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Increasing Yield More Than Maintaining Fertile Soils Motivated the Choice of Climate-Smart Soil Technologies Among Greater Lira Pigeon Pea Farmers

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ABSTRACT
Pigeon pea farmers in Gerater Lira, Uganda, fight the adverse effects of climate change and deteriorating soil fertility. They are combining different strategies and adopting climate-smart soil technologies (CSS technologies) to maintain fertile soil and increase yields. The study explored how the motive for maintaining fertile soils affected CSS technologies' choice. A sample of 39 farmers participated in laddering interviews. Data was analyzed by the means-end chain (MEC) framework and the centrality index (CI) technique. MEC results indicate that farmers predominantly linked crop diversification, addressed dietary needs, increased yields, and increased incomes. In addition, they paid less attention to maintaining fertile soils. Results of the CI highlight goal priorities by gender subgroups with females aged at least 40 paying more attention to producing food, soil fertility, and improving health, while male farmers of the same age category were inclined to spread production risk. Results further showed that male farmers below 40 years of age tend to produce for markets and benevolent, while their female counterparts tend to maintain soil nutrients. Our overall findings could help in the development of targeted strategies to encourage a wider spread of CSS technology use for climate-smart agriculture. This could enhance agricultural resilience in the face of climate change. We recommend encouraging farmers to apply CSS technologies while considering the long-term effects they might have on soil fertility. we further recommend that farmers intensify residual retention to improve soil fertility without requiring money to purchase inorganic fertilizer.

Introduction:
In the semi-arid farmlands of Gerater Lira, Uganda, determined pigeon pea farmers waged a protracted battle against climate change and deteriorating soil fertility. They face soils with low organic matter, unavailable essential plant nutrients, and high acidity. Soil pH is less than 6, which is required for plant growth (Kayuki et al., 2017). They also face one rainy season with prolonged dry spells and reduced rainfall (MAAIF, 2022; NEMA, 2016). Currently, cereal productivity is 25% below the national average. Maize yield was 1.3 MT/ha compared to the nation's 1.4 MT/ha; sorghum was 0.3 MT/ha compared to the

nation's 0.5 MT/ha; and rice was 0.7 MT/ha compared to 1 MT/ha. Even the bean yield was 0.4 MT/ha compared to the nation's 0.5 MT/ha and 0.4. Food shortages were reported at 65%, compared to 47% nationally (UBOS, 2020). Through their efforts, these pigeon pea farmers improve their own lives by producing food and increasing their incomes. They also contribute to climate-smart agriculture goals.

By growing more pigeon peas, a leguminous crop, they add soil nitrogen, which is critical to carbon sequestration. This reduces agriculture's environmental impact. Pigeon peas are also an excellent source of feedstock for biochar production (Munera-Echeverri et al., 2022). Pigeon peas improve soil fertility, sequester soil carbon, and are food and source of income (Nkwonta et al., 2023) thus supporting climate-smart agriculture locally. These farmers further adopted a range of locally available climate-smart soil technologies (CSS technology), including legume-cereal rotation, biochar application, minimum tillage, cover cropping, and farmyard manure. These improve soil fertility (Davies et al., 2021; Tibasiima et al., 2023; Zizinga et al., 2022).

Their innovative techniques of combining different strategies and their commitment to climate-smart agriculture go the extra mile in demonstrating the effectiveness of climate-smart soil technologies in improving soil fertility and increasing yields and serve as an inspiration to other farmers in the region faced with similar or even harsher conditions. With continued support and investment, these farmers show the potential to transform the agricultural sector and create a more resilient and sustainable future for all.

However, earlier studies in the region indicated that 1/3 of CSA technology was being used on a small fraction of farmland among farmers introduced to CSA agriculture (S. Kaweesa et al., 2018; S. H. Kaweesa et al., 2020). They pointed out that food and income motivated adoption and that increasing yield was central to it (S. Kaweesa et al., 2018, p.6). Moreover, CSA commitment refers to a farmer's persistent dedications of time, farmland and using CSS technologies to improve natural soil fertility (Locke & Latham, 2015; Mwanake et al., 2023; Tarifa, 2022). According to Data & Wang (2009), existing technologies are vital determinants of technology commitment. While Locke & Lathan emphasize goal commitment to affect behavior

In this case where display low technology commitment; we explored farmers' production goals in shaping CSS technology commitment. It was also our purport that because gender subgroups have contextual differences, this affects both production goals and CSS technology commitment. Goal scholarships point to differences in prioritizing goals for different farmers, revealing different levels of goal abstraction – goal hierarchy (Deutsch & Strack, 2020; Locke & Latham, 2019). Moreover, goal hierarchies reportedly influence CSS technology's choice (Atieno et al., 2023; Ngigi et al., 2018).

The study explored how the motive for maintaining fertile soils affects the choice of CSS technologies among pigeon pea farmers in Gerater Lira. This knowledge enriches the primary motives behind CSS technology commitment beyond the known. Was it to increase yield instead of long-term soil fertility concerns espoused in climate-smart agriculture? Further to this, the researchers applied centrality index techniques to highlight goal priorities by gender subgroups. The overall output could help in the development of targeted strategies to encourage a wider spread of CSS technology use for food insecurity and enhance agricultural resilience in the face of climate change in Gerater Lira.

Literature Review:

Our literature review demonstrates the multiple benefits of climate-smart soil technologies, making it difficult to ascertain the motives behind adopting these technologies. The central issue was whether farmers were more motivated by improving immediate yields than by maintaining fertile soils. Our review further discusses goal hierarchy and goal-setting theory by Edwin Locke and Gary Latham as the theoretical underpinnings of our study. It also discusses how we deployed the means-end chain (MEC) framework and centrality index (CI) techniques to address the research problem. The review further examines gender subgroups that present choice biases based on gender contextual differences occasioned by social norms and access to resources. Thus, it ushers in the study's analytical framework.

Normative commitment to climate-smart soil technologies:

Normative commitment refers to individuals' attitudes and beliefs towards technologies, which significantly influence the adoption of new technologies among farmers. It represents the determination to continuously use a technology to achieve a goal Hunter & Panagopoulos, 2015; Locke & Latham, 2006). Climate-smart agricultural technologies (CSA technologies) target soil to improve productivity, adaptation, and climate change mitigation. CSA technologies include water-smart, smart-food systems, smart fisheries, apiculture, energy-smart, smart soil, urban-smart, carbon-smart, knowledge-smart, weather-smart, and water-smart technologies (Venkatramanan & Shah, 2019).. These technologies, particularly those falling under the soil-smart category, are recommended for semi-arid regions and rain-fed agriculture. In Gerater Lira, CSA technologies are based on four strategies: crop diversification, residual retention, minimum tillage, and fertilizer application, offering benefits such as improved soil organic carbon, soil pH, essential plant nutrients availability, and enhanced soil fertility (Jones et al., 2023; Ngigi et al., 2018; Turyasingura et al., 2023).

Experimental studies support the argument that CSS technologies offer multiple benefits. For instance, Mbabazize et al. (2023) in Kenya found that the sole application of biochar at 5 t ha1 to potatoes (Destiny) resulted in an increase of up to 2.54 units in soil pH. Moreover, adding diammonium phosphate (DAP) at 250 kg ha1 increased soil available phosphorus from 30.7 mg kg1 to 136 mg kg1. An earlier study by Munera-Echeverri et al. (2022) in Zambia in an analysis of maize (Zea mays L.) plots found that the application of pigeon-pea biochar (4 t ha-1) and permanent planting basins (20 x 20 cm) increased soil nitrates and soil moisture more than conservation agriculture. Tibasiima et al. (2023) investigated legume benefits in coffee plantations. Kobusinge et al. (2023) implemented mulching; cover cropping, and irrigation management in a coffee plantation to evaluate the impact on moisture in central Uganda. Their positive results are similar to Ivanova et al. (2021) study that studied soil fertility and health under different soil management strategies in Uganda.

Further to the above, earlier studies indicated that SOC is higher in soils under the CSS technologies under consideration in this study. For instance, field surveys and soil sampling across multiple sites compared no-till, crop rotation, and residue retention practices with conventional agriculture, and results indicated that there is a potential increase in SOC after 7–16 years (Cheesman et al., 2016; Muchabi et al., 2014). A review by Morugán-Coronado et al. (2022) further highlights the potential of CSS technologies to improve soil properties, increase drought resilience, and improve water and nutrient use and efficiency. It also points out that these improvements are essential to maintaining agricultural production sustainability and mitigating climate change impacts on food production.

Particularly, inorganic fertilizer application, a sure way of providing plants with the essential minerals needed for plant health, is another strategy that can complicate the understanding of CSS technologies. The commonly applied fertilizers in the pigeon pea cereal cropping system are NPK and UREA (REDS, 2022; UBOS, 2020). These are essential in Gerater Lira because of the unavailable nitrogen, phosphorus, and potassium characteristic of the soils in the region (Kayuki et al., 2017). However, fertilizer application is criticized for endangering soil in the long-run (Inubushi et al., 2020; Ivanova et al., 2021). This raises a question about whether farmers are motivated by an immediate increase in yields or by maintaining fertile soils.

Recent experimental studies on soil fertility demonstrate the dangers of misuse of technology to increase yield without regard for its effects on the environment. Inubushi et al. (2020) reported higher organic matter in plots that did not receive fertilizers compared to plots that received fertilizers in the previous 10 years. They recommend proper fertilizer dosages for sustained soil fertility. An experiment on soil fertility conditions under different soil management practices by Ivanova et al. (2021) reported organic farming's soil fertility benefits compared to inorganic fertilizers. They also specify the need for sustainable soil management practices to maintain soil fertility.

The above CSS technologies have been promoted in Gerater Lira since 2011 (S. Kaweesa et al., 2018; REDS, 2022). Several studies in Uganda, including surveys (Egeru et al., 2022; S. H. Kaweesa et al., 2020); case studies and other qualitative approaches (Namulondo & Bashaasha, 2022); and mixed methods (Ebong & Mwesigwa, 2021; Namuyiga et al., 2022), indicate that farmers are aware of the multiple benefits of CSS technologies but are less motivated by environmental, ecological, and soil benefits (Quarshie et al., 2023; Sarker et al., 2023; Turyasingura et al., 2023, p.7) and that for ecological benefits to be realized, farmers may need to first meet food, income, and social goals (Gosling et al., 2020, p.1).

Therefore, the challenge was to even elicit soil-related benefits amidst the overarching economic and social benefits. Nevertheless, we postulated that farmers adopted different combinations of CSS technologies for multidimensional goals, to which we used the "why, why" questions**,** and tested the postulate that the choice depended on goal hierarchies linking technologies to the end goal of providing food for the family and enhancing incomes, as earlier reported. Below, we discuss "goal hierarchy."

Goal hierarchy:

Attributed to Henri Fayol in the early 20th century, goal hierarchies are visual representations of the relationships between different goals at various levels of prioritization. Goal hierarchy allows individuals or organizations to break down overarching objectives into smaller, more manageable sub-goals (Kumar & Pant, 2023; Voxted, 2017). To simultaneously pursue different types of production goals, farmers' motivations go through a complex analysis of relationships among short-term and long-term goals, contexts, and trends (Locke & Latham, 2015, p.169). To which hierarchical approaches are applied for multi-objective optimization (Kumar & Pant, 2023).

Goal hierarchies have been used to analyze farmers' seed potato choices in Kenya using a means-end chain (MEC) framework by Atieno et al. (2023). Results in HVM indicated that resource efficiency, healthy crops, planting large areas, and avoiding pests and diseases were at the lowest level of abstraction; improving yields, increasing income, and saving seeds were at the next level. Self-development, well-being, health, peace of mind, and happiness are at the highest levels. Ngigi et al. (2018) assessed farmers' motivations for CSA practices. They also used MEC. The resultant HVM revealed soil fertility, increased early maturity, and adaptation to drought at the lowest level; crop yield, food security, and income were next; and at the top were comfort, health, and peace.

Similarly, Kilwinger et al. (2020) examined perceptions regarding banana planting material sources in Uganda. Results indicated that high-yielding, marketable, fast-growing, and multipurpose crops were at the lowest level, and the next-level considerations were food, income, reduced risk, and energy savings.

The researchers suggest taking contextual realities into account when writing adaptation plans, varying approaches by group, and encouraging farmers to adopt green strategies.

Namulondo & Bashaasha (2022) used a three-wave household panel dataset to investigate the impact of labor-saving technologies on children's nutritional status in Uganda. They reported technology benefits to farmers as increased productivity and time-savings; at the next level, they are food, income from selling surplus food, time for preparing food and feeding children, followed by diet diversification, meal frequency, and health expenditure, and these determine the child's nutritional status. They recommend that future research should focus on specific farm activities using technology to reduce women's workload.

From the above studies, it can be inferred that perceived benefits motivate farmers to utilize CSS technologies to meet their goals. However, clear goal subdivisions are lacking in many studies. For proper planning and efficient allocation of resources by farmers and to commit to using combinations of CSS technologies, FPGs like economic, social, and environmental quality may need to be rearranged into goal hierarchies with specific immediate and end goals (Jeong et al., 2021, p.2; Locke & Latham, 2015, p.120).

Immediate goals

According to the study by Ngigi et al. (2018), the immediate goals of adopting climate-smart practices (soil-related) are to enhance soil fertility, retain soil moisture, prevent soil erosion, and retain soil nutrients to enhance soil fertility, maintain soil moisture, prevent soil erosion, and maintain soil nutrients. In the study by Atieno et al. (2023), farmers' immediate goals are to use resources efficiently, plant large areas, and have healthy crops. In the study by Okello et al. (2018) in Tanzania, the immediate goals are to increase yields and decrease costs. In Kilwinger et al. (2020) study, the immediate goals are high-yield, marketable, and fast-growing.

End goals

In the studies above (Atieno et al., 2023; Kilwinger et al., 2020; Ngigi et al., 2018), the end goals are to increase yields, maintain fertile soils, provide food, and boost income. While food and income are not the only FPGs in all studies, food and income are the main FPGs that motivate farmers to adopt CSS technologies (Gosling et al., 2020; Isubikalu et al., 1999; S. Kaweesa et al., 2018). and more specifically in Gerater Lira, Lango (Ebong & Mwesigwa, 2021; S. Kaweesa et al., 2018).

From the analysis of CSS technology benefits, the immediate and end goals above, the goal hierarchy for CSS technologies has "add soil nutrients," "maintain soil moisture," and "maintain soil nutrients" as immediate goals, "maintain fertile soils," "increase yield" at the next level, and "provide own food" and "increase farm income" as end goals. It is further recommended to validate goal and value constructs before concluding (Chen, 2013), given that one's goal may differ from another person's, and different elicitations generate distinct results (Kilwinger & van Dam, 2021). For example, Okello et al. (2018) showed that yield was an immediate goal, but not for Atieno et al. (2023). Thus, exploring goal hierarchies remains context-based, and the study hoped to use Goal Hierarchy Theory to shed more light on farmer production goals in Gerater Lira. Next, we turn to goal theory as the theoretical underpinning of the study.

Goal Hierarchy Theories, Mean-End Chain Frameworks, and the Centrality Index

Goal Hierarchy Theory, developed by Edwin Locke and Gary Latham in the 1960s, proposes that individuals have different levels of goals that influence their behavior and effort. The goals are indeed multidimensional and hierarchical, with higher-level goals providing motivation and direction for lower-level goals. The theory suggests that individuals are more likely to achieve their goals if they have a clear hierarchy of goals, with each level contributing to the overall achievement of the ultimate goal (Deutsch & Strack, 2020; Locke & Latham, 2019). Goal Theory has the major weakness of not focusing on the outcome instead of the process of goal attainment (Jeong et al., 2021; Locke & Latham, 2006). Nevertheless, we maintained its core conceptualization in our analysis and supplemented it with the means-end framework and the centrality index to link CSS technologies to end goals.

The means-end chain framework, attributed to Gutman in 1980, provides a framework for understanding decision-making processes individuals use to achieve their goals (Kilwinger & van Dam, 2021; Reynolds & Phillips, 2017). The framework suggests that individuals evaluate potential actions or strategies based on their ability to achieve their desired ends. In other words, individuals choose the means they believe will lead to the desired outcome.

A centrality index is a statistical measure that quantifies the importance of a node in a network of relationships. It provides a measure of how central a node is to the network, indicating its level of connectivity and influence (Kupilas et al., 2022). Bringmann et al. (2019) raise concerns about the applicability of traditional centrality measures, such as degree, betweenness, and closeness, in psychological networks, suggesting the need for tailored measures. For our study of goals, CI measured the importance of a sub-goal (node) to the entire hierarchy (Kupilas et al., 2022).

We found MEC and the centrality index to be more compelling since we were interested in the decision-making process, which is espoused under MEC, and the centrality index became more useful in facilitating the disaggregation of results into gender subgroups. The choice of these frameworks was based on the desire by the researchers to present a visual representation of the goal hierarchies that guide decision-making as farmers seek to mitigate the effects of climate change on soil fertility and, at the same time, use the centrality index because it can highlight subgroup differences without requiring more data, even when the samples of the subgroups were small (Kupilas et al., 2022). Thus, showcasing the different vulnerability of gender subgroups reported in earlier studies (Atieno et al., 2023; Ngigi et al., 2018).

Technology use is a behavior disposition further understood to be determined by the capacity to implement the desired actions for goal attainment (Locke & Latham, 2015). Furthermore, there was compelling evidence suggesting that sex and age affected what a farmer could and could not do in Gerater Lira. For instance, Ebong & Mwesigwa (2021) S. Kaweesa et al. (2018) and Namuyiga et al. (2022) reported sex and age differences in technology adoption; moreover, national statistics show differences in education and access to land between females and males (UBOS, 2019). It was on this basis that the researchers further interrogated gender differences in goal hierarchies and CSS technology use.

Gender Differences in Agriculture and Technology commitment Decisions

Gender disparities in agricultural technology adoption and commitment are a significant issue, with women often facing increased barriers due to sociocultural norms and a lack of resources. Recognizing and addressing these disparities is crucial for sustainable agriculture in Uganda and the Lango sub-region (S. H. Kaweesa et al., 2020). Women's differing needs and access to resources must be considered in policy and project design. Gender differences in technology adoption are influenced by access to resources, education, decision-making power, and participation in associations.

Moreover, agricultural adoption studies indicate gendered results, with female farmers lagging in agricultural technology adoption. Female farmers prioritize technologies that improve efficiency and labor productivity (Pellegrina, 2023; Zaman et al., 2023). While male farmers are more motivated by enhancing incomes and therefore respond to market demands (Ikendi et al., 2023; S. H. Kaweesa et al., 2020). In the study area, women are less educated, have smaller farm acreages, and report higher food shortage incidents. They are generally constrained by a lack of access to essential agricultural inputs, including land, credit, and information. Research further indicates that traditional norms limit women's access to markets, bargaining abilities, and decision-making abilities (Namuyiga et al., 2022; UBOS, 2020).

Therefore, based on the existing literature summarized above, the main postulate was that pigeon pea farmers respond to deteriorating soil fertility by adopting CSS technology to manage soil nutrients and soil moisture to maintain fertile soils to increase yields to levels sufficient for household food and as a source of farm income.

CSS technology commitment also depends on farmer capacity (Wang &Deta). The researchers further disaggregated the findings by gender subgroups (sex and age) to test for gender-based biases in the data. Two age groups young farmers (farmers aged below 40 years) and old farmers (those aged at least 40 years). Age classification was based on (Horng et al., 2001) where the emphasis is on the physical features of the subjects, and since farming in the Lango subregion is labor intensive, we believe this clarification is appropriate. More justification for the classification can be found in the analysis of population structure (Wang, 2019), where he gives a range of 15 – 65 years and the midpoint become 39.5 years. In similar studies, age has been found to influence (Bananuka et al., 2022; Egeru et al., 2022).

Analytical framework:

The study used the Means-End Chains (MEC) framework to analyze differences in CSS technology use attributed to production goals among pigeon pea farmers. MEC is widely used to generate a hierarchical model of attributes, consequences, and values (Kilwinger & van Dam, 2021; Reynolds & Phillips, 2017). We modified the hierarchical model to include technology, immediate consequences, and end goals.

To match a behavior/action consequence framework (Deutsch & Strack, 2020), the model was modified. Our model consists of CSS technologies, immediate goals, consequent goals and end goals. Pigeon pea farmers choose CSS technologies to add soil nutrients, maintain soil moisture and nutrients. These nutrients are vital for improved soil fertility, increased yields needed for food, and as a source of income. This adjustment was further justified by the fact that these farmers had previously reported food and income to motivate their adoption decisions (S. Kaweesa et al., 2018). We also validated other benefits not related to soil included in Table 3.1.

We further highlighted contextual differences among farmers based on sex, age, years of education, household size, farm size (acres), years of CSA experience, and monthly income. Our innovative use of the centrality index made it possible to report on goal hierarchical differences for gender subgroups. This broke the norm of HVM comparisons between men and women. We believe that our analysis enriches our understanding of gender subgroups since a young woman is contextually different from an old woman. Contextual differences affect adoption and commitment (Atieno; kilwnger ngigi) in similar studies. Figure 1.1 summarizes the overall analytical framework.

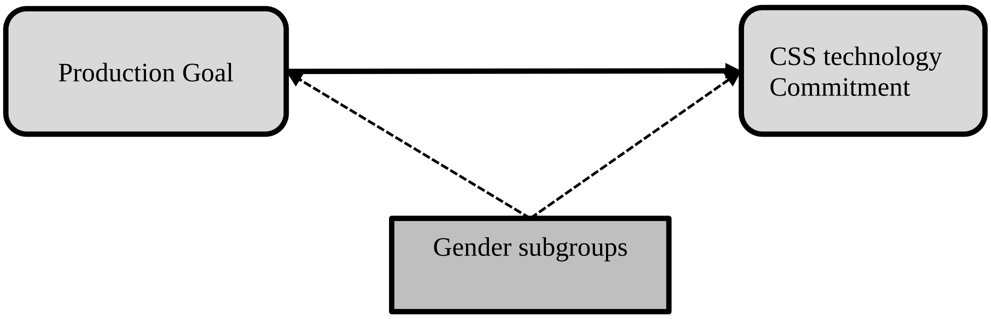

Figure 1.1: a conceptual framework of the study

Under MEC, a construct is linked to other constructs, and the more links running through a particular construct, the more central it is in the hierarchical value map (Kupilas et al., 2022). This is measured by a centrality index. This is the ratio of in-degrees plus out-degrees of a construct to the sum of all links in the hierarchical value map. The values are presented in an implications matrix (IM), and the CI calculation is represented in the equations that follow.

$$IM = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1i} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2i} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots & \cdots & \vdots \\ a_{j1} & a_{j2} & \cdots & a_{ji} & \cdots & a_{jn} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{ni} & \cdots & a_{nn} \end{bmatrix} \qquad (3.1)$$

The calculation of the centrality index is shown in equations 3.2, 3.3, and 3.4, and the final centrality index is 3.5. Column S includes the sum of our constructs in the row, and column T includes the sum of our constructs from both relevant rows and columns.

$$S_j = \sum_{j=1}^{n} a_{ji} \qquad (3.2)$$

$$T_j = S_j + \sum_{j=1}^{n} a_{jn} \qquad (3.3)$$

$$\sum T = \sum_{j=1}^{n} T_j \qquad (3.4)$$

Finally, the centrality index (CI) is given at 3.5

$$CI_j = \frac{T_j}{\sum T} \qquad (3.5)$$

CI, as reported by LadderUX software made it possible to highlight goal priorities by gender subgroups.

Research approach

Study area

This study was part of a climate-smart agricultural collaborative research project supported by NORHED II. In Uganda, the participating institutions include Makerere University, Rural Enterprise Development Solutions, and the Norwegian University of Life. The data is from four sub-counties of the Gerater Lira district, including Awei, Amugu, Omoro, and Gerater Lira Town Council.

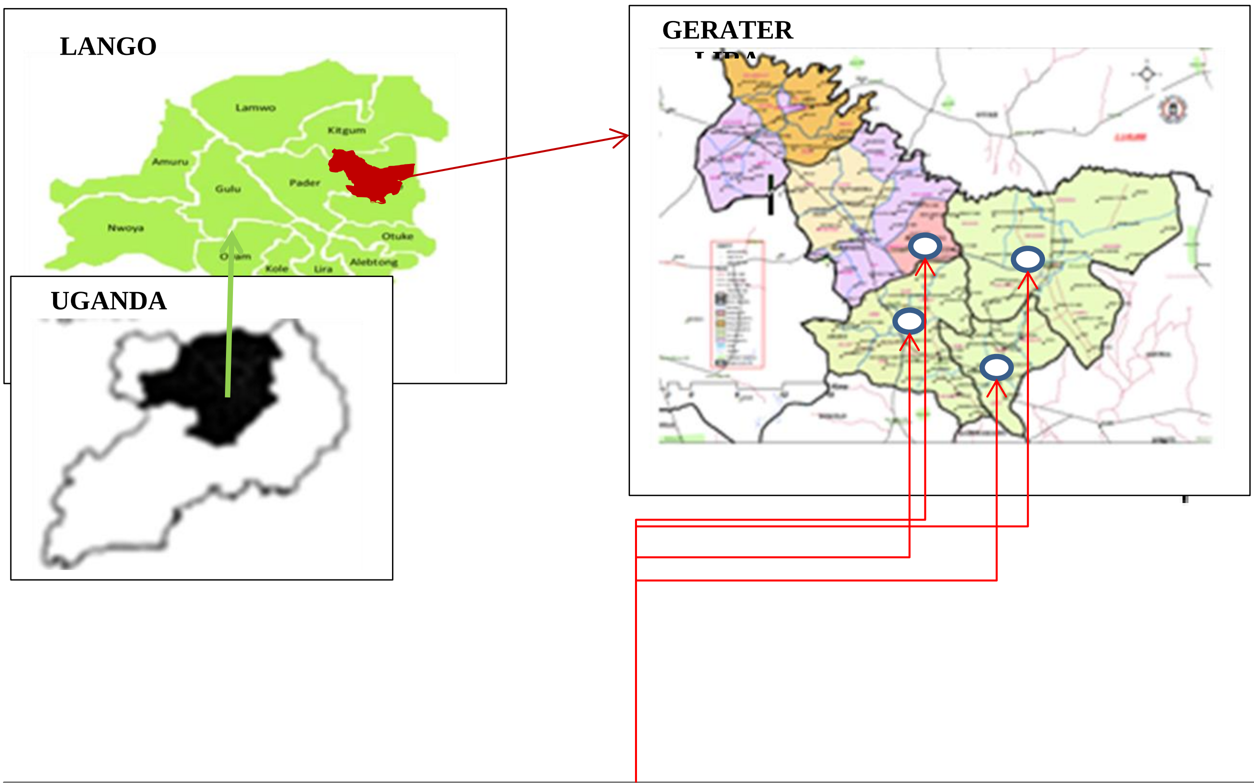

Figure 2: Map of the Study Area-Gerater Lira

These sub-counties represent diverse socioeconomic conditions, institutional arrangements, and susceptibility to climate change in the region. Awei and Amugu have received CSA training under this research project. Omoro is the most food-insecure sub-county, and Gerater Lira town council is the most urban in the Gerater Lira district. The researchers believe that these sub-counties represent Gerater Lira's diversity and context.

The area of study is in a region with one long rainy season, and the primary source of livelihood is smallholder farming (S. Kaweesa et al., 2018). Household food shortages are at 64.6%, compared to the national average of 47.3%. Climate-induced shocks such as floods and drought-invasive species are at 93.5%, compared to the national average of 74.2%. Productivity for major cereals (maize, rice, and sorghum) is 25% lower than the national average (UBOS, 2020).

Pigeon peas play a vital role for people in this region and are major contributors to CSA practices are concerned. The researchers thought they would paint a comparable picture of CSA practices based on locally available strategies. The districts were selected for being the highest producers of pigeon peas in the country (S. Kaweesa et al., 2018; Namuyiga et al., 2022). On top of other economies and cultures noted by previous scholars (Namuyiga et al., 2022; Nkwonta et al., 2023), they could also solve soil fertility, food insecurity, and carbon sequestration.

Sampling procedure:

The study purposively recruited 20 farmers from 150 farmers who had taken part in CSA training, and 20 more were recruited based on cultivating pigeon peas as a main household crop. The selected pigeon pea farmers were expected to have rich experience of pigeon pea production amidst changing production goals.

In addition, they were expected to face adverse climate change effects. In total, 40 farmers were recruited and interviewed in July, August, September and October 2022. 39 complete interviews were considered for the final analysis. They comprised 16 females and 23 males, of whom 53.8% were categorized as young farmers below 40 years. This sample size is sufficient because the major subgroups (male and female or young and old) exceeded 12, the number that Boddy (2016) recommends for in-depth interviews to achieve circulation. Moreover, the sample size generated sufficient ladders of 172 as compared to Ngigi et al.'s (2018) 125 and in a similar analysis, Atieno et al. (2023) used an equal sample size.

Data collection:

Empirical studies use in-depth interviews to elicit farmers' technologies and probe the respondents with a series of "Why is it important to you?" questions in the so called laddering interview (Atieno et al., 2023; Kilwinger et al., 2020; Kilwinger & van Dam, 2021; Ngigi et al., 2018). This technique is strong in data mining and elicitation of laddered responses that reveal numerous short-term and long-term benefits of a behavior (Kilwinger & van Dam, 2021; Reynolds & Phillips, 2017). The responses generate different levels of abstraction and when analyzed form hierarchical value maps (HVM). Here, we administered a semi-structured tool to elicit the contextual factors that determine climate change adaptive capacity and further asked the farmer to select the CSS technology they ever implemented on his or her farm. For each technology selected, the farmer was asked "why the technology was important?" We then probed the farmer for a response that pointed to soil-related goals. The adjustments to data collection, especially the laddering technique, were intended to capture soil-related benefits that are otherwise not a priority for farmers and are hardly recalled. Our actions were justified by (T. J. Reynolds & Phillips, 2017). They suggested that the laddering question could probe the direct benefit of an action or behavior. Pointing out that in laddering, a researcher can use preference differences or usage questions. Depending on the respondent's context and the direction in which the interview is conducted (T. J. Reynolds & Phillips, 2017).

Table 3.1 Production goal construct codes, descriptions, and percentages (%) in the data

Code	Theme Description	% in the data
CSA-technologies		
Crop diversification	The managing of more than one crop enterprise on the farm, ie: Growing many crops on the same plot at the same time; Growing two crops each in a season on the same plot; and Growing crops that maintain the well-being of other crops and/or soil.	100
Residual retention	The reuse of farm wastes to manage soil. Ie, Application of decomposed/burned farm wastes to the soil in the garden/plot. Spreading of farm/crop wastes the in garden Reapplication of decomposable farm wastes to the soil in the garden.	69
Fertilizer application	The application of inorganic fertilizer to the soil in the garden ie,	62

Code	Theme Description	% in the data
	Application of NPK to the soil in the garden Application of UREA to the soil in the garden. Application of any other inorganic fertilizer to the soil in the garden	
Minimum tillage	The planting of crops with minimum soil disturbance ie, Clearing the garden and planting without tilling. Having made basins (holes) for present and future planting. Having made rip lines for present and future planning.	38
Immediate Goals		
Address dietary needs	The goal or reason was to have different food types as needed to make a good or complete meal. To have different food types for different meals.	85
Spread production risk	The goal or reason was to have at least one crop to feed the family if other crops fail or to have at least one crop to sell if other crops cannot get to the market.	51
Retain soil moisture	The goal or reason was to keep the soil wet, to keep the soil humid, and to prevent the soil from getting dry.	62
Retain soil nutrients	The goal or reason was to prevent on-farm flooding, prevent soil runoff, or nutrient leaching.	54
Add soil nutrients	The goal or reason was to add organic matter, make soil have healthy crops, have crops with broad leaves, to have crops with a sizable stem.	41
Consequent Goal		
Maintain fertile soils	The goal or reason was to have a good or better or high or higher crop harvest in the following season, to have crops grow well; to keep soil dark, and to keep soil vegetative.	46
Produce for markets	The goal or reason was to produce crops that are of features (size or color content or quantity) that are demanded or preferred by the market.	56
Increase yield	The goal or reason was to have more volumes produced.	97
Improve own health	The goal or reason was to prevent or treat disease in a home. To have happy children, to have energetic members in a home.	56
End Goals/Personal Values		
Increase Income	The goal or reason was to gain monetary value (cash, assets...) or reduce expenditure at home	100
Provide own food	The goal or reason was to have or increase food for their home.	90
Benevolent	The goal or reason was too different from increasing income or providing own food.	38

Source: Field data

Data analysis

Laddering interviews were coded using mind maps and pre-stated themes. Mind maps provide a visual representation of ideas and concepts, making it easier to visualize connections and relationships between different pieces of information. The researchers listened to the farmer and manually analyzed their responses on their mind map (Mammen & Mammen, 2018). Our mind maps were developed using themes in related literature that applied laddering interviews to analyze goal structures for similar CSS technology adoption (Atieno et al., 2023; Ngigi et al., 2018). The codes presented in Table 3.1 were validated by two coders as part of the research team. The team met every evening to compare the codes, and only codes agreed to by both parties were considered. For codes that generated disagreements, the team sought consensus and often reached agreement after reengaging the farmer for clarifications. 16 goal hierarchy constructs emerged from 39 farmer interviews. The constructs were grouped into CSS technology, immediate goals, consequent goals, and personal values. Then individual mind maps with complete constructs of the goal hierarchy of CSS technology → immediate goals → consequent goals → personal values/end goal were entered into LadderUX-software (https://app.ladderux.org/luxapp/projects) for analysis. LadderUX reported a centrality index for each construct and the aggregate HVM for farmers. The 39 interviews with 16 constructs generated 172 ladders, 411 direct links, and 409 indirect links. This, according to the explanations given before (T. J. Reynolds & Phillips, 2017), was sufficient data to generate reliable conclusions under MEC.

We relied on the integrity of coders who are natives of Gerater Lira and on their commitment to remaining true to the study. We further compared our results with existing literature and found that our goal hierarchy constructs are consistent with those of Atieno et al. (2023), Kilwinger et al. (2020), and Ngigi et al. (2018). To generate hierarchical value maps, trivial repossess needed to be eliminated. A cut-off point technique was used. While it is recommended to try different cut-off points and select the one that most effectively presents an HVM logical structure. The study used a cut-off point of 7, where at least 82% of the links remained.

Results

Contextual factors of interviewed farmers

Table 4.1 shows young male farmers were the most educated subgroup with 9.36 years of formal education. The least educated were old female farmers. Old male farmers reported the highest monthly income and the largest farm size. In contrast, young male farmers had the smallest farm size, and old female farmers reported the lowest monthly income. On average, old female farmers were the oldest subgroup with 56.4 years, and the youngest lot was young male farmers with 29.5 years.

Table 4.1: Summary statistics by gender subgroup of laddering interview participants

Variables	Old Female (N=9		Young Female (N=7		Old Male (N=9)		Young Male (N=14)	
	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Age (year)	56.44	5.46	31.86	5.76	54.44	7.81	29.50	6.24
Education (years)	6.33	1.32	6.86	3.72	8.78	3.99	9.36	3.08
Household size	6.11	1.62	5.57	1.62	8.56	1.94	4.71	1.82
Farm size (acres)	2.22	0.97	2.79	1.15	3.78	1.99	2.11	1.18
CSA experience (years)	2.89	1.54	2.57	2.15	4.22	5.07	2.43	2.62
Monthly income (‘0000’ UGX)	12.00	5.77	18.43	16.86	16.00	14.30	14.54	15.95

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Note: old means a farmer was at least forty (40) years; young means a farmer was less than forty (40) years

Source: Field data

Female farmers interviewed exhibited less adaptive capacity than their male counterparts. This is demonstrated by their lower scores on key competence indicators of education, access to land, experience, and income.

Centrality indices for goal hierarchy construction:

Table 4.2 presents the results of centrality index calculations of 39 laddering interviews regarding CSS technology ever practiced. These interviews were organized into four (4) categories that included crop diversification, residue retention, minimum tillage, and fertilizer application. Among these technologies, as indicated by the centrality index, crop diversification (CI = 0.09) was predominant. This means the farmers asked for linked crop rotation or cover crops to other constructs.

Table 4.2: Centrality Index (CI) for the 16 goal constructs.

Construct code	Code no.	Centrality index (n=39)
CSS technologies		
Crop diversification	1	0.09*
Residual retention	2	0.05*
Fertilizer application	3	0.02*
Minimum tillage	4	0.02*
Immediate goals		
Address dietary needs	5	0.10
Spread production risk	6	0.05
Retain soil-moisture	7	0.06*
Retain soil-nutrients	8	0.05*
Add soil nutrients	9	0.04*
Consequence goals		
Maintain fertile soil	10	0.06*
Produce for markets	11	0.06
Increase yield	12	0.13*
Improve own health	13	0.05
End goals		
Increase own income	14	0.10*
Avail own food	15	0.08*
Others	16	0.03
Total CI		1.00
		$\sum CI^* = 0.72$

Where "" denotes a predicted soil-related goal construct*

Source: Field data

There were nine (9) goals linked to CSS technology. These goals had different levels of abstraction and were thus further regrouped into immediate goals—those presented as immediate during the interviews.

They included "address dietary needs," "spread production risk," "retain soil moisture," "retain soil nutrients," and "add soil nutrients." Among the immediate goals, as indicated by the centrality index, “address dietary needs” (CI 0.09) was predominant.

The other subgroup of goals was the consequent goals, which are realized after the immediate goals. They include “maintain fertile soils," “produce for markets," “increase yield," and “improve own health." The overall dominant goal was "increase yield" (CI = 0.13).

Three (3) personal values or end goals emerged from the 16 constructs of the production goal. In addition, they included increasing farm income, making self-sufficient food available, and being benevolent. Among personal values, "increase farm income," with a CI of 0.10, was predominant.

Goal Hierarchies

Figure 4.3 presents the aggregate hierarchical value map (HVM) for 39 farmers interviewed. This gives a visual picture of the goal hierarchy of how farmers link personal values to the CSS technology of choice. The boldness of the line gives a strong visual link between the two constructs. The bolder the line, the stronger the link between the two constructs. As shown in HVM, farmers are linked strongly to "increase yield" to "increase farm income" compared to other links. The choice of CSS technology is thus closely related to a farmer's objective of "increasing yield" and end objectives of "increasing farm income" and "providing own food."

The other dominant goal was to "address dietary needs" linked to "produce for markets" with the end goal of "increasing income." "Address dietary needs" was also related to "provide own food" and linked to "own health".

Finally, with the movable HVM in ladderUX, the researchers moved the nodes and regrouped them to highlight the predicted soil-related goals discussed in the conceptualization chapters. Accordingly, these formed 75% of the total production goal constructs for CSS technology. This is supported by the sum of centrality index values (CI*) for soil-related goal constructs in Table 4.

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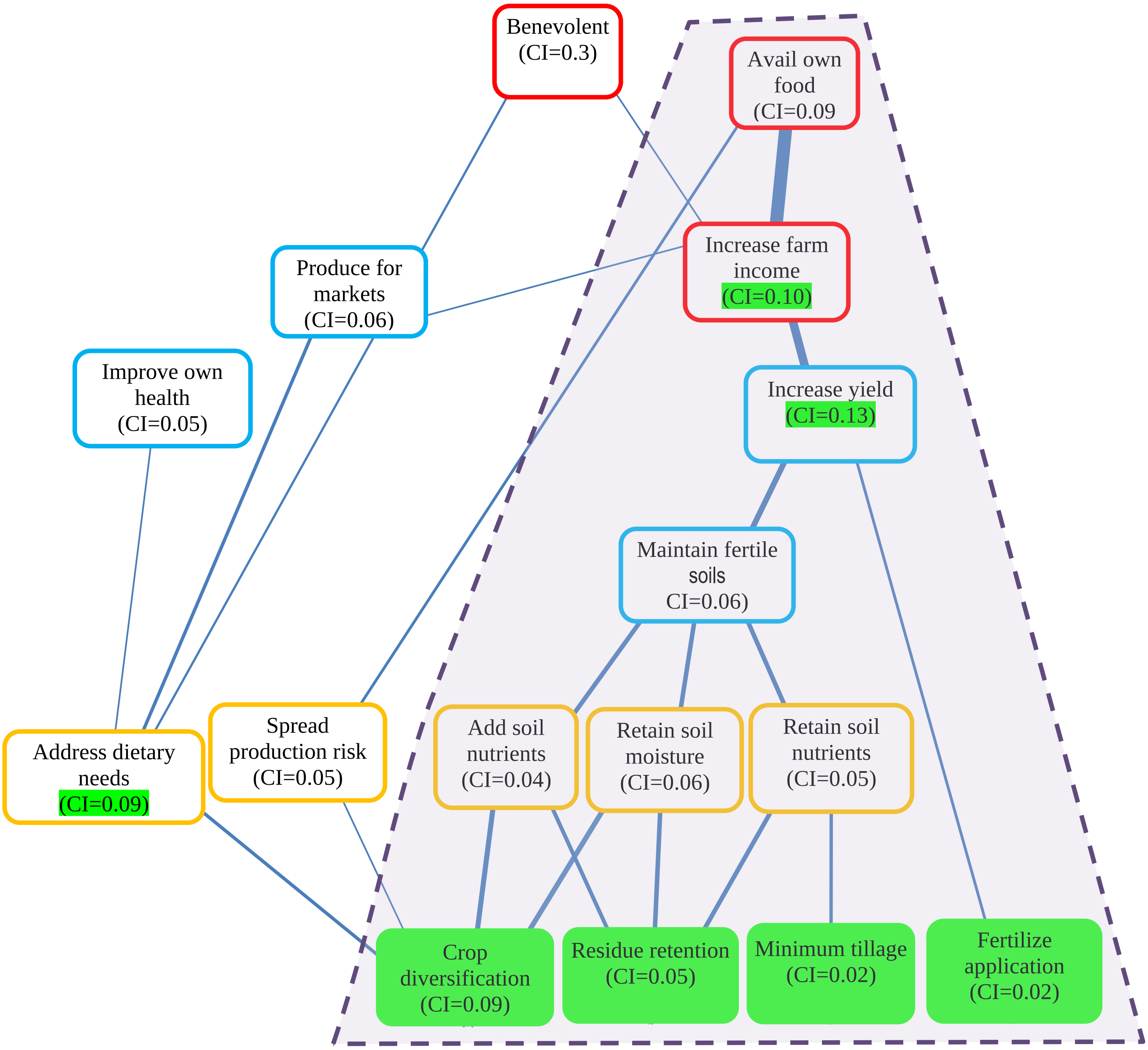

Figure 4.3: Aggregate HVM n=39) Cut-off point = 7

KEY:
Personal values Consequent goals Immediate CSA-technology Predicted Soil related goals

Centrality Index by Gender Subgroups

Table 4.3 presents the centrality index of gender subgroups. Accordingly, the constructs present different centrality indices, indicating differences in goal or value preference between gender subgroups.

Table 4.3: Centrality Index by Gender Subgroups

Construct	Aggregate (n=39)	Old Female (N=9)	Young Female (N=7)	Old Male (N=9)	Young Male (N=14)
End goals					
Increase own income	**0.10**	**0.08**	**0.10**	**0.12**	**0.12**
Avail own food	0.08	0.09	0.08	0.07	0.08
Others	0.03	0.02	0.02	0.01	0.05
Consequence goals					
Maintain fertile soil	0.06	**0.09**	0.07	0.05	0.05
Produce for markets	0.06	0.05	0.07	0.03	**0.09**
Increase yield	**0.13**	**0.12**	**0.13**	**0.15**	**0.14**
Improve own health	0.05	**0.07**	0.03	0.05	0.04
Immediate goals					
Address dietary needs	**0.10**	**0.11**	**0.11**	**0.06**	**0.10**
Spread production risk	0.05	0.02	0.04	**0.08**	0.07
Retain soil-moisture	0.06	**0.11**	0.03	0.08	0.04
Retain soil-nutrients	0.05	0.02	**0.08**	0.07	0.04
Add soil nutrients	0.04	**0.08**	0.05	0.03	0.02
CSS technologies					
Crop diversification	**0.09**	**0.09**	**0.09**	**0.09**	**0.09**
Residual retention	0.05	**0.06**	0.04	**0.06**	0.04
Fertilizer application	0.02	0.01	**0.03**	**0.03**	**0.03**
Minimum tillage	0.02	0.01	**0.03**	**0.03**	0.02
Total CI	1.00	1.00	1.00	1.00	1.00

Note: old means a farmer was at least forty (40) years; young means a farmer was less than forty (40) years

Source: Field data

By selecting a subgroup that linked the node (goal construct) the most, the researchers identified goals that inspired particular subgroups. Our results indicate that according to the aggregate HVM, old female farmers were inspired by goals such as producing their food (CI = 0.09) and improving their health (0.07). Female farmers, both old and young, tended to be motivated by improving soil fertility (CI = 0.09; CI = 0.11; CI = 0.08). Young male farmers were distinctively inspired by "benevolent" (CI = 0.05) and producing for markets (CI = 0.09). It was further established that old male farmers were also motivated by spreading production risks (CI = 0.08). Old farmers were more likely to reuse farm wastes (CI = 0.06) while fertilizer application and minimum tillage were least affected by subgroups (CI = 0.03 and CI = 0.01).

Discussion

Gender issues

The age structure reported in Table 4.1 contradicts Ngigi et al.(2018) findings that reported male farmers engaged in CSA being older than female farmers. The unusual age gap between women and men in Gerater Lira could be that the area was affected by civil wars until 2007 and paralyzed livelihoods. Since men tend to lose lives in wars than women both as fighters and captives (Micheletti et al., 2018; Plümper & Neumayer, 2006), this might have reduced the number of elderly men who were young during the civil war.

We, however, found persistent vulnerability among women, as indicated by their lower scores on income, education, and access to land as reported in other studies (S. Kaweesa et al., 2018; Ngigi et al., 2018; UBOS, 2020). Thus, as evidenced by adaptive research interpretations and similar findings, female farmers in the Gerater Lira district are more vulnerable to climate change than their male counterparts. Therefore efforts to empower women in the wake of climate change need to be emphasized.

CSS technology:

The study reports that farmers manage different crops, reuse farm waste, practice minimum tillage, and add fertilizers to achieve their end goals. This signals technology commitment among the sample and contradicts earlier assertions that reported low adoption of CSS technologies (S. Kaweesa et al., 2018; UBOS, 2020). This is likely because our sample was not random. We selected farmers who were introduced to CSS technologies and those who grow pigeon peas. Thus most of them were expected to be practicing CSA more than the average farmer in the district. Nevertheless, the centrality index figures for minimum tillage and fertilizer application (CI=0.02) reaffirm the low adoption especially of fertilizers in the region as reported before (UBOS, 2020). Farmers need money to buy fertilizers if they are to apply them to pigeon pea plots and the fact that most of them are low-income, they hardly can afford fertilizers. To improve the situation, it might require that they intensify residual retention and make their farmyard, compost, and biochar.

Production Goal

These results highlight the multidimensionality of production goals for CSS technology as espoused by the hierarchy goal theory (Jeong et al., 2021; Locke & Latham, 2006, 2019), means-end framework (Kilwinger & van Dam, 2021; Reynolds & Phillips, 2017) and in other empirical studies (Atieno et al., 2023; Kilwinger et al., 2020; Ngigi et al., 2018). It contrasts with earlier findings that place income and household food as the most critical end goals of production (Atieno et al., 2023), which would place those constructs at lower abstraction levels. Indeed, there might have been other goals beyond income and food that we would capture. However, because we were duty-bound to analyze soil-related goals within a production season, we felt comfortable having food and income as farmer production goals. Our comfort is further supported by earlier studies that reported income and food as the main farmer production goals in the region (Isubikalu et al., 1999; S. Kaweesa et al., 2018; S. H. Kaweesa et al., 2020).

Nevertheless, our results agree with previous research that indicated male farmers were more commercial-oriented and money-minded (Ikendi et al., 2023). The explanation for this could be that male farmers in the study area are the breadwinners for their homes; they are expected to pay school fees and medical bills and buy necessities, including clothes for their wives and children (Akpo et al., 2020). In this context, they look for money, and indeed, they earn almost double what female farmers earn.

In contrast, the finding that women are more concerned about food can also be corroborated with findings by Akpo et al. (2020) that reported female farmers tend to worry more about household food availability. The explanation for this could be that females in Gerater Lira prepare food at home. Children look up to their mothers for food, and females report higher incidents of household food shortages (UBOS, 2020). Another explanation is that female farmers have limited income sources because they are less educated. This means they have fewer chances to earn a living, forcing them to exchange food for income.

Goal hierarchies:

Goal hierarchies refer to farmers' mental structure. We set our objective to explore the relationship between these subdimensions (Chen, 2013; Reynolds & Phillips, 2017). Our results reaffirm our soil-related goals. We recognize that most farmers mention non-soil-related goals, but our deeper probe with why questions revealed the significance of soil-specific goal hierarchies, which are estimated at 75% of the total linkages in the framework. Using a series of why questions, we generated ladders of what inspires farmers' choice of technologies. This debunks earlier assertions that ecological goals are hardly elicited because farmers easily recall economic and social benefits (Gosling et al., 2020).

Immediate goals:

Farmers mentioned "retain soil moisture," "retain soil nutrients," and "add soil nutrients" as some of the immediate reasons for adopting CSA technology. Indeed, managing soil moisture and soil nutrients is a well-established goal among farmers in the literature literature (Jones et al., 2023; Thierfelder et al., 2018; Tibasiima et al., 2023). We sought to establish the extent to which these are deliberate goals for CSS technology being pursued in the wake of climate change's adverse effects in the area of study. It is consistent with Ngigi et al.'s (2018) and Atieno et al,'s (2023) findings that farmers use CSS technology to manage soil moisture and nutrients.

Consequent goals:

When asked why managing soil moisture and nutrients was important, farmers revealed that this would lead to higher yields. Others thought it would help maintain fertile soils. In earlier studies, some farmers used yields as a measure of soil fertility (Bajgai & Sangchyoswat, 2018; Buthelezi-Dube et al., 2020). Others observe the color of the soil and vegetative cover, among other indicators, to tell if the soil is fertile. As part of our study, the objective was to determine the motivation for CSS technology. We defined the goal of "maintaining fertile soil" as a deliberate effort to preserve soil capacity to support the same or more plants in the following season. Our finding is that farmers are less motivated by maintaining fertile soils than by increasing immediate yields.

A key point is that farmers aiming at increasing yield often do so without regard for soil health effects. This is supported by the high centrality index value of "increase yield," where up to 97% is linked or mentioned as a consequent goal. In contrast, "maintain fertile soil" scored a low centrality index, with only 46% mentioning it as a consequent goal. This suggests that farmers tend to boost yields with less regard for maintaining fertile soils or the environment. Our sample reaffirms earlier observations by Pagnani et al. (2021) that female farmers care more about soil fertility than male farmers. This further highlights the need to engage female farmers in soil fertility improvement efforts in Gerater Lira.

End goals:

As discussed, the study adopted end-of-season farming goals. "Increasing farm income" and "providing own food" emerged as end goals that inspired farmers to implement the CSS technology under study.

Conclusions and implications:

In this study, the authors attempted to validate farmers' production goals for CSS technologies. 39 farmers who had previously been introduced to CSS technology were engaged in laddering interviews. Using the Means-End Chain framework, the authors present soil-related goal constructs alongside other functional goals linked to CSS technologies. The authors further calculated the centrality index to estimate the strength linkage for each construct. They also produced a hierarchical value map to visualize the mental structure of goal constructs linked to CSS technologies.

The authors have derived the goal hierarchy by validating the goals and goal structure behind farmers' choice of CSS technology. The goals are divided into two broad categories: non-soil-related and soil-specific goals. Soil-related goals account for 72% of the total linkages in our framework; they include managing soil moisture and soil nutrients to maintain fertile soils and improving yields to meet farmer food and income goals. It is worth noting that 62% of the interviewed farmers used inorganic fertilizers and linked this mainly to increasing yields. There is a need to sensitize farmers about the long-term effects inorganic fertilizers might have on future soil fertility. This is to avert the looming danger posed by the higher desire to increase immediate yield (CI=0.13) than the maintain fertile soils (CI=0.06)

Farmers' choice of CSS technologies, especially crop diversification, was also linked to non-soil-related goals. A number of these goals were linked to "produce for markets" to increase farm income, improve health, and provide food for the family. Farmers also reported benevolence as an end goal. These non-soil-related goals and personal values are key determinants of technology commitment. However, the need to focus on farmers' perspectives regarding soil-specific goals inspiring CSS technology has been long overdue, especially in light of climate change's adverse effects. Nonetheless, as farmers venture into maintaining fertile soil, it is imperative to enhance their incomes to drive down the need for immediate increases in yields. This is detrimental to long-term soil fertility.

In general, farmers' choice of CSS technology is linked to "increased income," and old female farmers' choice of CSS technology is linked to producing their food. Again, the centrality index helps identify gender subgroup-preferred goals. This fits CSS technology in the context of farmers, as it has already been reported that these subgroups have differences in access to land, level of education, income earned, age, and experience. It also needs to be noted that female farmers are more inclined to care for soil moisture and soil nutrients than male farmers. Male farmers prefer to produce for markets than female farmers. The implication is that proponents of CSS technology may need to target gender subgroups to achieve better results with CSS technology.

Our work extends MEC use beyond identifying factors influencing CSS technology choice by gender subgroups. It uses the centrality index to isolate soil-related goal hierarchies that inform farmers' production goals for CSS technology. Constructs that appeal to soil-related benefits; also highlight gender tendencies predicated on the context of the interviewed farmers. While our findings are novel regarding farmer goal hierarchies and production goals in the context of CSS technology in Gerater Lira, these findings will benefit from future studies that test the proposed constructs using larger samples for more generalizable conclusions. Future studies could also consider mixed methods to apply multiple tools for triangulations and further reduces coder and individual researcher bias.

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