Hohenheim Working papers on Social and Institutional Change in Agricultural Development

Working Paper 025-2024

# Not all is lost – A case study of agrobiodiversity trends in Ghanaian and Burkinabe villages

Michael Olaitan Ademilola, Paul Effah, Viviane Yameogo, Thomas Daum, Lilli Scheiterle, Felix Asante, Nerbewende Sawadogo, Regina Birner

Universität Hohenheim

October 2024

Hohenheim Working Papers on Social and Institutional Change in Agricultural Development (025-2024)

# Not all is lost – A case study of agrobiodiversity trends in Ghanaian and Burkinabe villages


## Authors details[1]

Michael Olaitan Ademilola (University of Hohenheim)

Paul Effah (University of Hohenheim)

Viviane Yameogo (University of Hohenheim)

Thomas Daum (School of Global Studies, University of Gothenburg)

Lilli Scheiterle (German Institute for Tropical and Subtropical Agriculture, Germany)

Felix Asante (University of Ghana)

Nerbéwendé Sawadogo (University Joseph Ki-Zerbo)

Regina Birner (University of Hohenheim)

## Corresponding author

Viviane Yameogo (guesbeogo.yameogo@uni-hohenheim.de)




Suggested citation: Ademilola, O. M., Effah, P., Yameogo, V., Daum, T., Scheiterle, L., Asante, F., Sawadogo, N., Birner, R. (2024). Not all is lost – A case study of agrobiodiversity trends in Ghanaian and Burkinabe villages. Hohenheim Working Papers on Social and Institutional Change in Agricultural Development 025-2024. University of Hohenheim.

Title Picture Credit: pexels.com

Download this working paper from our homepage: https://490c.uni-hohenheim.de/en/75736

[1] Michael Ademilola and Paul Effah share equal contributions to this paper.

## Abstract

The conservation of crop and varietal diversity, which is an important component of agrobiodiversity, constitutes an important objective of sustainable agricultural development. Although there is an increasing number of scientific studies that have analysed the current state of crop and varietal diversity in Africa and identified trends, there are major contradictions as to whether diversity is being conserved or whether there are reasons for serious concern about a loss of this diversity due to the increasing predominance of a limited number of major crops and varieties. The aim of this study was to gain a better understanding of the status and patterns of crop and genetic diversity, using eight villages in selected regions of Burkina Faso and Ghana as case studies. The study used a mixed methods approach, combining a survey of 320 respondents with qualitative research methods, including focus group discussions, timelines, matrix scoring and four-square analysis, to identify the status and trends in crop and varietal diversity and examine the factors that help to explain the trends observed. Although there is some variation in the trends in crop and varietal diversity, the results indicate that -unlike often believed- the number of crops and varieties cultivated has increased in recent years, mainly due to socio-economic factors such as market demand, yield, market value, irrigation schemes, migration and government initiatives. The relatively high levels of crop diversity are also indicated by Shannon diversity indices of 1.303 and 1.596 in Burkina Faso and Ghana, respectively. The data suggest that certain crops, including bambara groundnut, sorghum, and millet, are cultivated not only for their economic benefits but also for their cultural significance. The findings from our case study villages show that “not all is lost” and that crop and varietal diversity is increasing in some parts of Africa – while it is declining in other parts. Moving forward, the findings indicate that policymakers and stakeholders can enhance the conservation of crop and varietal diversity by leveraging the identified economic drivers and cultural factors. Incorporating farmers' preferences and values into policy frameworks is crucial to align conservation efforts with the economic incentives and practical realities of agricultural production.

## Key Words

Agrobiodiversity, genetic erosion, diversity index, crop diversity, varietal diversity

## Acknowledgments

We extend our sincere thanks to the communities and farmers who participated in this study. We are particularly grateful for the financial support from the 'Program of Accompanying Research for Agricultural Innovation' (PARI), funded by the German Federal Ministry of Economic Cooperation and Development (BMZ). Our deep appreciation goes to the organizations that supported the fieldwork: Navrongo-Bolgatanga Catholic Diocesan Development Organization (NABOCADO), the Ministry of Agriculture in Ghana, and the Ministry of Agriculture in Burkina Faso. Special thanks to Dr. Eli Afetsi Gaveh, Senior Lecturer at Kwame Nkrumah University of Science and Technology (KNUST). Finally, we are thankful for the dedication and efforts of our research assistants: Moses Abaane, Isaac Anyinase, Isaac Amomgba, Happy Asati, Armel Sawadogo, and Samiratou Sané.

## 1. Introduction

Agrobiodiversity plays a crucial role in the sustainability of agri-food systems. It encompasses the diversity of plant and animal genetic resources, of which crop and varietal diversity is a component. Within plant production, both inter- and intraspecific crop diversity—which is the focus of this paper—holds significant implications for food and nutrition security (Amao et al., 2023; Baba & Abdulai, 2021; De Groote & Omondi, 2023; Morrissey et al., 2024). This diversity can contribute to overall household welfare (Tesfaye & Tirivayi, 2020) and enhance environmental resilience (Labeyrie et al., 2021; Menamo et al., 2021; Renard et al., 2023). The necessity to maintain and increase agricultural biodiversity has spurred increasing debates and efforts for both ex-situ and in-situ conservation of crop and varietal diversity (Dempewolf et al., 2023; Khoury et al., 2022; van Zonneveld et al., 2021). Furthermore, numerous research efforts have been undertaken to assess the status and trends of agrobiodiversity to provide robust evidence for establishing conservation priorities. In sub-Saharan Africa, several studies have raised alarming concerns regarding the loss and erosion of crop and varietal diversity (Ahmad et al., 2023; Assima et al., 2022; Abegaz & Tessema, 2021; Seburanga, 2013), while others offer a more nuanced view of the trends observed in the field (Deu et al., 2010; Rampersad et al., 2023), partially challenging the prevailing discourse surrounding the loss of crop and varietal diversity. These conflicting findings prompt critical inquiries into the underlying reasons for such disparities and, most importantly, into the conditions under which agrobiodiversity is preserved. Examining crop and varietal diversity in sub-Saharan Africa is particularly timely, given the region's historically high agrobiodiversity. While certain areas are experiencing declines similar to those observed in Asia (Gatto et al., 2021), sub-Saharan Africa presents a unique context where localised conservation efforts and traditional farming practices may still safeguard significant diversity. Understanding these dynamics can offer crucial lessons for both mitigating biodiversity loss and strengthening agrobiodiversity conservation strategies.

The existing literature has predominantly concentrated on scientific assessments and quantitative measures of agrobiodiversity (Ahmad et al., 2023; Appiah-Twumasi & Asale, 2022; Awiti et al., 2022; Baba & Abdulai, 2021; Porcuna-Ferrer et al., 2024; Teshome et al., 2016), often neglecting how trends are affected by the essential contributions of farmers' knowledge, attitudes, and practices, especially from a gender perspective. Additionally, there is a notable gap in studies that integrate both qualitative and quantitative methods to yield a more holistic understanding of agrobiodiversity.

This paper seeks to bridge these research gaps by investigating agrobiodiversity management strategies in sub-Saharan Africa, focusing on farmers perspective, including by taking a gender lens. By doing so, the paper aims to elucidate the factors influencing farmers' decisions to reduce, maintain, or enhance crop and varietal diversity, while also exploring the incentives that drive these choices, such as risk management and socio-cultural influences. Understanding farmers' perceptions is crucial, as these insights significantly shape the dynamics of crop and varietal diversity in situ. A more nuanced comprehension of how different types of farmers perceive the changes occurring on their farms, along with the motivations behind these changes, can help policymakers and other actors to develop more effective strategies for safeguarding crop and genetic diversity in the future. Furthermore, by incorporating farmers' viewpoints, researchers and policymakers can better assess the extent to which agrobiodiversity contributes to farm productivity and resilience. In instances where agrobiodiversity does not yield tangible benefits for farmers, policymakers can identify and implement appropriate institutional and policy frameworks to encourage positive behavioural shifts towards the conservation of agrobiodiversity.

Using selected regions of Ghana and Burkina Faso as case study examples, the following specific objectives are pursued: 1) to assess the current status of crop and varietal diversity in the study regions; 2) to identify temporal trends in crop and varietal diversity; and 3) to analyse the factors influencing farmers' crop choices.

To achieve these objectives, the paper adopts a mixed methods approach to illuminate both quantifiable trends in crop and varietal diversity and the underlying rationale behind farmers' crop and variety selections, paying special attention to gender dynamics. Data were gathered using a combination of quantitative and qualitative instruments from eight villages located in Northern Ghana and Southern Burkina Faso. These villages were strategically selected from adjacent border regions that exhibit similar biophysical and agro-ecological conditions, yet differ in their institutional and policy frameworks, thereby providing a robust basis for a comparative case study approach. Our selection of Ghana and Burkina Faso was driven by concerning reports highlighting the displacement of crops and the erosion of varietal diversity (Ahmad et al., 2023; Armah et al., 2013; Kondombo et al., 2016).

The remainder of the paper is organized as follows. The next section presents a review of the existing literature on crop and varietal diversity in Africa. The subsequent section outlines the methods and instruments employed to collect the data pertinent to this study. Thereafter, the results of the research are presented, followed by a discussion of the results. The final section concludes and provides policy recommendations.

# 2. Literature Review

## 2.1. Crop and varietal diversity in sub-Saharan Africa: status and trends

### Crop diversity

The extent and trend of crop diversity have been the subject of a number of studies conducted across sub-Saharan Africa. Several terms have been employed to characterize the status and patterns of crop diversity in agricultural landscapes, including "neglected crops", "orphan crops", and "underutilized crops" (Abrouk et al., 2020; Chivenge et al., 2015; Joseph et al., 2023; Tadele, 2019). These terms have been employed to evaluate the presence or absence of underutilized or orphan crops, such as fonio, Bambara groundnuts, and pigeon pea, including their incorporation into diets. A striking feature of this literature is the lack of consensus among experts on the topic. While a substantial body of literature has identified a downward trajectory in agricultural biodiversity (Gerrano et al., 2022; Porcuna-Ferrer et al., 2024; Seburanga, 2013), there are also studies that have presented an alternative view, suggesting that the decline may not be as pronounced as presented and that the notion of a loss of diversity is a myth (Deu et al., 2010; Rampersad et al., 2023). Other studies have highlighted mixed results, exhibiting varied trends in crop diversification (Khoury et al., 2022; Ochieng et al., 2020; Tesfaye & Tirivayi, 2020; Teshome et al., 2016).

In a study of indigenous crop diversity in Rwanda, Seburanga (2013) reported the loss of traditional crops to alien crops, which he relates to the “cultural disturbance” that took place during colonization. During that period, crops such as beans, bananas, and sweet potatoes, which were promoted by the colonial authority, accounted, according to that author, for more than 40% of the country's crop flora. This was achieved, however, at the expense of native crop species like Sorghum bicolor (Linn.), Moench “nyiragikori” (Gramineae), Amaranthus graecizans Linn. “inyabutongo” (Amaranthaceae), Eleusine coracana (Linn.). As documented by Seburanga (2013), the decline in the use of traditional crops continued unabated throughout the postcolonial period, with the substitution of crops such as rice and maize for traditional ones.

A more recent study by Porcuna-Ferrer et al. (2024) reinforced the argument concerning the negative impact of colonial and post-colonial agricultural policies in accounting for the loss of traditional crops, pointing to a loss of sorghum, fonio, and Bambara groundnut among Bassarati farmers in Senegal. Combining surveys with qualitative research methods, the authors posited that the prioritisation of cash and exotic crops like cotton, peanut and maize over traditional indigenous crop species has precipitated a decline in the latter, thereby reducing farmers’ crop portfolios, and jeopardizing their resilience to the effects of climate change. In the same line of argument, Theriault & Smale (2021) indicated a decline in crop species diversity in Mali, which they attributed to a distortion in farmers' incentives. Their analysis of data from 2,331 farm households has revealed that fertiliser subsidies targeted at specific crops, including maize, rice, and cotton, resulted in farmers allocating a greater proportion of their cropping areas to these crops at the expense of other crops, such as cowpea, peanut, and fonio. Using panel data at village level, Assima et al. (2022) reached similar conclusions on the effect of fertiliser subsidies on crop species richness in Mali. Nevertheless, they acknowledge that greater species richness at the village level is associated with a greater likelihood of cowpea cultivation. In Sudan, Abdalla et al. (2013) used the Shannon index to assess species richness in agricultural households. The authors reported a low level of crop diversity and found that the conservation of local seeds for the next cropping seasons was negatively correlated with on-farm crop diversity.

The proposition that crop diversity is in decline or even lost is, however, not a consensus view amongst the scientific community. There are recent studies that came to the opposite conclusion, namely that there is no decline in crop diversity. Using a dataset of 1,170 farms across the highlands of Southwest Ethiopia, Rampersad et al. (2023) have found that the introduction of new crops did not result in the displacement of indigenous crop, but rather contributed to greater crop diversification. The authors also found that on-farm crop richness increased with better access to market. Sseremba et al. (2017) found that farmers in Uganda still grow more than 20 indigenous African vegetables. They recommend improved variety development and germplasm conservation to prevent a possible biodiversity loss in the future.

### Varietal diversity

Research on varietal diversity has often revolved around the label of "genetic erosion", and, as with crop diversity, the literature shows conflicting findings on the state and trends of varietal diversity. While some studies suggest a decline in varietal diversity (e.g., Adewumi et al., 2021; Gatto et al., 2021; Kondombo et al., 2016; Mohammed et al., 2020), others find no such evidence (e.g., Bezançon et al., 2009; Deu et al., 2010).

A review by Mohammed et al. (2020) highlights a significant decline in the diversity of pearl millet varieties cultivated in Nigeria, attributed to the replacement of traditional local varieties with modern cultivars. Kondombo et al. (2016), who have assessed the richness of local sorghum varieties managed and cultivated by farmers in Burkina Faso, came to a similar conclusion. While the authors noted some degree of richness in sorghum varieties, they concluded that sorghum varietal diversity is at risk, and pointed to socio-cultural and environmental drivers as major constraints to sorghum varietal diversity. Dossou-Aminon et al. (2016) employed the Shannon–Weaver diversity index (H) to estimate the diversity of sorghum in the northwest region of Benin. Their findings revealed a significant decline in the number of sorghum varieties, raising concerns about the sustainability of genetic diversity in the country.

A study of farmers' perceptions of varietal diversity in Ethiopia appears to corroborate the finding of a loss of crop diversity. Using a sample of 395 farm households in Northern Ethiopia, Wale (2012) found that a majority of the surveyed farmers recognized a significant erosion of traditional varieties, and that increasingly smaller areas of their cropping fields were allocated to these varieties. These findings are consistent with the perceptions of farmers in the Wollo administrative zone of Ethiopia. In a survey of 1,200 farm household in the districts of Tenta, Mekdela, and Delanta, Delanta, Abegaz & Tessema, (2021) observed a notable decline in sorghum crop diversity. This included the complete abandonment of white sorghum by farmers in Tenta and Mekdela. Although the data indicated some discrepancies between districts, the findings collectively suggest a decline in the diversity of sorghum landraces.

A contrasting storyline is presented by Bezançon and colleagues (2009). The authors have conducted an analysis of the genetic diversity of two major crops in Niger, namely sorghum and millet, over a 26-year period. The findings of this study call into question the existing evidence concerning the loss of varietal diversity of sorghum and millet in this country. In a spatio-temporal analysis of sorghum diversity in Niger, Deu et al. (2010) had similar results, reporting an increase in the richness of sorghum varieties in the 28 villages included in their study. Both studies have posited, that, in general, farmers have been effective in maintaining the genetic diversity of sorghum in the region.

## 2.2. Determinants of crop and varietal diversity at farm level

The drivers of agrobiodiversity that are documented in the literature provide insights into the factors that influence farmers' decisions to specialize or diversify. The existing literature on agrobiodiversity indicates that the extent of on-farm crop and varietal diversity is embedded within a complex interplay of agronomic, environmental and socio-economic and institutional factors (Ahmad et al., 2023; Loko et al., 2021; Ochieng et al., 2020; Theriault & Smale, 2021).

In a study involving 445 soybean producers, Loko et al. (2021) demonstrated a correlation between a decline in genetic diversity and agronomic factors. The results of the study indicate that 44% of farmers have ceased the cultivation of two major soybean varieties. The farmers attributed this decision to a range of factors, including soil infertility, soil moisture, and lengthy cultivation cycles, in addition to other agronomic and socio-economic considerations, such as sensitivity to diseases and lack of funding. Abegaz & Tessema (2021) made comparable observations regarding the abandonment of sorghum landraces by farmers in Ethiopia. The authors indicated that the frequency of droughts in the country, which are associated with climate change, have prompted farmers to alter their preferences and cultivate alternative varieties of sorghum. Conversely, Teshome and colleagues (2016) observed an increase in the diversity of sorghum landraces in Ethiopia. A number of factors, including the presence of desirable traits in certain varieties and the possibility of growing them across two distinct cropping seasons, were found to influence the selection decision of farmers, together with the aim to conserve specific varieties.

Scholars have also identified socio-economic factors that shape crop and genetic diversity (Baba & Abdulai, 2021; Tesfaye & Tirivayi, 2020). Tesfaye & Tirivayi (2020) showed that in Ethiopia, households with more asset endowments, including land, are more likely to cultivate a large portfolio of crops. Furthermore, their study demonstrated that older farmers are more inclined to have a diversified crop portfolio than their younger counterparts. In their study of 200 farmers in Sudan, Abdalla et al. (2013) also found a significant effect of socio-economic variables on crop diversity. Specifically, a larger household size and a higher income were associated a higher crop diversity. Other scholars, including Ahmad et al., (2023), Assima et al., (2022) and Theriault & Smale, (2021), have examined the degree to which fertiliser subsidies influence the propensity of farmers to diversify. Theriault & Smale (2021) reported a negative influence of fertiliser subsidy on crop diversity in Mali, with farmers allocating more land to target crops, such as maize, rice and cotton. Ahmad et al. (2023) have also shown that farmers with access to fertilisers reduced their allocation of land to cowpea production, as opposed to crops like maize, rice and cotton that were targeted by the subsidy program.

## 2.3 Open questions

Of the thirty papers included in the survey of the literature presented here, more than half report a low level of diversity and a downward trend in agrobiodiversity. The remaining claim that there is no evidence to support this finding. This raises important questions: Are we losing crop and varietal diversity or not? Should there be concerns over crops genetic erosion? It may well be that diversity is declining in some regions, while it is increasing or remains unchanged in other regions. It is an open question under what conditions these diverse trends are to be expected.

It could also be the case that the methodology employed to define and measure agrobiodiversity, including the indicators applied in assessing the diversity, influences the findings reported. As Montenegro De Wit (2016) indicates, agrobiodiversity is “more easily invoked than measured, more easily wielded than understood” (p1). Furthermore Brown & Hodgkin (2015) identify three concepts that are often used to measure problems related to genetic diversity. These are genetic diversity, genetic vulnerability, and genetic erosion. They claim that the complexity of selecting the right indicators to measure diversity makes the task daunting. The literature review shows that agrobiodiversity is measured at different scales (Bezançon et al., 2009; Gomes et al., 2020, 2021; Seburanga, 2013), and with different tools, including crop count, Shannon diversity index, Herfindahl Index, and Menhinick index, are used to measure agrobiodiversity (Abdalla et al., 2013; Assima et al., 2022, 2022; Dossou-Aminon et al., 2016). There are also open questions regarding farmers' perceptions of crop and varietal diversity, and their actual agrobiodiversity practices on their farms. Additionally, the gendered nature of these perceptions needs to be further investigated. Finally, the extent to which socio-economic, agronomic and institutional factors interact to influence agrobiodiversity remains an open question, requiring further research.

## 3. Methods

### 3.1. Study areas

This research was carried out in eight villages[2] in two of the bordering regions of Ghana and Burkina Faso: The Upper East region of Ghana and the Centre-Sud and Centre-Est regions of Burkina Faso. The Upper East region of Ghana is in the north-eastern corner of the country, and the vegetation is made up of savannah woodland. The vegetation is characterized by short and scattered drought-resistant trees and patches of grasses (Kumasi et al., 2019), a relatively low and erratic uni-modal rainfall pattern (Adimassu et al., 2023; Issahaku et al., 2016; Quaye-Ballard et al., 2020), followed by a long spell of dry season with dusty harmattan[3] winds, high temperatures, and low humidity (Kumasi et al., 2019; GSS, 2013). The majority of the population engages in agriculture, combining a range of livestock species and crops such as millet, guinea-corn/sorghum, maize, groundnut, beans, and horticultural crops such as tomatoes and onions (Bellon et al., 2020; GSS, 2013).

The two selected regions in Burkina Faso share similar characteristics. The regions are located in the West Sudanian savannah of the country, and their agroecology is characterized by dense shrubland and woodland with high agricultural prospects. Ferrous soils make up almost 65% of the land (Ministere de l' Economie et des Finances, 2009). The rainy season occurs between May and October which is then followed by a long spell dry season with high temperatures caused by the harmattan hot winds from the North (Knauer et al., 2017). Rainfall in the Centre-Sud is abundant but poorly distributed in time and space, exacerbating farmers vulnerability. As in the case of Ghana, the majority of the local population practices agriculture on small areas of land (Fritz et al., 2015) and grows crops such as sorghum, millet, maize, and cotton.

[2] The names of the villages are withheld to protect confidentiality and anonymity.
[3] "The Harmattan is a season in West Africa that occurs between the end of November and the middle of March. It is characterized by the dry and dusty northeasterly trade wind, of the same name, which blows from the Sahara over West Africa into the Gulf of Guinea." https://en.wikipedia.org/wiki/Harmattan. Retrieved September 19, 2024.

## 3.2. Research design, sampling techniques and data collection instruments

As indicated above, a mixed methods approach was applied for this study, combining qualitative and quantitative methods. The details are provided in Table 1. A questionnaire was administered to 240 farm households, including 176 male-headed and 64 female-headed households. In order to capture intra-household dynamics, a subsample of 80 spouses from the male-headed households were interviewed. This resulted in a total sample of 320 respondents (240 household heads and 80 spouses). The original sample was obtained following a multi-stage sampling technique. The first stage consisted in selecting the three regions based on their proximity to the borders of Burkina Faso and Ghana. Within each region, districts or provinces were purposively selected based on their level of diversification. Experts from the Ministries of Agriculture in both countries, with relevant knowledge, informed the district selection process. In the third stage, two villages were selected -one with a relatively high level of diversity and the other with a lower level of diversity- identified with assistance from representatives of the Ministries of Agriculture and Non-Governmental Organisations (NGOs). Finally, a random sampling approach was used to select the surveyed households.

### Table 1. Research design and sample size

| Research instruments | Category | Ghana | Burkina Faso | Total |
|---|---|---|---|---|
| **Survey** | | | | |
| | Female household head | 32 | 32 | 64 |
| | Male household head | 88 | 88 | 176 |
| | Spouse (sub-sample of male headed households) | 40 | 40 | 80 |
| | **Total** | 160 | 160 | 320 |
| **Focus Group Discussions** | | | | |
| | Women | 4 | 4 | 8 |
| | Seniors (old men) | 4 | 4 | 8 |
| | Young and adult men | 4 | 4 | 8 |
| | **Total** | 12 | 12 | 24 |

Source. Authors

Qualitative data was collected through focus group discussions (FGDs) with three categories of respondents: women (including young, adult and old women), community elders (old men) and young and adult men. A total of 12 FGDs were conducted in each country, with 6-8 people participating in each FGD. To explore respondents' perceptions of crop/genetic diversity and trends, several participatory rural appraisal tools were used to facilitate the discussions. First, a historical timeline was used to assess the evolution of crop diversity and genetic diversity in the communities. It allowed respondents to provide an overview of the evolution of crop numbers within their community, while also providing an overview of the events that triggered the changes.

The four-square method (as described in Table 2 below) is a visual tool that helps respondents to categorize different crops according to their importance in terms of the proportion of area devoted to their production and the proportion of households that grow them (see Mulugo et al., 2021 for a detailed description of the method). Each quadrant describes the size of the area devoted to a particular crop and the number of households cultivating that crop. The categories are Many Households on a Large Area (MHLA), Many Households on a Small Area (MHSA), Few Households on a Small Area (FHSA) and Few Households on a Large Area (FHLA). The Four-square quadrant analysis was also used to visualize changes in crop importance over time in the village studied. Respondents were asked to indicate the direction of movement of a particular crop from one quadrant to another.

**Table 2. Four-square Diagram**

| | |
|---|---|
| **MHLA**: Many households, large area where the crop is grown | **MHSA**: Many households, small area where the crop is grown |
| **FHSA**: Few households, small area where the crop is grown | **FHLA**: Few households, large area where the crop is grown |

Source. Authors. Adapted from Mulugo et al. (2021)

## 3.3. Analytical tools

To analyse the quantitative data from the household survey, we used descriptive statistics, and an econometric approach. Apart from identifying the shares of crop land dedicated to different types of crops, we used the Shannon Diversity Index to analyse crop diversity. Drawing from the foundational work of Shannon (1948) and more recent contributions by Parré & Chagas (2022), we calculated the Shannon Diversity Index for crop diversity in the Upper East region of Ghana and Southern Burkina Faso. The Shannon Diversity Index is mathematically expressed as follows:

$$H' = -\sum_{i=1}^{n} P_i \ln(P_i) \qquad H' \geq 0 \qquad (1)$$

Where:

$H'$ = Shannon Diversity Index

$Pi$ = the proportional area of the i-th crop in the total area planted

n = the total number of crops grown in the area and

ln = the natural logarithm.

For the econometric approach, an Ordinary Least Squares (OLS) regression analysis was carried to determine the drivers of crop diversity. The regression model, which used the Shannon Index as dependent variable, is specified as follows:

$$H' = \beta 0 + \sum_i^n \beta i X i + \epsilon \qquad (2)$$

Where:

X1, X2…, Xn represent the explanatory variables (As outlined in Table 3, below)

β1, β2,…,βn are the coefficients of the variables and

$\epsilon$ is the Error term

The variables were identified based on the existing literature reviewed above.

### Table 3. Description of variables

| Variable | Description | Variable type |
|---|---|---|
| **Demographic characteristics** | | |
| Country | Country 1= Ghana 0= Burkina Faso | Dummy |
| Gender | Gender of the respondent 1=Male 0= Female | Dummy |
| Cooperative | The respondent is a member of a farmers' cooperative 1= Yes 0= No | Dummy |
| Education | Number of years of education | Continuous |
| Experience | Number of years of farming experience | Continuous |
| Extension | The number of times the farmer received extension advice in the last cropping season | Continuous |
| Training | Farmer underwent a vocational in agriculture 1= Yes 0= No | Dummy |
| Origin | Whether the household is indigenous to the village or else (immigrant, displaced…) 1= Indigenous and 0 = Not indigenous | Dummy |
| Size | Number of persons in the household | Continuous |
| **Farm characteristics** | | |
| Area | Total farm size under cultivation | Continuous |
| Livestock | Livestock number in tropical livestock units (TLU) | Continuous |
| **Farm practices** | | |
| Mechanization | Use of mechanization in land preparation 1= Yes 0= No | Dummy |
| Organic | Application of organic fertilisers 1= Yes 0= No | Dummy |
| Inorganic | Application of inorganic fertilisers 1= Yes 0= No | Dummy |
| Pesticides | Use of fungicides and insecticides 1= Yes 0= No | Dummy |
| Herbicides | Application of herbicides / weedicides 1= Yes 0= No | Dummy |

Source. Authors.

The information obtained from the Focus Group Discussions was analysed based on a content analysis, which focused on identifying farmers' rationale for selecting crops and varieties. The four-square diagrams were visually interpreted.

# 4. Findings

## 4.1. Descriptive statistics

Table 4 summarizes the socio-demographic characteristics of the respondents in Burkina Faso and Ghana. The results show that the age distribution is similar in both countries, although the average age is higher in Ghana than in Burkina Faso. The average household size is also almost identical between Ghanaian and Burkinabe households, an indication that family structures are similar. In addition, the majority of respondents in both countries are in monogamous marriages, with only a small percentage in polygamous unions. Similarly, few of the respondents are formally educated, accounting for less than a quarter of those surveyed. While membership of farmer cooperatives is low in both countries, there is a significant difference in membership of cooperatives, with Ghanaian farmers more likely to join cooperatives than their Burkinabe counterparts.

Table 5 and Table 6 provide an overview of the sample's farm characteristics and agricultural practices. The mean cultivated area is around 2 and 3 hectares, in Burkina Faso and Ghana, respectively. Comparatively, the number of plots cultivated in Ghana is on average higher than in Burkina Faso, although the number of staple crops cultivated in both countries is similar. More than half of households use mechanisation for land preparation, in both Burkina Faso, and Ghana. However, notable differences in irrigation adoption exist between the two countries. While irrigation usage remains relatively low in Ghana, nearly 90% of households in Burkina Faso reported engaging in irrigation practices. Fertiliser application is widespread in both countries, with a distinct preference for inorganic fertilisers among Burkinabe households, whereas Ghanaian households exhibit a stronger inclination toward organic fertilisers. Additionally, the data reveals that the use of pesticides and herbicides is more prevalent in Burkina Faso than in Ghana.

## Table 4. Respondents characteristics

| Variable (measurement) | | Ghana | | | | | Burkina Faso | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min. | Max. | Mean/ % | SD | Obs. | Min. | Max. | Mean/ % | SD | Obs. |
| Gender (%) | Male | - | - | 55 | - | 160 | | | 55 | | 160 |
| | Female | - | - | 45 | - | | | | 45 | | |
| Marital status (%) | Married-monogamy | - | - | 66.3 | - | 160 | | | 63.8 | | 160 |
| | Married-polygamy | - | - | 11.9 | - | | - | - | 15.6 | - | |
| | Single | - | - | 0.6 | - | | - | - | 1.3 | - | |
| | Divorced/ separated | - | - | 0 | - | | - | - | 2.5 | - | |
| | Widow/ Widower | - | - | 21.3 | - | | - | - | 16.9 | - | |
| Educational level (%) | Primary | - | - | 13.8 | - | 160 | - | - | 18.8 | - | 160 |
| | Intermediate (JHS, SHS, O'Level) | - | - | 12.5 | - | | - | - | 11.3 | - | |
| | Advanced higher education | - | - | 1.2 | - | | - | - | 2.6 | - | |
| | No formal education | - | - | 72.5 | - | | - | - | 67.5 | - | |
| Cooperative membership (%) | | - | - | 58.1 | - | 160 | - | - | 22.5 | - | 160 |
| Farm contract[4] (%) | | - | - | 0.6 | - | 160 | - | - | 11.3 | - | 160 |
| Household size (No. of persons) | | 1 | 20 | 7.3 | 3.1 | 160 | 2 | 14 | 7 | 2.6 | 160 |
| Age (years) | | 20 | 89 | 48.5 | 12.6 | 160 | 22 | 95 | 47 | 13.7 | 160 |
| Farming experience (years) | Male | 4 | 60 | 24.8 | 11.5 | 88 | 1 | 67 | 23 | 13.5 | 88 |
| | Spouse | 1 | 35 | 14.6 | 8.2 | 40 | 2 | 38 | 17 | 11.4 | 39 |
| | Female | 6 | 40 | 25.6 | 10.6 | 32 | 3 | 44 | 22.16 | 11.5 | 31 |
| Extension service (Freq. in the past year) | Male | 0 | 10 | 1.6 | 1.7 | 88 | 0 | 5 | 0.97 | 1.5 | 88 |
| | Spouse | 0 | 5 | 1.1 | 1.3 | 40 | 0 | 4 | 0.55 | 1.2 | 40 |
| | Female | 0 | 4 | 1.1 | 1.4 | 32 | 0 | 3 | 0.4 | 0.8 | 32 |

Source. Authors based on household survey

## Table 5. Farm characteristics

| Variable | Ghana | | | | | Burkina Faso | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | Mean | SD | Obs. | Min. | Max. | Mean | SD | Obs. |
| Cultivated farm size (acre) | 0.5 | 8 | 3.0 | 1.9 | 120 | 0.2 | 12 | 1.9 | 2.3 | 120 |
| Number of plots | 1 | 7 | 2.6 | 1.6 | 160 | 0.5 | 5 | 1.9 | 0.9 | 160 |
| Number of crops | 1 | 11 | 5 | 2.2 | 160 | 1 | 8 | 4 | 1.7 | 160 |

Source. Authors based on household survey. Crops mainly include staple and cash crops, excluding fruits and vegetables

[4] Any sort of arrangement/agreement, oral or written, *between farmers (producers) and buyers: both agree in advance on the terms and conditions for the production and marketing of farm products* FAO.

**Table 6. Agricultural practices**

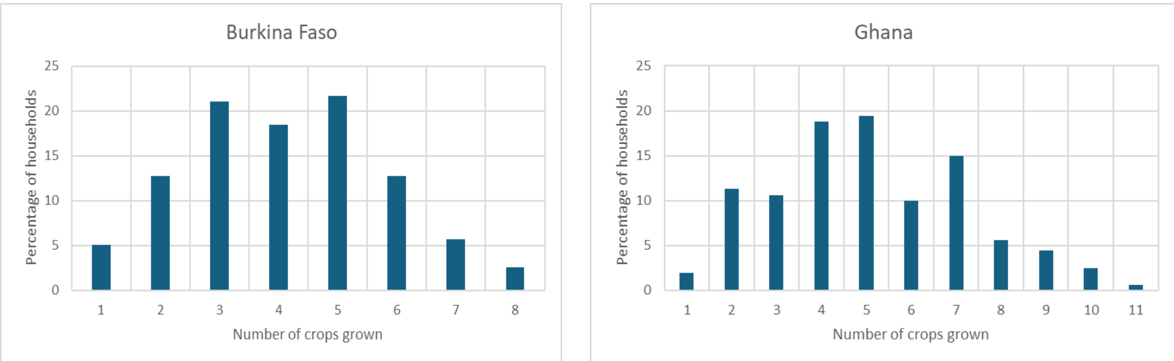
| Variable | Ghana [*N*=120] % | Burkina Faso [*N*=120] % |
|---|---|---|
| Mechanization (land preparation) | 58 | 59 |
| Inorganic fertiliser | 54 | 87 |
| Organic fertiliser | 92 | 76 |
| Irrigation | 11 | 88 |
| Pesticide (insecticides and fungicides) | 44 | 75 |
| Herbicide | 62 | 90 |

Source. Authors based on household survey

## 4.2. Status of crop and varietal diversity

Household level data indicated that there is considerable on-farm crop diversity. The number of crops grown by households ranges from 1 to 8 in Burkina Faso and from 1 to 11 in Ghana (see Figure 1 for a distribution of the data). The majority of households in both countries cultivate 5 different crops. The mean Shannon Diversity Index equally underscored the importance of crop diversity, with indexes of 1.303 and 1.596 in South Burkina Faso and in Upper Eastern Ghana, respectively. Figure 2 and Figure 3 provide further insights into the area shares devoted to different crops, and the percentage of households cultivating these crops.

**Figure 1. Distribution of households by number of crops grown in Burkina Faso and Ghana**

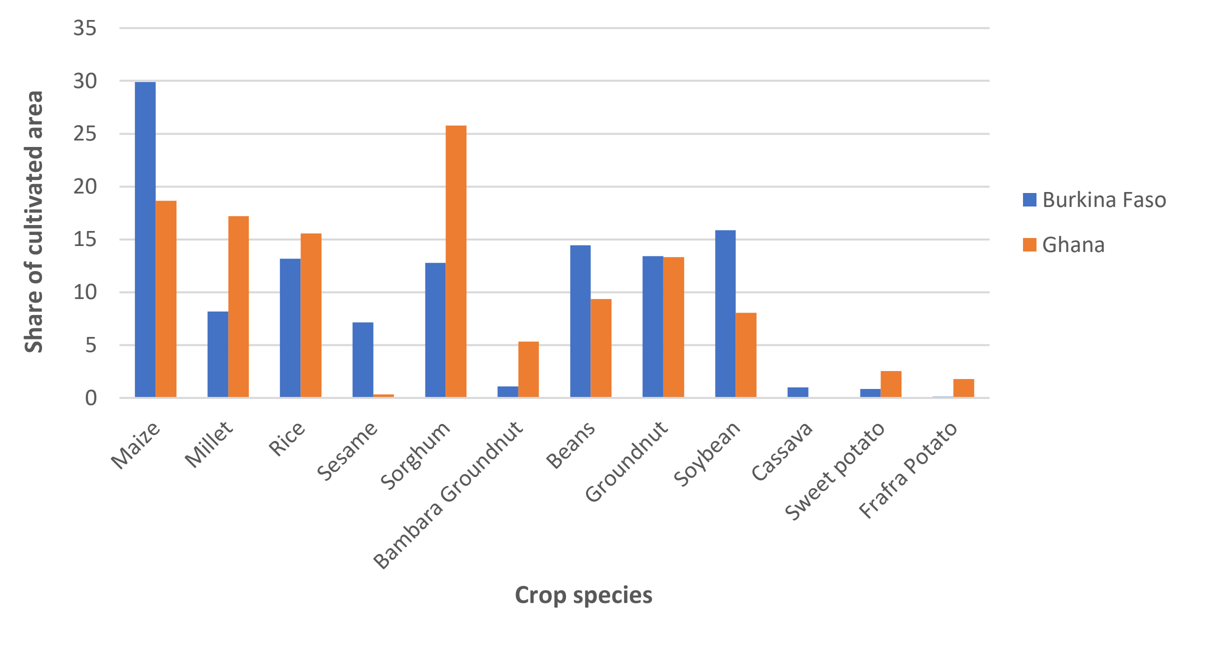



Source. Authors based on household survey

In Burkina Faso, the area shares calculations indicated that maize is the major crop, accounting for more than a quarter of the land allocated to crop production. In addition, about 95% of households produce maize. Similar results emerged from the four-square analyses (see Table 7 and Table 8 for a detailed mapping of crop distribution).

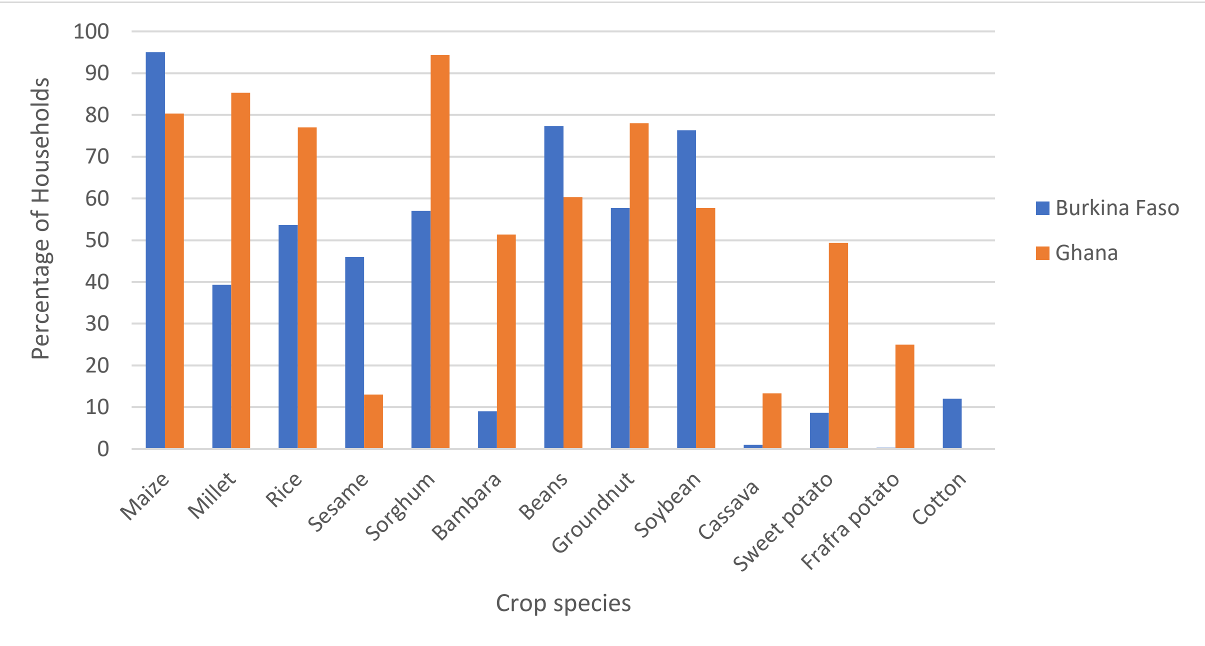
In all villages in Burkina Faso, FGD respondents classified maize in the upper left quadrant of the four-square diagram (see section 3.2 for a description), suggesting that this crop is mostly cultivated on large areas, and by most households. Other crops like soybean, beans, rice, groundnut and sorghum are cultivated on a little more than 10% of arable land.

**Figure 2. Average share of households' agricultural land dedicated to different crop in Burkina Faso and Ghana**




Source. Authors based on household survey

**Figure 3. Share of households growing specific crops species in Burkina Faso and Ghana**




Source. Authors based on household survey

Moreover, the proportion of households growing these crops is just as important, reaching almost 80% for beans and sorghum. In comparison, millet, sesame, bambara groundnut, and cassava and sweet potato are grown on smaller areas, each accounting for less than 10% of the cultivated area. The relative importance of these crops is reflected in the number of households engaged in their production, representing slightly less than 10% in the case of bambara groundnut, cassava, and sweet potato. The four-square analysis highlighted similar patterns, especially in the case of Bambara groundnut, which in most cases was placed in the lower right quadrant of the diagram.

## Table 7. Mapping crop species in Burkina Faso

| Village | Gender | Many Households Large Area (MHLA) | Many Households Small Area (MHSA) | Few Households Large Area (FHLA) | Few Households Small Area (FHSA) |
|---|---|---|---|---|---|
| B1 | Men | Soybean, maize, cotton | Sesame, beans, millet, rice, mango, cashew, okro, kenaf | | Sorghum, groundnut, bambara, pepper, Irish potato, sweet potato, cassava, yam, watermelon, cabbage, onion, pepper, tomato, eggplant, garden egg, orange, guava |
| | Women | Beans, sesame, maize | Groundnut, soybean, bambara, kenaf, okro | | Sorghum, rice |
| B2 | Men | Maize, beans, soybean, sesame | Groundnut, Bambara, Kenaf, Mango | | Millet, sorghum, rice, bambara,sweet potato, frafra potato, banana, guava, tomato, pepper, okro, |
| | Women | Soybean, sesame | Groundnut, beans, rice, okro, kenaf, hibiscus | | Bambara |
| B3 | Men | Maize, rice, beans, soybean, sesame, groundnut, pepper | Millet, bambara, onion, okro, kenaf | | Garden Egg, Nina melon |
| | Women | Groundnut, rice, soybean, beans | Maize, Bambara, okro, kenaf, | | Tomato, pepper |
| B4 | Men | Maize, sesame, soybean, groundnut | rice, millet, bambara, kenaf, okro, Nina melon, | Cabbage, onion | Beans, eggplant, pepper, tomato |
| | Women | Rice, soybean, beans, sesame, bambara, okro, kenaf | Maize, tomato, pepper, Nina melon, eggplant, cabbage | | Sorghum |

Source. Authors based on the four-square analysis

In Ghana, area shares revealed that sorghum accounts for the largest share of the area under cultivation. Furthermore, the majority of households, over 90%, grow sorghum. Results of the four-square analysis reinforced these findings (see Table 8), as most respondents in the FGDs placed sorghum in the upper left quadrant of the four-square diagram. Maize is only the second most important crop, although it is produced by a large proportion of households.

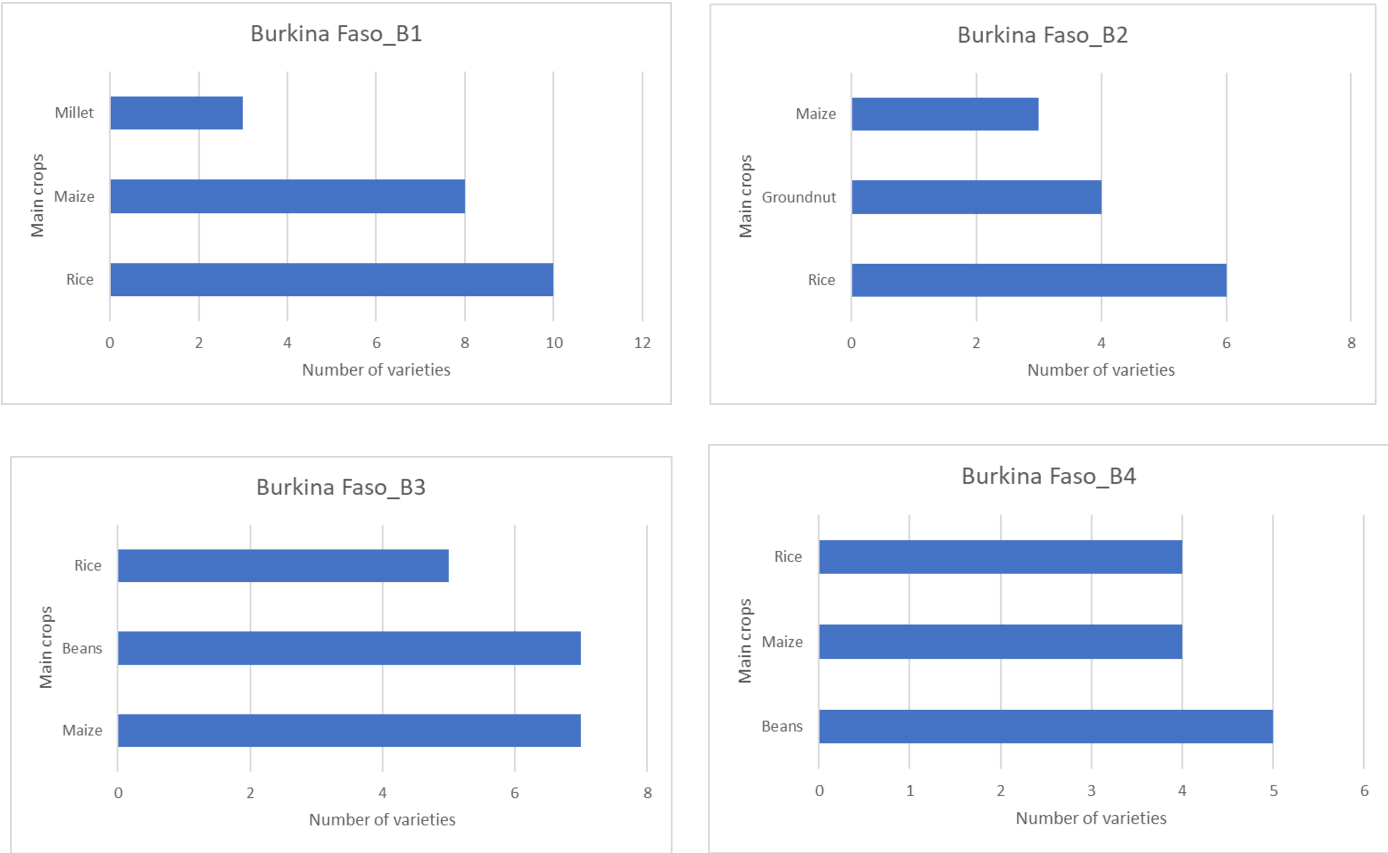
### Table 8. Mapping crop species in Ghana

| Village | | Many Households Large Area (MHLA) | Many Households Small Area (MHSA) | Few Households Large Area (FHLA) | Few Households Small Area (FHSA) |
|---|---|---|---|---|---|
| G1 | Men | Millet, sorghum, groundnut, rice | Bambara, pepper, beans, sweet potato, tomato | Maize, soybean, watermelon | Nina melon, frafra Potato |
| | Women | Rice, soybeans, maize, sorghum, groundnut, kenaf, okro | Bambara, frafra potato, sweet potato, tomato, onion, pepper | Beans | Watermelon, yellow melon |
| G2 | Men | Sorghum, millet, maize | Groundnut, beans | Rice, soybeans, tomato | Carrot, okro, kenaf, frafra potato, sweet potato, sesame, melon, pepper, onions, watermelon, garden eggs, ginger |
| | Women | Rice, groundnut, bambara, sorghum, kenaf, beans, okro, melon | Soybean, pumpkin, pepper, tomato | Maize | Sweet potato, onions |
| G3 | Men | Maize, sorghum, groundnut, soybean | Bambara, beans, frafra potato, sweet potato, millet | | Okro, pepper, melon, sesame |
| | Women | Soybean, millet, sorghum, beans, melon, okro, kenaf, Nina melon, sweet potato, frafra potato | Maize, rice, tomato | | Cabbage, bambara, sesame, Nina melon |
| G4 | Men | Millet, guinea corn, maize, groundnut, rice | Bambara, beans, soybeans, sweet potato, frafra potato, pumpkin, kenaf, okro, pepper, melon | Watermelon, carrot, cabbage | Mango, cashew, garden egg, sesame, Nina melon, banana, palm tree, cassava, cocoyam |
| | Women | Sorghum, millet, groundnut, beans | Soybean, bambara, kenaf, okro, amaranth, sweet potato, pepper, tomato, pumpkin | Maize, rice | Frafra potato, sesame, melon |

Source. Authors based on the Four-square analysis

While variations were observed across FGDs, the results from the four-square analysis indicated the relative importance of maize, as respondents placed the crop in either the upper left (MHLA) or upper right quadrant (MHSA) of the diagram. Although millet is grown on no more than 15% of arable land, the proportion of households producing the crop remains high, reaching 85%.

**Figure 4. Number of varieties of the three key crops cultivated in the selected villages in Burkina Faso**

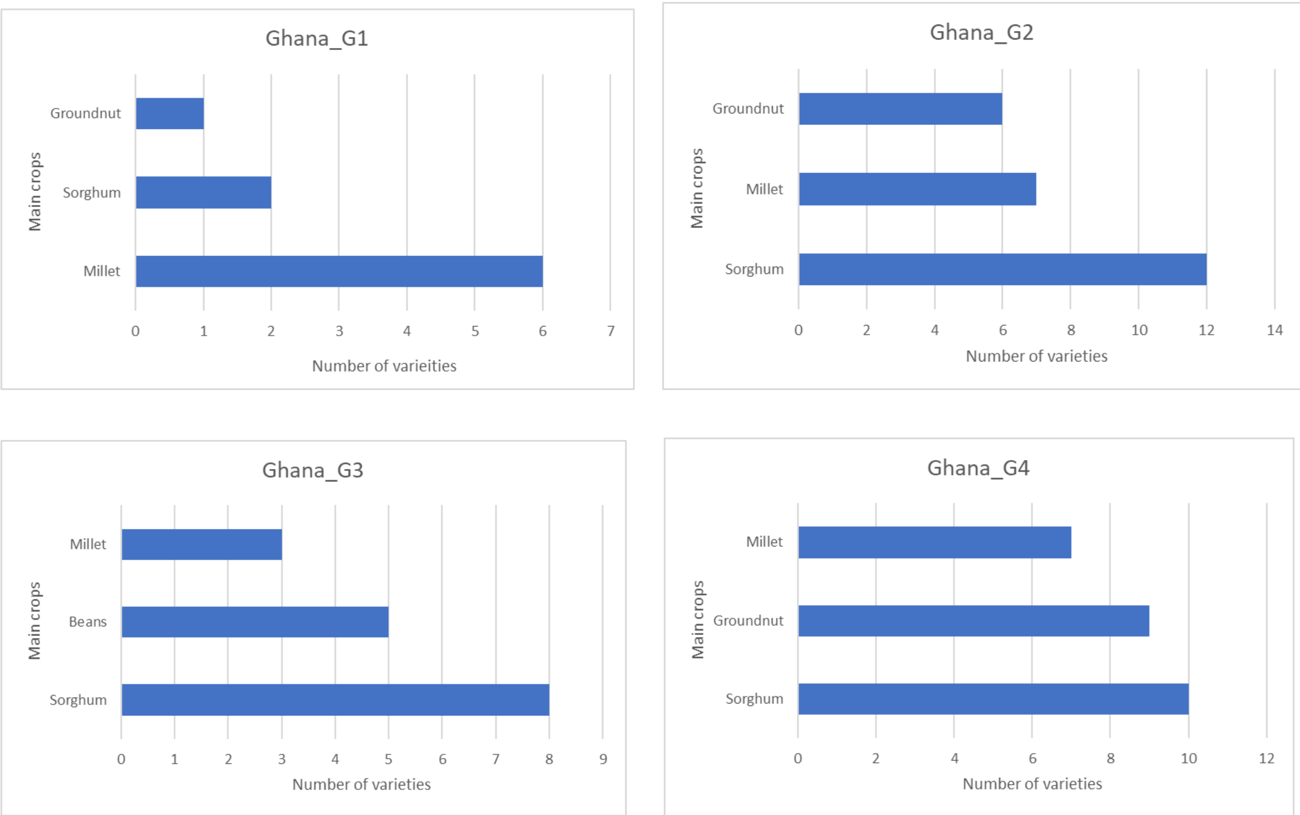



Source. Authors based on historical timeline

Other crops such as rice and groundnut are grown on similar areas, and equally engage important shares of households. Crops like soybeans, beans, Bambara groundnut, cassava and sweet potato, each account for less than a tenth of the arable land, with variations on the share of households growing these crops. While more than half of households produce groundnuts and soybeans, sesame, cassava and sweet potatoes are grown by less than a quarter of households.

To assess varietal diversity, FGD participants in each village were asked to specify the number of varieties that are grown locally. The assessment focused on the three main crops identified by the participants. Figure 4 and Figure 5 illustrate their responses.

**Figure 5. Number of varieties of the three key crops cultivated in the selected villages in Ghana**




Source. Authors based on historical timeline

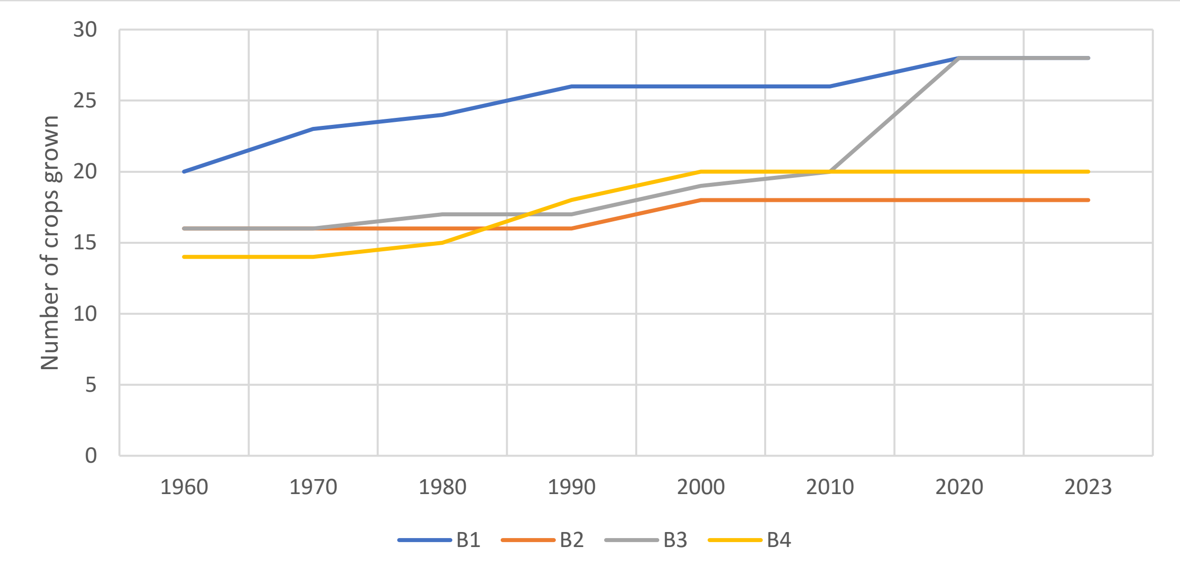
Respondents across all villages in Burkina Faso, listed maize and rice as major crops. Beans were identified as a major crop in two villages, while millet and groundnut were each listed as a major crop in only one village. In Ghana, respondents from all villages ranked millet and sorghum among the top three crops. Groundnut was considered a main crop in three villages, though it appeared in the top three crops in only one village. Among these key crops, respondents from the FGDs reported the highest varietal diversity for rice in Burkina Faso and sorghum in Ghana. The number of groundnut varieties varied between villages, with Ghana reporting both the highest (9) and lowest numbers. Maize followed, with up to 8 varieties reported in Burkina Faso, while beans and millet also displayed variability across villages and countries. A greater number of millet varieties were reported in Ghana compared to Burkina Faso, where only three varieties were documented in the selected village.

## 4.3. Trends in crop and varietal diversity

### 4.3.1. Changes in crop diversity

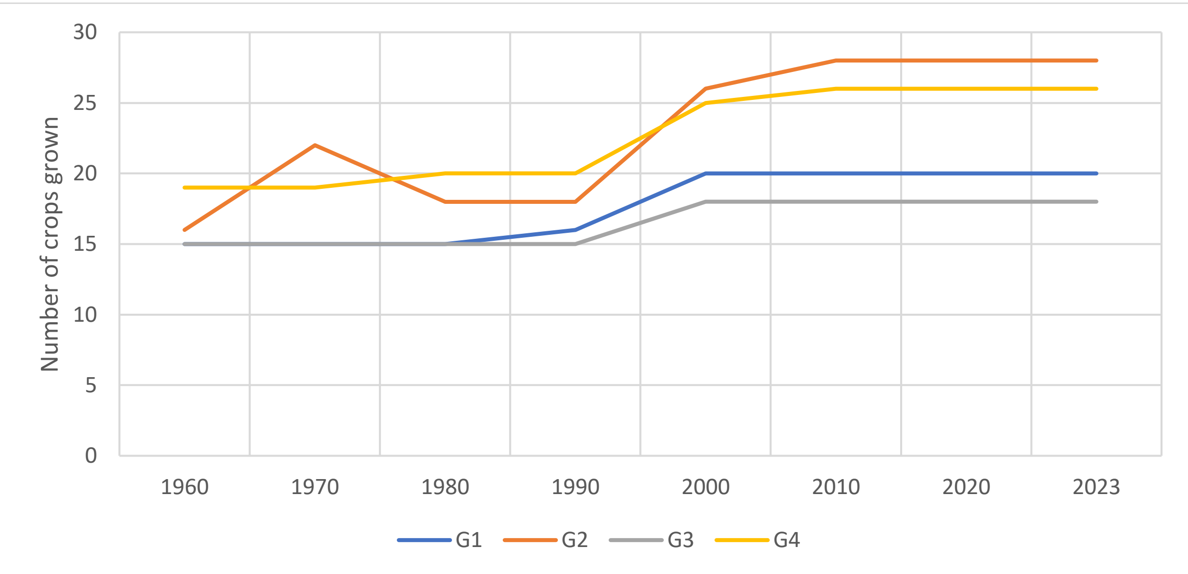
The historical timelines highlighted an upward trend in the number of crops grown across all villages (see Figure 6 and Figure 7). In Ghana, for example, the average number of crops cultivated has increased by almost 44% over the past six decades. Similar trends were observed in Burkina Faso, with a 41% increase between 1960 to 2022 (Figure 8).

**Figure 6. Total number of crops species cultivated at different times in selected villages in Burkina Faso**



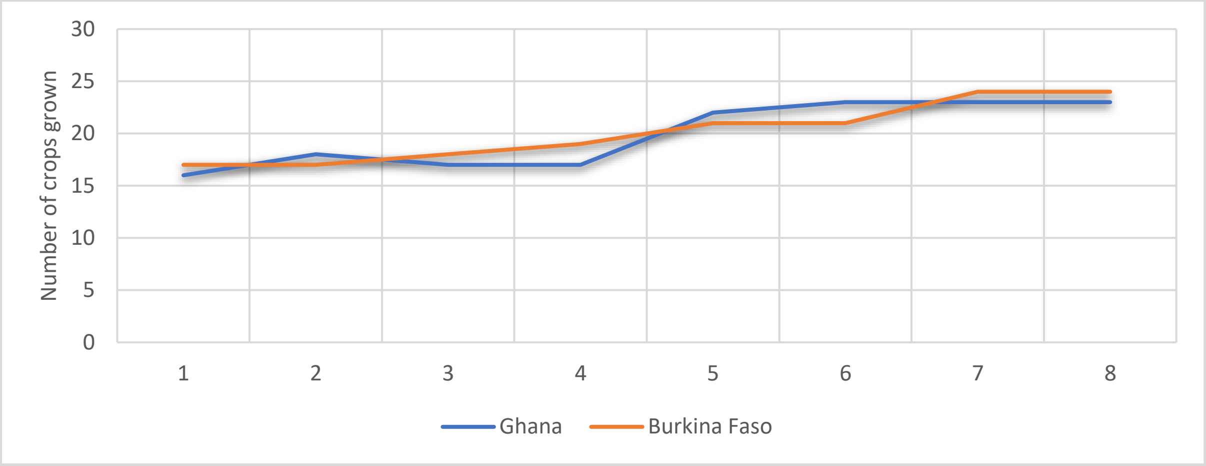

Source. Authors based on historical timeline (data represents the total number of crops cultivated at village scale)

**Figure 7. Total number of crops species cultivated at different times in selected villages in Ghana**




Source. Authors based on historical timeline (data represents the total number of crops cultivated at village scale)

**Figure 8. Total number of crops species cultivated at different times in Ghana and Burkina Faso**




Source. Authors based on historical timeline (data represents the average number of crops grown per country)

In Burkina Faso, the increase in the number of crops grown can be attributed to a number of factors, ranging from improved agronomic practices to political actions. In one of the villages for instance, respondents reported that the introduction of soybeans, cotton and sesame was facilitated by the development of mechanisation (i.e. the use of tractors), the digging of boreholes and better access to fertilisers and pesticides. The promotion of diversified farming by state government also create strong incentives to diversify production, as is indicated by the following quote.

> *"In 1983, the hunger in most parts of West Africa caused by severe drought and bushfires affected us as well. The grow-what-you-eat agenda led by Sankara[5] inspired us to grow different crops. This was a success and we had a surplus for sale."*
>
> (male farmer, FGD; Burkina Faso, 2023)

In both countries, the promotion of dry-season farming initiatives has facilitated the introduction of new crops that would not have been cultivated under normal water-scarce conditions. In Ghana, for example, respondents noted that the Ministry of Agriculture played a crucial role in introducing new crops like tomato and pepper during the 1990s. Locally based initiatives, such as the construction of boreholes, have facilitated the introduction of water-intensive crops. The introduction of crops such as maize and soybean in the 1990s was facilitated, in part, by the support of the government and NGOs, and through the influence of migrant workers who returned from Burkina Faso. Seed exchange with farmers from nearby villages played a role, as well. Respondents from Burkina Faso and Ghana expressed their perceptions on the subject as follows:

[5]Thomas Noel isidore Sankara; Former president of Burkina Faso (1983-1987)

> *"We did not know other crops apart from our traditional ones (millet, sorghum/guinea corn, rice, groundnut, bambara beans, etc.). Native migrant farm workers who returned brought new seeds such as watermelon and onions from Burkina Faso and maize, cassava, cashew, and guava from Southern Ghana."*
>
> (male farmer, FGD; Ghana, 2023)

> *"The sinking of boreholes, wells, and the creation of dams in the 1970s made irrigation possible. This boosted the production of vegetables like pepper and tomatoes, which were later introduced to us by agricultural extension officers."*
>
> (male farmer, FGD; Ghana, 2023)

### 4.3.2. Trends in crop varietal diversity

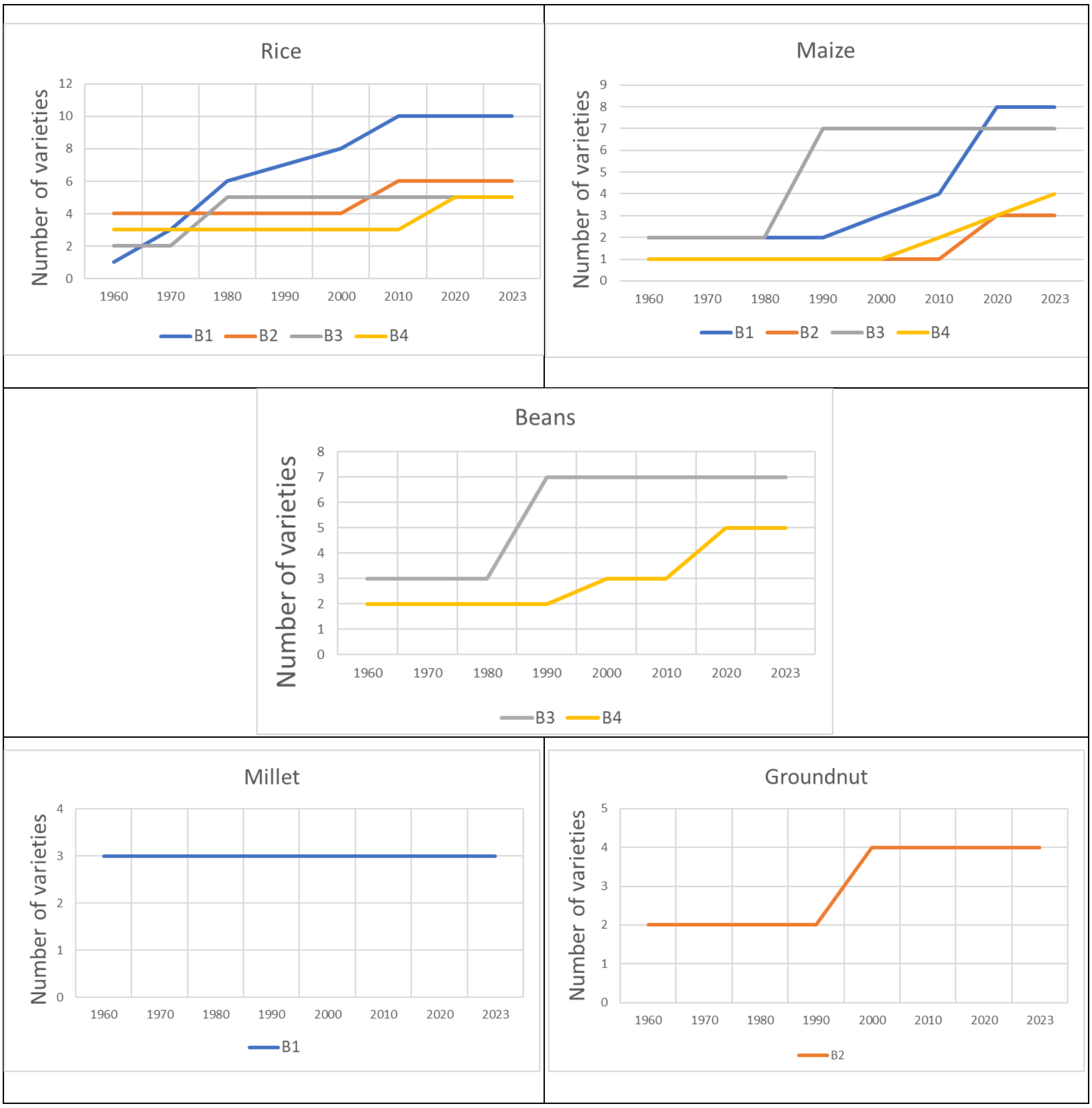
The trends in the varietal diversity of the three most important crops[6] identified in each of the eight villages are shown in Figure 9 and Figure 10. In Burkina Faso, with the exception of millet, FGD respondents reported an increase in the number of varieties grown over the past six decades. Rice experienced the sharpest increase in varietal diversity, going from a single variety to ten varieties in village B1. The expansion of rice varieties in the villages has been influenced by multiple factors, including the development of irrigation schemes and increased interaction with neighbouring communities in other countries. For instance, one of the male participants in the FGDs highlighted that during the 1970s, three new rice varieties were introduced by villagers who had travelled to Côte d'Ivoire. Upon their return, they brought these new varieties back, showcasing the role of cross-border exchanges in driving varietal diversification. The number of maize varieties has also increased in recent decades, though variation exists across villages. This increase can largely be attributed to the government's efforts in disseminating new varieties. As one farmer stated:

> *"Kamandaa, a new variety of maize was introduced by the agricultural extension officers (between 2010-2019). Different varieties of rice and groundnut were also introduced by agricultural extension within the same period. Our chief also introduced a new maize variety of maize we call Kamanyaaga. Masongo is another maize variety we grow. This was brought from Ghana in the 1990s. Between 1970-1979, native migrant workers returned from Côte d' Ivoire with three rice varieties: Alkam, Abadowinia, and Bulubi. We have cultivated those varieties to date."*
>
> (male farmer, FGD; Burkina Faso, 2023)

[6] In each village, respondents listed the three most important crops and the exercise consisted of discussing trends in the number of varieties for each of these crops. Data is only presented for the crops that were listed among the top three. The three main crops listed varied from village to village.

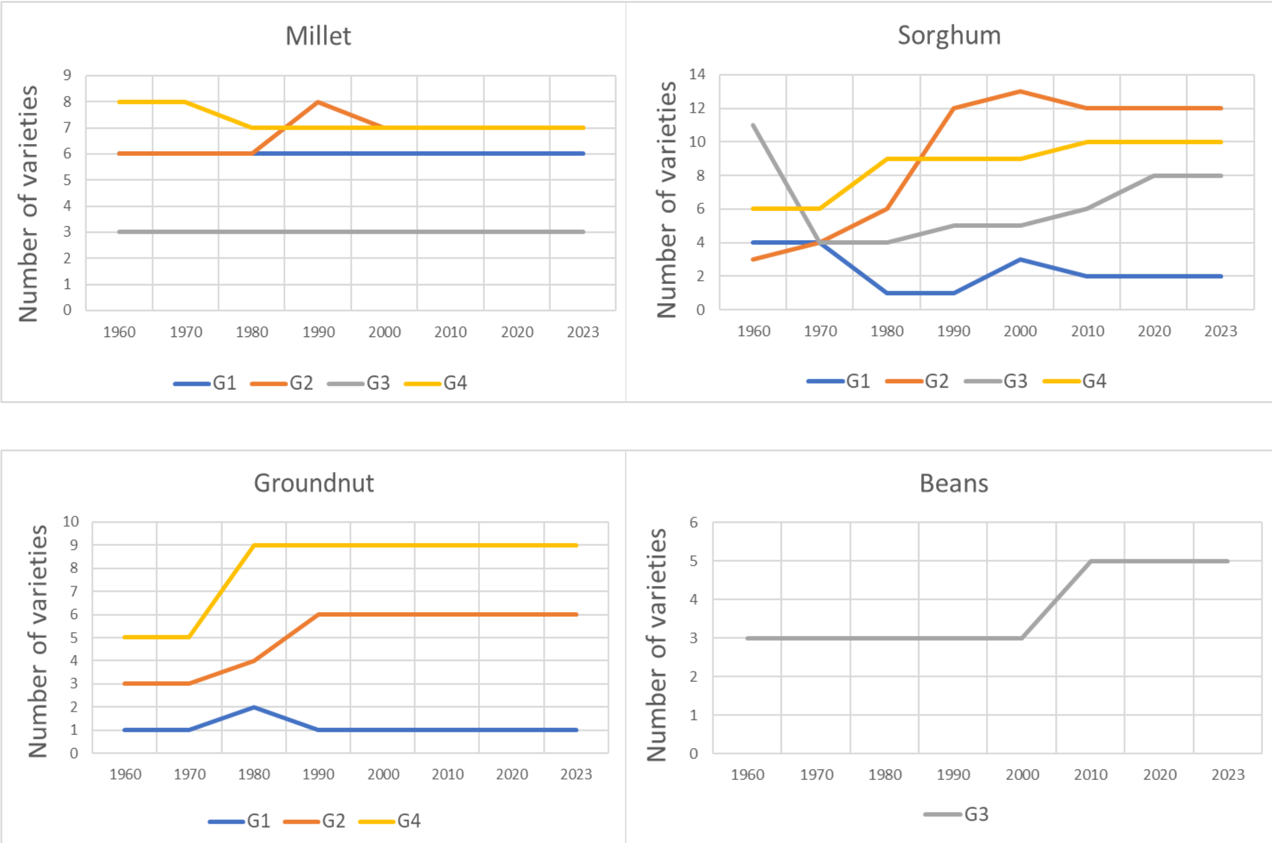
Similar trends were observed for groundnut varieties, but their number has stagnated in latest years. In villages where beans were listed as a major crop, respondents reported an increase in the number of varieties grown, however, the number has remained constant in recent years. The increase was as a result of government action, with extension officers who promoted early maturing varieties.

**Figure 9. Trends in varietal diversity of the three major crops in case study villages in Burkina Faso**




Source. Authors based on historical timeline

**Figure 10. Trends in varietal diversity of the three major crops in case study villages in Ghana**




Source. Authors based on historical timeline

On the average, the varietal diversity in Upper East Ghana has exhibited an upward trend over the past decades. Sorghum experienced a drastic increase in village G2, going up from three to twelve different varieties between 1960 and 2023, according to the respondents. During the 1970s, seasonal migrant workers introduced new varieties that were both wind-resistant and high-yielding. Conversely, in village G3, the number of varieties declined over the same period. Respondents attributed this decrease to the poor yield performance of certain varieties and the destruction caused by strong winds in the 1970s. In the 1980s and 1990s, however, new varieties were introduced by the Ministry of Agriculture through demonstration plots, while others were brought in by farmers who had travelled to neighbouring villages, and through seed exchange. This exchange of seeds facilitated by both formal government initiatives and informal farmer networks contributed to the diversification of varieties in the region. Conversely, millet varieties have remained stagnant over the past decades, with only slight variation observed across villages. Respondents indicated that this consistency is largely due to the inadequate yielding capacity of alternative varieties. Although some millet varieties may possess unique characteristics, farmers predominantly prioritize yield performance, early maturing and late maturing varieties in their selection criteria, and the varieties that continue to be cultivated effectively meet these expectations. On average, the number of groundnut varieties cultivated has increased, except in village G1, where it has remained stagnant at one variety after a brief rise to two. The abandonment of one of the varieties was attributed to its challenging harvesting process and extended maturation period, which discouraged its production.

*"We stopped growing some varieties after we found new ones that performed better. For instance, with groundnut, Menka was the sole variety we cultivated from the 1960s to the 1980s. This variety had a longer maturity of 4-5 months. Harvesting this variety was also difficult because the seeds and roots develop deeper into the soil. When rains stop and the soil hardens up, harvesting becomes tedious. In the early 1980s, Ndoba, a new groundnut cultivar arrived. This variety was high-yielding, early-maturing within 3 months, and was used for cultural activities. We, therefore, preferred growing Ndoba."*

(male farmer, FGD; Ghana, 2023)

In village G4, respondents attributed the increase in groundnut varieties from 1960 to 2023 to the initiatives undertaken by the Ministry of Agriculture. Additionally, seed exchanges with farmers from Togo have also facilitated the growth of groundnut varieties. These new varieties were preserved due to their high yield, early maturation, and reduced fertiliser requirements.

Where respondents recognized beans as a key crop, the number of varieties has increased slightly in the years 2000 to 2010, and remained constant ever since. The observed increase was due to the Ministry of Agriculture, which promoted high yielding and early maturing varieties that were quickly adopted by farmers.

## 4.4. Factors influencing crop selection, crop diversity and emerging trends

### 4.4.1. Households characteristics and crop diversity

The Ordinary Least Squares (OLS) regression analysis revealed several significant factors influencing crop diversity (measured as the Shannon diversity index). The results of the analysis are shown in Table 9.

Among demographic factors, the country of origin and the gender of the household head are strongly associated with crop diversity. Being a farmer in Ghana is linked to a 0.19 unit increase in the Shannon Diversity Index compared to being a farmer in Burkina Faso. Conversely, male household heads are associated with a 0.18 unit decrease in crop diversity, as indicated by the negative coefficient for gender. The frequency of receiving extension advice also shows a positive relationship with crop diversity, with the coefficient being significant at the 5% level. A one-unit increase in the use of extension services results in a 0.04 rise in the Shannon Diversity Index.

### Table 9. Regression analysis results using the Shannon Diversity Index as dependent variable (N=239)

| Explanatory variables | **Coefficient** | **Std. error** | **t** | **P>t** |
|---|---|---|---|---|
| ***Demographic factors*** | | | | |
| Country | 0.1927** | 0.0772 | 2.50 | 0.013 |
| Gender | -0.1785*** | 0.0577 | -3.09 | 0.002 |
| Cooperative | 0.0287 | 0.0522 | 0.55 | 0.583 |
| Education | -0.0065 | 0.0059 | -1.09 | 0.278 |
| Experience | 0.0004 | 0.0020 | 0.22 | 0.827 |
| Extension | 0.0371** | 0.0171 | 2.16 | 0.032 |
| Training | -0.0633 | 0.0703 | -0.90 | 0.369 |
| Origin | 0.0472 | 0.0640 | 0.74 | 0.462 |
| Size | -0.0068 | 0.0088 | -0.78 | 0.438 |
| ***Farm characteristics*** | | | | |
| Area | 0.0307*** | 0.0057 | 5.39 | 0.000 |
| Livestock | -0.0022*** | .0007 | -3.22 | 0.001 |
| ***Farm practices*** | | | | |
| Mechanisation | 0.0072 | 0.0511 | 0.14 | 0.887 |
| Inorganic | 0.1805** | 0.0785 | 2.30 | 0.022 |
| Organic | -.0254 | .0630 | -0.40 | 0.687 |
| Pesticides | 0.0179 | .0534 | 0.34 | 0.737 |
| Herbicides | 0.1007 | 0.0643 | 1.57 | 0.119 |
| **Constant** | 1.0501*** | 0.1238 | 8.48 | 0.000 |
| **R2** | 37.64% | | | |

Source. Authors based on household survey. Significant at *p<0.10, **p<0.05, ***p<0.01

Farm-specific factors also influence crop diversity. The coefficient for farm size is positive and statistically significant at the 1% level. The analysis shows that an acre increase in farm size is associated with an increase in the Shannon Diversity Index by 0.03. The number of animals, measured in tropical livestock units, shows an inverse relationship with the extent of crop diversity.  The analysis shows that a unit increase in livestock numbers is associated with a decrease in the Shannon Diversity Index by 0.0022 units.

With regards to farming practices, the use of inorganic fertilisers was found to positively correlated with crop diversity. Application of inorganic fertilisers is linked to a 0.18 unit increase in the Shannon Diversity Index. Interestingly, some factors traditionally associated with crop diversity, including years of education, farm experience, and cooperative membership, do not show a statistically significant relationship with crop diversity in the regression model presented here.

### 4.4.2. Trait preferences in farmer crop and variety selection

In order to examine farmers' preferences in crop and variety selection, participants in the focus group discussions (FGDs) were asked to identify key traits they consider during the selection process. They were further asked to rank their top three prioritized traits when choosing a crop or variety (as outlined in Table 10 and Table 11). The significance of each characteristic in influencing farmers' decisions was rated on a scale of 1 to 5, where 5 represented "very important." Scores where only assigned for listed traits.

### Table 10. Crop and variety trait preferences and assigned scores in selected villages in Burkina Faso

| Preferred traits | VILLAGE | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | B1 | | B2 | | B3 | | B4 | |
| | Female | Male | Female | Male | Female | Male | Female | Male |
| **High yield** | 5 (I) | 5 | 5 (I) | 5 | 5 (I) | 5 (III) | 5 (II) | 3 (III) |
| **Low fertiliser requirement** | 3 | 5 | - | 4 | - | 4 | - | - |
| **Early maturing** | 5 (III) | 5 (I) | - | 5 (II) | - | 4 | 5 (I) | 5 |
| **Drought resistant** | - | 5 (III) | - | - | - | - | 5 | - |
| **Pest resistant** | 4 (II) | 3 | - | - | - | - | - | - |
| **Market demand** | 4 | 5 (II) | 5 (II) | 5 (III) | - | 5 (I) | - | 4 |
| **Market value** | - | 2 | 2 | 4 | 5 (II) | 5 (II) | 5 (III) | 3 (II) |
| **Cultural Use** | - | - | - | 3 (I) | - | - | - | - |
| **Storability** | - | - | 4 | - | 4 | - | - | - |
| **Short Cooking time** | - | - | 2 | - | 3 (III) | - | 4 | - |
| **Taste** | - | - | 2 | - | - | - | - | 5 (I) |
| **Ease of harvest** | - | - | - | 1 | - | - | - | - |
| **Water lodging** | - | - | - | - | - | 3 | - | - |
| **Price** | - | - | 5 (III) | - | - | - | - | - |

Source. Authors based on FGDs. The most important traits are ranked, with values presented in parentheses: I represents the most important trait, II denotes the second most important trait, and III indicates the third most important trait.

Preferences and perceptions regarding important traits in crop and variety selection varied across villages and between gender groups. In Burkina Faso, high yield was identified as an important trait in all villages and by all respondents across both female and male FGDs. Market value, market demand, early maturity, and low input requirements also emerged as key determining traits in the selection of crops and varieties. Other traits, such as cultural value, seed water lodging capacity, price, and ease of harvest, were reported in only a few villages. A few gender differences were also observed. For instance, cooking time and storability were preferred traits identified exclusively during the female FGDs. Additionally, the importance of price was mentioned in only one focus group discussion, which involved female participants.

**Table 11. Crop and variety trait preferences and assigned scores in selected villages in Ghana[7]**

| Preferred traits | VILLAGE | | |
|---|---|---|---|
| | G2 | G3 | G4 |
| | Female | Male | Female |
| **High yield** | 5 (III) | - | 5 |
| **Early maturing** | 5 (II) | 3 (II) | 4 (III) |
| **Weed resistant** | - | 4 | - |
| **Market demand** | 4 (I) | 3 (I) | - |
| **Market value** | - | - | 4 |
| **Cultural Use** | 5 | - | 5 (I) |
| **Taste** | 5 | 3 (III) | 5 (II) |
| **Nutritional value** | 5 | 5 | 5 |
| **Short Cooking time** | 5 | - | - |
| **Water lodging** | - | 4 | - |

Source. Authors based on FGDs. The most important traits are ranked, with values presented in parentheses: I represents the most important trait, II denotes the second most important trait, and III indicates the third most important trait.

A closer examination of the ranking of these various traits revealed that high yield, early maturing and as well as market value and market demand, were frequently ranked among the top three preferred traits by both male and female respondents. Low fertiliser requirement, while recognized, was not prioritized. Due to unpredictable weather conditions and rainfall patterns, farmers acknowledged a preference for early maturing crops and varieties. A farmer expressed the importance of market demand as follows:

> "*When preparing for the cultivation and selection of crop and which variety to grow, we prefer crops in high demand in the market; it is usually a great motivation for cultivating such crops in the next season.*"
>
> (male farmer, FGD; Burkina Faso, 2023)

In Ghana, early maturing and nutritional value and taste were listed in all of the FGDs that were conducted. Short cooking time was identified as a key trait in one of the female FGDs, while weed resistance and water lodging were highlighted in a male FGD. Respondents identified high yield, cultural value, early maturity, nutritional value, and market demand as the key traits influencing farmers' choices of crops and varieties.

High yield and cultural value received the highest ratings, while market demand scored the lowest. Respondents stressed the significance of high yield for food security, with one farmer emphasizing this aspect by stating:

[7] Trait preferences were not collected in all villages and during all FGDs. In G1, for example, no such exercise was conducted. In G2 and G4, preferences were listed only during female FGDs, and in G3 during men FGDs.

"*What is the essence of cultivating a crop that does not yield enough to feed my family? I want food to be available for them at every point; this is why I prefer high-yielding crop varieties to any other trait*."

(male farmer, FGD Ghana 2023)

Cultural value was also prioritized, especially for crops like bambara, millet, maize, and sorghum, which are essential for cultural rites such as burials, naming, and marriage ceremonies. For these ceremonies, attendees are expected to provide specific crops. This is influenced by social and cultural expectations, where gifts are required, so that farmers must purchase the necessary crops if they do not cultivate them on their own fields. These culturally significant crops are utilized for food during funerals and other events. Traditional dishes must be prepared using millet and sorghum (a particularly appreciated beer is made from this crop) and beans for making bean cakes. Additionally, sacrifices to the gods necessitate the use of certain crops, such as millet, bambara beans, and sorghum, which are offered at shrines. A participant noted:

"*When it is time for the cultural rites, no one wants to be left out, so there is the need to cultivate crops like Bambara, sorghum, and millet to serve this purpose so that one can contribute to the celebrant like every other farmer in the community*."

(male farmer, FGD Ghana 2023)

While market value played an important role in farmers' choices, food provision appeared as the most important characteristic. One farmer explained this dominant role as follows:

"*Although the values placed on a crop are important to us, we prefer making food available in the household; other things can come later*."

(male farmer, FGD Ghana 2023)

### 4.4.3. Key factors shaping crop selection trends

The four-square analysis provided further insights into the changing position of crops within the different quadrants in the past few decades. The FGDs revealed distinct patterns both between and within countries, as well as across gender groups.

**Maize**

With a few exceptions, where maize consistently appeared in the upper left quadrant, discussions revealed that a decade ago, only a small number of households grew maize, and they did so on small plots of land. This trend was observed in both Burkina Faso and Ghana, across male and female FGDs.

### Table 12. Female and male perceptions on changes in maize production

| Country | Village | Female | | Male | |
|---|---|---|---|---|---|
| | | Past | Current | Past | Current |
| Burkina Faso | B1 | MHSA | MHSA | MHLA | MHLA |
| | B2 | MHSA | MHSA | MHSA | MHLA |
| | B3 | MHLA | MHLA | MHLA | MHLA |
| | B4 | MHSA | MHSA | FHSA | MHLA |
| Ghana | G1 | FHSA | MHLA | FHSA | FHLA |
| | G2 | FHSA | FHLA | FHSA | MHLA |
| | G3 | FHSA | MHSA | FHSA | MHLA |
| | G4 | FHSA | FHLA | FHSA | MHLA |

**MHLA**: Many households on a Large Area; **FHLA**: Few Households on a Large Area; **MHSA**: Many Households on a Small Area; **FHSA**: Few Households on a Small Area

Source. Authors based on four-square analysis

The shift in maize production from small to larger areas was frequently highlighted during most FGDs in Burkina Faso, with participants explaining that:

"*Short maturity and high yielding largely encouraged the cultivation of maize on a large area by a large number of households; it was not popular thirteen years ago, only a few of us cultivated it, but after the introduction of the short maturing and high yielding varieties by the Ministry of Agriculture, we adopted maize on a large scale*."

(male farmer, FGD; Burkina Faso, 2023)

Similar perceptions were expressed by women in one of the villages in Burkina Faso. Female respondents in this village claimed that maize had always been in the MHLA quadrant. A slightly different perception was reported in the other three villages, where women thought there had been no change in maize production over the past decade, which remained in the Many Households on a Small Area (MHSA) quadrant.

A farmer in Ghana explained the increase in maize production stating that:

"*Maize became really popular and accessible ten years ago, this was as a result of the intervention of the Ministry of Food and Agriculture. They gave us seeds and trained us on the cultivation- the extension agents were also accessible during this period to see us through the cultivation stage*."

(male farmer, FGD Ghana 2023)

Female respondents in Ghana highlighted the fact that, historically, maize was grown by only a few households and was not very popular. However, the last decade has seen a rapid increase in the number of households growing the crop. As one female farmer reported:

"*Maize is one of the most popular crops in this village, all households have maize farm field, and this is because it is very important in the households, we derive many food varieties such as 'kenkey,' porridge, 'tuo zaafi' (TZ), rasta porridge, 'banku' and many more from it*."

(female farmer, FGD; Ghana 2023)

**Millet and Sorghum**

In Burkina Faso, male respondents in three of the villages reported no significant change in millet production over the last decade, with the crop remaining in the Many Households on a Small Area (MHSA) quadrant. Only in one village did respondents report a decline in the number of households producing millet and the proportion of land devoted to millet production. This decline was mainly attributed to low rainfall and declining yields. One farmer explained this in the following way:

"*Millet was our favourite crop of cultivation as we met our grandparents cultivating it, but as a result of the low rainfall pattern that causes low yield, we could not cultivate it on a large scale any longer; the few that cultivate it do so on a small area*."

(male farmer, FGD; Burkina Faso, 2023)

### Table 13. Female and male perceptions on changes in millet production

| Country | Village | Female | | Male | |
|---|---|---|---|---|---|
| | | Past | Current | Past | Current |
| Burkina Faso | B1 | FHSA | FHSA | MHSA | MHSA |
| | B2 | FHSA | FHSA | MHSA | MHSA |
| | B3 | FHSA | FHSA | MHSA | MHSA |
| | B4 | FHSA | FHSA | FHSA | MHLA |
| Ghana | G1 | MHLA | MHLA | MHLA | MHLA |
| | G2 | MHLA | MHLA | MHLA | MHLA |
| | G3 | MHLA | MHLA | MHLA | MHLA |
| | G4 | MHLA | MHLA | MHLA | MHLA |

**MHLA**: Many households on a Large Area; **FHLA**: Few Households on a Large Area; **MHSA**: Many Households on a Small Area; **FHSA**: Few Households on a Small Area

Source. Authors based on four-square analysis

Women's perceptions differed slightly from men's. For them, millet has always been produced by a few households on a small area of land, and this has not changed over the past decade. One female respondent echoed the men's sentiments, noting that:

"*There is no motivation or intention to increase millet cultivation; even our husbands are complaining bitterly about its poor performance, and some will reduce the plot size in the coming season*."

(female farmer, FGD; Burkina Faso 2023)

FGD respondents in Ghana did not note any major changes in millet production in terms of area and number of households involved. Respondents in all female and male FGDs maintained that millet is still grown on large areas by many households, as it was a decade ago. A male farmer underlines this status quo by stating:

"*Millet is a very important crop in every household; we grew up knowing it, and since then, we have been cultivating millet on a large area of land*."

(male farmer, FGD; Ghana 2023)

Female respondents across all villages in Ghana expressed similar motivations for growing millet.

### Table 14. Female and male perceptions on changes in sorghum production

| Country | Village | Female | | Male | |
|---|---|---|---|---|---|
| | | Past | Current | Past | Current |
| Burkina Faso | B1 | FHSA | FHSA | MHSA | MHLA |
| | B2 | FHSA | FHSA | FHSA | MHLA |
| | B3 | FHSA | FHLA | FHSA | MHLA |
| | B4 | MHSA | MHSA | FHSA | MHLA |
| Ghana | G1 | MHLA | MHLA | MHLA | MHLA |
| | G2 | MHLA | MHLA | MHLA | MHLA |
| | G3 | MHLA | MHLA | MHLA | MHLA |
| | G4 | MHLA | MHLA | MHLA | MHLA |

**MHLA**: Many households on a Large Area; **FHLA**: Few Households on a Large Area; **MHSA**: Many Households on a Small Area; **FHSA**: Few Households on a Small Area

Source. Authors based on four-square analysis

Trends for sorghum show varying positions within the four-square quadrants across countries. With the exception of one village, respondents in Burkina Faso reported a shift of sorghum production from a small number of households on small areas (FHSA) to many households producing sorghum on large areas of land, over the past decade. The main reasons given were low yields and climate change. As one farmer put it:

"*Low yield is the sole reason why I personally stopped the cultivation of sorghum on a large area; I cannot waste my land space on a crop that will yield almost nothing due to climate change*".

(male farmer, FGD; Burkina Faso, 2023)

In the other village, respondents noted a slight shift from the upper right quadrant to the upper left quadrant over the past decade, attributing this change to the increased market demand. As one farmer remarked:

"*About ten years ago, many people within and outside our village started requesting sorghum in the market at every market day; this motivated us to cultivate sorghum and generate income from its sales after setting aside the portion needed for household consumption*."
(male farmer, FGD; Burkina Faso, 2023)

Female respondents in most villages in Burkina Faso reported no change in the area devoted to sorghum production or the number of households involved in sorghum production. In two villages, women respondents mentioned that sorghum was produced on small plots by a few households, while in one of the villages sorghum production remained in the upper right quadrant, suggesting no change over the past decade. However, women in one of the other villages had different perceptions, where they noted a decrease in the number of households and the area devoted to sorghum production.

Conversely, respondents in both women's and men's FGDs, and across all villages in Ghana, kept sorghum in the upper left quadrant of the four-square diagram, suggesting that its production was sustained over large areas and by a large number of households.

**Sesame and Soybean**

Respondents also expressed their views on trends for two of the major cash crops: sesame and soybean (see Table 15 and Table 16).

### Table 15. Female and male perceptions on changes in sesame production

| Country | Village | Female | | Male | |
|---|---|---|---|---|---|
| | | Past | Current | Past | Current |
| Burkina Faso | B1 | MHLA | MHLA | MHLA | MHLA |
| | B2 | MHLA | MHLA | MHLA | MHLA |
| | B3 | MHLA | MHLA | FHSA | MHSA |
| | B4 | MHLA | MHLA | MHLA | MHLA |
| Ghana | G1 | FHLA | FHLA | FHLA | FHLA |
| | G2 | FHLA | FHLA | FHLA | FHLA |
| | G3 | FHLA | FHLA | FHLA | FHLA |
| | G4 | FHLA | FHLA | FHLA | FHLA |
| **MHLA**: Many households on a Large Area; **FHLA**: Few Households on a Large Area; **MHSA**: Many Households on a Small Area; **FHSA**: Few Households on a Small Area | | | | | |

Source. Authors based on four-square analysis

In Burkina Faso, with the exception of one village, male respondents reported no change in the extent of sesame production. Female respondents argued that sesame have always been cultivated on large areas by a large proportion of households. In one of the villages, however, female respondents reported a movement of sesame production from the SHSA to the LHLA quadrant. A female participant made the following remark to explain the observed changes in sesame production:

*"Income generation and the high value placed on sesame made us shift the positioning of sesame; we used to cultivate it in a small area twelve years ago but have largely been cultivating it on a large area for the last decade."*
(female farmer, FGD; Burkina Faso 2023)

In the other villages, there was a reported shift of sesame from FHLA to many households on a small area (MHSA), which they attributed to the financial benefits the crop offered.

Female and male respondents in in Ghana expressed different perceptions than those in Burkina Faso. In Ghana, there have not been major changes on the extent of sesame production across all four villages. FGD respondents indicated that sesame has consistently been cultivated on large areas by a small number of households (SHLA) across both genders. Both male and female groups in Ghana shared this perception. The limited adoption of the crop by a larger proportion of households was attributed to resource constraints, including limited access to sesame seeds, and the increased demand in fertilisers.

### Table 16. Female and male perceptions on changes in soybean production

| Country | Village | Female | | Male | |
|---|---|---|---|---|---|
| | | Past | Current | Past | Current |
| Burkina Faso | B1 | FHSA | MHLA | MHSA | MHLA |
| | B2 | FHSA | MHLA | MHSA | MHLA |
| | B3 | MHSA | MHSA | MHLA | MHLA |
| | B4 | FHSA | MHLA | MHLA | MHLA |
| Ghana | G1 | FHSA | MHLA | FHSA | FHLA |
| | G2 | MHSA | MHSA | FHSA | FHLA |
| | G3 | MHLA | MHLA | MHLA | MHLA |
| | G4 | MHSA | MHSA | MHSA | MHSA |

**MHLA**: Many households on a Large Area; **FHLA**: Few Households on a Large Area; **MHSA**: Many Households on a Small Area; **FHSA**: Few Households on a Small Area

Source. Authors based on four-square analysis

Perceptions of soybean production differed between male and female respondents, and between and within countries. In Burkina Faso, male farmers in two of the selected villages reported no change in the extent of soybean production, which remained in the MHLA quadrant. Conversely, respondents in the other two villages reported a shift from the MHSA to the MHLA quadrant. Women farmers in all but one village shifted soybean production to the LHLA quadrant, which they attributed to better education, marketing and the high market value of soybeans. As one of them declared:

*"We were not aware of the economic importance of soybean some decades ago, but after awareness and education from the Ministry of Education and extension agents, we became aware. For this reason, many female farmers adopted soybean cultivation for commercial purposes on a large land area."*

(female farmer, FGD; Burkina Faso 2023)

In two of the villages in Ghana, male interviewees reported that soybean used to be grown on small plots by a few households, but now larger areas are devoted to soybean production, although only a few households produce soybean. In the other two villages, male and female respondents noted no shift soybean production patterns, which was either maintained in the Many Households Large Area quadrant or the Many Households on Small Areas quadrant. Like respondents in Burkina Faso, respondents in all four villages in Ghana were motivated by the financial gains associated with soybean production. As one farmer noted:

"*soybean cultivation comes with financial rewards; we make some money on its cultivation, and this is why some of us have soybean farms*."
(male farmer, FGD; Ghana 2023)

One woman echoed this feeling stating that:

"*We do not joke with the cultivation of soybean; every farm household has a portion set aside for the cultivation of soybean on a large area of land because we make the most money from the sales of soybean*."
(female farmer, FGD; Ghana, 2023)

This financial incentive was also expressed by women in one of the villages where soybean moved from being cultivated by small households on small areas to being grown on larger areas by a large number of households:

"*Soybean was not popular about twelve years ago, but about ten years ago, it became popular after seeing other villages making money from its cultivation*."
(female farmer, FGD; Ghana, 2023)

## 5. Discussion

The objective of this research was to examine current trends in crop and varietal diversity and to identify the factors that might explain variations in the observed trends in neighbouring regions of Burkina Faso and Ghana. The results showed that the selected case study villages have high levels of crop and genetic diversity, with farmers generally growing a large portfolio of crops and varieties. The data also suggest that the number of crops and varieties grown has increased in recent years, suggesting that farmers are adapting their cropping strategies to new opportunities to increase income or adapt to socio-economic and environmental challenges. While certain crops, like maize or sorghum, play a relatively dominant role in the agricultural landscape in both countries, this does not translate into the abandonment of other important crops, as farmers continue to cultivate a diverse range of species to meet food security and nutritional needs, adapt to environmental conditions, and address market demands. The results also indicate gender differences in perceptions regarding trends in crop diversity and crop selection. The next section discusses these findings and their implications for research and policy.

## 5.1. Crop diversity and crop replacement

The question of whether crop diversity is being maintained remains debated in the literature, as was shown in Section 2. Our findings contribute to this discussion by aligning with studies that report the preservation of diversity. In the case study villages, data at both farm and village level suggest an upward trend in the number of crops grown. These results align with those of Baba & Abdulai (2021) who reported high levels of crop diversity in a sample of 1,235 farmers in Ghana. The results are also consistent with those of Appiah-Twumasi & Asale (2022), who found an average Herfindahl-Hirschman index of 0.92 in a sample of 240 households in northern Ghana. The observed increase in the number of crops grown in the selected villages indicates a trend toward expanding crop portfolios, which reflect farmers' adaptive responses to shifting opportunities and constraints. This is in line with Rampersad et al. (2023), who observed that farmers in Ethiopia tend to integrate new crops into their existing portfolios primarily to capitalize on emerging market opportunities.

Similarly, our findings do not support the observation that certain crops are displacing those that have been characterized as underutilized or neglected crops in the literature. The finding that maize accounts for approximatively 30% of the area allocated to crop production in Burkina Faso can be seen as an indication that this crop is becoming more dominant than others in the agricultural landscape. However, as indicated above, this trend did not lead to a replacement of other crops. As shown in Figure 2, there were only three crops in Burkina Faso that had small area shares of about one percent, and two of these crops, sweet potatoes and cassava, are not considered under the category of underutilized or neglected crops globally. In our study villages in Burkina Faso, only the bambara could be considered to be in a problematic state. These findings are consistent with Temegne et al. (2020) who found that Bambara groundnut is mostly produced by the elderly on small plots of land. In Ghana, only two crops had small area shares of about two percent: sweet potato and frafra potato (Figure 2). Only the latter is considered to be in the underutilized or neglected category. Moreover, contrary to studies that suggest that maize is replacing crops such as millet and sorghum in Ghana (Darfour & Rosentrater, 2016; Rahman & Chima, 2016; Tetteh & Nurudeen, 2015), our results show that in our study villages, maize is second only to sorghum.

To demonstrate a decline in areas allocated to millet production, data indicating a reduction in millet's share of cultivated land over recent years would be necessary. However, our analysis using the four-square method reveals no such trend. In Ghana, perceptions indicate that millet has consistently been cultivated on substantial areas by a large proportion of households over the past decades. Similarly, in Burkina Faso, trends suggest a stable proportion of both households and land allocated to millet production. These findings contradict Rouamba et al. (2021), who reported that farmers in Burkina Faso are gradually replacing millet with sorghum. Instead, it appears that farmers are expanding the total cultivated area to meet the growing demand for crops like maize, while maintaining the existing allocation of land to traditional crops. This implies that the production of certain dominant crops is being integrated into broader land-use strategies rather than displacing millet or other staple crops. Additionally, in both Burkina Faso and Ghana, weak market systems and low demand uncertainty regarding output markets and prices force farmers to rely heavily on their own production. If market systems were more efficient and competitive, farmers could manage risks more effectively and focus on cultivating fewer crops, which they would sell in the market.

## 5.2. Crop genetic resources: diversity and vulnerability

As can be derived from the literature review, there are concerns that the homogenization of crop varieties poses a serious threat to farm resilience and the conservation of agrobiodiversity. In our case study villages, we did not find evidence that supports this concern. Our varietal assessment across selected crops indicates a clear trend toward overall diversification. In our case study villages in Burkina Faso, the three major crops grown included rice and maize in all four villages, as well as millet (one village), groundnuts (one village) and beans (two villages). For all these crops, the number of varieties grown increased since the 1960s, except for millet in one village, where the number of varieties has remained unchanged. These results are comparable to those of Olodo et al. (2020) who found that millet varieties in Senegal remained unchanged over a forty-year period. The persistence of a rather fixed number of millet varieties may indicate that they are best suited to local conditions and that farmers have limited access to varieties that meet and adapt to their needs. In Ghana, the picture is somewhat more differentiated. The number of varieties of millet did not increase, but -with the exception of one village- remained relatively high with six or more varieties cultivated.

Similar trends were observed for sorghum. Although variations were observed across countries and time periods, the overall trend has been an increase in sorghum varieties from the early post-independence period to the present. These findings align with Teshome et al. (2016), who reported an increase in sorghum variety richness across various regions of Ethiopia between 2002 and 2012. However, our results contrast with those of Dossou-Aminon et al. (2016), who identified a threat of genetic erosion among sorghum varieties in Benin.

Similarly, the number of groundnut and rice varieties (in the case study villages in Burkina Faso) has also increased over the same period. The rise in the number of rice varieties in Burkina Faso align with Yokouchi & Saito (2016), found widespread adoption of the New Rice for Africa (NERICA) varieties in a study of over a thousand farmers. Hence, the overall picture of our case study villages does not indicate a general homogenization of crop varieties, but rather points to a trend in the opposite direction.

Several factors may explain this divergence from some strands of the literature. In the regions studied, farmers appear to be responding to evolving market opportunities, climate variability, and the availability of new crop varieties through both formal and informal seed systems. Additionally, agricultural policies promoting agrobiodiversity and local seed exchanges have likely played a role in sustaining and increasing varietal diversity. More importantly, the institutional environment may not be conducive to the abandonment of certain varieties. Weak market infrastructures and limited adaptive capacities to climate change have driven many farmers to mitigate risks by increasing the number of varieties they cultivate. While farmers highlighted a few key trait preferences, the diversity of varieties they maintain suggests that each variety serves a distinct function. Since no single variety meets all their needs, farmers retain multiple varieties on-farm to better cope with challenges related to climate variability, climate change, and economic uncertainties.

## 5.3. Determinants of crop diversity

Crop diversity is embedded in a complex web of socio-economic and environmental factors that influence the conservation of agrobiodiversity. Our regression analysis revealed that female-headed households cultivate a more diverse crop portfolio compared to their male counterparts. This contrasts with the findings of Dube et al (2016), which indicated that the likelihood of crop diversification is 16.5% greater for households headed by males than for those headed by females. The higher tendency for women to diversify may stem from various barriers they face, including limited access to land. It may also be the case that women are more vulnerable to risks and therefore engage in greater crop diversification as a risk management strategy. Our results also showed that the more frequently extension services are used, the more likely households are to be diversified. These results are consistent with Abdalla et al. (2013) who found that a 1% increase in extension services increased crop diversity by 12%.

Surprisingly, our results indicated an inverse relationship between the number of animals owned and crop diversity. This finding contradicts Whitney et al. (2018), who reported a positive correlation between livestock ownership and crop diversity in Uganda. While our results were initially surprising, they may reflect different risk management strategies employed by households. Specifically, households with larger livestock holdings may be better protected from external shocks, such as droughts or market fluctuations, due to the economic and food security benefits provided by their livestock. In contrast, households with fewer or no livestock may lack this safety net, leading them to rely more heavily on crop diversification as their primary risk mitigation strategy. By cultivating a variety of crops, these households can spread their risk and secure a more stable food supply, even amidst environmental or economic challenges.

Our findings also indicated a positive relationship between inorganic fertiliser use and crop diversity. This result suggests that access to inorganic fertilisers may enhance crop diversity as soil fertility improves and yield increases may be achieved for a large number of crops. Farmers who use fertilisers may not need to allocate large areas of land for the production of some crops: by intensifying production, more land can be released for the production of additional crops.

## 5.4. Reconciling farmers' preferences with the need for crop and varietal diversity

Sustaining crop and varietal diversity requires a comprehensive understanding of farmers' preferences and of how these preferences influence crop and variety selection and cultivation practices. The focus group discussions provided valuable insights into the traits that farmers prioritize when selecting crops or varieties. The results from the trait scoring and ranking highlighted a range of environmental, economic, agronomic, and socio-cultural factors that influence farmers' choices. Expectedly, the yield performance of the crop or variety played a significant role in the decision to grow a specific crop or variety. This finding is consistent with Martey (2022) who observed that in Ghana, farmers' decisions to adopt specific cowpea varieties were strongly linked to the yield performance of those varieties. The findings also underscored the importance of economic factors, such as market demand and market value, in shaping farmers' decisions to select specific crops or varieties. Both the trait scoring exercises and the four-square analysis revealed that market opportunities significantly influence these decisions. The four-square analysis further indicated that the integration and expansion of sesame and soybean production were primarily driven by economic and financial incentives. This observation is in line with the study by Regassa et al. (2023), who found that the market demand for groundnut varieties significantly influenced farmers' decisions in Tanzania.

In addition to economic considerations, socio-cultural factors play a crucial role in farmers' cultivation choices. Certain crops have cultural significance, particularly in rituals and ceremonies, as evidenced by insights from focus group discussions. Farmers select specific crops to fulfil cultural obligations, with some crops regarded as sacred taxa, cultivated irrespective of their economic performance. This finding resonates with the research by

Obidiegwu & Akpabio (2017), which highlighted yam's cultural and religious importance in Nigeria, where many farmers cultivate it for religious purposes, including for making sacrifices at shrines.

The scoring and ranking activities also illuminate gender differences in crop preferences. Women participants prioritized crops and varieties with shorter cooking times, a trend consistent with the research of Jinbaani et al. (2023), which demonstrated that female farmers in Northern Ghana identified cooking time as a significant selection factor for cowpea varieties. These results reinforce the importance of recognizing social differences and the heterogeneity among men and women. Furthermore, taste emerged as a crucial trait among respondents in Ghana, where it ranked among the top three most important characteristics, underscoring that organoleptic qualities influence farmers' decisions.

The preceding discussion illustrates that farmers act as custodians of crop and varietal diversity. Their risk management strategies, economic pursuits, and cultural practices are integral to the conservation of biodiversity on farms. By balancing economic pursuits with agronomic needs, farmers do not only enhance their livelihoods but also contribute significantly to the preservation of agrobiodiversity.

## 5.5. Limitations of study

There are some limitations to this study that are worth highlighting. First, as this research is designed as a case study, the findings may have limited generalizability beyond the specific context in which the study was conducted. While the insights give us an overview of agrobiodiversity in the study areas, they may not necessarily apply to different regions or agricultural systems, particularly those with different agroecological or socio-economic conditions. Additionally, our investigation into crop and genetic diversity relied on local nomenclature, which may have influenced the responses obtained during focus group discussions. Farmers' knowledge of crop varieties often varies, and their identification of varieties may be based on observable traits such as colour or size, rather than on scientifically recognized classifications (Kosmowski et al., 2019). This reliance on local terms could have led to discrepancies in how diversity was reported, potentially affecting the accuracy and comprehensiveness of our findings. Future research could address these limitations by incorporating larger, more diverse samples, and by using standardized classifications of crop varieties to enhance the reliability and generalizability of the results.

## 6. Conclusions and policy implications

The conservation of agrobiodiversity is critical for achieving agricultural sustainability. Although the risk of losing crop and genetic diversity poses a significant threat to agricultural sustainability, our study advocates for a differentiated perspective. The findings indicate that farmers maintain a diverse array of crops, with their selection influenced by a variety of traits that meet specific needs under various circumstances. Farmers’ decisions are not arbitrary; instead, they reflect a strategic approach to navigate challenges and capitalize on opportunities.

While economic considerations motivate the cultivation of certain crops, others are retained due to their intrinsic cultural significance, highlighting the complex interplay between economic and cultural values in farmers' decisions. This underscores the need for a nuanced understanding of the diverse motivations that drive farmers to integrate specific crops and varieties into their portfolios. Cultural factors can sustain crops in farmers' portfolios. However, it is important to keep in mind that these cultural values vary by location and can evolve over time.

Enhancing farmers' access to information and knowledge about diverse crops and varieties is also vital for their adoption and sustainability. Given the importance of economic factors, it is essential to strike a balance in breeding efforts and advisory services across a broad range of crops. This approach can prevent the dominance of single crops, such as maize, and promote a more resilient agricultural system. Encouraging practices like crop rotations and mixed cropping aligns with this objective, supporting the maintenance of crop diversity. Additionally, incorporating nutrition advice into agricultural extension services can help retain crops that offer high nutritional value, such as grain legumes.

To support the ongoing conservation of crop and varietal diversity, it is essential for policymakers to consider farmers' preferences and the factors influencing their decisions. Tailored policies that promote market access, provide resources for high-yielding varieties, and facilitate the integration of socio-cultural values into agricultural practices could enhance the sustainability of agrobiodiversity. Furthermore, demand-driven breeding strategies that consider gender sensitivities are well suited to ensure the development and adoption of crops and varieties that align with farmers' needs and preferences, while at the same time contributing to agro-biodiversity.

## References


Abdalla, S., Leonhäuser, I., Siegfried, S. B., & Elamin, E. (2013). Factors influencing crop diversity in dry land sector of Sudan. *Sky Journal of Agricultural Research*, *2*(7), 88–97.

Abrouk, M., Ahmed, H. I., Cubry, P., Šimoníková, D., Cauet, S., Pailles, Y., Bettgenhaeuser, J., Gapa, L., Scarcelli, N., Couderc, M., Zekraoui, L., Kathiresan, N., Čížková, J., Hřibová, E., Doležel, J., Arribat, S., Bergès, H., Wieringa, J. J., Gueye, M., … Krattinger, S. G. (2020). Fonio millet genome unlocks African orphan crop diversity for agriculture in a changing climate. *Nature Communications*, *11*(1), 4488. https://doi.org/10.1038/s41467-020-18329-4

Adewumi, A. S., Asare, P. A., Adu, M. O., Taah, K. J., Akaba, S., Mondo, J. M., & Agre, P. A. (2021). Farmers' perceptions on varietal diversity, trait preferences and diversity management of bush yam (*Dioscorea praehensilis* Benth.) in Ghana. *Scientific African*, *12*, e00808. https://doi.org/10.1016/j.sciaf.2021.e00808

Adimassu, Z., Mul, M., & Owusu, A. (2023). Intra-seasonal rainfall variability and crop yield in the Upper East Region of Ghana. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-023-03861-2

Ahmad, S., Smale, M., Theriault, V., & Maiga, E. (2023). Input subsidies and crop diversity on family farms in Burkina Faso. *Journal of Agricultural Economics*, *74*(1), 237–254. https://doi.org/10.1111/1477-9552.12504

Amao, I. O., Ogunniyi, A. I., Mavrotas, G., & Omotayo, A. O. (2023). Factors Affecting Food Security among Households in Nigeria: The Role of Crop Diversity. *Sustainability*, *15*(11), 8534. https://doi.org/10.3390/su15118534

Appiah-Twumasi, M., & Asale, M. A. (2022). Crop diversification and farm household food and nutrition security in Northern Ghana. *Environment, Development and Sustainability*, *26*(1), 157–185. https://doi.org/10.1007/s10668-022-02703-x

Armah, R. N., Al-Hassan, R. M., Kuwornu, J. K., & Osei-Owusu, Y. (2013). *What influences farmers' choice of indigenous adaptation strategies for agrobiodiversity loss in Northern Ghana?* http://www.taccire.sua.ac.tz/handle/123456789/162

Assima, A., Smale, M., & Kone, B. (2022). Diverse crops and input subsidies: A village-scale analysis in Mali. *International Journal of Agricultural Sustainability*, *20*(5), 926–941. https://doi.org/10.1080/14735903.2021.2016261

Awiti, H. A., Gido, E. O., & Obare, G. A. (2022). Smallholder Farmers Climate-Smart Crop Diversification Cost Structure: Empirical Evidence From Western Kenya. *Frontiers in Sustainable Food Systems*, *6*, 842987. https://doi.org/10.3389/fsufs.2022.842987

Baba, A. R., & Abdulai, A.-M. (2021). Determinants of Crop Diversification and Its Effects on Household Food Security in Northern Ghana. *Arthaniti: Journal of Economic Theory and Practice*, *20*(2), 227–245. https://doi.org/10.1177/0976747920936818

Bennett-Lartey, S. O., & Adu-Dapaah, H. (2015). Biodiversity loss in Ghana: The human factor. *Ghana Journal of Agricultural Science*, *49*(1), 115–122.

Bezançon, G., Pham, J.-L., Deu, M., Vigouroux, Y., Sagnard, F., Mariac, C., Kapran, I., Mamadou, A., Gérard, B., Ndjeunga, J., & Chantereau, J. (2009). Changes in the diversity and geographic distribution of cultivated millet (Pennisetum glaucum (L.) R. Br.) and sorghum (Sorghum bicolor (L.) Moench) varieties in Niger between 1976 and 2003. *Genetic Resources and Crop Evolution*, *56*(2), 223–236. https://doi.org/10.1007/s10722-008-9357-3

Birhanu Abegaz, S., & Hailu Tessema, F. (2021). Farmers' Perception about the Use of Sorghum (Sorghum bicolor (L.) Moench) Landraces and Their Genetic Erosion in South Wollo Administrative Zone, Ethiopia. *International Journal of Agronomy*, *2021*(1), 3601897. https://doi.org/10.1155/2021/3601897

Brown, A. H. D., & Hodgkin, T. (2015). Indicators of Genetic Diversity, Genetic Erosion, and Genetic Vulnerability for Plant Genetic Resources. In M. R. Ahuja & S. M. Jain (Eds.), *Genetic Diversity and Erosion in Plants* (Vol. 7, pp. 25–53). Springer International Publishing. https://doi.org/10.1007/978-3-319-25637-5_2

Chivenge, P., Mabhaudhi, T., Modi, A. T., & Mafongoya, P. (2015). The potential role of neglected and underutilised crop species as future crops under water scarce conditions in Sub-Saharan Africa. *International Journal of Environmental Research and Public Health*, *12*(6), 5685–5711.

Cissé, A., Clermont-Dauphin, C., Sall, S. N., Gie, S., Groupement, M. P., Ndiaye, A., Diouf, M., Traore, B., Ndir, K., Kane, N. A., Renard, D., Violle, C., Barnaud, A., & Berthouly-Salazar, C. (2023). Sahelian smallholders' varietal mixtures reconcile yield and agrobiodiversity conservation. *Basic and Applied Ecology*, *67*, 48–60. https://doi.org/10.1016/j.baae.2022.12.006

Darfour, B., & Rosentrater, K. A. (2016). Maize in Ghana: An overview of cultivation to processing. *2016 ASABE Annual International Meeting*, 1. https://elibrary.asabe.org/abstract.asp?aid=47204

De Groote, H., & Omondi, L. B. (2023). Varietal turn-over and their effect on yield and food security–Evidence from 20 years of household surveys in Kenya. *Global Food Security*, *36*, 100676.

Dempewolf, H., Krishnan, S., & Guarino, L. (2023). Our shared global responsibility: Safeguarding crop diversity for future generations. *Proceedings of the National Academy of Sciences*, *120*(14), e2205768119. https://doi.org/10.1073/pnas.2205768119

Deu, M., Sagnard, F., Chantereau, J., Calatayud, C., Vigouroux, Y., Pham, J. L., Mariac, C., Kapran, I., Mamadou, A., Gérard, B., Ndjeunga, J., & Bezançon, G. (2010). Spatio-temporal dynamics of genetic diversity in Sorghum bicolor in Niger. *Theoretical and Applied Genetics*, *120*(7), 1301–1313. https://doi.org/10.1007/s00122-009-1257-1

Dossou-Aminon, I., Dansi, A., Ahissou, H., Cissé, N., Vodouhè, R., & Sanni, A. (2016). Climate variability and status of the production and diversity of sorghum (Sorghum bicolor (L.) Moench) in the arid zone of northwest Benin. *Genetic Resources and Crop Evolution*, *63*(7), 1181–1201. https://doi.org/10.1007/s10722-015-0310-y

Dube, L., Numbwa, R., & Guveya, E. (2016). Determinants of crop diversification amongst agricultural co-operators in Dundwa agricultural camp, Choma district, Zambia. *Asian Journal of Agriculture and Rural Development*, *6*(1), 1–13. https://doi.org/10.18488/journal.1005/2016.6.1/1005.1.1.13

Gatto, M., de Haan, S., Laborte, A., Bonierbale, M., Labarta, R., & Hareau, G. (2021). Trends in varietal diversity of main staple crops in Asia and Africa and implications for sustainable food systems. *Frontiers in Sustainable Food Systems*, *5*, 626714.

Gerrano, A. S., Lubinga, M. H., & Bairu, M. W. (2022). Genetic resources management, seed production constraints and trade performance of orphan crops in Southern Africa: A case of Cowpea. *South African Journal of Botany*, *146*, 340–347.

Gomes, A. M. F., Draper, D., Nhantumbo, N., Massinga, R., Ramalho, J. C., Marques, I., & Ribeiro-Barros, A. I. (2021). Diversity of Cowpea [Vigna unguiculata (L.) Walp] Landraces in Mozambique: New Opportunities for Crop Improvement and Future Breeding Programs. *Agronomy*, *11*(5), 991. https://doi.org/10.3390/agronomy11050991

Gomes, A. M. F., Draper, D., Talhinhas, P., Santos, P. B., Simões, F., Nhantumbo, N., Massinga, R., Ramalho, J. C., Marques, I., & Ribeiro-Barros, A. I. (2020). Genetic Diversity among Cowpea (Vigna unguiculata (L.) Walp.) Landraces Suggests Central Mozambique as an Important Hotspot of Variation. *Agronomy*, *10*(12), 1893. https://doi.org/10.3390/agronomy10121893

Issahaku, A., Campion, B. B., & Edziyie, R. (2016). Rainfall and temperature changes and variability in the Upper East Region of Ghana. *Earth and Space Science*, *3*(8), 284–294. https://doi.org/10.1002/2016EA000161

Jinbaani, A. N., Owusu, E. Y., Mohammed, A.-R., Tengey, T. K., Mawunya, M., Kusi, F., & Mohammed, H. (2023). Gender trait preferences among smallholder cowpea farmers in northern Ghana: Lessons from a case study. *Frontiers in Sociology*, *8*. https://doi.org/10.3389/fsoc.2023.1260407

Joseph, B., Matilda Ntowa, B., Edmund Osei, O., Rashied, T., Richard, A. A., Yaw, K., Lawrence Misa, A., Stephen, N., & Daniel Ashie, K. (2023). Sustainable Food System in Ghana: Role of Neglected and Underutilized Crop Species and Diversity. *Anthropocene Science*, *2*(1), 62–70. https://doi.org/10.1007/s44177-023-00049-1

Khoury, C. K., Brush, S., Costich, D. E., Curry, H. A., De Haan, S., Engels, J. M. M., Guarino, L., Hoban, S., Mercer, K. L., Miller, A. J., Nabhan, G. P., Perales, H. R., Richards, C., Riggins, C., & Thormann,

I. (2022). Crop genetic erosion: Understanding and responding to loss of crop diversity. *New Phytologist*, *233*(1), 84–118. https://doi.org/10.1111/nph.17733

Kondombo, C. P., Barro, A., Kaboré, B., & Bazié, J.-M. (2016). On-farm diversity of sorghum [Sorghum bicolor (L.) Moench] and risks of varietal erosion in four regions of Burkina Faso. *International Journal of Biodiversity and Conservation*, *8*(8), 171–179.

Kosmowski, F., Aragaw, A., Kilian, A., Ambel, A., Ilukor, J., Yigezu, B., & Stevenson, J. (2019). Varietal identification in household surveys: Results from three household-based methods against the benchmark of DNA fingerprinting in southern Ethiopia. *Experimental Agriculture*, *55*(3), 371–385.

Labeyrie, V., Renard, D., Aumeeruddy-Thomas, Y., Benyei, P., Caillon, S., Calvet-Mir, L., Carrière, S. M., Demongeot, M., Descamps, E., & Junqueira, A. B. (2021). The role of crop diversity in climate change adaptation: Insights from local observations to inform decision making in agriculture. *Current Opinion in Environmental Sustainability*, *51*, 15–23.

Loko, Y. L. E., Ewedje, E.-E., Orobiyi, A., Djedatin, G., Toffa, J., Gbemavo, C. D. S. J., Tchakpa, C., Gavoedo, D., Sedah, P., & Sabot, F. (2021). On-Farm Management of Rice Diversity, Varietal Preference Criteria, and Farmers' Perceptions of the African (Oryza glaberrima Steud.) Versus Asian Rice (Oryza sativa L.) in the Republic of Benin (West Africa): Implications for Breeding and Conservation. *Economic Botany*, *75*(1), 1–29. https://doi.org/10.1007/s12231-021-09515-6

Martey, E. (2022). Empirical analysis of crop diversification and energy poverty in Ghana. *Energy Policy*, *165*, 112952. https://doi.org/10.1016/j.enpol.2022.112952

Menamo, T., Kassahun, B., Borrell, A. K., Jordan, D. R., Tao, Y., Hunt, C., & Mace, E. (2021). Genetic diversity of Ethiopian sorghum reveals signatures of climatic adaptation. *Theoretical and Applied Genetics*, *134*(2), 731–742. https://doi.org/10.1007/s00122-020-03727-5

Ministere de l' Economie et des Finances. (2009). *Monographie de la region du Centre-Sud* (p. 196).

Mohammed, S., Lewu, F. B., Danjuma, M. N., Adetunji, A. T., & Kioko, J. I. (2020). Pearl Millet (Pennisetum glaucum [LR Rr.]) varietal loss and its potential impact on smallholder farmers in Northern Nigeria: A review. *Journal of Techno-Social*, *12*(2), 1–11.

Montenegro De Wit, M. (2016). Are we losing diversity? Navigating ecological, political, and epistemic dimensions of agrobiodiversity conservation. *Agriculture and Human Values*, *33*(3), 625–640. https://doi.org/10.1007/s10460-015-9642-7

Morrissey, K., Reynolds, T., Tobin, D., & Isbell, C. (2024). Market engagement, crop diversity, dietary diversity, and food security: Evidence from small-scale agricultural households in Uganda. *Food Security*, *16*(1), 133–147. https://doi.org/10.1007/s12571-023-01411-2

Mulugo, L., Ajambo, S., & Kikulwe, E. M. (2021). User guide to the four-square method for intervening in root, tuber and banana seed systems. RTB User Guide. *RTB User Guide*. https://cgspace.cgiar.org/bitstream/10568/111350/1/us20213.pdf

Obidiegwu, J. E., & Akpabio, E. M. (2017). The geography of yam cultivation in southern Nigeria: Exploring its social meanings and cultural functions. *Journal of Ethnic Foods*, *4*(1), 28–35. https://doi.org/10.1016/j.jef.2017.02.004

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*, *162*(3), 1107–1125. https://doi.org/10.1007/s10584-020-02727-0

Olodo, K. F., Barnaud, A., Kane, N. A., Mariac, C., Faye, A., Couderc, M., Zekraoui, L., Dequincey, A., Diouf, D., & Vigouroux, Y. (2020). Abandonment of pearl millet cropping and homogenization of its diversity over a 40 year period in Senegal. *Plos One*, *15*(9), e0239123.

Parré, J. L., & Chagas, A. L. S. (2022). Determinants of agricultural diversification in Brazil: A spatial econometric analysis. *Letters in Spatial and Resource Sciences*, *15*(2), 173–195. https://doi.org/10.1007/s12076-021-00295-0

Porcuna-Ferrer, A., Calvet-Mir, L., Faye, N. F., Klappoth, B., Reyes-García, V., & Labeyrie, V. (2024). Drought-tolerant indigenous crops decline in the face of climate change: A political agroecology account from south-eastern Senegal. *Journal of Rural Studies*, *105*, 103163. https://doi.org/10.1016/j.jrurstud.2023.103163

Quaye-Ballard, J. A., Okrah, T. M., Andam-Akorful, S. A., Awotwi, A., Antwi, T., Osei-Wusu, W., Tang, X., & Quaye-Ballard, N. L. (2020). Spatiotemporal dynamics of rainfall in Upper East Region of Ghana, West Africa, 1981–2016. *SN Applied Sciences*, *2*(10), 1675. https://doi.org/10.1007/s42452-020-03463-x

Rahman, S., & Chima, C. (2016). Determinants of Food Crop Diversity and Profitability in Southeastern Nigeria: A Multivariate Tobit Approach. *Agriculture*, *6*(2), 14. https://doi.org/10.3390/agriculture6020014

Rampersad, C., Geto, T., Samuel, T., Abebe, M., Gomez, M. S., Pironon, S., Büchi, L., Haggar, J., Stocks, J., Ryan, P., Buggs, R. J. A., Demissew, S., Wilkin, P., Abebe, W. M., & Borrell, J. S. (2023). Indigenous crop diversity maintained despite the introduction of major global crops in an African centre of agrobiodiversity. *PLANTS, PEOPLE, PLANET*, *5*(6), 985–996. https://doi.org/10.1002/ppp3.10407

Regassa, M. D., Miriti, P. K., & Melesse, M. B. (2023). Farmers' heterogeneous preferences for traits of improved varieties: Informing demand-oriented crop breeding in Tanzania. *Experimental Agriculture*, *59*, e19. https://doi.org/10.1017/S0014479723000169

Renard, D., Mahaut, L., & Noack, F. (2023). Crop diversity buffers the impact of droughts and high temperatures on food production. *Environmental Research Letters*, *18*(4), 045002. https://doi.org/10.1088/1748-9326/acc2d6

Rouamba, A., Shimelis, H., Drabo, I., Laing, M., Gangashetty, P., Mathew, I., Mrema, E., & Shayanowako, A. I. T. (2021). Constraints to Pearl Millet (Pennisetum glaucum) Production and Farmers' Approaches to Striga hermonthica Management in Burkina Faso. *Sustainability*, *13*(15), 8460. https://doi.org/10.3390/su13158460

Seburanga, J. L. (2013). Decline of Indigenous Crop Diversity in Colonial and Postcolonial Rwanda. *International Journal of Biodiversity*, *2013*, 1–10. https://doi.org/10.1155/2013/401938

Sseremba, G., Kabod, N. P., Kasharu, A. K., Jaggwe, J. N., Masanza, M., & Kizito, E. B. (2017). Diversity and distribution of African indigenous vegetable species in Uganda. *International Journal of Biodiversity and Conservation*, *9*(11), 334–341. https://doi.org/10.5897/IJBC2017.1120

Tadele, Z. (2019). Orphan crops: Their importance and the urgency of improvement. *Planta*, *250*(3), 677–694. https://doi.org/10.1007/s00425-019-03210-6

Temegne, N. C., Dooh, J. P. N., Nbendah, P., Ntsomboh-Ntsefong, G., Taffouo, V. D., & Youmbi, E. (2020). Cultivation and utilization of Bambara groundnut (Vigna subterranea (L.) verdc.), a neglected plant in Cameroon. *Asian Plant Research Journal*, *4*(2), 9–21.

Tesfaye, W., & Tirivayi, N. (2020). Crop diversity, household welfare and consumption smoothing under risk: Evidence from rural Uganda. *World Development*, *125*, 104686. https://doi.org/10.1016/j.worlddev.2019.104686

Teshome, A., Patterson, D., Asfaw, Z., Dalle, S., & Torrance, J. K. (2016). Changes of Sorghum bicolor landrace diversity and farmers' selection criteria over space and time, Ethiopia. *Genetic Resources and Crop Evolution*, *63*(1), 55–77. https://doi.org/10.1007/s10722-015-0235-5

Tetteh, F. M., & Nurudeen, A. R. (2015). Modeling site-specific fertiliser recommendations for maize production in the Sudan savannah agro-ecology of Ghana. *African Journal of Agricultural Research*, *10*(11), 1136–1141.

Theriault, V., & Smale, M. (2021). The unintended consequences of the fertiliser subsidy program on crop species diversity in Mali. *Food Policy*, *102*, 102121. https://doi.org/10.1016/j.foodpol.2021.102121

van Zonneveld, M., Kindt, R., Solberg, S. Ø., N'Danikou, S., & Dawson, I. K. (2021). Diversity and conservation of traditional African vegetables: Priorities for action. *Diversity and Distributions*, *27*(2), 216–232. https://doi.org/10.1111/ddi.13188

Wale, E. (2012). Farmers' Perceptions on Replacement and Loss of Traditional Crop Varieties: Examples from Ethiopia and Implications. In *The Economics of Managing Crop Diversity On-farm*. Routledge.

Whitney, C. W., Luedeling, E., Tabuti, J. R. S., Nyamukuru, A., Hensel, O., Gebauer, J., & Kehlenbeck, K. (2018). Crop diversity in homegardens of southwest Uganda and its importance for rural livelihoods. *Agriculture and Human Values*, *35*(2), 399–424. https://doi.org/10.1007/s10460-017-9835-3

Yokouchi, T., & Saito, K. (2016). Factors affecting farmers' adoption of NERICA upland rice varieties: The case of a seed producing village in central Benin. *Food Security*, *8*(1), 197–209. https://doi.org/10.1007/s12571-015-0545-7

**Social and Institutional Change in Agricultural Development**
**Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute)**
**Universität Hohenheim**
Wollgrasweg 43 | 70599 Stuttgart | Deutschland
**T** +49 (0)711-459-23517 | **F** +49 (0)711-459-23812
**E** regina.birner@uni-hohenheim.de | https://490c.uni-hohenheim.de/en