FARMER PREFERENCES FOR COWPEA VARIETIES IN SENEGAL: A CHOICE EXPERIMENT

A Thesis

Presented to the Faculty of the Graduate School

of Cornell University

In Partial Fulfillment of the Requirements for the Degree of

Master of Science in Applied Economics and Management

by

Rishabh Mukerjee

August 2023

ABSTRACT

Cowpea plays a vital role in West Africa, significantly contributing to food security and the livelihoods of farmers. Despite its importance, the adoption of cowpea varieties among farmers in the region remains low, highlighting the need to understand their trait preferences. While plant breeding programs traditionally rely on the preferences of household heads to determine trait priorities, it is crucial to acknowledge the existence of diverse preferences among household members. Limited research has been conducted on the preferences of multiple household members regarding crop attributes. This study focuses on Senegal and aims to examine how the influence of household members in decision-making regarding cowpea management affects their trait preferences for cowpea varieties. By utilizing an intrahousehold crop management survey and conducting discrete choice experiments, I investigate the preferences of Senegalese farmers for cowpea traits. Additionally, I explore the heterogeneity of these preferences based on the decision-making status of household members. Furthermore, I analyze variations in trait preferences during pre-harvest, harvest, and post-harvest activities, considering the decision-making authority of farmers and their spouses. To gather data, separate information is collected from household heads and their spouses, resulting in 12,960 choice observations from a random sample of 540 farmers. A decision-making index is created to identify the key decision-makers in cowpea farming within each household, based on survey responses. The results reveal that Senegalese farmers prefer cowpea varieties with high seed price, grain yield, biomass yield, short maturity, more seeds per pod, and large grain size. Decision-makers prioritize higher biomass yield, shorter maturity, and smaller seed size compared to non-decision-makers. Household members with greater decision power in the pre-harvest and harvest stages prioritize high biomass yield, while those with higher decision-making authority in the post-harvest stage prefer high grain yield and short maturity. This study underscores the importance of inclusive approaches in crop breeding, ensuring that breeders' objectives align with household needs. Considering multiple household members' preferences can increase the adoption of improved cowpea varieties, fostering sustainable agricultural development in Senegal. This inclusive approach can promote social equity and enhance household consumption utility.

BIOGRAPHICAL SKETCH

Rishabh Mukerjee is a graduate student at the Dyson School of Applied Economics and Management at Cornell University. He completed his BA in Economics from the University of Delhi in 2020. His research interests include understanding stakeholder preferences and exploring the application of microeconomics theory. At Cornell, he was associated with the Feed the Future Innovation Lab for Crop Improvement (ILCI), which provided him the opportunity to pursue his MS Thesis. Prior to his academic pursuits, Rishabh gained professional experience as a risk analyst at KPMG India, where he handled clients from various industries including pharmaceuticals, aviation, and manufacturing. Following the completion of his graduate degree at Cornell, he will be joining the International Food Policy Research Institute (IFPRI) in Washington DC as a Research Analyst.

ACKNOWLEDGEMENT

This publication is made possible by the generous support of the American people through the United States Agency of International Development (USAID). The contents are the responsibility of the author and do not necessarily reflect the views of USAID or the United States Government. The program activities have been funded by the United States Agency for International Development (USAID) under Cooperative Agreement No. 7200AA-19LE-00005.

I would like to express my heartfelt gratitude to Dr. Miguel Gómez for his unwavering support and trust in me, enabling me to take on a project of such significant importance and granting me the opportunity to conduct independent field visit in Senegal. Dr. Gomez has been an exceptional mentor, consistently pushing me to excel as a researcher. I am also grateful to Dr. Hale Tufan for her invaluable feedback and constant encouragement, which have motivated me to strive for excellence in my work. Her expertise, knowledge, and dedication have been instrumental in shaping and refining my research. Additionally, I would like to extend my appreciation to Dr. Martina Ocelli for her patience, understanding, and accessibility. Her open-door policy and willingness to engage in discussions on ideas, challenges, and concerns have created a supportive and nurturing environment that has greatly contributed to my academic growth and success.

Furthermore, I would like to extend my sincere gratitude and appreciation to the enumerators of the Senegal Institute of Agricultural Research (ISRA) who helped me in the data collection activity and the cowpea farmers of Senegal who generously participated in the survey. Their invaluable contributions and unwavering dedication have played a vital role in the successful completion of my research project.

Finally, I would like to thank my family and friends for always believing in me. Specifically, my parents, for always standing by me and encouraging me to achieve the impossible.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. Introduction

Agricultural production in developing countries involves multiple household members managing land and sharing limited resources (Haider, 2018). Specifically in West Africa, the collective management of crops by family members is influenced by social norms and traditional farm practices (Theriault et al., 2017; West, 2010). The roles, responsibilities, and resources of each member within these households determine their involvement in crop management decisions. While men in Sub-Saharan Africa (SSA) have traditionally dominated decision-making in crop management and household matters, women's increased access to land ownership and household assets has led to their greater involvement in farm-related decisions (Lusiba et al., 2017; Ochieng et al., 2014; Akeredolu et al., 2007; Sikod, 2007). Farmers in SSA actively decide to adopt improved crop varieties to address food insecurity and improve agricultural output, but face challenges due to high seed costs, lack of information, mistrust, and unavailability (Almekinders et al., 2019; Macours, 2019; Ndiritu et al., 2019; Mugabe & Mugabe, 2019; Eriksson et al., 2018; Tesfaye, 2018). Additionally, not all farmers may equally accept improved crop varieties as varietal trait preferences may vary among households and even by members within the same household (Krishna and Veettil, 2022; Maligalig et al., 2021; Michler et al., 2019).

Members within a household diverge in crop trait preferences when they face varying constraints and have different responsibilities and production goals (Weltzien et al., 2019; Teeken et al., 2018; Doss, 2001). Moreover, farmers' roles in crop management are acknowledged to impact users' acceptability of improved varieties delivered by breeding programs (Ashby et al., 2019; Laborte et al., 2015). Yet, for setting trait priorities, breeding programs frequently collect only the preferences of one member of the family, typically the household head which are implicitly assumed to be reflective of the entire household (Mengistu et al. 2019; Pant et al. 2012; Asrat et al. 2010). The rationale behind this is the assumption of the household as a single decision-making unit that considers a shared utility function among family members (Becker 1965). Empirical evidence has shown that the unitary household model is limited in exploring preference heterogeneity among household members for public goods and services (Duflo and Udry, 2004; Attanasio and Lechene, 2002; Hoddinott and Haddad, 1995). By conducting interview with only one-person, valuable insights from other members involved in crop cultivation are overlooked, resulting in only a partial understanding of the adoption process (Doss et al., 2020; Joshi et al., 2019). Moreover, relying solely on sex-disaggregated data of household heads fails to capture the preferences and farming experiences of other women farmers within male-headed households, potentially missing significant variations. The challenge of directly observing individual preferences leads researchers to frequently depend on aggregated revealed preference data, resulting in a limited availability of data on crop trait preferences among different members of a single household (Maligalig et al., 2017; Gulati et al., 2016).

Farmers' social and demographic characteristics strongly influence their preferences for traits and decisions to adopt new agricultural technologies (Deißler et al., 2023; Molua et al., 2011; Simtowe, 2010). Recent research recognizes the impact of multiple identities on individuals' roles and decision making in agriculture, highlighting the importance of considering factors beyond gender when studying outcomes in agrarian practices (Kaijser et al. 2014; Djoudi et al., 2011; MacGregor, 2009). While some studies have examined gendered seed trait preferences and their connections to gendered on-farm roles, few have analyzed the preference differences alongside other social or crop management factors, such as decision-making power in crop cultivation (Teeken et al., 2021; Maligalig et al., 2019).

Recognizing this research gap, this study focuses on Senegal and aims to examine how household members' influence in decision-making related to cowpea crop management affects their trait preferences for cowpea varieties. To do this, I first investigate the seed trait preferences of Senegalese farmers regarding cowpea attributes. Second, I examine how these preferences are influenced by the decision-making status of household members involved in cowpea farming. Lastly, I explore potential variations in preferences based on the decision-making authority of cowpea farmers during pre-harvest, harvest, and post-harvest activities.

Preference heterogeneity based on crop decision-making status is an important factor to consider when analyzing adoption of improved varieties, as even non-decision-making household members can influence the choices made by the decision-makers regarding agricultural technology uptake (Fisher et al., 2015; Lope-Alzina, 2007). For example, although wives may not actively participate in purchasing improved seeds, they can communicate their preferences to their husbands, which can potentially influence the household's decisions regarding seed adoption (idem). Agricultural reports like *FAO State of Food and Agriculture* and *Gender in Agriculture Sourcebook* fail to address the crucial aspect of decision-making within households and overlooks the reality that multiple individuals can be involved in the decision-making process (Twyman et al. 2015). Empirical evidence from previous studies, show that farm production decisions, including adoption, can be jointly made by both husbands and wives within a household (Alwang et al., 2017; Sumner et al., 2017). Additionally, using headship as a gender indicator may fail to accurately reflect the actual decision-makers and overlook the decision-making roles and preferences of women in male-headed households and vice versa. (Gebre et al. 2019; Twyman et al., 2015). Considering the crop trait preferences of multiple household members, including spouses and children, is critical to ensure that varietal adoption aligns with the needs and priorities of the entire household. This inclusive approach in agricultural innovations and interventions can improve crop productivity, income, and household welfare for farmers in developing countries.

The study significantly contributes to the existing literature on varietal adoption and intrahousehold decision making by focusing specifically on cowpea farm households and their preferences for cowpea seed attributes. To accomplish this, I employ an innovative approach that combines the choice experiment technique with an intrahousehold cowpea crop management questionnaire. This approach yields unique data on the involvement of each household member in cowpea cultivation, including their decision-making, years of farming experience, and level of engagement on the cowpea plot, setting it apart from previous intrahousehold studies. The survey addresses crucial aspects of crop management that have received limited attention but have the potential to affect intra-household heterogeneity in crop trait preferences. Moreover, I use "who decides" questions for each step of the cowpea cultivation process to identify the primary decision-makers responsible for cowpea management within the sampled households. These data allows me to construct a decision-making index for each participant, quantifying the decision-making dynamics within these households. Through separate interviews conducted with both the household head and their spouses, this study reveals intrahousehold variations in cowpea trait preferences, based on the decision-making status of the household member.

The analysis reveals that Senegalese farmers prefer cowpea varieties with high seed price, high grain yield, high biomass yield, short maturity, more seeds per pod, and large grain size. Within households, decision-makers demonstrate a stronger preference for higher biomass yield, shorter maturity, and smaller seed size compared to non-decision-makers. Farmers with greater decision power during the pre-harvest and harvest stages prioritize high biomass yield, while those with higher decision-making authority in the post-harvest stage prefer varieties with high grain yield and short maturity.

The paper is structured as follows: Section 2 reviews the literature, Section 3 discusses the importance of cowpea in Senegal, and Section 4 presents the study area and data sources. Section 5 explains the econometric methodology, while Section 6 presents descriptive statistics, results, and discussions. Finally, Section 7 concludes the paper, summarizing key findings and offering breeding implications.

2. Literature Review

This section consists of three parts. The first part reviews intrahousehold trait preference studies conducted in agricultural economics and focuses on their relevance to crop breeding research. The next part discusses the choice experiment methodology and previous studies that have explored farmers' preferences using this method. The last part highlights the uniqueness of the study and its contribution to the current body of literature.

2.1 Intrahousehold Trait Preferences

Empirical evidence has prompted a paradigm shift in understanding households, moving away from perceiving them as unified decision-making entities to embracing a collective model. In this model, individual members possess distinct preferences, allocate resources differently, and negotiate outcomes in both production and consumption (Doss et al., 2020). To empirically examine this shift, researchers have primarily conducted intrahousehold preference studies in environmental and health economics. For example, Prabhu (2010) investigated intrahousehold demand for malaria vaccines, and Scarpa et al. (2012) explored couples' preferences for tap water attributes.

In the field of agricultural economics, this approach has been applied to address development issues by exploring the individual and joint preferences of husbands and wives for new agricultural technologies. Using an experimental methodology in the Philippines, Maligalig (2021) investigated individual and joint preferences of husbands and wives for rice varietal trait improvements, further providing insights into the intrahousehold decision-making dynamics related to investment decisions. The author found no statistically significant differences in individual and joint preferences of men and women farmers during the wet season. Husband and wife individually preferred the most stress-tolerant traits like disease resistance, lodging tolerance, and insect resistance that matched with preferences when discussed jointly. However, in the dry season, there were significant differences in trait preferences (like lodging tolerance, disease, and insect resistance) between the husband as an individual decision-maker and joint decisions involving both spouses. Gulati (2016) examined intra-household decision-making dynamics and heterogeneity in the demand for mechanical rice transplanting technology (MRT) adoption in India. The study used stated Willingness to Pay (WTP) data from men and women in the same households and measured household WTP through village-level experimental auctions. The results highlighted that, despite women valuing MRT more than men, their valuation had little effect on household demand for technological adoption. The study by Krishna and Veettil (2022) stands as the only example of an intra-household choice experiment focusing on preferences for crop variety attributes. The authors evaluated preferences for wheat varieties among 420 households in the central Indian state of Madhya Pradesh, encompassing a total of 818 respondents. Although most women respondents were not actively involved in decisions related to wheat cultivation, including varietal selection, the results indicated that women farmers exhibited a greater openness to experimenting with new varieties compared to men, as evidenced by their positive WTP for improved varietal traits. Furthermore, Joshi et al. (2019) combined measures of WTP with results from the Women's Empowerment in Agriculture Index (WEAI) and found that the respective on farm roles of women and men within the family were aligned with their preferences for labor-saving rice technology.

In the context of intrahousehold methods used in crop breeding research, two distinct strands of literature emerge. One focuses on women's empowerment and agency, as characterized by WEAI (Alkire et al., 2013; Seymour et al., 2017, 2018), while the other delves into the dimensions of varietal decision making (Farnworth et al., 2022, 2019; Leigh et al., 2017). Methods centered on women's empowerment encompass multiple facets but often lack comprehensive emphasis on trait preferences, crop management, and roles. Conversely, methods focused on intra-household varietal decision making are typically used to map out crop roles and preferences but often overlook crucial aspects of crop management, such as farming experience and time commitment on the plot, which significantly contribute to preference heterogeneity (Peralta, 2022).

Traditionally, surveys have been the primary method used by researchers to assess intrahousehold decision-making patterns among spouses in agriculture. However, the advancement of modern methods and tools, such as WEAI, pro-WEAI indexes, vignettes, and experimental games, is leading to a shift in the study of intrahousehold decision-making dynamics and the crop management roles of household members (Hoel et al., 2021; Bernard et al., 2019; Anderson et al., 2017). However, these approaches study individual's decision-making power in limited activities like crop selection, input utilization and harvest usage. While many studies acknowledge the importance of joint decision making by including it in their surveys, it is noteworthy that some of them lack specificity in their survey questions. These studies often focus on identifying decision makers for a limited range of activities, rather than expanding their scope to cover all stages, including pre-harvest to post-harvest activities.

Surveys like WEAI and the World Bank's Living Standard Measurement Study (LSMS) collect intrahousehold data at the plot level and evaluate the extent of household members' involvement in joint decision-making. However, these approaches lack the ability to capture detailed micro-level data on additional dimensions, such as individual members' farming experience and the specific time allocated to various farming activities on farm plots. Incorporating such information would offer a more comprehensive understanding of how these factors impact intrahousehold crop management and decision-making dynamics. While there are established indexes to measure women's economic empowerment and decision-making within a household, limited studies construct decision-making power indexes for participants based on the primary data collected through the surveys (e.g, Peralta, 2022; Kafle et al., 2019; Twyman et al., 2015). This highlights the need for developing innovative intrahousehold methods that build upon widely known data collection tools and incorporate best practices from intrahousehold decision making related research.

2.2 Exploring Farmers' Crop Trait Preferences through Choice Experiments

With the low level of adoption of new crop varieties, plant breeders have started to place increasing importance on setting trait priorities based on farmers' preferences (Martey et al., 2022; Ceccarelli et al., 2020; Sánchez et al., 2017). Farmers' adoption decisions depend on the utility they derive from the introduced cultivar, which, in turn, depends on the specific attributes of the variety. The use of discrete choice experiments (DCE) has proven to be effective in quantifying farmers' preferences and generating tangible results for breeders and plant scientists (Miriti et al., 2022; Anugwa et al., 2022). A DCE is a stated preference multi-attribute method to elicit stakeholder preferences and Willingness to pay (WTP) for both public and private goods. Despite the drawbacks of DCEs, such as the inclusion of a limited number of traits and susceptibility to hypothetical bias, they still offer substantial advantages over survey approaches (Burns et al. 2022). One key advantage is that DCEs do not rely on longitudinal market data, which can be challenging to collect and may not effectively capture the impact of each trait on farmers' choices due to trait correlations (Miriti et al. 2022). Additionally, DCE analysis provides valuable insights into decision-making processes by uncovering implicit trade-offs between different traits (Khanal et al. 2017). By using DCEs, bundles of attributes are evaluated to assess how individual choices are influenced by random variations in one or more attributes. When prices are incorporated into the choice experiment, individual preferences can be expressed in terms of WTP for one attribute over another.

Many studies have examined farmers' crop trait preferences using DCEs, focusing on sub-Saharan countries (Waldman et al., 2017; Labarta et al., 2009; Kimathi et al., 2022). Meressa and Navrud (2020) examined farmers' preferences for coffee traits in northern Ethiopia and showed that farmers prefer and are WTP more for weather-tolerant and disease-resistant varieties compared to varieties with other traits like high yield and early maturity. Gender-disaggregated data on trait preferences have been collected through choice experiments. For instance, Marenya et al. (2021) showed that men and women farmers in Kenya have similar choices for maize traits but exhibit different rates of trade-offs between traits. Similarly, Asrat et al. (2010) explored Ethiopian households' WTP for various crop traits and found that male household heads are willing to sacrifice yield and income to obtain more environmentally adaptable crop varieties than female-headed households. While discrete choice experiments have been valuable for studying trait preferences, their combination with intra-household methods has received limited attention, particularly regarding crop trait preferences. Few studies have explored the use of choice experiments with an intra-household approach, making it an area with untapped potential for understanding intra-household heterogeneity in crop trait preferences.

Looking specifically at the literature on trait preferences for cowpea, I find that not many studies have used DCEs to investigate the factors that affect cowpea varietal adoption and trait preferences among various stakeholders. Martey et al. (2022) is the only study that uses a DCE to investigate Ghanaian farmers' preferences for improved cowpea variety attributes. Their results showed that farmers valued high yield, early maturity, and white seed color. Their estimates revealed that females are more likely to adopt new varieties than male farmers, and risk-averse farmers are less likely to pay for each attribute relative to risk-taker farmers. Meanwhile, researchers have used other methods such as simple logistic regression, rank-based methodologies, hedonic pricing, focus groups, pairwise ranking, and Participatory Varietal Selection (PVS) to assess farmers' preferences for cowpea attributes (e.g., Afful, 2020; Bolarinwa et al., 2021; Kassali et al., 2018; Ishikawa et al., 2020). Despite these studies, there is a lack of evidence on how cowpea attributes specifically drive adoption among smallholder farmers in SSA (especially in Senegal).

2.3 Novelty and Contribution to the Literature

This study makes a methodological contribution by introducing an innovative approach that combines discrete choice experiments with a survey module on intrahousehold cowpea crop management. Using this approach, I propose a novel intrahousehold stated preference method to identify the varied trait preferences among household members and explore how such preferences differ based on the decision-making status of individuals, a disaggregation factor that has not been explored before for crop trait preferences.

The survey protocol is unique as it focuses on three dimensions of crop management: decision-making, farming experience, and time spent working on the plot. This study expands the understanding of decision-making dynamics in cowpea-producing households by asking "who decides" at each stage of the cultivation process, going beyond the usual questions about crop selection, input management, and harvest sale. By creating a decision-making index, I am able to quantify the intricacies of cowpea decision-making within these households. Instead of relying on standard decision-making indicators or assuming the household head as the main decision-maker, my novel approach sheds light on the possibility of a non-household head being responsible for cowpea management. Additionally, the survey captures valuable information on cowpea farming experience and the level of engagement for each household member, an important factor not commonly seen in other surveys.

To the best of my knowledge, this study is the first to follow an intrahousehold discrete choice methodology to explore crop trait preferences of farmers in Senegal. The research presented in this thesis makes a unique contribution to the extant literature on crop trait preferences and varietal adoption, as well as to the growing body of knowledge on intrahousehold decision-making in rural areas. In addition, it adds to the scarce research available on Senegal and Cowpea in general. The results will help plant breeding programs and cowpea breeders understand the trait preferences of cowpea farmers to design preferred product profiles and facilitate the increased use of improved cowpea varieties in Senegal. Further it will validate whether there are differences in cowpea trait preferences among household members, based on their level of influence in decision making regarding cowpea cultivation.

3. Importance of Cowpea in Senegal

The agriculture sector plays a major role in Senegal's economy, serving not only as a vital source of food but also as an employer, particularly for women (Maisonnave, H et al. 2022). According to the World Bank, in 2020, the agriculture sector accounted for approximately 15% of Senegal's Gross Domestic Product (GDP) and employed 29.3% of the country's working population. In terms of production volume, staple food crops such as pearl millet (38%), cowpea (24%), maize (20%), rice (9%), and sorghum (9%) dominate the agricultural sector, all of which are primarily grown during the monsoon season (ANSD 2019). Senegal's growing population poses the need of expanding agricultural productivity to meet food demand. Cowpea is essential for promoting food security and generating income for smallholder farmers. (Beye et al. 2022; Mishili et al. 2009). It is a high-protein, low-calorie vegetable legume crop that provides more than half of the protein in the diets of the Senegalese population having the potential to ameliorate protein-calorie malnutrition (Bodian et al. 2022; Gonçalves et al. 2016). Due to its short maturation cycle and ability to resist extreme weather conditions, it has become popular among farmers in Sahelian nations including Senegal, making it a reliable crop, particularly during the mid-season when other crops do not achieve full maturity (Sarr et al. 2022; Beye et al. 2022).

Most of the world's cowpea is grown in West Africa, with Nigeria, Niger, Burkina Faso, Mali, Ghana, and Senegal accounting for more than 85% of global production (Guendel 2009). Cowpea is heavily traded in local and regional markets because of its excellent nutritional properties and versatility of uses. In Senegal, farmers harvest cowpeas dry or green and use them as a dual-purpose crop for human food and for animal feed. About 52% of cowpea production in SSA gets used as food, 13% as animal feed, 10% for seed, 9% for other uses, while 16% gets wasted (Nkomo et al. 2021, IITA 2021). Senegalese consume nutrient-rich leaves, pods, and seeds at various stages of maturity, while the stems, leaves, and vines provide nourishing fodder to livestock (Smale et al. 2022). Furthermore, the crop is of prime economic importance to women as they use it for making popular cowpea-based food products that fetch them additional income (Bodian et al. 2022).

Cowpea is a crop grown throughout all the agroecological zones in Senegal. However, the north-central region of the peanut basin contributes significantly to the country's total production, accounting for 80% of the national output and 82% of the seeded area. Both men and women farmers cultivate cowpea on family and individual plots, making it a unique setting where management, marketing and use of the crop are not limited to one gender category Although cowpea is primarily used as a subsistence crop for home consumption, its possible multipurpose uses and nutritional significance have led to its emergence as a key cash crop in Senegal and around the world. (Karikari et al. 2023; Kitch et al. 1998). Despite its importance, cowpea productivity is relatively low in the country, with yields of less than 340kg/ha, mainly due to biotic, abiotic, and socio-economic factors (Beye et al. 2022; ANSD 2021). According to the Diffusion and Impact of Improved Varieties in Africa (DIIVA) estimates, in 2009, only 27% of the total cowpea cultivation area in Senegal, which amounted to 218,904 hectares, was planted with improved varieties (DIIVA CGIAR 2009).

4. Research Design

4.1 Study Area and Sampling Methodology

I carried out the research in Senegal's Peanut Basin area, which includes six administrative regions, namely Louga, Kaolack, Fatick, Diourbel, Thies, and Kaffrine. It accounts for a sizeable portion of the country's land area and is home to about half of the population (Beye et al. 2022). The selection of these regions was based on their substantial agricultural productivity, which plays a crucial role in the country's economy (Toure et al. 2020). The cropping systems in this region are primarily cereal-leguminous rotations, with millet, maize, groundnuts, cowpeas, and bissap being the main subsistence crops (USAID 2016). However, the area has experienced a decrease in rainfall levels in recent years, leading to environmental degradation and loss of plant cover (Faye et al. 2021). Despite these challenges, cowpea remains a strategic crop choice for farmers in the region due to its drought tolerance ability compared to other rainfed crops. This makes it an essential crop for the region, where agriculture is the primary source of income for many inhabitants. About 80% of the national cowpea production in Senegal comes from this area (Beye 2022).

To ensure a representative sample, five of the six regions in the peanut basin were selected for the study, excluding Thies[1]. The selection was based on factors such as rainfall, acreage, climatic conditions, and volume of cowpea production (Figure 1). To ensure comprehensive geographic coverage, all departments within the selected regions were included[2]. I followed a three-stage sampling process, to select communes/municipalities, villages, and agricultural households. The number of communes per region was determined by considering the agricultural weight, which was calculated based on each region's 2017-18 cowpea production. On average, four communes were randomly selected from each region. With the assistance of experts from the Senegal Institute of Agricultural Research (ISRA)'s Geographic Information

[1] Thies was excluded, as it is becoming more urbanized with number of villages being reduced.
[2] The Linguere Department in Louga was excluded, due to its low population density and cowpea production as it is predominantly a pastoral area.

System (GIS) team, two villages were randomly chosen from each selected commune, resulting in a total of 45 villages where the surveys were conducted.

To focus on intrahousehold cowpea trait preferences, the survey team conducted interviews with household heads and spouses from both monogamous and polygamous agricultural households who produced cowpea on their managed plot. At the village level, the team randomly selected six households from a non-exhaustive list of cowpea-growing households in the region provided by the village chief. In cases where the original households were absent or unwilling to participate, the team chose five additional households from the list as proxies. Eligibility for the study was limited to married participants who produced cowpea on their own or household plot to measure the differences in cowpea trait preferences between husbands and wives. Separate interviews were conducted with husbands and wives at the household level (i.e., without each other’s presence) and the order of interviews was randomized within each household. In polygamous households, surveyors interviewed any spouse who was involved in cowpea production and could provide time, as no established ranking among the spouses was found in the study area. A total of 270 households were surveyed, resulting in data collection from 540 farmers. The field visit was conducted from February 20th to March 3rd, 2023, which was a convenient time between the cowpea harvesting and planting seasons. This timing increased the likelihood of farmers' participation in the study.

The survey team consisted of six enumerators from the Senegalese Institute of Agricultural Research, including four men and two women. Initially, the plan was to pair enumerators with same-sex respondents to prevent biases and mistrust in responses. However, difficulties arose during the recruitment of women enumerators. Nevertheless, throughout the fieldwork, it was observed that there was no strict gender-based restrictions on interviews, allowing both male and female surveyors to collect data effectively from respondents of all genders and contribute to the overall efficiency of the data collection process. The enumerators were selected based on their prior surveying experience and proficiency in local languages, particularly Wolof, to effectively communicate with the participants. Prior to conducting the interviews, the enumerators underwent a week-long training on the objectives of the study, the survey procedures, and the DCE implementation. This training aimed to ensure consistent and clear execution of the survey and DCE, and to provide comprehensive conceptual explanations to the participants.

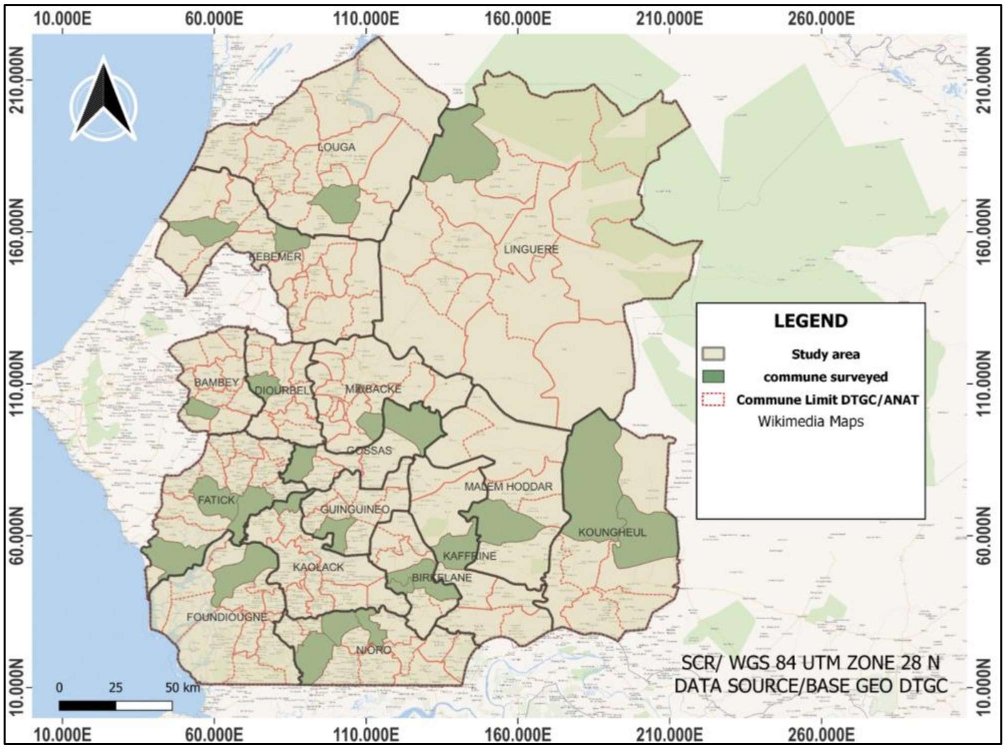


Figure 1 | Study area showing the commune surveyed

4.2 Selection of Attributes

A DCE allows researchers to introduce external variations into a revealed preference situation, facilitating the estimation of the marginal values associated with different product attributes (Fu et al. 2022; Timsina et al. 2016). This method applies the conceptual framework of the Lancaster theory of consumption which suggests that the user derives utility from the characteristics the product possesses rather than from the product itself (Lancaster 1996). In choice experiments, the enumerator presents participants with a series of hypothetical choice scenarios consisting of multiple attributes with varying levels. Participants then select their preferred option from a distinct set of alternatives presented in each choice scenario, based on the given attributes and pre-specified levels. Hence, the selection of appropriate and relevant attributes is a critical aspect of this research.

I used a three-step method to finalize the cowpea varietal traits and their associated levels. First, I conducted an intensive literature review on prior studies related to trait preferences for cowpea, discrete choice methodology, and willingness to pay for crop varieties. The primary aim was to finalize a list of traits that were potentially considered important by cowpea farmers. Moreover, the existing studies helped in identifying disaggregated trait preferences based on several dimensions like gender, age, region, years of experience, etc. Due to the lack of literature on farmers' cowpea trait preferences in Senegal, I considered the studies that focused on stakeholders' trait preferences for cowpea in other West African countries. While I focused on all members of the value chain, the emphasis was mainly on farmers' trait preferences. The primary list of traits was inspired by the seminal paper by Kitch et al. (1998), which classified each cowpea-related trait into three categories – yield, quality, and labor-related (Appendix 1)

In the second stage, I analyzed a quantitative survey conducted by the Senegalese Institute of Agricultural Research (ISRA) in July 2022. The survey aimed to gather an array of socioeconomic and agronomic information on cowpea producers in the Peanut Basin area. This analysis helped me obtain insights into the sociodemographic characteristics of cowpea producers in the area, including plot size, number of cowpea varieties produced, and the primary and secondary cowpea trait preferences identified by the household heads. Based on this analysis, I created a list of the top ten traits to be prioritized in the choice experiment (Appendix 1). However, to reduce the study complexity while maintain the efficiency of choice experiment design, I had to further restrict the number of traits. Previous research suggests that farmers tend to make more realistic choices when presented with a smaller number of attributes in a choice set, reducing the likelihood of disregarding certain attributes in the experiment (Hensher & Greene, 2010).

Therefore, in the final step in this approach, I consulted two cowpea breeders at the Senegalese Institute of Agricultural Research and presented them with the list of 10 traits which were co-evaluated to decide which traits must be included in the choice experiment. Following this approach, decisions regarding trait selection were based on the preferences of cowpea producers, the breedability of traits and the priorities set by the national breeding program for current and future breeding cycles. To illustrate how this process was carried out, consider the example of grain and biomass yield, which were identified as top ranked traits by producers in the baseline survey. In addition, cowpea breeders expressed a strong interest in understanding the tradeoff between these two traits, as cowpea is considered a dual-purpose (food and feed) crop. Given the importance of these traits for both stakeholders and the national breeding program's mandate to breed for dual-purpose cowpea in the next breeding cycle, both grain yield and biomass yield were included in the choice experiment. On the other hand, taste was highly ranked by growers, but the breeders lacked the necessary resources and expertise to breed for taste in the current or upcoming breeding cycles. As a result, taste was excluded from the choice experiment. This approach ensured that the selected traits aligned with the preferences of cowpea producers, the feasibility of breeding for those traits, and the strategic objectives of the national breeding program.

Based on the process defined, six final traits were included in the choice experiment (Table 1). The levels for each non-price attribute were specified in qualitative form (e.g., short and long cycle, instead of providing the exact number of days) since there was not enough evidence in the literature to quantitively construct all levels appropriately.

Table 1 | Attributes and their levels included in the discrete choice experiment

Attribute	Levels 1	2	3	4	Description
Grain Yield	High	Low			The average grain yield obtained per hectare by cultivating a specific cowpea variety
Biomass Yield	High	Low			The average forage yield obtained per hectare by cultivating a specific cowpea
Maturity	Short Cycle	Long Cycle			Length of time between planting and harvesting cowpea variety
Pod Filling	Less Seeds per Pod	More Seeds per pod			The number of seeds per pod produced by cowpea variety
Seed Size	Small	Medium	Large		The size of harvested grain
Price of seeds/Kg (CFA)	450	500	550	600	The cost of purchasing one kilogram bag of cowpea variety in local currency (CFA)

As discussed previously, the reason behind including grain and biomass yield in the choice experiment was driven by producers' and breeders' preferences. The inclusion of maturity in the choice experiment was a response to the long dry spells experienced in Senegal. Given the limited duration of rainfall in the study area, cultivating early maturing varieties is highly needed. This strategy helps farmers mitigate the risks associated with prolonged drought periods, such as increased pest and disease incidence, compromised crop growth and development, and ultimately, reduced yield (Sylla et al. 2023; Karikari et al. 2023). Another trait included in the experiment was seed size, which was categorized into three levels - small, medium, and large. Buyers and consumers generally show a preference for larger grain sizes, resulting in a premium for such seeds (Martey et al. 2022). Since trade in Senegal is often conducted by weight, smaller grain sizes produce less volume within the standard 100 kg bag. Pod filling, on the other hand, was included as a labor-saving trait. The presence of more seeds per pod is associated with easier threshing and seed handling. With a higher quantity of seeds per pod, farmers can obtain a larger number of viable seeds from a smaller number of pods. This feature simplifies the process of seed extraction and reduces labor requirements.

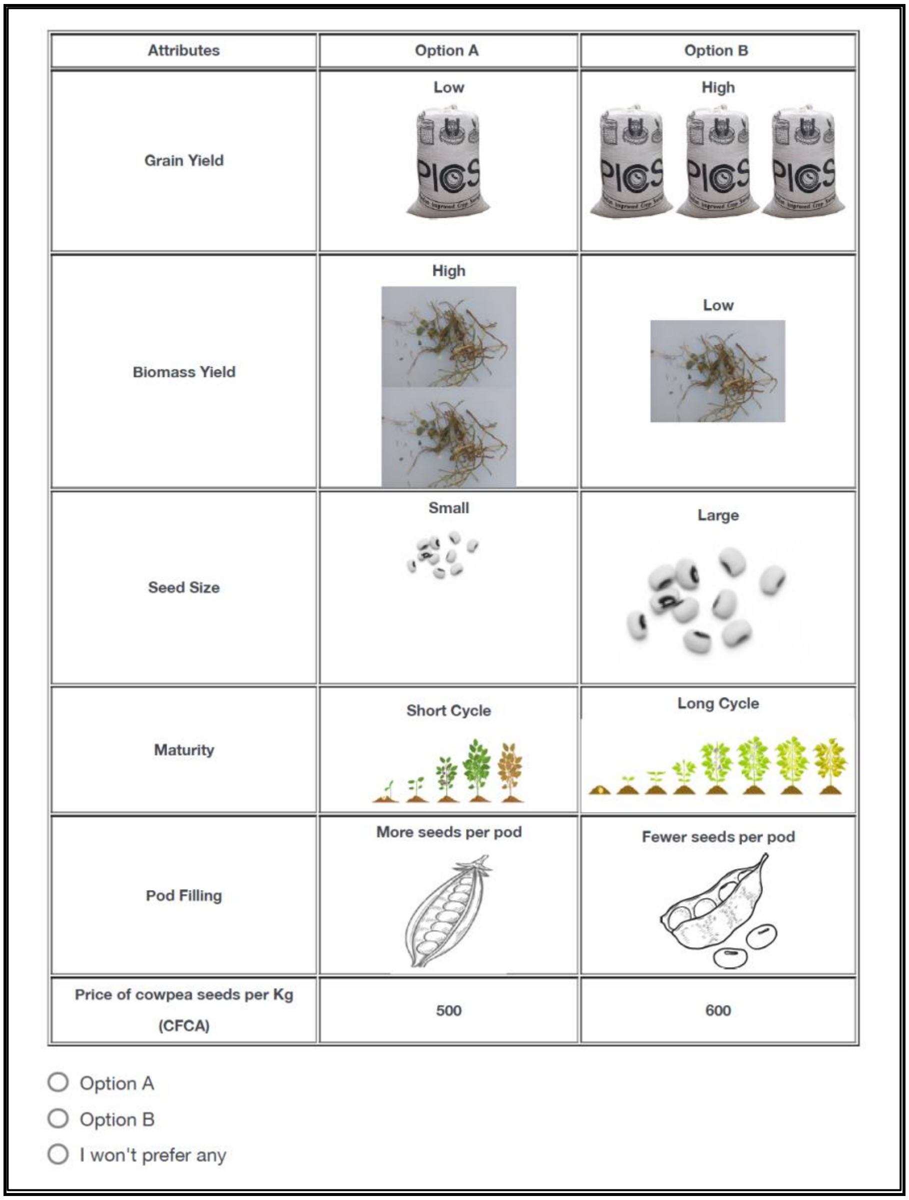
During the planning phase of the study, I carefully considered the price attribute for cowpea varieties. To determine the price levels, I relied on historical estimates spanning over 10 years for the five selected regions. However, considering the recent substantial increase in cowpea seed prices, I excluded price estimates from the last two years[3]. On consulting with local social scientists in Senegal, they confirmed that prices were expected to stabilize once the consequences of the COVID-19 pandemic on value chains subsided. This approach allowed us to account for recent changes in price trends while maintaining reliable historical estimates in our analysis.

4.3 Design of Choice Sets

I used JMP, a statistical software, to create the choice profiles included in the experiment based on the attributes and levels described in Table 1. A full-factorial design of 192 possible combinations (2^4 x 3 x 4) was obtained, given that I had 4 attributes with two levels, 1 attribute with three levels, and 1 attribute with four levels. However, since it is impractical to expect farmers to evaluate 192 choices, I used a D-optimal design using the JMP software. A D-optimal design is an algorithmic approach used in choice experiments to maximize the determinant of the information set used in the design of experiments with multiple treatments. It is designed to maximize the differences in attribute levels across alternatives, provide the best subset of all possible combinations and yield data that enables the estimation of parameters with low standard errors (Kimathi et al. 2022). My generated design had a D-efficiency value of 99.28, indicating a high level of D-optimality (Kuhfeld 2010). Further, I used a blocking strategy to mitigate the potential impact of presenting too many choice tasks on the respondents' decisions, as this helps to improve response efficiency by reducing the cognitive effort required from each respondent (Johnson et al. 2013; Hanley et al. 2002). A fractional factorial design with 24 choice sets was generated and put into three blocks, each consisting of 8 choice sets. Participants in the choice experiment were randomly assigned to one of the blocks and presented with 8 independent choice sets, with the sequence of the sets randomized within each block. Each choice set depicted a real market situation with two alternatives and an opt-out option, and participants were asked to choose their preferred alternative based on the attribute levels presented. To

[3] The price of cowpea seeds in Senegal has increased dramatically in the last two years (2020-2022). This increase could be due to several factors such as impact of COVID-19 pandemic on the value chain, shortage in production, bad weather condition and insect attacks. An instance of this is when I compared the average prices of cowpea seeds in Kaffrine between 2022 and 2020, I found that the prices in 2022 had increased by 58% compared to the average prices in 2020. A similar effect was found for other included regions as well (source: weekly cowpea price data provided by ISRA)

enhance comprehension of alternatives among respondents and improve the quality of choice data, I followed the standard practice of using images to describe the levels for each attribute in the choice set (Patterson et al. 2017). In total, the study gathered 12,960 individual choices (540 farmers x 8 choice sets x 3 alternatives). Figure 2 provides an example of a choice card presented to a farmer[4].



Attributes	Option A	Option B
Grain Yield	Low	High
Biomass Yield	High	Low
Seed Size	Small	Large
Maturity	Short Cycle	Long Cycle
Pod Filling	More seeds per pod	Fewer seeds per pod
Price of cowpea seeds per Kg (CFCA)	500	600

- Option A
- Option B
- I won't prefer any

Figure 2 | Example of choice set presented to a respondent

[4] While the choice sets provided to farmers were in French, I present here an English translated example for illustrative purposes.

4.4 Survey Design and Protocol

I utilized Qualtrics, an online survey software, to create and conduct the intrahousehold survey and the choice experiment (both are reported in full in Appendix II). Unlike other experimental studies that collect data in controlled laboratory settings, this study was conducted in farmers' households. The survey team used electronic tablets to record participants' responses to the choice experiments however, as a backup they also printed physical copies of choice cards in case the farmer felt difficult to assess the choice scenarios digitally.

To facilitate data collection, I leveraged Qualtrics' offline feature, enabling enumerators to download the survey onto their electronic tablets and administer it to farmers in their households. Since most respondents did not speak English, the survey team conducted the surveys in French, the official language of Senegal. In cases where respondents were not familiar with French, the enumerators were trained to conduct the survey in Senegal's local language (Wolof). To ensure consistency between the two languages, I initially drafted the survey in English and then translated it to French with the help of the research team in ISRA. I subsequently back-translated it to English and resolved any differences in word choice through discussions with both parties.

The interview began by providing the respondent with an explanation of the research objectives and their importance as a stakeholder in achieving those objectives. The interview started only after the farmer provided oral consent and demonstrated their understanding of the research conditions. The survey was divided into three sections. In the first section, enumerators asked farmers about their socioeconomic and farming-related information such as age, gender, region, marital status, education level, primary occupation, household size, involvement with farmer association, crops produced, land size, and their income through cowpea production. Additionally, they asked respondents to fill out a household roster and specify which members were involved in cowpea production. In the second section, respondents identified the major decision-maker(s) in their household for activities related to cowpea production, including pre-harvest decisions such as choosing the cowpea variety, input usage, land allocation, and intercropping; harvest decisions such as the timing of harvest; and post-harvest decisions such as determining what to do with the harvested cowpea crop. Taking inspiration from the WEAI 2016 questionnaire, I designed these questions in a multiple-choice format with four options: *the respondent alone/the respondent's spouse alone/the respondent and spouse together / other members in the household.* This module aligns closely with traditional intra-household agricultural indices such as the WEAI (Alkire et al., 2013) and draws inspiration from tools utilized in studies focusing on intra-household bargaining outcomes and technology preferences (e.g., Akresh, 2005; Chiappori et al., 2002; Anderson et al., 2017). However, decision-making is not the sole factor determining intra-household trait preferences. Research indicates that experience, often represented by age, influences crop management decisions within the household (Amare et al., 2018; Deressa et al., 2009). Similarly, the amount of time spent working on the plot where the specific crop is cultivated has been observed to shape intra-household roles related to crop management (Udry, 1996). In line with these studies, I enriched the intrahousehold survey by adding a module on household member's crop experience and a module on time commitment to the household's cowpea plot. In these modules, participants reported the number of years of cowpea cultivation experience for each member involved in cowpea production and provided information on their level of engagement in each cultivation stage. This section helped us to evaluate the role of husband and wife in cowpea crop management within their household.

In the last section, the enumerators presented the respondents with a choice experiment where they were shown pictorial choice sets and asked to choose their preferred option. Since the stated preference methods are based on hypothetical scenarios and do not involve actual monetary transactions, they are susceptible to hypothetical bias. Therefore, I used the Cheap Talk (CT) and Repeated Opt-Out Reminder (OOR) strategies to mitigate this bias in this study. Before the experiment enumerators explained the instructions and defined each seed attribute and associated levels using CT. Further, they requested the participants to provide honest answers, as the results of the study could lead to the production of new cowpea seeds marketable to them. During the experiment, the enumerators used OOR to remind the farmers to consider the “no option” if the price levels in both alternatives exceeded their general budget.

Overall, the experimental protocol along with the choice experiment design and related scripts were approved by the Internal Review Board (IRB), at Cornell University (protocol no: IRB0146740) ensuring that it adhered to the ethical standards.

5. Empirical Methodology

5.1 Creation of Decision-Making Index

Studies have shown that a farmer's ability to acquire and choose their preferred seeds is closely linked to their specific context and can be subject to change based on various factors such as their social standing, the importance of the crop in their farming system, and the ecological conditions of their area (Almekinders et al. 2019). As more intrahousehold level data becomes available, practitioners are increasingly directing their attention towards understanding household dynamics and decision-making processes and their impact on different outcomes, particularly in agriculture (Acosta et al. 2020; Bernard et al. 2019; Singh et al. 2016). Given the significant temporal and spatial variations in intrahousehold decision-making and resource allocation, it becomes crucial to gather context-specific information that delves into the intricacies of decision-making processes at the household level. While it is often assumed that the male spouse or husband takes the role of the household head and primary decision-maker in farming households, there is a growing recognition that prompts us to question this assumption and strive for a deeper understanding of intra-household decision-making dynamics (Meijer et al., 2015; Rogan et al., 2013; Deere et al., 2012).

In line with this, I create a decision-making index for each participant to quantify their decision power in cowpea cultivation. The index considers the decision authority of individuals in pre-harvest, harvest, and post-harvest activities related to cowpea cultivation. It not only identifies the primary decision-maker for cowpea cultivation within the household but also acknowledges the possibility of a non-household head assuming responsibility for these activities. By considering this possibility, the index provides a comprehensive perspective on decision-making dynamics within the household, going beyond traditional measures. It allows for a more nuanced understanding of how decisions regarding cowpea cultivation are made and the influence of different individuals within the household.

While examining intrahousehold decision making dynamics, a significant hurdle is the inability to measure individual bargaining power directly. To overcome this, researchers employ a variety of proxies, such as individual's involvement in decision-making, potential income, assets, legal frameworks, education, and other financial, and economic indicators (Doss 2014). Following Bernard et al. (2019)[5], I create decision-making indicators using the "who decides" questions included in the survey, which are then aggregated into an index of individuals' decision-making[6]. The idea is to create a farmer's decision-making index from questions related to pre-harvest, harvest, and post-harvest decisions with equal weight assigned to each category (Table 2). This approach acknowledges that the choice of seed variety, typically made before the harvest stage, has significant implications for subsequent activities during the harvest and post-harvest stages. For instance, different seed varieties may exhibit variations in maturation times, yield potential, and resistance to pests and diseases, influencing factors such as harvest timing, produce quantity and quality, and storage or processing requirements. Consequently, individuals overseeing the post-harvest or harvest stage possess the ability to influence the household's selection of a specific seed. They ensure that the chosen seed aligns with their specific cultivation stage objectives (Melomey et al. 2022; Paris et al. 2008). Building upon this understanding, I consider the decision-making roles of individuals at different stages of cowpea cultivation to calculate their respective decision-making index.

Table 2 | Classification of decision-making questions based on crop cultivation stage

Pre - Harvest	Harvest	Post-Harvest
Purchase of cowpea variety Usage of inputs Cowpea intercropping Land allocation for cowpea cultivation	Timing of cowpea task and harvest	Usage of Cowpea Harvested Crop

[5] While Bernard et al. (2019) utilize vignettes to investigate intrahousehold decision-making in agricultural households, this study diverges in terms of methodology and research objective.

[6] It is important to note that the survey collected data on farmers' time use and farming experience. However, to align with the research objective and maintain simplicity in the composition of the decision-making index, I only utilized the data collected through the decision-making module included in the survey. I did not find any evidence or previous studies that combined factors such as farmers' experience, time, and decision-making to create an index. A potential area for future work would involve devising methods to create a more comprehensive decision-making index for household members by incorporating data on other crop management factors, such as time and farming experience.

I calculate the farmer's decision-power index for each question as:

$$index_Q = \begin{cases} 1\ if\ farmer\ selects\ \text{"}respondent\ alone\text{"} \\ 0\ if\ farmer\ selects\ \text{"}spouse/others\text{"} \\ 0.5\ if\ farmer\ selects\ \text{"}joint\ decision\text{"} \end{cases}$$

$$where\ Q = decision\ making\ questions\ in\ Table\ 2$$

Based on the above-computed values, I generate a crop management index for each stage of cowpea cultivation, which represents farmers' decision power for that specific production stage. Each index is a continuous variable ranging from 0 to 1, where a higher value indicates a greater decision influence pertaining to the respective stage. The index for each stage is calculated as follows:

$$index_{preharvest} = \frac{index_{input} + index_{intercrop} + index_{variety} + index_{land}}{4} \tag{1}$$

$$index_{harvest} = index_{cowpea\_task\_harvest} \tag{2}$$

$$index_{postharvest} = index_{cowpea\_postharvest\_usage} \tag{3}$$

Finally, I calculate the farmer's overall decision index as the mean of the crop management decision indices.

$$Decision\ Index = \frac{index_{preharvest} + index_{harvest} + index_{postharvest}}{3} \tag{4}$$

To identify the decision-maker within each household, I compare the individual decision index of husbands and wives from the same household. The person with the higher decision index is assigned a value of 1, indicating their role as the decision-maker. Subsequently, I incorporate this dummy variable (*DM*) into the regression analysis to account for the influence of the household decision-maker on trait preferences for cowpea. Particularly, if *i* and *j* are two individuals from the same household then,

$$DM_i = \begin{cases} 1\ if\ Decision\ Index_i \geq Decision\ Index_j \\ 0\ otherwise \end{cases}$$

5.2 Econometric Model

The approach to modeling individual choice behavior is based on the econometric framework of the random utility theory (McFadden 1973, 2001), which offers a structured methodology for analyzing individual preferences and decision-making. This theory assumes that individuals make choices based on their preferences for different alternatives and the associated utility they derive from each alternative. In the present study, each farmer *i* faces *j* cowpea variety alternatives from which they obtain utility U_{ij}. A farmer would choose alternative *j* over alternative *k* if, $U_{ij} > U_{ik}$ $\forall j \neq k$. As per random utility theory, a participant's utility function contains a deterministic component, V_{ij}, observed by the researcher through alternative specific attributes X_{ij} and estimated preference parameter β, and an unobservable random error term ε_{ij} and is specified as:

$$U_{ij} = V_{ij} + \varepsilon_{ij}$$
$$U_{ij} = \beta X_{ij} + \varepsilon_{ij} \quad (5)$$

In equation (5) the deterministic part, V_{ij} is parameterized by the vector of coefficients β, which allows to estimate the effect of the variable X_{ij} on utility. Using this I can present the probability of farmer *i* selecting alternative *j* as:

$$P_{ij} = Prob(V_{ij} + \varepsilon_{ij} > V_{ik} + \varepsilon_{ik} \forall j \neq k) \quad (6)$$

A logit model assumes that ε_{ij} is independently and identically distributed (iid) across alternatives in the choice set and follows an extreme type 1 distribution. By using this assumption, I can derive a closed-form formula for the choice probability that individual *i* will choose alternative *j* among *J* choices as (Mc Fadden 1973):

$$P_{ij} = \frac{\exp(\beta X_{ij})}{\sum_{k=1}^{k=J} \exp(\beta X_{ik})} \quad (7)$$

However, this assumption implies that the unobserved factors are uncorrelated over alternatives and have the same variance for all alternatives, which may not always hold. To address this issue and account for preference heterogeneity among farmers, I employ a Mixed Logit (or Random Parameters Logit) model in this paper. Compared to other models like multinomial, conditional, and standard logit, Mixed Logit is a highly flexible model that permits heterogeneity across individuals and time, and it overcomes the limitations of the conditional logit model by allowing for random taste variation, unrestricted substitution patterns, and correction in unobserved factors over time, thereby relaxing the assumption of independence from irrelevant alternatives (IIA) (Train 2009). The only difference between the Mixed Logit and Conditional Logit model is that the response parameter now varies over decision makers, *i*. Let $\bar{\beta}$ be the vector of mean attribute utility weights in the sample and σ_i be the vector representing farmer *i* specific deviation from the mean, then the Mixed Logit utility function can be specified as:

$$U_{ij} = \beta_i X_{ij} + \varepsilon_{ij} \tag{8}$$

where, X_{ij} are observed cowpea attribute variables associated with the alternative and decision-makers, β_i is a vector of coefficients of these variables for farmer *i* representing their tastes, and ε_{ij} is a random term with iid extreme value. The coefficients vary among decision-makers in the population with density $f(\beta)$. Therefore, conditional on observing β_i, we can write the logit probability as:

$$P_{ij} = \frac{\exp(\beta_i X_{ij})}{\sum_{k=1}^{k=J} \exp(\beta_i X_{ik})} \tag{9}$$

However, researchers cannot observe β_i as its coefficients are random, therefore the logit probability is found by taking the expectation over the distribution of heterogeneity of decision-makers:

$$P_{ij} = \int \frac{\exp(\beta_i X_{ij})}{\sum_{k=1}^{k=J} \exp(\beta_i X_{ik})} f(\beta)\, d\beta \tag{10}$$

Unlike the conditional logit model, there is no closed-form solution for the mean utility in the mixed logit case. I estimate the mixed logit models in this study using the maximum likelihood simulation method in STATA with 100 Halton draws[7] (Train 2009). Additionally, this study assumes all variables to be random and normally distributed. I depart from other studies by considering the price variable as random, as there may be considerable preference heterogeneity regarding price. Meijer and Rouwendal (2006) observed that

[7] Train (1999) and Bhatt (1999) found simulation variance in the estimation of mixlogit parameter to be lower with 100 Halton draws than with 1000 random draws. (https://escholarship.org/content/qt6zs694tp/qt6zs694tp.pdf)

allowing the price coefficient to vary enhances the model fit, despite the downsides identified by Revelt and Train (1998).

A common approach to address preference heterogeneity in the analysis of DCEs is to estimate the logit models with interactions between alternative specific attributes and socio-demographic/respondent characteristics (Asrat et al. 2010; Hole 2008; Scott 2001). It is not possible to estimate the effects of attributes of the decision maker that do not vary across alternatives, such as age or gender. Hence researchers create or measure variables that vary across both alternatives and decision-makers to include them in the model (Train 2009 and Mazzanti 2003). The inclusion of demographic variables impacts the utility differences through their interaction with the alternative attributes. Following Martey et al.(2022) and Asrat et al. (2010) key farmer characteristics enter the utility framework through interaction with the attributes. I can rewrite equation (8) as follows:

$$U_{ij} = \beta_i X_{ij} + \lambda_i Z_{ij} + \varepsilon_{ij} \tag{11}$$

where X_{ij} is the vector of choice-specific cowpea attributes and Z_{ij} is a vector interaction between farmers' decision-making variables (such as decision-maker dummy and decision-making index for each stage of cultivation) and choice attributes. β and λ are the respective parameter estimates.

I estimate Model 1 below by including only the cowpea variety attributes (grain yield, biomass yield, maturity, pod filling, seed size, and price) as explanatory variables and estimate its main effect on farmers' choice utility. The utility derived by farmer *i* from choosing cowpea bundle *j* at choice occasion *t* is shown as:

$$U_{ij\,t} = \beta_1 Price_{ijt} + \beta_2 GrainYield_{ijt} + \beta_3 BiomassYield_{ijt} + \beta_4 Maturity_{ijt} + \beta_5 PodFilling_{ijt} + \beta_6 SeedMedium_{ijt} + \beta_7 SeedLarge_{ijt} + \varepsilon_{ijt} \tag{12}$$

Here the dependent variable is a binary variable defined as 1 if farmer *i* chooses cowpea alternative *j* in a choice set *t*. I encode all non-price attributes in the model using a dummy variable. The base level for each attribute, is not included in the model, and is used as the reference to compare all the other attribute levels. The base level used across all model specifications is low grain yield, low biomass yield, long maturity, fewer seeds per pod, and small seed size. Table 3 below shows the non-price variables description along with the base category for each attribute.

Table 3 | Non-price attribute variables included in econometric analysis

Variable	Definition	Levels
Grain Yield	Grain Yield = 1 if high yield, 0 otherwise	• Low (Base) • High
Biomass Yield	Biomass Yield = 1 if high biomass yield, 0 otherwise	• Low (Base) • High
Maturity	Maturity = 1 if short maturity, 0 otherwise	• Long (Base) • Short
Pod Filling	Pod Filling = 1 if more seeds per pod, 0 otherwise	• Fewer seeds per pod (Base) • More seeds per pod
Seed Medium Seed Large	Seed Medium= 1 if seed size is medium Seed Large = 1 if seed size is large	• Small (Base) • Medium • Large

To identify the trait preferences of cowpea farmers with and without decision-making powers, I extend Model 1 and include the interactions of attributes with farmer-specific dummy variable for decision makers (*DM*), where *DM* is equal to 1 if the individual has a higher overall decision-making influence in all cowpea cultivation stages within a household and zero otherwise. I define Model 2 as:

$$U_{ij\,t} = \beta_1 Price_{ijt} + \beta_2 GrainYield_{ijt} + \beta_3 BiomassYield_{ijt} + \beta_4 Maturity_{ijt} + \beta_5 PodFilling_{ijt} + \beta_6 SeedMedium_{ijt} + \beta_7 SeedLarge_{ijt} + \beta_8 (Price_{ijt} * DM_i) + \beta_9 (GrainYield_{ijt} * DM_i) + \beta_{10} (BiomassYield_{ijt} * DM_i) + \beta_{11} (Maturity_{ijt} * DM_i) + \beta_{12} (PodFilling_{ijt} * DM_i) + \beta_{13} (SeedMedium * DM_i) + \beta_{14} (SeedLarge_{ijt} * DM_i) + \varepsilon_{ijt} \quad (13)$$

Next, I estimate three models to examine differences in trait preferences among farmers based on their level of decision-making influence in crop management roles before harvest, during harvest, and after harvest. To achieve this, I interact the cowpea attributes with the continuous decision index (defined previously) for each stage of the crop management process. I define the three models as:

$$U_{ijt} = \beta_1 Price_{ijt} + \beta_2 GrainYield_{ijt} + \beta_3 BiomassYield_{ijt} + \beta_4 Maturity_{ijt} + \beta_5 PodFilling_{ijt} + \beta_6 SeedMedium_{ijt} + \beta_7 SeedLarge_{ijt} + \beta_8 (Price_{ijt} * index_{H_i}) + \beta_9 (GrainYield_{ijt} * index_{H_i}) + \beta_{10} (BiomassYield_{ijt} * index_{H_i}) + \beta_{11} (Maturity_{ijt} * index_{H_i}) + \beta_{12} (PodFilling_{ijt} * index_{H_i}) + \beta_{13} (SeedMedium * index_{H_i}) + \beta_{14} (SeedLarge_{ijt} * index_{H_i}) + \varepsilon_{ijt} \quad (14)$$

$$\text{where H} = \text{preharvest, harvest, and postharvest}$$

5.3 Bundle Probability Analysis

Following Kolstad 2011, Ryan et al. 2012 and Wasserman 2020, I use DCE output to look at how the probability of choosing a cowpea variety changes as the levels of attributes change. To analyze the utility of the cowpea bundle, I use the coefficients from Model 1 and transform them into probabilities of selection as compared to the base level. I calculate the utility of the cowpea bundle as:

$$U_b = \beta_1 Price_b + \beta_2 GrainYield_b + \beta_3 BiomassYield_b + \beta_4 Maturity_b + \beta_5 PodFilling_b + \beta_6 SeedMedium_b + \beta_7 SeedLarge_b \, , \quad (15)$$

where bundle utility (b) is the sum of the utility for each attribute category (Lemmens n.d). The attribute categories in bundle b are dummy variables, taking the value 1 if included and 0 if not. To find the probability of selecting each bundle relative to the base bundle, I transform the ordinal utility calculations into odds. In this analysis, all probabilities indicate the likelihood of selecting a particular bundle in comparison to the base bundle. I consider the base bundle as a cowpea variety with a price of 450 CFA, low grain and biomass yield, long maturity, fewer seeds per pod, and small seed size.

$$Odds_b = e^{U_b} \quad (16)$$

$$P_b = \frac{Odds_b}{Odds_b + Odds_{base}} \quad (17)$$

6. Results and Discussion

6.1 Farmers' Socio-Demographic Characteristics

Table 4 presents the descriptive statistics of the farmers surveyed in the study, highlighting their characteristics. By following an intrahousehold protocol, this study ensures an equal representation of both genders in the sample. Notably, all households interviewed in the study area are headed by males. The male farmers surveyed have an average age of 54 years, whereas their female counterparts have an average age of 41 years. The average household size is approximately 11 people, with around 62% of the respondents having a monogamous marital status. An intriguing finding emerges regarding membership in farmer cooperative associations, with only 28% of the male farmers considering themselves as members, but higher than the 20% for the female farmers. Additionally, it is interesting to note that 27% of the male farmers sold cowpea harvest last year, while the corresponding percentage for female farmers is 32%. This suggests a slightly higher inclination among females to value cowpea for commercial purposes. However, since the majority of farmers do not sell cowpea, these statistics suggest that cowpea cultivation in the study region is primarily used for household or livestock consumption. The number of cowpea plots owned by respondents ranges from 1 to 12, with an average of 1.68 for males and 1.44 for females. Moreover, most male farmers (78%) and female farmers (87%) own less than 3 hectares of land for cowpea cultivation. This indicates that the sample predominantly consists of small-landholder farmers. Further analysis reveals that household members' involvement in cowpea cultivation ranges from 2 to 15 individuals, with an average of 6 members per household participating. This signifies an increasing dependence on household labor for farming activities in the study locations.

Additionally, the data reveals that 76% of males and 69% of females are responsible for managing their cowpea plots, while the remaining individuals provide labor support to spouse-managed fields or household plots. When examining regional breakdown, Fatick exhibits the highest participation rate in the study at 26.67%, followed by Kaffrine at 24.81%, and Louga at 17.78%. Regarding education levels, there is a disparity between male and female farmers, with the majority having little or no formal education in French (males: 76%, females: 84%). Interestingly, a significant proportion of participants, both males (83%) and females (81%), consider agriculture as their primary activity. However, it is important to note that a small percentage of males (5%) and females (15%) cite trade as their primary activity. Furthermore, a subset of males (11%) engage in occupations such as being a driver, teacher, religious singer, or livestock farmer and consider it as their primary activity. Although their primary activities are not exclusively agriculture-related, as household heads, they actively participate in making crucial cowpea related farming decisions, which warranted their inclusion in the study.

Furthermore, there is a difference in cowpea farming experience between male and female farmers, with 79% of males and 64% of females having more than 20 years of cowpea cultivation experience, demonstrating their considerable expertise in the field. Unlike previous studies that assume the household head as the sole decision-maker (Diarra et al. 2021), the decision-making index calculation identifies household members with decision-making power based on their primary roles in cowpea crop management. The analysis reveals that 51% of farmers associate themselves as decision-makers, with 15% being women and 85% being men (Figure 3). In our sample, seven households have equal decision-making indices for both the husband and wife, making them identify as decision-makers of the household. These households have large family sizes, averaging 10 members, with 50% of them having 2 or more cowpea plots, allowing for individual management of their own plots. For such households, both the household head and spouse were categorized as decision-makers.

Table 5 presents a breakdown of decision makers across the three stages of cowpea cultivation, disaggregated by gender. The analysis reveals that male farmers predominantly hold decision-making authority in the pre-harvest (89.8%) and harvest (79.3%) stages. However, a shift in power dynamics is observed in the post-harvest stage, where a higher percentage of female farmers (52.4%) are identified as decision makers.

Table 4| Descriptive statistics of selected farmer characteristics

Total Number of Households= 270; Total Participants=540

Variable	Definition of Variable	Mean	SD	Min	Max				
sex	Gender of the respondent (1=male; 0=female)	0.5	0.5	0	1				
hhsize	Size of the household	11.33	5.09	2	30				
maritalstatus	Marital Status (1=monogamous; 0=polygamous)	0.62	0.48	0	1				
cowpeahhmember	Number of household members involved in cowpea production	6.53	2.64	2	15				
		Male (n =270)				**Female (n =270)**			
		Mean	SD	Min	Max	Mean	SD	Min	Max
age	Age of the respondent (in completed years)	54.77	12.59	25	98	41.22	11.63	18	72
memberassociation	Member of farmer cooperative association (1=yes; 0=no)	0.28	0.45	0	1	0.20	0.40	0	1
sellcowpea	Whether the respondent usually sells cowpea harvest (1=yes; 0=no)	0.27	0.44	0	1	0.32	0.46	0	1
cowpea_plot_own1	Total number of cowpea plots owned by respondent	1.68	1.20	1	12	1.44	1.12	1	12
cowpea_plot_manage1	Whether the respondent manages their cowpea plot (1=yes; 0=no)	0.76	0.42	0	1	0.69	0.46	0	1

Variable	Categories	Observation	% of total sample		
region	Kaffrine	134	24.81		
	Diourbel	72	13.33		
	Fatick	144	26.67		
	Kaolack	94	17.41		
	Louga	96	17.78		
		Male (n = 270)		**Female (n =270)**	
		Observation	% of total male sample	Observation	% of total female sample
edu_french	No Education	207	76.66	228	84.44
	Elementary	47	17.40	32	11.85
	Average	9	3.33	7	2.59
	Secondary	3	1.11	3	1.11
	University	4	1.48	0	0
cowpealand_size	Less than 3 Ha	211	78.14	237	87.77
	3-5 Ha	44	16.29	28	10.37
	5-8 Ha	14	5.18	5	1.85
	More than 8 Ha	1	0.37	0	0
cowpea_experience	Less than 5 years	17	6.29	17	6.29
	5-10 years	5	1.85	26	9.62
	11-15 years	9	3.33	26	9.62
	16-20 years	24	8.88	27	10
	More than 20 years	215	79.62	174	64.44
primaryactivity	Agriculture	225	83.33	219	81.11
	Commerce	15	5.55	43	15.92
	Others	30	11.11	8	2.96

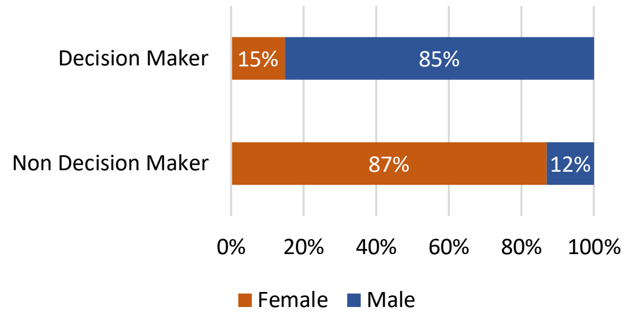


Figure 3 | Disaggregation of decision-makers basis gender

Table 5| Gender-disaggregated breakdown of decision makers in three stages of cowpea cultivation

Cowpea Cultivation Stage	Male	Female
Pre-Harvest	89.8%	10.1%
Harvest	79.3%	20.6%
Post-Harvest	47.5%	52.4%

6.2 Mixed Logit Model Results

6.2.1 Farmers' Preferences for Cowpea Attributes

The estimated coefficients of cowpea attributes of the Mixed Logit Model 1 are shown in Table 6. This model evaluates the influence of independent cowpea attributes on farmers' choice utility and signals their preferences for each trait. As discussed, Model 1 does not account for any decision-making characteristic of farmers. The model comprises 12,960 choice observations with a corresponding log-likelihood value of -2527. In addition, I report the model's Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values where it is generally accepted that a smaller value indicates a better fit of the model. As seen in the table, all the mean attribute coefficients are statistically significant at the 1% level. The findings support the hypotheses that there is heterogeneity among individuals for preferences between different levels of attributes, except for medium seed size, as the reported standard deviations are statistically significant at the 1 percent level.

Table 6 | Mixed logit estimates for choice of cowpea traits

	Mean		Standard Deviation	
Variables	Coefficients	Standard Error	Coefficients	Standard Error
Price	0.171***	(0.0399)	0.528***	(0.0383)
Grain Yield	2.068***	(0.115)	1.569***	(0.120)
Biomass Yield	1.318***	(0.0962)	1.365***	(0.120)
Maturity	1.209***	(0.0961)	1.416***	(0.103)
Pod Filling	0.507***	(0.0702)	0.884***	(0.107)
Medium Seed Size	0.378***	(0.0895)	0.0784	(0.210)
Large Seed Size	0.716***	(0.0930)	-0.775***	(0.139)
Observations	12,960			
LL	-2527			
AIC	5082			
BIC	5187			

Note: *** denotes significance at 1%

The estimated coefficients in Mixed Logit Model 1 provide insights into farmers' trait preferences for cowpea varieties in Senegal. The positive signs of the two yield coefficients indicate that farmers prefer cowpea varieties with high grain and biomass yields, as opposed to low-yield varieties. This finding aligns with the results of Martey et al. (2022) in Ghana, where they found that farmers are less likely to adopt cowpea varieties with low grain yield and perceive them as less desirable. Similarly, Horn et al. (2015) reported that cowpea farmers in Northern Namibia prioritize high above-ground biomass as their most preferred trait. Additionally, Kitch et al. (1998) demonstrated that farmers in Northern Cameroon select cowpea breeding lines based on grain and fodder yield during on-station trials. The descriptive statistics highlight that most farmers in the study area do not sell their cowpea harvest, indicating that their preference for high grain yield may be driven by the crop's predominant use for self-consumption. During discussions with the farmers, it became apparent that households with livestock use cowpea as a source of animal feed, thereby explaining their association of higher utility with a high biomass yield. Moreover, farmers take advantage of the surplus forage yield by selling it in local markets, enabling them to earn additional income. This establishes biomass yield as a desirable trait that holds market value.

Given that cowpea is valued for its dual-purpose use, it is important to understand the trade-offs and priorities that farmers have regarding grain and biomass yield in cowpea. In a scenario where both grain and biomass yields are low, the comparison of the yield coefficients indicates that farmers would achieve a greater utility and value a cowpea variety and with a high grain yield more than a variety with high biomass yield. More on this topic is discussed in *Section 6.3: Bundle Utilities and Probabilities*, where further insights are provided on the utilities associated with different traits.

The coefficient of Maturity and Pod Filling suggest that farmers exhibit a stronger preference for short maturity compared to long maturity, and for more seeds per pod over fewer seeds per pod. Senegal's short rainy season can be one of the potential reasons behind farmers' preference for short maturity. Cavatassi et al. (2011) reported that early maturity in crop varieties helps sorghum farmers in Eastern Ethiopia cope with drought by allowing for production during the short rainy season and enabling double planting on the same plot. Moreover, early maturity in cowpea allows farmers to avoid pest and disease infestation that typically occurs at a later stage of cropping season (Owusu et al. 2021). The preference for more seeds per pod can be viewed as a labor-saving trait, as it reduces the effort required for threshing a given quantity of seeds, as highlighted by Kitch et al. (1998). Furthermore, our analysis indicates that farmers, in general, prefer cowpea varieties with larger or medium seed sizes over those with smaller seed sizes. Similar studies conducted in Senegal and other West African countries have also shown a preference for larger seed sizes among cowpea value chain actors. They believe that consumers in West African regions are willing to pay a premium for such quality (Mohammed et al. 2021; Bolarinwa et al. 2021; Mishili et al. 2009; Faye et al., 2004; Langyintuo et al. 2003).

It is surprising to note that the model yields a positive coefficient for the price attribute. This suggests that farmers show a preference for adopting a higher-priced cowpea seed variety. This preference may be attributed to the design of the choice experiment, which does not explicitly account for seed quality, leading farmers to intuitively associate higher costs with better-quality inputs. Farmers' positive preference for higher input or seed costs reflects their willingness to pay more for high-quality farm inputs (Oyinbo et al., 2019). This finding aligns with other studies, such as Palma et al. (2016) and Lambrecht et al. (2015), which indicate that a positive cost preference can be interpreted as a signal of quality in choice modeling. As the study does not explore the trait preferences of current improved cowpea seed varieties, farmers rely on their desired traits and expectations for seed quality when making future seed purchases. Among the various cues considered, price plays a crucial role in shaping the perceived quality of the seed. Leavitt (1954) emphasizes the association of higher prices with higher product quality, a notion commonly held by stakeholders. Similarly, Birol et al. (2011) found that farmers in Maharashtra, India, preferred higher-priced pearl millet seed, interpreting it as a preference for quality. Additionally, Lambrecht et al. (2015) observed that farmers facing lower to moderate food insecurity and having access to input credit did not exhibit a significant preference for seed prices.

Furthermore, the findings of Beye et al. (2022) support our positive price results, as they found that cowpea farmers in the Senegal Peanut Basin Area consider price as a secondary selection criterion when making seed adoption decisions. Their survey revealed that only 5.8% of the farmers identified high prices as a barrier to adopting improved cowpea varieties, while 29% of farmers prioritized affordable seed prices as their main attribute preference. It is important to note that the price levels used in our experiment do not reflect the current market prices, which have significantly increased due to external factors such as disruptions in supply chains accruing to the COVID-19 pandemic. This disparity between experimental and actual prices could explain the positive price coefficient in our model. Farmers may perceive the price increase as a long-term trend rather than a short and reversible fluctuation, contrary to the views of social scientists. The experiment's proposed prices are lower than the prevailing market prices that farmers encounter. As a result, farmers may choose the choice card with the highest price and preferred traits, as they are willing to pay the stated price, which is still lower than the prevailing market rates.

6.2.2 Influence of Crop Decision-Making Index on Cowpea Trait Preferences

Table 7 displays the results of Model 2, illustrating the preferences of decision-maker farmers compared to non-decision makers regarding cowpea attributes. The findings indicate that decision-makers among farmers place a higher value on biomass yield than non-decision makers, supporting the assumption that they prioritize traits that have market value and can generate additional income. The limited availability of forage in breeding areas, such as Kebemer (a town in north-west Senegal), prompts herders to migrate seasonally towards the peanut basin, especially during the dry season. This movement of herders and their livestock creates a demand for cowpea fodder, which explains why farmers in the study region select and prefer cowpea varieties with higher yields of forage (Beye et al. 2022). This observation also aligns with the fact that men typically control the income derived from the sale of biomass, and since the majority of men are identified as decision-makers in the analysis, their preference for biomass yield is understandable.

Additionally, it indicates that decision-makers value cowpea more for its forage use than for consumption needs. In West and Central Africa, farmers have been found to obtain up to 25% of their annual income by cutting and storing cowpea fodder for subsequent sale during the peak of the dry season, which suggests that farmers prefer biomass production as a means of generating additional income sustainably (Digrado et al. 2022).

Furthermore, they exhibit a greater preference for short-maturity cowpea varieties compared to long-maturity ones, likely due to their knowledge of cowpea cultivation and their risk-averse nature. Decision makers also show a higher preference for small seed size over medium size relative to non-decision makers. This could be driven by their motive to increase the number of seeds per kilogram when planting and household utilization, as explained by Martey et al. (2022).

Table 7 | Mixed logit estimates for choice of cowpea traits (decision makers relative to non-decision makers)

	Mean		Standard Deviation	
Variables	Coefficients	Standard Error	Coefficients	Standard Error
Price	0.174***	(0.0516)	0.514***	(0.0423)
Grain Yield	2.234***	(0.148)	1.549***	(0.126)
Biomass Yield	0.790***	(0.110)	1.033***	(0.136)
Maturity	1.060***	(0.132)	1.428***	(0.115)
Pod Filling	0.463***	(0.0995)	0.864***	(0.118)
Medium Seed Size	0.582***	(0.127)	-0.0875	(0.215)
Large Seed Size	0.812***	(0.135)	-0.885***	(0.139)
Price*DM	0.0193	(0.0777)	-0.453***	(0.0608)
Grain*DM	-0.212	(0.192)	0.598*	(0.312)
Bio*DM	1.203***	(0.186)	1.305***	(0.185)
Maturity*DM	0.381**	(0.180)	-0.494*	(0.282)
Pod*DM	0.192	(0.143)	-0.410*	(0.248)
Medium Seed Size*DM	-0.425**	(0.181)	-0.0715	(0.236)
Large Seed Size*DM	-0.178	(0.189)	0.232	(0.230)
Observations	12,960			
LL	-2498			
AIC	5052			
BIC	5261			

Note: ***, ** and * denote significance at 1%, 5% and 10%

6.2.3 Trait Preferences Based on Decision-Making Influence in Crop Cultivation Stages

In Table 8 I explore the difference in trait preferences among farmers based on their level of decision-making influence in each stage of cultivation. For ease of comparison, I only present the mean coefficients of all three models.

Table 8 | Mixed logit estimates for choice of cowpea traits after accounting for decision influence in each stage

	Model 3	Model 4	Model 5
Variables	Preharvest	Harvest	Post-Harvest
Price	0.261***	0.169***	0.138**
	(0.0740)	(0.0579)	(0.0577)
Grain Yield	2.181***	2.113***	1.833***
	(0.201)	(0.168)	(0.155)
Biomass Yield	0.530***	0.804***	1.345***
	(0.154)	(0.120)	(0.151)
Maturity	1.106***	1.157***	0.884***
	(0.193)	(0.149)	(0.144)
Pod Filling	0.622***	0.606***	0.558***
	(0.146)	(0.117)	(0.110)
Seed Medium	0.542***	0.444***	0.518***
	(0.184)	(0.143)	(0.143)
Seed Large	0.787***	0.747***	0.719***
	(0.187)	(0.150)	(0.150)
Price*preharvest	-0.0874		
	(0.109)		
Grain*preharvest	0.0246		
	(0.305)		
Bio*preharvest	1.601***		
	(0.277)		
Maturity*preharvest	0.317		
	(0.298)		
Pod*preharvest	-0.123		
	(0.227)		
Medium Seed Size*preharvest	-0.305		
	(0.291)		
Large Seed Size*preharvest	-0.103		
	(0.298)		
Price*harvest		0.0272	
		(0.0742)	
Grain*harvest		0.128	
		(0.224)	
Bio*harvest		1.085***	
		(0.187)	
Maturity*harvest		0.259	
		(0.191)	
Pod*harvest		-0.101	
		(0.155)	
Medium Seed Size*harvest		-0.130	
		(0.193)	
Large Seed Size*harvest		-0.0221	
		(0.206)	
Price*postharvest			0.112

			(0.0754)
Grain*postharvest			0.529**
			(0.213)
Bio*postharvest			0.137
			(0.210)
Maturity*postharvest			0.649***
			(0.204)
Pod*postharvest			-0.00695
			(0.160)
Medium Seed Size*postharvest			-0.231
			(0.204)
Large Seed Size*postharvest			0.117
			(0.211)
Observations	12,960	12,960	12,960

Note: ***, ** and * denote significance at 1%, 5% and 10%
Standard Errors in Parenthesis

The above results suggest that farmers' preferences for the biomass yield attribute are influenced by their status of having higher decision-making authority in the pre-harvest and harvest cultivation stages. Such farmers prefer cowpea varieties with higher biomass yield to a greater extent compared to those with lesser influence. The preference for higher biomass yields, particularly at the pre-harvest stage, among decision-makers, can be attributed to several factors. Firstly, cowpea forage plays a significant role in soil conservation and fertility improvement through nitrogen fixation (Oyewale et al. 2013). Farmers who prioritize sustainable farming practices and long-term soil health attach great value to achieving high forage yield as it enhances soil fertility and reduces erosion (Ngalamu et al., 2015). Additionally, the decision to intercrop cowpea with other crops, such as sorghum or maize, is often made at the pre-harvest stage. In uncertain farming environments, farmers with greater decision-making authority at this stage adopt a risk management strategy by giving priority to dual-purpose crops like cowpea, which offer both forage and grain benefits (Sanfo et al., 2023). By cultivating cowpea alongside other crops, farmers can derive value from both crop residues as feed and grain as food within the same land area. Considering that adult men in Senegal predominantly manage livestock, it is no surprise that they prefer to use cowpea forage as animal feed, especially when natural grazing resources are scarce (Eeswaran et al., 2022 Ishikawa et al., 2020; Diagne et al. 2020). This preference aligns with the observation that the majority of decision-makers at the pre-harvest and harvest stages are identified as men (Table 3). By utilizing cowpea haulms as livestock fodder, farmers effectively address feed scarcity issues and obtain nitrogen-rich manure from animals. This not only reduces their reliance on purchasing commercial fertilizers but also leads to significant cost savings within their households (Lensa, 2023; Boote et al., 2022; Tarawali et al. 1997).

Upon examining the results of the post-harvest model, it is clear that farmers with greater decision-making authority at this stage place a higher value on high grain yield and short maturity compared to those with less decision-making authority. This preference is driven by the advantages it offers, including quicker harvesting and faster turnover. By prioritizing these traits, such farmers can capitalize on market demand and address the food scarcity that occurs during the "hungry period" of August and September in Senegal, when granaries are nearly empty (Beye et al., 2022; Nkomo et al., 2021; Hall 2012). Additionally, the cultivation of early maturing varieties presents an opportunity for farmers to improve cowpea yield in their fields, as it allows them to mitigate the detrimental effects of terminal drought, which can result in significant yield losses of up to 80% (Abdou, 2021; Ishikawa et al., 2020).

6.3 Bundle Utilities and Probabilities

As described in the Bundle Probability Analysis section, the utility of bundles of goods is calculated using the coefficients from Table 6. Figure 4 displays the probability analysis of sampled farmers adopting a cowpea variety when one attribute level is changed from the base bundle. The base level represents the least-attractive bundle from the farmer's perspective. However, there are opportunities to significantly enhance both the utility and the probability of a farmer adopting the seed variety by modifying just one feature of the seed. It is important to note that the base cowpea bundle serves as a reference point with a 50% likelihood of being chosen by farmers. The findings reveal that farmers, in general, prioritize high grain yield as the most important attribute in cowpea varieties, followed by biomass yield and short maturity. Specifically, when a high grain yield is offered instead of a low grain yield, the likelihood of farmers adopting the new cowpea variety increases from 50% (base bundle) to 88% for the new bundle assuming that all other attributes remain constant. Similarly, when a high biomass yield is offered instead of a low biomass yield, the probability of farmers selecting the new cowpea variety increases from 50% to 79% ceteris paribus.

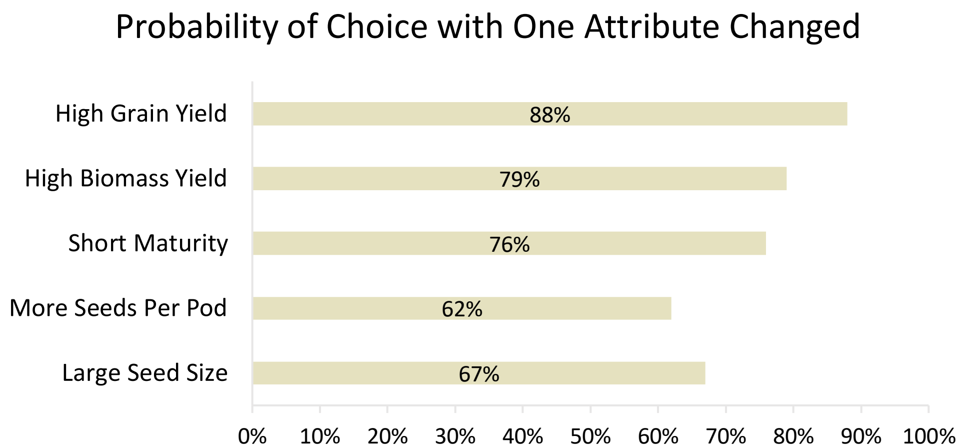


Figure 4 | Cowpea variety bundle probability analysis

7. Conclusion

The present study utilizes a mixed logit model to examine the heterogeneity in preferences among farmers in Senegal regarding cowpea variety traits, taking into account the decision-making status of husbands and wives in cowpea crop management. By incorporating questions related to decision-making authority and constructing a decision-making index, the study reveals that the household head, typically a man, is not always the primary decision-maker for cowpea cultivation within the household. Based on the decision-making index, it is identified that 51% of farmers are considered decision-makers, with 15% being women and 85% being men. The analysis of trait preferences uncovers that Senegalese farmers, overall, prioritize cowpea varieties with a high seed price, high grain yield, high biomass yield, short maturity, more seeds per pod, and large grain size. The bundle probability analysis further sheds light on the trade-offs and priorities of farmers concerning these attributes. According to the analysis, farmers derive higher utility when offered a variety with higher grain yield, followed by higher biomass yield and short maturity. Furthermore, the study delves into detailed insights of farmer preferences through segmentation analysis based on the decision-making status of individuals. The results highlight that decision-makers exhibit a stronger preference for higher biomass yield, short maturity, and small seed size compared to non-decision-makers within the household. Additionally, when comparing farmers with varying levels of decision-making influence at different stages, the findings emphasize that farmers with greater decision power in the pre-harvest and harvest stages express a stronger preference for cowpea varieties with high biomass yield. Conversely, farmers with higher decision-making authority in the post-harvest stage demonstrate a stronger preference for varieties with high grain yield and short maturity.

These findings have significant implications for cowpea breeding programs. By identifying farmers' preferences, cowpea breeders can design efficient participatory breeding projects that lead to the development and utilization of improved cowpea varieties in Senegal. The study emphasizes the importance of a participatory approach in identifying end-user preferences, enhancing utility, and promoting varietal adoption. Based on the results, plant breeders in Senegal should prioritize desirable cowpea traits such as grain and fodder yield, maturity, and grain size to enhance agricultural productivity and maximize output from land and labor.

As highlighted earlier, the research reveals intrahousehold differences in trait preferences among individuals based on their decision-making power in cowpea crop management. This suggests that if breeders incorporate only the perspectives of decision-makers, they may overly focus on a single trait, such as high biomass yield, which may not provide the same utility to other household members who prioritize different traits. This study emphasizes the need for methodological improvements to uncover household members' crop trait preferences, enabling breeders to cater to the demands of different individuals within the household. By incorporating the preferences of multiple members, breeders can prioritize traits that maximize overall household utility, facilitating the adoption of improved varieties. These findings shed light on the diverse preferences and priorities of household members and contribute to the development of targeted interventions and breeding programs that effectively address the needs of Senegalese farmers within a household. This information is crucial for researchers, plant breeding programs, and breeders to enhance household utility, promote social equity in plant breeding priority setting, and achieve inclusive agricultural development.

While this study provides valuable insights, it is important to address certain limitations. Firstly, the study's cowpea seed prices do not reflect the current market prices, potentially introducing bias in farmers' choices and preferences. Secondly, the constructed decision-making index follows a normative ranking of female empowerment, but its applicability may vary. Joint decision-making and independent decisions by women can be influenced by various factors, including necessity and family responsibilities. Further exploration is needed to improve the decision index and consider factors such as preference for joint decision-making and women's responsibilities. Lastly, while responses from both husbands and wives are incorporated, their explicit comparison is beyond the scope of this research.

8. References

Abdou, S. (2021). Grain and fodder yields of early-maturity cowpea (Vigna unguiculata L. Walp) lines in Niger Republic. Journal of Applied Biosciences, 164(1), 16931-16942.

Acosta, M., van Wessel, M., Van Bommel, S., Ampaire, E. L., Twyman, J., Jassogne, L., & Feindt, P. H. (2020). What does it mean to make a 'joint'decision? Unpacking intra-household decision making in agriculture: Implications for policy and practice. The journal of development studies, 56(6), 1210-1229.

Afful, J. (2020). Stakeholders' preference and adoption of improved cowpea varieties in the Northern Region, Ghana (Doctoral dissertation, University of Cape Coast)

Agence Nationale de la Statistique et de la Démographie (ANSD). (2021). Bulletin mensuel des statistiques économiques et financières d'Avril, p. 110.

Akeredolu, M., Asinobi, C. O., & Ilesanmi, I. (2007, May). Gender and trends in production constraints among the Bambara people of Mali. In Proceedings of the 23rd annual meeting of the Association for International Agricultural and Extension Education (pp. 1-13). Montana: Polson.

Akresh, R., 2005. Understanding Pareto inefficient intrahousehold allocations. IZA Discussion paper n. 1858.

Alkire, S., Meinzen-Dick, R., Peterman, A., Quisumbing, A., Seymour, G., & Vaz, A. (2013). The women's empowerment in agriculture index. World development, 52, 71-91

Almekinders, C. J., Beumer, K., Hauser, M., Misiko, M., Gatto, M., Nkurumwa, A. O., & Erenstein, O. (2019). Understanding the relations between farmers' seed demand and research methods: The challenge to do better. Outlook on agriculture, 48(1), 16-21.

Alwang, J., Larochelle, C., & Barrera, V. (2017). Farm decision making and gender: results from a randomized experiment in Ecuador. World Development, 92, 117-129.

Amare, Z.Y., Ayoade, J.O., Adelekan, I.O. and Zeleke, M.T. 2018. Barriers to and determinants of the choice of crop management strategies to combat climate change in Dejen District, Nile Basin of Ethiopia. Agriculture & Food Security, 7(1): 1-11.

Anderson, C.L., Reynolds, T.W. and Gugerty, M.K. 2017. Husband and wife perspectives on farm household decision-making authority and evidence on intra-household accord in rural Tanzania. World development, 90: 169-183.

Anugwa, I.Q., Onwubuya, E.A., Chah, J.M., Abonyi, C.C. and Nduka, E.K. 2022. Farmers' preferences and willingness to pay for climate-smart agricultural technologies on rice production in Nigeria. Climate Policy, 22(1): 112-131.

Ashby, J. A., & Polar, V. (2019). The implications of gender relations for modern approaches to crop improvement and plant breeding. In Gender, Agriculture and Agrarian Transformations (pp. 11-34). Routledge.

Asrat, S., Yesuf, M., Carlsson, F., & Wale, E. (2010). Farmers' preferences for crop variety traits: Lessons for on-farm conservation and technology adoption. Ecological Economics, 69(12), 2394-2401.

Attanasio, O., & Lechene, V. (2002). Tests of income pooling in household decisions. Review of economic dynamics, 5(4), 720-748.

Becker, G.S. 1965. "A Theory of the Allocation of Time." Economic Journal 75:493-517.

Bernard, T., Doss, C., Hidrobo, M., Hoel, J., & Kieran, C. (2019). Ask me why: Patterns of intrahousehold decision-making. World Development, 125.

Beye, A., Diakhate, P. B., Diouf, O., Faye, A., Obour, A. K., Stewart, Z. P., ... & Prasad, P. V. (2022). Socio-Economic Constraints of Adopting New Cowpea Varieties in Three Agro-Ecological Zones in the Senegalese Peanut Basin. Sustainability, 14(21), 14550.

Birol, E., Asare-Marfo, D., Karandikar, B., & Roy, D. (2011). A latent class approach to investigating farmer demand for biofortified staple food crops in developing countries: The case of high-iron pearl millet in Maharashtra, India (No. 7). International Food Policy Research Institute (IFPRI).

Bodian, Amy & Sarr, Awa & Guèye, Badara & Diangar, Mouhamadou & Wade, Tatiana & Dramé, Demba & Cisse, Ndiaga & Diouf, Diaga. (2022). Management of Cowpea [Vigna unguiculata L. (Walp.)] Germplasm Diversity in Senegal: A Crucial Asset for Breeding Programs

Bolarinwa, K. A., Ogunkanmi, L. A., Ogundipe, O. T., Agboola, O. O., & Amusa, O. D. (2021). An investigation of cowpea production constraints and preferences among small holder farmers in Nigeria. GeoJournal, 1-13.

Boote, K. J., Adesogan, A. T., Balehegn, M., Duncan, A., Muir, J. P., Dubeux Jr, J. C., & Rios, E. F. (2022). Fodder development in sub-Saharan Africa: An introduction. Agronomy Journal, 114(1), 1-7.

Burns, J.G., Eory, V., Butler, A., Simm, G. and Wall, E. 2022. Preference elicitation methods for appropriate breeding objectives. Animal, 16(6): 100535.

Cavatassi, R., Lipper, L., & Narloch, U. (2011). Modern variety adoption and risk management in drought-prone areas: insights from the sorghum farmers of eastern Ethiopia. Agricultural Economics, 42(3), 279-292.

Ceccarelli, S. and Grando, S. 2020. Participatory plant breeding: Who did it, who does it and where? Experimental Agriculture, 56(1): 1-11.

Chiappori, P.A., Fortin, B. and Lacroix, G. 2002. Marriage market, divorce legislation, and household labor supply. Journal of political Economy, 110(1): 37-72.

Deere, C. D., Alvarado, G. E. and Twyman, J. (2012) 'Gender Inequality in Asset Ownership in Latin America: Female Owners vs Household Heads', Development and Change, 43(2), pp. 505-530

Deißler, L., Mausch, K., Karanja, A., McMullin, S., & Grote, U. (2023). A complex web of interactions: Personality traits and aspirations in the context of smallholder agriculture. Bio-based and Applied Economics.

Deressa, T.T., Hassan, R.M., Ringler, C., Alemu, T. and Yesuf, M. 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global environmental change, 19(2): 248-255.

Diagne, A., Smale, M., Thériault, V., & Wade, I. (2020). Quantifying the scale and scope of nutritious cowpea products in local markets of West Africa Research Protocole: Part I.

Diarra, F. B., Ouédraogo, M., Zougmoré, R. B., Partey, S. T., Houessionon, P., & Mensah, A. (2021). Are perception and adaptation to climate variability and change of cowpea growers in Mali gender differentiated?. Environment, Development and Sustainability, 1-17.

Digrado, A., Gonzalez-Escobar, E., Owston, N., Page, R., Mohammed, S. B., Umar, M. L., ... & Carmo-Silva, E. (2022). Cowpea leaf width correlates with above ground biomass across diverse environments. Legume Science.

DIIVA 2009 https://www.asti.cgiar.org/diiva/senegal/cowpeas

Djoudi, H., & Brockhaus, M. (2011). Is adaptation to climate change gender neutral? Lessons from communities dependent on livestock and forests in northern Mali. International Forestry Review, 13(2), 123-135.

Doss C (2001) How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. Agricultural Economics 25(1): 27–39.

Doss, C. (2014). Data needs for gender analysis in agriculture. Gender in agriculture: Closing the knowledge gap, 55-68.

Doss, C. R., & Quisumbing, A. R. (2020). Understanding rural household behavior: Beyond Boserup and Becker. Agricultural Economics, 51(1), 47-58.

Duflo, E., & Udry, C. R. (2004). Intrahousehold resource allocation in Cote d'Ivoire: Social norms, separate accounts and consumption choices.

Eeswaran, R., Nejadhashemi, A. P., Faye, A., Min, D., Prasad, P. V., & Ciampitti, I. A. (2022). Current and future challenges and opportunities for livestock farming in west africa: perspectives from the case of senegal. Agronomy, 12(8), 1818.

Eriksson, D., Akoroda, M., Azmach, G., Labuschagne, M., Mahungu, N., & Ortiz, R. (2018). Measuring the impact of plant breeding on sub-Saharan African staple crops. Outlook on Agriculture, 47(3), 163-180

Farnworth, C. R., Jafry, T., Lama, K., Nepali, S. C., & Badstue, L. B. (2019). From working in the wheat field to managing wheat: Women innovators in Nepal. The European Journal of Development Research, 31(2), 293–313. https://doi.org/10.1057/s41287-018-0153-4

Farnworth, C. R., Bharati, P., Krishna, V. V., Roeven, L., & Badstue, L. (2022). Caste-gender intersectionalities in wheat-growing communities in Madhya Pradesh, India. Gender, Technology and Development, 26(1), 28-57.

Faye, B., & Du, G. (2021). Agricultural Land Transition in the “Groundnut Basin” of Senegal: 2009 to 2018. Land, 10(10), 996.

Fisher, M., & Carr, E. R. (2015). The influence of gendered roles and responsibilities on the adoption of technologies that mitigate drought risk: The case of drought-tolerant maize seed in eastern Uganda. Global Environmental Change, 35, 82-92.

Fu, H., Zhang, Y., An, Y., Zhou, L., Peng, Y., Kong, R., & Turvey, C. G. (2022). Subjective and objective risk perceptions and the willingness to pay for agricultural insurance: evidence from an in-the-field choice experiment in rural China. The Geneva Risk and Insurance Review, 1-24.

Gebre, G. G., Isoda, H., Amekawa, Y., & Nomura, H. (2019, September). Gender differences in the adoption of agricultural technology: The case of improved maize varieties in southern Ethiopia. In Women's studies international forum (Vol. 76, p. 102264). Pergamon.

Gonçalves, A.; Goufo, P.; Barros, A.; Domínguez-Perles, R.; Trindade, H.; Rosa, E.A.; Ferreira, L.; Rodrigues, M. Cowpea [Vigna unguiculata (L.) Walp] a renewed multipurpose crop for a more sustainable agri-food system: Nutritional advantages and constraints. J. Sci. Food Agric. 2016, 96, 2941–2951.

Guendel S,2009. What are 'women'scrops', and why? Food and Agriculture Organization of the United Nations. Available at https://.www.fao.org/gender/insights/detail/en/c/36003/

Gulati, K. (2016). Who's the Boss? Intrahousehold Valuation, Preference Heterogeneity, and Demand for an Agricultural Technology in India. en. In, 44.

Gulati, K., Ward, P., Lybbert, T., & Spielman, D. (2016). Intrahousehold valuation, preference heterogeneity, and demand of an agricultural technology in Bihar, India (No. 333-2016-14384)

Haider, H., Smale, M., & Theriault, V. (2018). Intensification and intrahousehold decisions: Fertilizer adoption in Burkina Faso. World Development, 105, 310-320.

Hall, A. E. (2012). Phenotyping cowpeas for adaptation to drought. Frontiers in physiology, 3, 155.

Hanley, N., Wright, R.E. and Koop, G. (2002) 'Modeling recreation demand using choice experiments: climbing in Scotland', Environmental and Resource Economics, Vol. 22, No. 3, pp.449–466.

Hensher, D. A., & Greene, W. (2010). Non-attendance and dual processing of CommonMetric attributes in choice analysis: A latent class specification. Empirical Economics, 39(2), 413–426. doi:10.1007/s00181009-0310-x

Hoddinott, J., & Haddad, L. (1995). Does female income share influence household expenditures? Evidence from Côte d'Ivoire. oxford Bulletin of Economics and Statistics, 57(1), 77-96.

Hoel, J. B., Hidrobo, M., Bernard, T., & Ashour, M. (2021). What do intra-household experiments measure? Evidence from the lab and field. Journal of Economic Behavior & Organization, 188, 337-350.

Hole, A. R. (2008). Modelling heterogeneity in patients' preferences for the attributes of a general practitioner appointment. Journal of health economics, 27(4), 1078-1094.

Horn, L., Shimelis, H., & Laing, M. (2015). Participatory appraisal of production constraints, preferred traits and farming system of cowpea in the northern Namibia: implications for breeding. Legume Research-An International Journal, 38(5), 691-700.

International Institute of Tropical Agriculture (IITA),2021. Cowpea. Available at https://www.iita.org/crops new/cowpea/(Accessed 3 March 2023)

Ishikawa, H., Drabo, I., Joseph, B. B., Muranaka, S., Fatokun, C., & Boukar, O. (2020). Characteristics of farmers' selection criteria for cowpea (Vigna unguiculata) varieties differ between north and south regions of Burkina Faso. Experimental Agriculture, 56(1), 94-103.

Johnson, F.R.; Lancsar, E.; Marshall, D.; Kilambi, V.; Bs, B.A.; Mu, A.; Regier, D.A.; Bresnahan, B.W.; Kanninen, B.; Bridges, J.F. Constructing Experimental Designs for Discrete-Choice Experiments: Report of the ISPOR Conjoint Analysis Experimental Design Good Research Practices Task Force. Value Health 2013, 61, 3–13.

Joshi, P.K., Khan, M.T. and Kishore, A. 2019. Heterogeneity in male and female farmers' preference for a profit-enhancing and labor-saving technology: The case of Direct-Seeded Rice (DSR) in India. Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie, 67(3): 303-320.

Kafle, K., Michelson, H., & Winter-Nelson, A. (2019). His, hers, or ours: Impacts of a training and asset transfer programme on intra-household decision-making in Zambia. The Journal of Development Studies, 55(9), 2046-2064.

Kaijser, A., & Kronsell, A. (2014). Climate change through the lens of intersectionality. Environmental politics, 23(3), 417-433.

Karikari, B., Maale, M. D., Anning, E., Akakpo, D. B., Abujaja, A. M., & Addai, I. K. (2023). Cowpea cropping systems, traits preference and production constraints in the upper west region of Ghana: farmers' consultation and implications for breeding. CABI Agriculture and Bioscience, 4(1), 1-11.

Kassali, R., Oyewale, A. Y., & Yesufu, O. A. (2018). Analysis of consumer's WTP for cowpea varieties in Osun State, Nigeria: the Hedonic pricing approach. Turkish Journal of Agriculture-Food Science and Technology, 6(9), 1120-1128.

Khanal, U., Adhikari, A. and Wilson, C. 2017. Evaluating smallholder farmers' demand for rice variety attributes in Nepal. Journal of Crop Improvement, 31(3): 438-452.

Kimathi, S. M., Ayuya, O. I., & Mutai, B. (2022). Stated Farmers' Preferences and Willingness to Pay for Climate Resilient Potato Varieties in Kenya: A Discrete Choice Experiment.

Kitch, L. W., Boukar, O., Endondo, C., & Murdock, L. L. (1998). Farmer acceptability criteria in breeding cowpea. Experimental Agriculture, 34(4), 475-486.

Kolstad, J. R. (2011). How to make rural jobs more attractive to health workers. Findings from a discrete choice experiment in Tanzania. Health economics, 20(2), 196-211.

Krishna V.V. and Veettil P.C. 2022. Gender, caste, and heterogeneous farmer preferences for wheat varietal traits in rural India. PLoS ONE 17(8): e0272126. https://doi.org/10.1371/journal.pone.0272126

Kuhfeld, Warren F. 2010. Marketing Research Methods in SAS.

Labarta, R. A. (2009). Are small sub-Sahara African farmers willing to pay for vegetative propagated orange fleshed sweetpotato planting material? Evidence from Central Mozambique (No. 319-2016-9823).

Laborte, A.G., Paguirigan, N.C., Moya, P.F., Nelson, A., Sparks, A.H. and Gregorio, G.B. 2015. Farmers' preference for rice traits: insights from farm surveys in Central Luzon, Philippines, PLoS One, 10(8): e0136562.

Lambrecht, I., Vranken, L., Merckx, R., Vanlauwe, B., & Maertens, M. (2015). Ex ante appraisal of agricultural research and extension: a choice experiment on climbing beans in Burundi. Outlook on AGRICULTURE, 44(1), 61-67.

Lancaster, K.J. (1966) 'A new approach to consumer theory', Journal of Political Economy, Vol. 74, pp.132–157.

Langyintuo, A. S., Lowenberg-DeBoer, J., Faye, M., Lambert, D., Ibro, G., Moussa, B., Kergna, A., Kushwaha, S., Musa, S., & Ntoukam, G. (2003). Cowpea supply and demand in West Africa. Field Crops Research, 82, 215–231. https://doi.org/10.1016/S0378-4290(03)00039-X

Leavitt, H. J. (1954). A note on some experimental findings about the meanings of price. *The Journal of Business*, *27*(3), 205-210.

Leigh, A. C., Reynolds, T. W., & Gugerty, M. K. (2017). Husband and wife perspectives on farm household decision-making authority and evidence on intra-household accord in rural Tanzania. World Development, 90(February), 169–183.

Lemmens, Aurélie. n.d. Analysis of Conjoint Data: Part II: Logit.

Lensa Urgesa. (2023). Review on Cowpea Production, Utilization and Research Achievements in Ethiopia. Int. J. Adv. Res. Biol. Sci. 10(1): 172-180.

Lope-Alzina, D. G. (2007). Gendered production spaces and crop varietal selection: Case study in Yucatán, Mexico. Singapore Journal of Tropical Geography, 28(1), 21-38.

Lusiba, G. S., Kibwika, P., & Kyazze, F. B. (2017). Intra-household gender division of labour and decision-making on rice postharvest handling practices: A case of Eastern Uganda. Cogent Social Sciences, 3(1), 1296323.

MacGregor, S. (2009). A stranger silence still: The need for feminist social research on climate change. The Sociological Review, 57(2_suppl), 124-140.

Macours, K. (2019). Farmers' demand and the traits and diffusion of agricultural innovations in developing countries. Annual Review of Resource Economics, 11, 483-499.

Maisonnave, H., & Mamboundou, P. N. (2022). Agricultural economic reforms, gender inequality and poverty in Senegal. Journal of Policy Modeling, 44(2), 361-374.

Maligalig, R., Demont, M., Umberger, W. J., & Peralta, A. (2021). Understanding Filipino rice farmer preference heterogeneity for varietal trait improvements: a latent class analysis. Journal of agricultural economics, 72(1), 134-157.

Maligalig, R., Demont, M., Umberger, W. J., & Peralta, A. (2019). Off-farm employment increases women's empowerment: Evidence from rice farms in the Philippines. Journal of Rural Studies, 71, 62-72.

Maligalig, R. L., Demont, M., Umberger, W. J., & Peralta, A. (2017). Intrahousehold decision making on rice varietal trait improvements: Using experiments to estimate gender influence.

Marenya, P. P., Wanyama, R., Alemu, S., & Woyengo, V. (2021). Trait preference trade-offs among maize farmers in western Kenya. Heliyon, 7(3), e06389.

Martey, E., Etwire, P. M., Adogoba, D. S., & Tengey, T. K. (2022). Farmers' preferences for climate-smart cowpea varieties: implications for crop breeding programmes. Climate and Development, 14(2), 105-120.

Mazzanti, M. (2003). Discrete choice models and valuation experiments. Journal of economic studies, 30(6), 584-604.

McFadden, D. 1973. Conditional logit analysis of qualitative choice behavior: Chapter 4. In Frontiers in economics, ed. P. Zarambka, 105–142. New York: Academic Press.

McFadden, D. 2001. Economic choices. American Economic Review 91 (3): 351–378.

Meijer E, Rouwendal J. 2006. Measuring welfare effects in models with random coefficients. Journal of Applied Econometrics 21: 227-244.

Meijer, S. S., Sileshi, G. W., Kundhlande, G., Catacutan, D., & Nieuwenhuis, M. (2015). The role of gender and kinship structure in household decision-making for agriculture and tree planting in Malawi. Journal of Gender, Agriculture and Food Security (Agri-Gender), 1(302-2016-4750), 54-76.

Melomey, L. D., Ayenan, M. A., Marechera, G., Abu, P., Danquah, A., Tarus, D., & Danquah, E. Y. (2022). Pre-and post-harvest practices and varietal preferences of tomato in Ghana. Sustainability, 14(3), 1436.

Mengistu, G., Shimelis, H., Laing, M., & Lule, D. (2019). Assessment of farmers' perceptions of production constraints, and their trait preferences of sorghum in western Ethiopia: implications for anthracnose resistance breeding. Acta Agriculturae Scandinavica, Section B—Soil & Plant Science, 69(3), 241-249.

Meressa, A. M., & Navrud, S. (2020). Not my cup of coffee: Farmers' preferences for coffee variety traits–Lessons for crop breeding in the age of climate change. Bio-based and Applied Economics, 9(3), 263-282.

Michler, J.D., Tjernström, E., Verkaart, S. and Mausch, K. 2019. Money matters: The role of yields and profits in agricultural technology adoption. American Journal of Agricultural Economics, 101(3): 710-731.

Miriti, P., Regassa, M.D., Ojiewo, C.O. and Melesse, M.B. 2022. Farmers' preferences and willingness to pay for traits of sorghum varieties: Informing product development and breeding programs in Tanzania. Journal of Crop Improvement, 1-20.

Mishili, F.G., J. Fulton, M. Shehu, S. Kushwaha, K. Marfo, M. Jamal, A. Kergna, J. Lowenberg-DeBoer. 2009. Consumer Preferences for Quality Characteristics along the Cowpea Value Chain in Nigeria, Ghana and Mali. Journal of Agribusiness, 25 (1): 16-35.

Mohammed, S. B., Dzidzienyo, D. K., Umar, M. L., Ishiyaku, M. F., Tongoona, P. B., & Gracen, V. (2021). Appraisal of cowpea cropping systems and farmers' perceptions of production constraints and preferences in the dry savannah areas of Nigeria. AgriRxiv, (2021), 20210152201.

Molua, E. L. (2011). Farm income, gender differentials and climate risk in Cameroon: typology of male and female adaptation options across agroecologies. Sustainability Science, 6, 21-35.

Mugabe, J. O., & Mugabe, F. T. (2019). Factors influencing smallholder farmer adoption of improved maize varieties in Zimbabwe. Agrekon, 58(3), 284-298.

National Agency for Statistics and Demography (ANSD). Economic and Social Situation; National Agency for Statistics and Demography (ANSD): Dakar, Senegal, 2019.

Ndiritu, S. W., Ritho, C. N., & Nyang'au, J. O. (2019). Factors influencing adoption of improved maize varieties among smallholder farmers in rural Kenya. Agricultural and Food Economics, 7(1), 1-14.

Ngalamu, T., Odra, J., & Tongun, N. (2015). Cowpea production handbook. IFS/AGRA.

Nkomo, G. V., Sedibe, M. M., & Mofokeng, M. A. (2021). Production constraints and improvement strategies of cowpea (Vigna unguiculata L. Walp.) genotypes for drought tolerance. International Journal of Agronomy, 2021, 1-9.

Ochieng, J., Ouma, E., & Birachi, E. (2014). Gender participation and decision making in crop management in Great Lakes Region of Central Africa. Gender, Technology and Development, 18(3), 341-362.

Owusu, E. Y., Karikari, B., Kusi, F., Haruna, M., Amoah, R. A., Attamah, P., ... & Issahaku, M. (2021). Genetic variability, heritability and correlation analysis among maturity and yield traits in Cowpea (Vigna unguiculata (L) Walp) in Northern Ghana. Heliyon, 7(9), e07890.

Oyewale, R. O., & Bamaiyi, L. J. (2013). Management of cowpea insect pests.

Oyinbo, O., Chamberlin, J., Vanlauwe, B., Vranken, L., Kamara, Y. A., Craufurd, P., & Maertens, M. (2019). Farmers' preferences for high-input agriculture supported by site-specific extension services: Evidence from a choice experiment in Nigeria. Agricultural systems, 173, 12-26.

Palma, D., de Dios Ortúzar, J., Rizzi, L. I., Guevara, C. A., Casaubon, G., & Ma, H. (2016). Modelling choice when the price is a cue for quality: a case study with Chinese consumers. Journal of Choice Modelling, 19, 24-39.

Pant, K. P., Gautam, J. C., & Wale, E. (2012). Valuation of rice diversity in Nepal: a trait-based approach. In The Economics of Managing Crop Diversity On-farm (pp. 45-64). Routledge.

Paris, T. R., Singh, A., Cueno, A. D., & Singh, V. N. (2008). Assessing the impact of participatory research in rice breeding on women farmers: a case study in eastern Uttar Pradesh, India. Experimental Agriculture, 44(1), 97-112.

Patterson, Z., Darbani, J. M., Rezaei, A., Zacharias, J., & Yazdizadeh, A. (2017). Comparing text-only and virtual reality discrete choice experiments of neighbourhood choice. Landscape and Urban Planning, 157, 63-74.

Peralta, A. (2022). The role of men and women in agriculture and agricultural decisions in Vanuatu. Asia & the Pacific Policy Studies, 9(1), 59-80.

Prabhu, V. S. (2010). Tests of intrahousehold resource allocation using a CV framework: A comparison of husbands' and wives' separate and joint WTP in the slums of Navi-Mumbai, India. World Development, 38(4), 606-619.

Revelt, D., & Train, K. (1998). Mixed logit with repeated choices: households' choices of appliance efficiency level. Review of economics and statistics, 80(4), 647-657.
Rogan, M. (2013). Alternative definitions of headship and the 'feminisation'of income poverty in post-apartheid South Africa. The Journal of Development Studies, 49(10), 1344-1357.

Ryan, Mandy; Kolstad, Julie R.; Rockers, Peter C.; Dolea, Carmen.How to conduct a discrete choice experiment for health workforce recruitment and retention in remote and rural areas: a user guide with case studies (English). Washington, D.C. : World Bank Group.

Sarr, A., Bodian, A., Gueye, M. C., Gueye, B., Kanfany, G., Diatta, C., ... & Leclerc, C. (2022). Ethnobotanical study of cowpea (Vigna unguiculata (L.) Walp.) in Senegal. Journal of Ethnobiology and Ethnomedicine, 18(1), 1-15.

Sánchez, B. I., Kallas, Z., & Gil Roig, J. M. (2017). Farmer preference for improved corn seeds in Chiapas, Mexico: A choice experiment approach. Spanish journal of agricultural research, 15(3).

Sanfo, A., Zampaligré, N., Kulo, A. E., Somé, S., Traoré, K., Rios, E. F., ... & Adesogan, A. (2023). Performance of food–feed maize and cowpea cultivars under monoculture and intercropping systems: Grain yield, fodder biomass, and nutritive value. Frontiers in Animal Science, 3, 998012.

Scarpa, R., Thiene, M., & Hensher, D. A. (2012). Preferences for tap water attributes within couples: an exploration of alternative mixed logit parameterizations. Water Resources Research, 48(1).

Scott, A. (2001). Eliciting GPs' preferences for pecuniary and non-pecuniary job characteristics. Journal of health economics, 20(3), 329-347.

Seymour, G. (2017). Women's empowerment in agriculture: Implications for technical efficiency in rural Bangladesh. Agricultural Economics, 48(4), 513-522.

Seymour, G., & Peterman, A. (2018). Context and measurement: An analysis of the relationship between intrahousehold decision making and autonomy. World Development, 111, 97–112.

Sikod, Fondo. (2007). Gender division of labour and women decision-making power in rural households in Cameroon. African Development, 32(3), 58–71.

Simtowe, F. P. (2010). Livelihoods diversification and gender in Malawi. African Journal of Agricultural Research, 5(3), 204-216.

Singh, C., Dorward, P., & Osbahr, H. (2016). Developing a holistic approach to the analysis of farmer decision-making: Implications for adaptation policy and practice in developing countries. Land use policy, 59, 329-343.

Smale, M., Theriault, V., Allen, A., & Sissoko, M. (2022) Is cowpea a 'women's crop' in Mali? Implications for value chain development. African Journal of Agricultural and Resource Economics.

Sumner, D., Christie, M. E., & Boulakia, S. (2017). Conservation agriculture and gendered livelihoods in Northwestern Cambodia: decision-making, space and access. Agriculture and human values, 34, 347-362

Sylla, A., Yila, J. O., Diallo, S., & Traoré, S. (2023). Importance of the Social Structures in Cowpea Varietal Demands for Women and Men Farmers in Segou Region, Mali. Sustainability, 15(4), 3433.

Tarawali, S. A., Singh, B. B., Peters, M., & Blade, S. F. (1997). Cowpea haulms as fodder. Advances in cowpea research, 313.

Teeken, B., Garner, E., Agbona, A., Balogun, I., Olaosebikan, O., Bello, A., ... & Tufan, H. A. (2021). Beyond “women's traits”: Exploring how gender, social difference, and household characteristics influence trait preferences. Frontiers in Sustainable Food Systems, 490.

Teeken, B., Olaosebikan, O., Haleegoah, J., Oladejo, E., Madu, T., Bello, A., ... & Tufan, H. A. (2018). Cassava trait preferences of men and women farmers in Nigeria: implications for breeding. Economic Botany, 72, 263-277.

Tesfaye, W. (2018). Factors affecting adoption of improved maize varieties in Ethiopia: evidence from rural Tigrai. Journal of Agricultural Extension and Rural Development, 10(10), 272-279.

Timsina, K. P., Jourdain, D., & Shivakoti, G. P. (2016). Farmer preference for seed quality: a discrete choice experiment with tomato growers in Nepal. International Journal of Value Chain Management, 7(4), 368-390.

Theriault, V., Smale, M., & Haider, H. (2017). How does gender affect sustainable intensification of cereal production in the West African Sahel? Evidence from Burkina Faso. World Development, 92, 177-191.

Toure, A.K.; Diakhate, M. Descriptive Analysis of The Influence of Rainfall and Temperature Indicators on Agricultural Yields in Senegal. 2020. Available online: https://www.researchgate.net/publication/338698842_Analyse_descriptive_de_l%27

Train, K.E. 2009. Discrete choice methods with simulation. Cambridge: Cambridge University Press.

Twyman, J., Useche, P., & Deere, C. D. (2015). Gendered perceptions of land ownership and agricultural decision-making in Ecuador: Who are the farm managers?. Land Economics, 91(3), 479-500.

Udry, C. 1996. Gender, agricultural production, and the theory of the household. Journal of political Economy, 104(5): 1010-1046.

United States Agency for International Development. Feed the Future Senegal Naatal Mbay Project: Women’s Economic Empowerment Strategy. 2016.

Waldman, K. B., Ortega, D. L., Richardson, R. B., & Snapp, S. S. (2017). Estimating demand for perennial pigeon pea in Malawi using choice experiments. Ecological economics, 131, 222-230

Wasserman-Olin, R. (2020). Marketing Decisions of Farmers Via Wholesalers: A Choice Experiment.

West, C. T. (2010). Household extension and fragmentation: Investigating the socio-environmental dynamics of Mossi domestic transitions. Human Ecology, 38, 363-376.

Weltzien, E., Rattunde, F., Christinck, A., Isaacs, K., & Ashby, J. (2019). Gender and farmer preferences for varietal traits: evidence and issues for crop improvement. Plant breeding reviews, 43, 243-278.

WEAI 2016 https://weai.ifpri.info/weai-resource-center/guides-and-instruments/

World Bank, Food and Agriculture Organization, & International Fund for Agricultural Development. (2008). Gender in agriculture sourcebook. The World Bank.

9.Appendix

Appendix 1: Cowpea Traits

i) List 1: The initial list of traits provided below was inspired by Kitch et al. (1998), which classified cowpea-related traits into three categories: yield-related, quality-related, and labor-saving.

Trait Criteria	Trait Name
Yield Related Criteria	Grain Yield Fodder Yield Leaf Retention Continuous Flowering Early Maturity Insect/Pest Resistance Drought Tolerant Disease Resistance
Preferences and quality-related	large seeds/grain size white seeds/seed color seed taste rough seed coats smooth seed coats pod color preference fodder quality Floury seed Eye color leaves for eating/tenderness of leaves
Labor-related criteria	long pods large pods medium pods straight pods erect growth habit (ease of harvest) semi-erect habit (ease of harvest) spreading habit (weed suppression) pods easy to harvest easy to thresh many seeds per pod
Other	high market acceptability high storability

ii) List 2: Based on the literature review and quantitative survey data collected by the Senegalese Institute of Agricultural Research (ISRA), a list of 10 traits was compiled. These traits were subsequently discussed with cowpea breeders.

Traits
Seed Size
Maturity
Seed Color
Biomass Yield
Taste
Grain Yield
Pod Filling
Preservation Time
Easy to Peel
Seed Price

Appendix 2: Intra-household full method protocol

Enumerator's first and last name
Enter the household number (1-15) to be surveyed in the village
Enter the tablet code
Consent? *Code: 1= Yes; 2= No*

Section A: Area and Household Information

Respondent's first and last name
Region
Municipality
Village

Sex *Code: 1= Male; 2= Female*
Age (in completed years)
Ethnic Group *Code: 1=Wolof; 2=Lébou; 3=Sérère; 4=Halpulaar; 5=Diola; 6=Malinké; 7=Mandingue; 8=Bambara; 9= Other (to be specified)*
Marital Status *Code: 1= Single; 2= Monogamous Married; 3= Married Polygamist; 4= Divorced; 5= Widowed; 6= Co-Habitation 7=Others (to be specified)*

Level of Education in French

- No Education
- Elementary
- Secondary
- High School
- University

Level of Education in Arabic

- No Education

- Elementary
- Secondary
- High School
- University

Are you a member of any farmer's group, cooperative or association? *Code: 1= Yes; 2= No*

What is your primary activity?

Primary activity: activity through which you earn the majority of income
Code: 1= Agriculture; 2= Trade; 3= Trades or crafts; 4=Salaried Employment; 5= Fishing; 6= Others (to be specified)

How many people are there in your household over the age of 15?

For each person currently eating and sleeping at the household and not a guest living in your household, please provide their names, relationship to the household head, age, sex, and whether they are involved in the agricultural production of cowpea in the table below.

Person x	Full Name (or initials)	Relationship to Household Head (*)	Age (in years)	Sex (Male/Female)	Involved in Cowpea Production (Yes/No)
Person 1					
Person 2					
Person 3					
Person 4					
Person 5					
Person 6					
Person 7					
Person 8					
Person 9					
Person 10					

(*) Code: 1=Self; 2= Wife/Husband/Partner; 3= Child/Adopted Child; 4= Grandchild; 5= Niece/Nephew; 6= Father/Mother; 7= Sister/Brother; 8= Son-in-Law/Daughter-in-Law; 9= Brother-in-law/Sister-in-law; 10= Grandfather/Grandmother; 11= father-in-law/mother-in-law; 12= Co-Wife; 13= Other (to be specified)

How many people are there in your household under the age of 15?

Which crops did the household produce in all harvesting seasons of 2022? (Choose all that apply)

Code: 1= Peanut; 2= Millet; 3= Sorghum; 4= Maize; 5= Sesame; 6= Cowpea; 7= Watermelon; 8= Cassava; 9= Okra; 10= Others (to be specified)

What is the total area of land under cultivation of cowpea? (in hectares)
Code: 1= Less than 3 ha; 2=3-5 ha; 3= 5-8 ha; 4=More than 8 ha

Do you usually sell the cowpea you produced?
Code: 1 = Yes; 2 = No

As of today, what is the total income generated by the cowpea agricultural activity in year 2022? (in CFA)

How many cowpea plots do you own?

Do you manage your own cowpea plot?
Code: 1 = Yes; 2 = No

Section B: Decision Making

Within the household, who makes the **most** decisions regarding the **cowpea varieties** to be planted?

- ☐ Respondent alone
- ☐ Respondent's spouse alone
- ☐ Respondent and his or her spouse together
- ☐ Other household members

Within the household, who makes the **most** production decisions regarding the following **inputs**?

	Respondent Alone	Respondent's Spouse Alone	Respondent and his or her spouse together	Other household members
Fertilizer	○	○	○	○
Manure	○	○	○	○
Labor	○	○	○	○
Machinery	○	○	○	○
Cowpea Seeds	○	○	○	○

Within the household, who makes the **most** decisions regarding **the timing of** the cowpea cropping activities? *For example: if person "A" decides the timing for harvesting the cowpea crop, then the answer to this question will be "Person A"*

- ☐ Respondent alone
- ☐ Respondent's spouse alone
- ☐ Respondent and his or her spouse together

- ☐ Other household members

Within the household, who makes the **most** decision regarding **the allocation of** land for cowpea cultivation?

- ☐ Respondent alone
- ☐ Respondent's spouse alone
- ☐ Respondent and his or her spouse together
- ☐ Other household members

In case cowpea intercropping is practiced then, within a household, who makes the **most** decision regarding **which crop is to be cultivated** along with cowpea?

- ☐ Respondent alone
- ☐ Respondent's spouse alone
- ☐ Respondent and his or her spouse together
- ☐ Other household members

Within the household, who makes the **most** decision regarding **what to do with the harvested crop**?

- ☐ Respondent alone
- ☐ Respondent's spouse alone
- ☐ Respondent and his or her spouse together
- ☐ Other household members

Section C: Knowledge/Years of Experience

For all the household members who are involved in cowpea cultivation, specify how long they have contributed to growing cowpea within the household. Please consider all activities related to cowpea, from choosing the cowpea variety to planting to selling that variety in the market.

Person x	Full Name (or initials)	Years of Experience (**)
Person 1		
Person 2		
Person 3		
Person 4		
Person 5		
Person 6		

Person 7		
Person 8		
Person 9		
Person 10		

***Years of Experience*
1= Less than 5 years; 2= 5-10 years; 3= 11-15 years; 4= 16-20 years; 5= More than 20 years

Section D: Time Commitment to Plot

For each of the activities related to cowpea cultivation, list the household members who are involved and specify their degree of engagement.

(a) Pre-Harvest (includes land preparation, planting, ridging, weeding and application of fertilizers)

	Least Involved	Involved as much as the majority	Most Involved
Self	○	○	○
Person 2	○	○	○
Person 3	○	○	○
Person 4	○	○	○
Person 5	○	○	○

(b) Harvesting

	Least Involved	Involved as much as the majority	Most Involved
Self	○	○	○
Person 2	○	○	○
Person 3	○	○	○
Person 4	○	○	○
Person 5	○	○	○

(c) Post-Harvest (includes threshing, sorting, storage, processing, transportation, marketing)

	Least Involved	Involved as much as the majority	Most Involved
Self	○	○	○
Person 2	○	○	○
Person 3	○	○	○
Person 4	○	○	○
Person 5	○	○	○

Cheap Talk to Mitigate Hypothetical Bias
In a moment, we will ask you a couple of questions about whether you would purchase cowpea seeds with specific attributes at a particular price level. However, before answering the question, we would like to inform you the following information.

Experience from other studies has shown that people tend to respond differently to hypothetical situations than they would to real-life situations. This is most likely because they do not actually have to follow through with their choices in hypothetical situations. Although the study described here is a hypothetical situation, real cowpea seeds like this may be produced and marketed in stores. It is important that the results from this study are accurate if we are to use them to develop a real cowpea product profile.

Therefore, we would like you to answer the questions as if you were really faced with these decisions in the real market (i.e., as if the purchasing price, grain yield, biomass yield, seed size, maturity, and pod filling were real).

Section E: Choice Experiment

Sample choice card that was presented to the farmers is already shown in the main document.