings from panel data revealed that the farmer-to-farmer approach was effective in equipping MAFFA members with smart and sustainable land management practices that improved their resilience to climate change (Kansanga and others 2021).

Furthermore, in line with resilience and vulnerability thinking, the study indicated the relevance of seed sources in climate resilience building. Our study highlights that sourcing seeds from social networks and NGOs was associated with reporting good resilience. This finding is inconsistent with other studies that found local seed markets as an important source for the poorest smallholder farmers, and that social networks and seed aid contribute minimally to total seed supply (CIAT and others 2011; Sperling and others 2021). This variation in findings may be explained by differences in sample sizes and geographical location. This underscores the value of case studies, as they offer insights into nuanced aspects that might otherwise be overlooked in large-scale studies. Mzimba District is an important food basket for Malawi and many NGOs are actively working with farmers to improve food production and nutrition. In the last decade, in response to climate change and the gradual phasing out of government farm input subsidies, many NGOs have stepped in to provide additional support buffers to farmers, including the provisioning of seeds to vulnerable households. Sourcing seeds from local NGOs and through social networks is often associated with socioeconomically disadvantaged farmers. These channels provide supportive buffers to poor farmers, enabling them to bypass expensive seed sources such as agro-input dealers when sourcing seeds for their main crop of cultivation. Additionally, the involvement of NGOs in the seed sector has prompted advocacy for farmers' rights and acknowledgment of farmer-managed seed systems (Hunga and others 2023). The importance of NGOs and social networks in resilience building is underscored by concerns raised by farmers regarding seeds from agro-input dealers in Malawi. Scholars have noted concerns from farmers that due to poor regulations, oversight, and low education, especially in remote regions of Malawi, some agro-input dealers may still sell expired seeds or damaged seeds from poor storage and pest infestation to local farmers (Mudege and others 2015; Brearley and Kramer 2020). To offset these challenges and to provide low-cost alternatives in northern Malawi, some NGOs in seed systems development have established seed banks and seed-sharing networks, providing farmers with a repository of diverse seed sources. The seed banks also double as a safety net in times of crisis, thereby allowing farmers to access alternative seed varieties in the advent of seed germination or crop failure due to extreme weather events. Farmers with access to these networks and seed banks are hedged from climate-related shocks, enabling them to quickly recover and resume their agricultural activities compared to those without these necessary support systems (Kangmennaang and others 2017; Kansanga 2021). Notably, in addition to seeds, these NGOs provide farmers with relevant knowledge, information, demonstration trials, and climate-smart agricultural practices, such as agroecology, which emphasizes ecological principles and biodiversity conservation. The adoption of these practices works to ensure an overall resilient farming system through improved soil health, better water management, and natural pest control, which are necessary for building resilience against climate impacts, including soil erosion, pests, and evapotranspiration.

Despite these noteworthy findings, there are some limitations to this study. First, our study may be limited by recall bias. As a self-reported measure, it is possible that some respondents may overestimate or underestimate their level of exposure and perceived resilience levels. Furthermore, given that the data is collected contemporaneously, it is difficult to establish a causal relationship between the variables. Therefore, our findings are limited to statistical association and should be interpreted cautiously. Another limitation of this study pertains to the definition and scope of seed security as delineated by the 12 questions employed. Notably, these questions may not fully capture the nuanced aspect of access to a diverse range of seeds, a crucial dimension highlighted in the literature. Farmers seed sources are complex. Hence, there is the need for further research to explore seed security on a seed-to-seed basis, rather than broad categorizations. Future studies could consider triangulating the self-reported resilience measure with other resilience measures. Likewise, the paper acknowledges that not all determinants of climate change resilience were controlled for, including water security, which is beyond the scope of this paper. Despite these limitations, this study is the first to assess the relationship between seed security and resilience to climate change in Malawi.

Implications for the Future Geographies of Food

In reflecting on the future geographies of food in Africa, there is an urgent need to build a climate-resilient agricultural regime in order to safeguard present and future food production and to achieve the sustainable development goals. Notably, in relation to Malawi's future food landscape, strengthening farmers' seed security—a key foundation of the agricultural system—can serve as a critical entry point for enhancing farmers' resilience to climate change as well as food and nutrition security. This study has revealed that seed-secure farmers are more likely to report good resilience to climate change than their seed-insecure counterparts, pointing to the importance of seed security and seed sovereignty in safeguarding farmers' livelihoods and establishing a food system that can satisfy present needs without compromising its long-term viability and ecological harmony. Our finding contributes empirical evidence and supports the need to implement and strengthen seed-based strategies to improve resilience building in high-climate-stress agricultural regions. Other noteworthy resilience-building factors that can complement seed security include higher educational attainment, wealth, practising agroecology, stronger social networks and seed aid.

We conclude by suggesting that to shape a resilient and sustainable food future for Malawi, it is imperative to rethink agricultural strategies with seed security at the forefront. Safeguarding Malawi's future food security requires more than just increased yields; it demands a holistic approach. This includes bolstering seed security through diversifying and strengthening seed access, such as promoting local seed-saving/sharing initiatives and bridging access inequalities in the seed system. Alongside seed security, efforts should integrate comprehensive nutrition education; foster crop diversification suited to local agroecological conditions; implement gender-inclusive policies; foster greater farmers' engagement with seed banks; enhance agricultural extension services, including the use of farmer-to-farmer approaches; and cultivate community-based seed sharing mechanisms. Additionally, social networks play a vital role in preserving traditional seed varieties and indigenous knowledge, which is crucial in building resilience. Strengthening these networks through seed sharing and knowledge transfer can help enhance agricultural biodiversity and maintain a diverse genetic pool, which is crucial for adapting to changing environmental conditions.

Moreover, amid a diminishing scope and effectiveness of several government-led agricultural programs in the Mzimba district, such as the farm-input subsidy program, there is an urgent need for the central government to collaborate with nonprofits in the domain of seed systems development. Such partnerships are essential to ensure the provision of quality seeds to farmers, particularly those in financially challenged circumstances. Such a collaborative approach ensures that farmers have access to a wide range of seeds, including those tailored to their specific needs and environments. Furthermore, agroecology is shown as a noteworthy predictor of resilience, underscoring the mutually beneficial association between ecological concepts and farming methodologies. Agroecological systems, which put biodiversity, soil health, and ecological balance first, provide sustainable solutions as we traverse the difficulties of climate change, environmental degradation, and food insecurity. Through the integration of seed sovereignty, agroecology, and seed security, we may imagine a future in which food systems are based on sustainability and social justice principles.

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Notes

1 FARMS4Biodiversity is an ambitious, interdisciplinary, multi-scalar project designed to address biodiversity conservation, support ecosystem services and improve food security under scenarios of land-use change in the Global South.

2 A village area is the smallest local administrative unit and building blocks of a district, governed by a community chief, whose lands are subjected to communal law.

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