JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

FACHBEREICH 09
Agrarwissenschaften, Ökotrophologie und Umweltmanagement

Institute for Agricultural Policy and Market Research

Professorship for Agricultural, Food and Environmental policy

International PhD Program for Agricultural Economics, Bioeconomy and Sustainable Food Systems (IPPAE), Justus-Liebig University Giessen

Agroecology as a political concept: A case study of the Southeast geopolitical region of Nigeria

DISSERTATION

For the award of the degree of Doktor der Agrarwissenschaften (Dr. agr.)

In the Faculty of Agricultural Sciences, Nutritional Sciences and Environmental Management, Justus-Liebig University Giessen

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September 2023, Giessen

DECLARATION

According to the §17 of the Doctoral Examination Regulations of the Faculty 09, from July 7 2004, last changed on May 29 2019

I declare: this dissertation submitted is a work of my own, written without any illegitimate help by any third party and only with materials indicated in the dissertation. I have indicated in the text where I have used texts from already published sources, either word for word or in substance, and where I have made statements based on oral information given to me. At any time during the investigations carried out by me and described in the dissertation, I followed the principles of good scientific practice as defined in the "Statutes of the Justus Liebig University Giessen for the Safeguarding of Good Scientific Practice".

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Date Chukwuma Otum Ume

Zusammenfassung

Die Studie basiert auf einer Fallstudie einer Agroökologie-Gruppe aus ländlichen Agrargemeinden im Südosten Nigerias. 2016 starteten Forscher des Centre for Agroecology der Coventry University eine Agroökologie-Bewegung, die zur Gründung einer Agroökologie-Gruppe im Südosten Nigerias führte. Die Agrarökologie-Bauern nutzten nachhaltige Methoden wie Mehrfachanbau, Nullbearbeitung und Interkulturation. Außerdem richteten sie ein Handelssystem für den Austausch von Lebensmitteln und ein Peer-to-Peer-Netzwerk für den Austausch von indigenem Wissen ein. Deskriptive Statistiken unserer Daten zeigten, dass Frauen 89% der Agrarökologie-Bauern in der Gruppe ausmachen. Neben den Agrarökologie-Bauern gibt es auch die "konventionellen" Bauern. Auch die sogenannten konventionellen Bauern gehören zum FADAMA-Projekt, einem Regierungsprojekt, das die landwirtschaftliche Produktivität durch die Versorgung der Bauern mit externen Chemikalien und Saatgut steigern will.

Anhand dieser Fallstudie und unter Anwendung der feministischen Ökonomie-Theorie beantwortete die Doktorarbeit die Frage, wie Agrarökologie mit Ernährungssicherheit bei Kleinbauern verbunden sein könnte. Konkret ging es darum, (i) aufzudecken, wie die Literatur über Ernährungssicherheit und Ernährung in Afrika die Rolle der Agrarökologie umrahmt, (ii) zu untersuchen, wie die Agrarökologie die Ernährungssicherheit und Ernährung von Kleinbauern verbessert und (iii) ein besseres Verständnis dafür zu vermitteln, wie die Agrarökologie die Handlungsfähigkeit bei der Fortpflanzung von Landbauern fördert.

Die Studie beginnt mit einem narrativen Review, bei dem ich mir mit empirischer Literatur zu Agrarökologie und Ernährungssicherheit auseinandersetzen, um Wege zu finden, auf denen Agrarökologie zu Ernährungs- und Ernährungssicherheit führt. Die Studie verwendete einen Mixed-Methoden-Ansatz, der quantitative und kontextspezifische qualitative Daten kombiniert, um die aus der Literaturrecherche resultierenden Pfade empirisch zu testen. Die Primärdaten für diese Studie wurden in 334 Erhebungen (davon 111 Agrarökologie- und 223 Nicht-Agrarökologie-Landwirte) und 24 Interviews mit Landwirtinnen der Agrarökologie-Gruppe erhoben. Zur Analyse der quantitativen Daten wurde ein Quantile Propensity Score Matching-Verfahren eingesetzt, während die qualitativen Interviews mittels thematischer Analyse analysiert wurden.

Die Studie ergab, dass die Landwirte sowohl in der agrarökologischen als auch in der konventionellen Gruppe kaum Zugang zu Land hatten, noch weniger Land besaßen, kaum Beratungsdienste in Anspruch nahmen und keinen Zugang zu Finanzkrediten hatten. Die von uns untersuchte Gruppe von Landwirten besteht also aus marginalen Kleinbauern. Im Gegensatz zu den Erwartungen der konventionellen Hypothesen zeigen ich, dass Landwirte, die agroökologisch wirtschaften, im Durchschnitt weniger Erfahrungen mit Ernährungsunsicherheit gemacht haben und höhere Werte bei der Ernährungsvielfalt aufwiesen. Eine detailliertere Untersuchung innerhalb der Agrarökologie-Gruppe mit Hilfe eines semiparametrischen Quantil-Propensity-Score-Matching zeigt, dass Frauen, die von konventionellen Beratungsdiensten ausgeschlossen sind, stärker von der Zugehörigkeit zur

Agrarökologie-Gruppe profitieren. In ähnlicher Weise war der Anstieg der Ernährungssicherheit und des Nährwerts bei denjenigen Landwirten am höchsten, die eine ausgewogene Mischung aus Selbstversorgung und Markt als Nahrungsquellen anstrebten, im Vergleich zu Strategien, die hauptsächlich eine dieser Quellen verfolgten. Für diese Bauern, vor allem Frauen, bietet die Agroökologie-Gruppe eine Alternative zum Zugang zu lebenswichtigen Ressourcen und Wissen, die sie normalerweise im kapitalistischen Ernährungssystem nicht hätten, und die es ihnen ermöglicht, ihre Ernährungsziele zu erreichen.

Die Ergebnisse dieser Studie deuten darauf hin, dass die Umsetzung unterschiedlicher agrarökologischer Praktiken die breiteren gesellschaftlichen Beziehungen beeinflusst und bestimmt, die vorherrschende Ernährungssysteme definieren und umgekehrt. Der Erfolg nachhaltiger und innovativer agrarökologischer Verfahren hängt oft vom Sozialkapital und den Wissensnetzwerken ab, die die Landwirte in ihren Gemeinden aufbauen. Diese sozialen Beziehungen erleichtern die Verbreitung von Informationen, die gemeinsame Nutzung von Ressourcen und die gemeinsame Übernahme agrarökologischer Techniken. Umgekehrt können die verstärkten sozialen Bindungen und gemeinsamen Erfahrungen, die sich aus sozialen Reproduktionstätigkeiten ergeben, die Übernahme und den Erfolg physischer Fortpflanzungsstrategien im landwirtschaftlichen Betrieb direkt beeinflussen. Im Wesentlichen betont die Studie, dass der ganzheitliche Ansatz der Agrarökologie über das Feld hinausgeht und das soziale Gefüge der landwirtschaftlichen Gemeinschaften umfasst. Dieser integrierte Ansatz trägt letztlich zu einer verbesserten Produktionseffizienz und Ernährungssicherheit der Kleinbauern bei.

Summary

This study is based on a case study of an agroecology group from rural agricultural communities in Southeast Nigeria. In 2016, researchers from the Centre for Agroecology, Coventry University, started an agroecology extension service that led to the establishment of an agroecology group in Southeast Nigeria. The agroecology farmers utilized sustainable methods such as multiple cropping, zero tillage, and intercropping. In addition, they established a trade-by-barter market system for food exchanges and a peer-to-peer indigenous knowledge exchange network. Women make up 89% of the agroecology farmers in the group. Apart from the agroecology farmers, there are also the "conventional" farmers in the study area. The so-called conventional farmers also belong to the FADAMA project, which seeks to increase agricultural productivity by supplying external chemical inputs and seeds to the farmers.

Using this case study and employing the feminist economics theory, this PhD study answered the question of how agroecology might be linked to food security among smallholder farmers. Specifically, the objectives of the research were to (i) uncover how the literature on food security and nutrition in Africa framed the role of agroecology, (ii) investigate the pathways through which agroecology improves food security and nutrition of smallholder farmers, and (iii) provide a better understanding on how agroecology promotes agency in pursuing reproduction activities among rural farmers?

The study begins with a narrative review whereby I engage with empirical literature on agroecology and food security to find the pathways through which agroecology leads to food and nutrition security. The literature review is followed by an empirical investigation. I used a mixed-method approach combining quantitative and context-specific qualitative data to test the pathways emanating from the literature review empirically. The primary data for this study was collected from 334 small-scale farmers (comprising 111 agroecology farmers and 223 non-agroecology farmers) and 24 interviews with women farmers in the agroecology group. A quantile propensity score matching was employed to analyze the quantitative data, while the qualitative interviews were analyzed using thematic analysis.

The study found that in both the agroecology and the conventional groups, farmers had little access to land, even lower ownership of land, little exposure to extension services, and no access to financial credits. Consequently, the study sample predominantly consisted of marginalized smallholder farmers. In contrast to the expectation of conventional hypotheses, this study demonstrates that, on average, agroecology farmers experienced lower levels of food insecurity and exhibited higher dietary diversity scores. Exploring more detail within the agroecology group via a quantile semi-parametric propensity score matching, the study further revealed that women excluded from conventional extension services derived greater benefits from their participation in the agroecology group. Similarly, the research indicated that the most substantial improvements in food security and nutrition were observed among farmers who balanced their food sources between self-provisioning and market-based approaches instead of exclusively relying on one of these sources. Notably, this strategy was

predominantly adopted by women. For these farmers, the agroecology group serves as an alternative avenue for accessing crucial resources and knowledge that would otherwise be out of reach within the capitalist food system. This access empowers them to achieve their nutritional goals.

Findings from this study suggest that implementing different agroecological practices influences and determines the broader social relations that define prevailing food systems and vice versa. The success of sustainable and innovative agroecological practices often hinges on the social capital and knowledge networks that farmers build within their communities. These social relationships facilitate the dissemination of information, the sharing of resources, and the collective adoption of agroecological techniques. Conversely, the strengthened social bonds and shared experiences that result from social relationships can directly influence the adoption and success of agroecological sustainable practices on the farm. In essence, the study emphasizes that the holistic approach of agroecology extends beyond the field and encompasses the social fabric of farming communities. This integrated approach ultimately contributes to improved production efficiency and enhanced food security among smallholder farmers.

List of peer-reviewed publications

1) Ume, C., Nuppenau, E., & Domptail, S. E. (2022). A feminist economics perspective on the agroecology-food and nutrition security nexus. *Environmental and Sustainability Indicators*, 16, 100212. https://doi.org/10.1016/j.indic.2022.100212

2) Ume C, Nuppenau E-A and Domptail SE (2023). Who profits from agroecology to secure food and nutrition? On access of women to markets and assets. *Frontiers in Sustainable Food Systems*. 7:1082944. doi: https://doi.org/10.3389/fsufs.2023.1082944

3) Ume C, Nuppenau E-A, Wahlen S, and Domptail SE (2023). How agroecology group empowered women smallholders to achieve food security. Submitted to *the journal of peasant studies* (Submitted).

Acknowledgements

My special appreciation goes to God almighty for his faithfulness and sustenance throughout this PhD work.

My sincere appreciation goes out to everyone who supported my PhD research project and without whom I would not have been able to complete it. First, I want to express my profound gratitude to my supervisors, Prof. Dr. Ernst-August Nuppenau, Prof. Dr. Stefan and Wahlen, and Dr Stephanie Domptail. I am extremely grateful for their wise support and guidance throughout the research project. In the course of my research, I was greatly assisted and guided by Dr. Stephanie Domptail. I want to express my profound gratitude, and I am deeply indebted to her for the academic and moral support she gave me throughout the research. I want to thank Prof. Dr. Martin Petrick and Dr. Nadia Keudel, who have been a great source of academic and leadership inspiration. They provided an excellent atmosphere and friendly academic guidance. Special thanks to Mrs. Sandra Drebes for her critical role in providing administrative support. I am also thankful for the support from Dr. Ezinne Emeana during the case study selection. I also appreciate the valuable comments and insights from the postdoctoral fellows at the Institute of Agricultural Policy and Market Research. Special thanks also to my enumerators who risked the COVID pandemic to collect data for this PhD.

I want to say a big thank you to all my colleagues at the International Ph.D. Program in Agricultural Economics and Sustainable Food Systems (IPPAE) for their contributions, constructive criticisms, and useful suggestions. In no particular order, I wish to extend special thanks to my senior colleagues - Dr Hussein Luswaga, Dr Emily Mutota, Dr Surajit Haldar, Dr Adriana Gomez, Dr Bashiru Haruna, Dr Simon Gicheha, Dr Shimelis Araya, Dr Gabriel Specht, Azim Baibagyssov, and Miriam Kasebele. Also to my peers, Alisher Kosimov, Nixon Kiratu, Mustafa Nasiri, Sakeus Kadhikwa, Rovshen Ishangulyyev, Alexander Cano, Jakhongir Babadjanov, Evi Mariana, Ifeoluwa Abulude, Charity Masole, Lennart Flavio, Denis Soldera, Kadyrbek Sultakeev, Titilayo Akinwehinmi, Akansha Mishra, Felix Ndayisaba, Manale Embiyale. Andres Suarez, Irina Hopp.

My special gratitude goes to my family members, especially my dear wife, Mrs. Nice Nneoma Chukwuma Ume, and my daughter, Adannaya Oriaku Chukwuma Ume, who dared to be born at the peak of my PhD. I also appreciate my late dad, Mr. Ume O. Ume, who has always been a mentor and teacher. I appreciate my mother, Mrs. Nnenna Ume, who has been my reason for striving harder in life, and to my siblings, thank you very much for the love and support you have endlessly given me.

Finally, I am also grateful to my funders, DAAD; this study would not be possible without their financial support. Sincere gratitude goes to the Foundation Fiat Panis for the research grant used for my fieldwork, and special thanks to the dissertation completion grants offered on the basis of JLU's Gender Equality Concept.

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List of Abbreviations

ADP	Agricultural Development Programme
AE	Agroecology
DD	Dietary Diversity
DDS	Dietary Diversity Score
FADAMA	Land that is capable of being irrigated
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
FNS	Food and Nutrition Security
FS	Food Security
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
HLPE	High Level Panel of Experts on Food Security and Nutrition
IPCC	Intergovernmental Panel on Climate Change
NFE	No Formal Education
OA	Organic Agriculture
PSM	Propensity Score Matching

Chapter 1

Extended Summary

1.1 Introduction

On a global scale, agroecology has garnered substantial attention within the environmental and developmental discourse. It is increasingly perceived as a viable alternative food system capable of making significant contributions to attaining food security and improved nutrition while preserving the integrity of natural resources (HLPE, 2019). Wezel *et al.* (2014) and FAO (2019) attribute the popularity of agroecology to the emergence and increase in crosscutting socioeconomic and environmental issues that underscore the limitations of prevailing agri-industrial farming systems. According to the Food and Agricultural Organization of the United Nations, Agroecology is:

> *"a holistic and integrated approach that applies ecological and social concepts and principles to sustainable agriculture and food systems design and management. It seeks to optimize the interactions between plants, animals, humans and the environment while also addressing the need for socially equitable food systems within which people can exercise choice over what they eat and how and where it is produced"* (FAO, 2019a).

Research points to two ways by which agroecology improves food security and nutrition: (i) through maintaining the health and fertility of the land, which is foundational to the agricultural economy (Altieri et al., 2012; Khadse, 2017; Pimbert, 2015). (ii) By fostering social interdependence among smallholder farmers, agroecology empowers farmers to make independent decisions about food and agriculture (Boillat & Bottazzi, 2020; De Schutter, 2019; Ng'endo et al., 2015). In recent times, the second pathway has been framed under the concept of agency and food sovereignty, which highlights the need for people who produce, distribute, and consume food to control the policies and mechanisms of production (Akram-Lodhi, 2013; Beuchelt & Virchow, 2012; Nyéléni Declaration, 2015). In this study, I conceptualise agroecology as a complex socio-ecological system comprising agronomic practices and social reciprocal and political activities mobilizing local production and exchanging production factors (land, labour) and inputs (seeds, knowledge).

1.1.1 Agroecology in Africa

In Africa, international institutions such as the World Bank, the World Trade Organization (WTO), and the African Development Bank (AFDP) have presided over a system that has prioritized agri-industrialization, resulting in the alienation of millions of smallholder farmers from productive assets and resources like land, water, seeds, fish, technology, and experience (Akram-Lodhi, 2013). As an alternative to the agri-industrial system, agroecology practices have emerged in Africa following a substantial development in the rest of the world (particularly South and Central America, Asia, and Europe). Agroecology consists of agricultural practices

that mimic natural ecological processes in soils and agroecosystems to regenerate soils and increase production (Dalgaard, Nicholas, and John, 2003). Yet, the word agroecology also is used to denominate an alternative food system based on systems thinking, which can secure food and nutrition (HLPE, 2019; FAO, 2020). According to FAO (2019), the term can be employed in Africa to promote more socially and environmentally sensitive agriculture by focusing not only on production practices but also on the economic and social context in which these practices are introduced, implemented, and passed on.

In parts of Africa such as Kenya, Malawi, and Tanzania, there has been evidence of how effective Agroecology has been developed to foster sustainable agriculture (Bezner Kerr, Hickey, et al., 2019; Bezner Kerr, Young, et al., 2019; Nyantakyi-Frimpong et al., 2016). However, in Nigeria, agroecology is still at an infant stage. There is currently no policy framework to support agroecological practices, and only one non-governmental organized agroecology group exists. This study is based on both quantitative and qualitative data collected among farmers from this informal agroecology group, which was formed in response to the neo-liberal Agri-industrial Transformation Agenda (ATA) of the Federal Republic of Nigeria.

1.1.2 Problem statement

The last decade has witnessed conscious and concerted efforts from the Nigerian government, the World Bank, and other international agencies to advance commercial agriculture through a corporate food regime that shifted the locus of control of food security away from the local farmers to the global market. The push for the commercialization of the agricultural sector has been based on the notion that increased food production is needed if the food supply must keep up with the increasing demand from a rising population. In July 2017, the Presidential Economic Diversification Initiative was established with funding from the World Bank to revive the agri-industries and boost the commercialization of the agricultural sector of the economy (PEDI, 2020). Furthermore, in 2018, the United States African Development Foundation (USADF) established a substantial commitment, spanning a five-year duration, to allocate a total of $5 million towards advancing agribusiness development (USADF, 2018). The World Bank, on the other hand, spent $200m in Nigeria to support agricultural productivity and improve livelihoods (World Bank, 2020).

With these agricultural investments, there has been a corresponding rise in agricultural production (measured by the contribution of agriculture to GDP). However, whether this performance translates into food security and rural development (in terms of poverty alleviation

and nutrition improvement) is still unclear. In 2019, the country ranked 159 out of 162 nations in progress toward eliminating hunger and malnutrition (Sachs et al., 2019). In 2018, 69% of the population lived below the poverty line (UNICEF, 2020), significantly declining from 27% in 1980 (Dauda, 2017). It is estimated that 2 million children in the country suffer from severe acute malnutrition (Figure 1). The extent of acute malnutrition worsened from 14% in 2008 to 18% in 2013 (Nigeria Demographic and Health Survey, 2019), and as of 2018, over 43.6% suffer from chronic malnutrition (Figure 1).

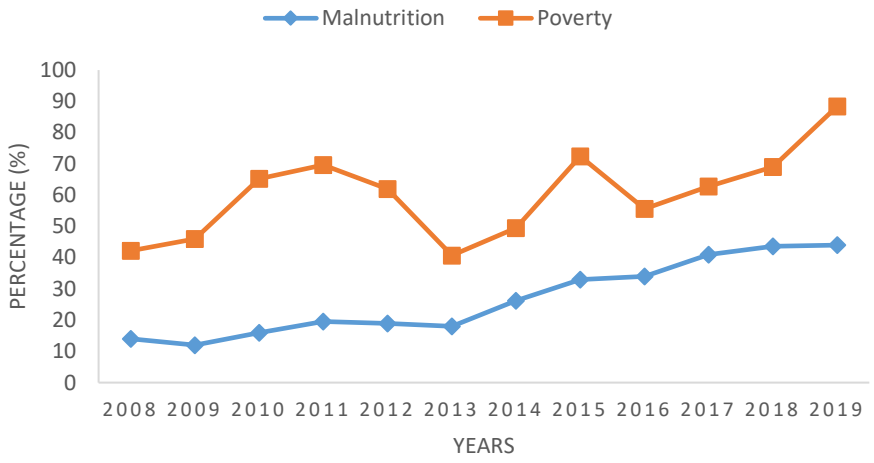

Figure 1: Poverty and Malnutrition Status in Nigeria (2008 – 2019)
Source: UNICEF, 2020

The Food and Agricultural Organization report showed that most of the hungry and malnourished are found in rural areas and among smallholder farmers who depend on agriculture for their livelihoods and food security (FAO, 2020). Conversely, research has shown that these smallholder farmers produce almost 70% of all food consumed in the country (Mgbenka and Mbah, 2016). Therefore, these farmers are expected to be relatively food secure, but they are not. This turn of events shows that efforts to increase food production through the current corporate food regime are an essential but insufficient response to food security. According to Burchi and De Muro (2016), food insecurities are not food shortage conditions but lack of food access. The importance of economic and material capabilities of farmers, the networks and power structures (the way individuals organize themselves into groups), and social norms (people's ideologies) are critical in shaping food security outcomes as they institutionalize hegemonic structures that contribute to food insecurity (Patricia, 2014). Analysis of these relationships and how they interplay can provide better insights into food security challenges. The study aims to improve our understanding of how transitioning to agroecology, even at the farm level, can help transform agroecology farmers' social and political Status, thereby affecting the overall food and nutrition status of smallholder farm households in the Southeast region of Nigeria. The central claim is that adopting agroecological practices and

being in an agroecology group expands smallholder farmers' capabilities. The claim is based on the hypothesis that placing as much emphasis on reproductive activities as on productive roles provides autonomy for women smallholder farmers to make independent food decisions (Burchi and De Muro, 2016).

1.1.2.1 Framing of agroecology-food Security Nexus

How agroecology is framed in literature is critical in shaping policy. Search in the Web of Knowledge, google scholar, and research gate shows only three studies in Nigeria on agroecology (Emeana & Trenchard, 2018; Emeanaa et al., 2017; Tiffen, 2013). When a search was expanded to include "organic farming," 136 studies dealing with agroecology concentrated on sustainable farming practices, indicating that many studies on agroecology perceive agroecology as synonymous with sustainable farming practices. In some studies like Emeana & Trenchard (2018), organic farming and agroecology were used interchangeably. Such framing of the term "Agroecology" shows that most of the research(ers) in agroecology still focuses on the farm level, with little or no attention to the social and political dimensions of agroecology. Framing agroecology only as a practice has one significant and limiting impact on the agroecology-food security nexus. While sustainable farming practices will focus on the farm management system and food production, agroecology will broadly focus on redesigning the agricultural and food systems (Bellon, Lamine, Ollivier, & de Abreu, 2011). While agroecology ensures a better and more sustainable food production practice, limiting agroecology to the practice level will ignore the social and power dimension components necessary to build a robust food system.

Agroecology is a widely used term with multiple dimensions. According to FAO (2019), the word Agroecology integrates ideas that promote more socially and environmentally sensitive dimensions to agriculture by focusing not only on production but also on the political and social dimensions of the productive system. Critics suggest that agroecology may not be able to address the sub-Sahara African nutrition and development challenges in the long term (Mugwanya, 2019) because they are oblivious to the social and power dimensions intrinsically linked to agroecology-based farming. Understanding these dimensions/pathways is necessary and can be uncovered by investigating how the agroecology-food security nexus is framed in agroecology-food security literature in Africa.

1.1.2.2 Empirical evidence on agroecology – FNS nexus

The role of agroecology in maintaining the natural resource base is evident. Literature is replete with studies that attempt to link agroecology to sustainable and cleaner production. However, empirical evidence linking agroecology to food security and nutrition thus far has produced mixed results (Bezner Kerr, Young, et al., 2019; Nyantakyi-Frimpong et al., 2017; Wezel et al., 2014). For instance, Pretty et al. (2003) conclude that agroecology practices influenced food security and nutrition by analyzing 208 projects among 8.98 million farmers and 28.92 million hectares. In contrast, Rogé et al. (2017) observed no significant difference in farm productivity between agroecology and non-agroecology farmers.

Relatedly, there is a paucity of empirical evidence on the role of agroecology as a social farm group, in enhancing smallholder farmers' food and nutrition security. The approaches adopted during the Green Revolution to combat malnutrition were primarily centred around promoting an industrial input-based intensification strategy. This strategy aimed to integrate farming activities more closely with formal commercial markets, to increase the production and consumption of higher-calorie foods (Fanzo, 2015). Notably, the Green Revolution strategy, which still maintains a dominant position in development and agricultural policies across sub-Saharan Africa, hinges on the active participation of farmers within the cash economy. Yet, external input-based intensification has been ineffective in changing rural smallholder households' nutrition status (Welle-Deutsche, 2020). Therefore, the persistence of malnutrition among farming households may be related to the specific economic and social context in sub-Saharan African agricultural regions. Hence, there is a need to rethink green revolution strategies from a feminist economics perspective that bridges inequalities between production and reproduction activities, especially in regions with deeply entrenched power inequalities in agri-food systems.

There is a need to introduce and discuss the institutional and social structures at the households and society that moderate the relationship between agroecology and food and nutrition security. Our review of research conducted in sub-Saharan Africa on the link between agroecology and food security shows that research and evidence depicting pathways through which agroecology fosters FNS are sparser than expected (Ume, Nuppenau, & Domptail, 2022). The social dimensions of agroecological at the level of households and territories are not well documented in research linking agroecology to nutrition in sub-Saharan Africa. The paucity of empirical evidence could result from methodological and measurement issues. For instance, identifying accurate indicators and measures of social and institutional aspects of agroecology is quite

challenging. Similarly, it is also a challenge to implement any identifying strategy to establish the link between these social and institutional indicators of agroecology to food security and nutrition.

1.1.3 Research questions and claim

This research intends to provide answers to the following questions:

i. How has literature on food security and nutrition in Africa framed the role of agroecology?
ii. Does adopting agroecology practices and belonging to an agroecology group influence smallholder farmers' food security and nutrition status?
iii. How can agroecology be effectively employed to address food system inequality?

The study claims that transitioning to agroecology, even at the farm level, also transforms farming households' social and political characteristics, affecting their overall food and nutrition handling.

1.1.4 Objectives of the study

The broad objective of the study is to consolidate evidence that agroecology group has contributed to food and nutrition security in southeast Nigeria. The specific goals were to:

i. Determine how literature has framed the relationship between agroecology and food security in Africa.
ii. Empirically test the effect of agroecology group on the food security and nutrition of smallholder farmers.
iii. Understand the role agroecology, as a farm social group, can play in bridging food system inequalities in rural communities.

1.1.5 Thesis Structure and Organization

The cumulative dissertation is organized into four chapters and proceeds as follows.
Chapter 1 introduces the study, presenting the background and research questions addressed in the study. In addition, the definitions of the various concepts used in the study as well as the methodology followed in realizing the objectives of the study, that is, the data collection methods, including sampling procedures, are presented in chapter one. In this chapter, the study

also provides the descriptive results of the socioeconomic characteristics of agroecology farmers, contrasting them with conventional farmers.

The remaining chapters comprise two peer-reviewed scientific articles and a submitted paper for publication.

Chapter 2 (article 1) presents the different pathways through which agroecology is linked to food security and nutrition in literature, which include the physical or ecological reproduction pathways, the household reproduction pathway, and the social reproduction pathway. It provides detailed information on how the agroecology-FNS nexus is framed in literature.

Chapter 3 (Article 2) empirically tested the different pathways identified in the literature using quantitative data from the study area. It evaluates the agroecology group's food security effect using the propensity score matching technique. The chapter began by considering the motivation for joining the agroecology group and empirically testing the transmission channels from agroecology to food security and nutrition.

Chapter 4 presents a qualitative analysis of the farmers' view of the role of agroecology in enhancing their food security and nutrition status. The chapter provides a deeper and more critical perspective on agroecology and food security from the perspective of women who are members of the agroecology group. The objectives of the respective papers, key results, and their contribution to knowledge are presented in Table 1.

Table 1: List of papers and their objectives, key results, and contribution to knowledge

Paper	Objectives	Key findings/results	Contribution to knowledge
Paper 1: Ume, C., Nuppenau, E., & Domptail, S. E. (2022). A feminist economics perspective on the agroecology-food and nutrition security nexus. Environmental and Sustainability Indicators, 16, 100212. https://doi.org/10.1016/j.indic.2022.100212	The study employed a narrative literature review to: • assess whether agroecology practices have improved food and nutrition security in rural Africa. • uncover which pathways of causalities between agroecology and FNS have been investigated in literature and which pathways have not.	• About Ninety per cent of the accessed literature showed that adopting agroecology has contributed to food and nutrition security (FNS) in Africa. • Agroecology improves FNS through the physical, social, and household reproduction pathways. • The nexus between agroecology and FSN has been framed mainly from an agronomic perspective. • Social and power structures around the introduction of agroecological practices at the level of households and territories are not well documented in literature.	• The study consolidates evidence on agroecology as a vector for an efficient production model for small-scale farming units. • The study might be the first to have conceptualised the different pathways between agroecology and FNS.

Table 2: (Contd.)

Paper	Objectives	Key findings/results	Contribution to knowledge
Paper 2: Ume C, Nuppenau E-A and Domptail SE (2023) Who profits from agroecology to secure food and nutrition? On access of women to markets and assets. *Frontiers in Sustainable Food Systems.* 7:1082944. doi: https://doi.org/10.3389/fsufs.2023.1082944	The study employed a Quantie Propensity Score Matching technique on primary data comprising 111 agroecology farmers and 223 non-agroecology to: • empirically assess the FSN status of agroecology members in comparison to conventional smallholders operating in the market-based agro-industrial system. • understand who appears to benefit most among the agroecology farmers. • assess what motivates the farmers to join the agroecology group	• The average treatment effect indicates that food insecurity experience points amongst those in the agroecology group would be 0.45 points higher if they were not in the agroecology group. Dietary diversity will be 2.18 points lower if they were not in the agroecology group. • Our findings further showed that the improvement in food security is more significant among agroecology members who utilise elements such as production diversity, peer-to-peer resource sharing, and local food markets. • Farmers who balance food self-provisioning and market access have better FNS status than comparable farmers who depend more extensively on either self-provisioning or food purchased from the market. • Gender, farm size, number of relatives, family size and number of extension visits significantly predict the propensity of joining the agroecology group.	• In contrast to the extensive empirical literature on agroecology practices and improved FNS, the social innovation inherent in agroecology is sparse. This paper addresses this complex dimension of agroecology as a social system that characterises an agroecology group. • The paper makes a substantial methodological contribution by introducing a "quantile" propensity score matching technique that reflects the variations of impact across different variables of interest (peer-to-peer activities, gain in time use, self-provisioning, and production diversity)

Table 3: (Contd.)

Paper	Objectives	Key findings/results	Contribution to knowledge
Paper 3: Ume C, Nuppenau E-A, Wahlen S, and Domptail SE (Submitted) How agroecology group empowered women smallholder to achieve food security. *Journal of Peasant Studies*	This paper employed a qualitative thematic method to analyse interviews with 24 women in the agroecology group. The aim was to: • Understand how adopting agroecological practices and being in the agroecology group fosters an alternative food system that can strengthen the agency of women smallholder farmers to achieve food and nutrition security.	• In general, adopting agroecological practices provides autonomy for women agroecology farmers in decision-making at two levels – at the household and the community or food system level. • At the household level, it has become common for women to depend on their husbands for land and other production inputs. The solidarity and reciprocity nature of the agroecology group emancipated women from relying on their husbands for cash, thereby granting them higher decision-making power within the household and agency to reach their reproduction and food security goals. • At the community or food system level, adopting agroecological practices made the women less dependent on fertilisers, seeds and other inputs supplied by actors who decide what and how the women will put their land to use.	• This study contributes to the existing literature by showing how implementing agroecological practices influences and determines the broader relations that define prevailing food systems. • The study also highlights the importance of autonomy and agency at the household and food system levels in addressing food insecurity challenges, especially among small and marginalized households.

1.2 Conceptualization of key terms

Many concepts have been propounded to explain the economic, environmental, and social elements predetermining food security. Although previous studies cover a wide variety of such concepts, the meanings of such words as agroecology, agency, reproduction, etc., still appear contentious in literature (Wezel et al., 2014). Here, the study identifies and contextualizes four relevant concepts used in this thesis that will contribute to understanding how agroecology affects food security and nutrition. These concepts are food security and nutrition, agroecology, agency, and social reproduction. These concepts have been discussed in a broader context in previous studies Dalgaard et al., 2002; Francis et al., 2002; Fujishige et al., 2022). However, this review will focus on the African context to identify advances, debates, and gaps in research in Africa since that is the context in which the study is grounded.

1.2.1 Food security and nutrition

Over the past 50 years, the definition of food security has evolved to accommodate new advancements and insights on what constitutes or drives food insecurity, and this also reflects the extent to which our understanding of food security has advanced and changed over time (Figure 2). Before 1960, food security was defined narrowly as achieving self-sufficiency in primary staple foods (FAO, 1943). A decade later, arising from the notion that food might be available but individuals might not have adequate resources, the ‘accessibility’ component was introduced into the definition (FAO, 1974). Subsequently, the emphasis shifted to the temporal aspect of food security, highlighting the need for food to always be available (FAO, 1983). Since then, the concept has continued to evolve.

As a result of the World Food Summit definition of 1996, the term food security has come to be widely used as a term that is broadly construed as access to sufficient, safe, nutritious food at all times, including food preferences for an active and healthy life (World Food Summit, 1996). These current conceptualizations highlight food security's four key elements: availability, accessibility, stability, and utilization.

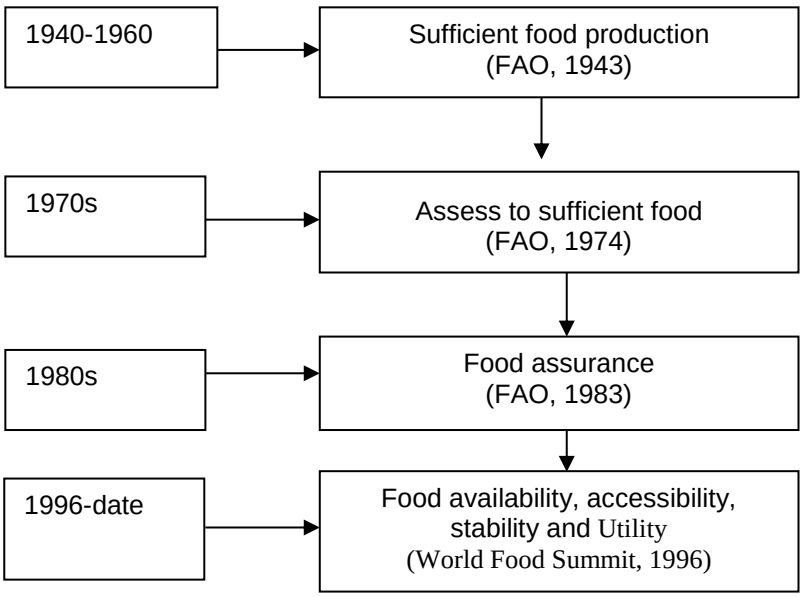

Figure 2: Evolution of the concept of food security
Source: Authors

1.2.2 Agency

In their conceptualization of food security, the High-Level Panel of Experts on food security and Nutrition (HLPE) highlighted the necessity of incorporating the dimension of "agency" as an additional pillar of food security (HLPE, 2019). HLPE (2019: p.16) defined agency as the "capacity of individuals or communities to define their desired food systems and nutritional outcomes, and to take action and make strategic life choices in securing them." Inherent in this definition is the need to bridge the power imbalances and persistent hunger among the least advantaged in society. From a system perspective, "agency" is important in boosting food security as it expands the capacity of groups or individuals to control the food value chain and exercise a voice in the governance processes, including addressing the widening inequalities within the food system (Clapp et al., 2022; Ngodoo, 2014). The proponents of agency as vital in enhancing food security are not necessarily against external interventions but to scrutinize what is being attempted through those interventions, for whom, and the emerging food systems being fostered.

Sen (2005) conceptualizes agency for food security as a collection of empowerment indicators or conditions that empower smallholder farmers to assert control over the established social norms within their food environment. In contrast, Thompson (2015) delineates agency for food security into two distinct dimensions: economic agency and non-economic or political agency. Economic agency within rural households pertains to their capacity to independently manage

and control their livelihoods without being excessively reliant on external economic entities. This form of agency is rooted in factors such as having relational access to assets, diversifying their sources of livelihood, exercising control over income, and making decisions regarding production activities. Conversely, non-economic agency encompasses various capabilities developed through the expression of one's opinions, which subsequently lead to the influence of power dynamics, prevailing circumstances, and inputs in the process of social decision-making. As stated by Thompson (2015; p.343), "it is the non-economic agency that is most crucial for food availability and access … since it determines capability – what we can and cannot do." This dimension of agency is closely aligned with established literature on ethics and political economy, as elucidated by Sen (2001). Moreover, Sen (1992) contends that agency, in and of itself, is insufficient for addressing issues related to food security. Instead, it should encompass capabilities that are cultivated through various organizations and networks aimed at exerting pressure on the social reproduction process and engaging in power struggles within society.

1.2.3 Agroecology

1.2.3.1 Definition of Agroecology

Wezel, Bellon, and Doré (2009) trace the origin of the term 'agroecology' back to its first mention by Bensin in 1928. Since that initial reference, this term has progressively garnered significant attention from a wide array of stakeholders, including policymakers, advocacy groups, and researchers representing various disciplines. Wezel et al. (2014) attribute this growing interest to the pressing need for agriculture to effectively address a multitude of sustainability challenges, encompassing issues such as food security, biodiversity preservation, and rural development.

However, due to the inherently multidisciplinary and cross-disciplinary nature of the concept of "agroecology," a diverse array of definitions and conceptualizations has emerged over the years. Table 2, presented here, outlines the evolving meanings and conceptualizations of agroecology, commencing with its original use by Bensin in 1928.

Table 2: Definitions and synthesis of the concepts of agroecology in literature

Article	Definition	Main concept
Bensin (1928)	"agroecology as the application of ecology in agriculture"	The use of principles of ecology on crop production
Azzi (1956)	" the study of the physical characteristics of the environment, climate, and soil, in relation to the development of agricultural plants."	Climate and land management for better plant production
Gliessman (1998)	"Agroecology is defined as the application of ecological concepts and principles to the design and management of sustainable agroecosystems."	Increased farm production with reduced immediate ecological consequences
Dalgaard, Hutchings, & Porter (2003)	"the study of the interactions between plants, animals, humans, and the environment within food production and consumption systems"	This definition sees agroecology as an integrative discipline covering studies in agronomy, sociology, ecology, and economics
Clements & Shrestha (2004)	"Agroecology deals with the applications of ecological principles in agroecosystems"	Application of these principles brings "logical response" to the shortfalls of conventional agriculture."
United States Department of Agriculture (USDA) (2007)	"Agroecology incorporates ideas about a more environmentally and socially sensitive approach to agriculture, focusing not only on production but also on the ecological sustainability of the productive system."	This concept shows the need to combine social and environmental elements in production, going beyond the limits of field and farm plots.
Francis et al (2008)	"Agroecology as the ecology of food systems"	Agroecology is viewed beyond farm-level analysis and immediate biophysical impacts at the farm and field.
Olivier De Schutter (2011)	Agroecology applies ecological science to the design of agricultural systems that can help end food crises and address climate change and poverty challenges.	Agroecology protects the right of all, including small-scale farmers, to live free from hunger, malnutrition, and food insecurity.
FAO (2014) - International Symposium on Agroecology for Food Security and Nutrition	"Agroecology is an approach that will help to address the challenge of ending hunger and malnutrition in all its forms."	A tool for achieving food security (right to food)
Edwards (2017)	Agroecology is a concept that is "committed to a more socially just and sustainable future by reshaping power relations from farm to table."	This view introduces the "Transformative Agroecology" concept, where agroecology incorporates policy-oriented actors and broader forces, including government institutions and the market, that undermine the right to food.
Agroecology Europe (2019)	"Agroecology is considered jointly as a science, a practice and a social movement. It encompasses the whole food system, from the soil to the organization of human societies. It is value-laden and based on core principles."	The necessity of agroecology's multidisciplinary and interdisciplinary nature is acknowledged, going beyond the sociocultural and political aspects.

1.2.3.2 Evolution of agroecology

As delineated chronologically in Table 2, the evolving definitions of agroecology highlight the dynamic nature of this concept in both research and practice. Up until the year 2000, agroecology was primarily conceived as a method rooted in the application of ecological principles to manage climate and land, with the overarching aim of increasing farm production while minimizing immediate ecological consequences (Azzi, 1956; Bensin, 1928; Gliessman, 1998).

However, a pivotal shift occurred in the year 2000 when the definition of agroecology expanded to encompass the 'food system component.' This transformation meant that agroecology was no longer solely confined to farm-level analysis and immediate biophysical impacts at the farm and field. Instead, it came to embrace a broader perspective, considering how all the elements within a food production-distribution-consumption system interacted with one another (Clements & Shrestha, 2004; Dalgaard, Hutchings, Porter, et al., 2003; Francis et al., 2003; United States Department of Agriculture (USDA), 2007). Subsequently, the emphasis within the definition shifted towards concepts such as food sovereignty and the right to food, without relinquishing the core components of sustainable production and the food system (De Schutter, 2011; Edwards, 2017; FAO, 2014).

Over time, the concept of agroecology has continued to evolve and adapt. Its multifaceted nature is evidenced by the Food and Agricultural Organization (FAO) maintaining a comprehensive database of agroecology definitions sourced from various documents, including those authored by researchers, academia, civil society, legal texts, governments, and policies (FAO, 2019b). As of the latest update in 2019, the FAO database contains 401 definitions in English, French, and Spanish, underscoring the diverse ways in which agroecology is approached and conceptualized. Overall, three specific conceptualizations can be unpacked from these definitions; sustainable farm system, sustainable food system, and food sovereignty (Figure 3). This study will adopt the food sovereignty element to describe the agroecological implication of small-scale farming communities in Nigeria. According to Appropedia (2018), one of the significant determinants of food sovereignty is the localization of the food systems. In Nigeria, over 72 per cent of food production is carried out in rural areas (Mgbenka & Mbah, 2016), which shows the need for a strong connection between peasant communities and food security.

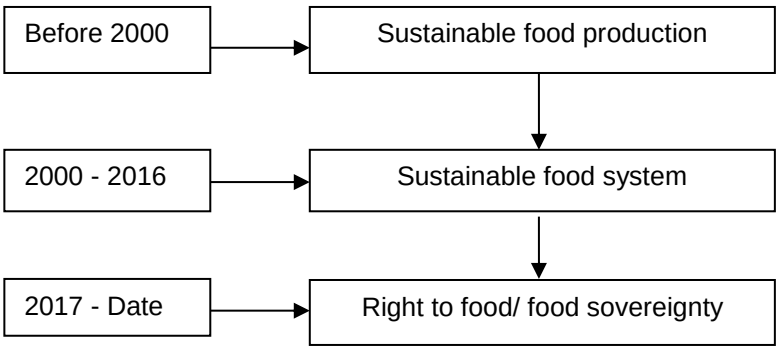

Figure 3: Evolution of the concept of Agroecology
Source: Authors

1.2.3.3 Dimensions of Agroecology Implementation

From the literature on Agroecology, a scale/level dimensions of application can be deduced (Edwards, 2017; Francis et al., 2003; Khadse, & Rosset, 2017; Silici, 2014; Wezel et al., 2009; Wezel & Jauneau, 2011; Wezel & Soldat, 2009). These approaches to thinking about agroecology can be closely linked to the evolution of the concept, as discussed above. The different dimensions of operation or scales of application are outlined in Table 3. It starts from the plot level to the farm-scale dimension and then to the larger food system scale.

Table 3: Different conceptualization and implementation of agroecology

(Francis et al., 2003; USDA, 2007; Wezel & Soldat, 2009; Wezel et al., 2009)	Plot and field scales	The science investigating interactions between the soil and crop systems and the ecological practices that drive sustainable production. Innovations are taking place at all the plot levels, leveraging local knowledge for a more efficient and sustainable food system. Different sustainable practices taking place at the farm scales
(Dalgaard et al., 2003; Clements & Shrestha, 2004; Vadrevu et al., 2008; Cabel & Oelofse, 2012)	farm scales/ Agroecosystem approach	Agroecosystem functions and how farmers relate with the environment to ensure sustainability
(Francis et al., 2003; United States Department of Agriculture (USDA), 2007; Edwards, 2017)	Food system scale	Building a parallel food system driven by peasant and small-scale producers, including knowledge sharing and interaction among all actors within the production level and players in the food system

Plot or field approach

According to Wezel & Soldat (2009)**,** most plot or field scale research mainly concentrates on the interaction between crop and pests or crop and weed. The impact pesticides have on the natural flora and fauna and how natural processes can be beneficial. In animal production, the interactions between animals and pastures are analyzed. However, plot and farm-scale studies do not consider the environmental and ecosystem components. With increased intensification occasioned by the need to feed the ever-increasing population, the natural processes of soil regulation are constantly being replaced by chemical and mechanical inputs. However, as indicated in Giller, Beare, Lavelle, Izac, & Swift (1997), peasant farmers are constrained regarding access to inputs with this increasing intensification. They, therefore, must be encouraged to maintain and enhance soil biodiversity to increase productivity. The causality between agroecological practices at the field scale and sustained soil fertility has been well-established in literature (Risch, Andow, & Altieri, 1983; Holland & Coleman, 1987; Palm, Gachengo, Delve, Cadisch, & Giller, 2001; Altieri & Nicholls, 2003). However, the nature and drivers of these agroecological practices remain complex and unclear in literature (Pimbert, 2015). Understanding what drives farmers' choices is crucial in determining how agroecological methods can be more widely adopted (Silici, 2014). Recent studies have also shown that these drivers are location-specific and can differ from region to region (Khadse & Rosset, 2017). In addition, the influence they can have on adoption also varies, making it difficult to generalize findings (Khadse & Rosset, 2017). This lack of understanding of human behavior at the flot and field approach led to the emergence if the agroecosystem approach in agroecolgy.

Agroecosystem approach

The plot and field approach gradually transitioned to the agroecosystem approach, where the environmental component was introduced. Here, the exchange and interactions between the farm plot and the environment are researched (see: Fuhrer 2003; Rasmussen et al. 1998). Authors such as Wezel & Soldat (2009) posit that the agroecosystem approach goes beyond the immediate site of farming activities to include all the areas impacted by the activities. A preponderance of activities and research in agroecology falls within this domain, especially studies before 2013. However, these studies pay close attention to energy flows and the subsequent changes in species assemblages and complexities, with no interactions with the economy, politics, and society. According to Vadrevu et al. (2008), agroecosystems must be analyzed at the scale of landscapes. Using a set of geo-referenced indicators, the authors could

describe the underlying attributes of an agroecosystem to quantify the Status of an agroecosystem at any point in time, using a so-called "Agroecosystem Health Index".
Similarly, Cabel & Oelofse (2012) developed an agrosystem index by combining 13 behaviour-based indicators from the literature on agroecosystem resilience. These two indexes to date have been the only known matrices for measuring the resilience of the agroecosystem. "System" is used here in the term agroecosystem to capture the interconnection between the field practices and human behaviour and activities, which forms the basic unit of study in Agroecology. However, a critical gap can be uncovered from these two matrices of agroecosystem measurement. Whereas the "Agroecosystem Health Index" of Vadrevu et al. (2008) included the biophysical indicators lacking in the behaviour-based indicators of Cabel & Oelofse (2012), it failed to capture the behavioural elements included by Cabel & Oelofse (2012).

Food systems/sovereignty approach

More recently, the social, economic, and political elements are introduced. In the food system approach/scale of agroecology, the concept of agroecology goes beyond science and practices. Still, it aims to facilitate knowledge sharing and interactions between actors in practice, science, and movements (Wezel et al., 2009). It is at this stage that agroecology as a movement differs from major sustainable agricultural concepts: Climate Smart Agriculture (CSA), Conservational Farming (CF), etc. (Forum for Agroecology, 2015). As posited at the international symposium on agroecology in Nyéléni, Mali, agroecology must be fashioned within a food system that defends peasants and smallholders through local and short food supply chains that entrust the policies and mechanisms of food production, distribution and consumption back to the peasants and rural communities (Forum for Agroecology, 2015). According to the declaration, any form of sustainable agricultural practices (Climate Smart Agriculture, Organic Agriculture, Conservation Farming, etc.) that does not recognize the rights and voice of peasants, indigenous persons, and smallholders must not be regarded as agroecology but a cooption of the concepts to modify the industrial food system. That is to say that "true agroecology" must be that which aims at fostering an alternative food system led by peasants and smallholder producers.

1.3 Context of this study

The study area is the Southeastern geopolitical region of Nigeria. This study uses data collected in 2021 from a sample of rural farmers in southeastern Nigeria to assess the impact of agroecology on food security and dietary diversity. In the region, agroecology was introduced in 2016 by a team of researchers from the Center for Agroecology, water, and Resilience. The group comprises farmers from adopted villages under Nigeria's Research Extension Farmer Input Linkage Systems (REFILS) (Emeana et al., 2019).

1.3.1 Farming Community in Nigeria

According to the definition provided by CGIAR in 2013, farms with a landholding size not exceeding 5 hectares fall into the category of small-scale farms. Applying this classification, it is notable that in Nigeria, a significant majority, exceeding 80% of farmers, can be categorized as smallholder farmers (Mgbenka & Mbah, 2016). This high prevalence of smallholder farmers is primarily due to the fact that more than 80% of farmers in Nigeria operate on land holdings smaller than 5 hectares. This segment of smallholder farmers is responsible for producing a substantial portion of Nigeria's food supply, accounting for over 98% of the food consumed in the country, excluding wheat, and contributing to approximately 99% of the overall crop output (Mgbenka & Mbah, 2016). The importance of smallholder farming underscores the pivotal role of smallholder farmers in Nigeria's economy's agricultural sector. It is evident that the predominant characteristic of the country's agricultural production system is the concentration of a disproportionately large share of farming output within the purview of smallholder farmers. Consequently, one can reasonably assert that a typical farming community in Nigeria comprises predominantly smallholder farmers. These farmers engage in cultivating crops and rearing animals, not only for household consumption but also for commercial purposes. As Adewumi & Omoresho (2002) have asserted, the progress and advancement of these farming communities will substantially influence the overall trajectory of the agricultural sector in Nigeria.

Nigeria is a federation comprising 36 states and six geopolitical zones. In all these zones, farming is predominantly small-scale. Nigeria is the highest producer of cassava globally, followed by Brazil (FAO, 2018), the highest producer of rice in Africa (FAO, 2019c). A greater percentage of these two products are produced by small-scale farmers as there is currently no evidence of any large farm in Nigeria into cassava production, and only a few are into rice

production. In fact, according to the Animal Science Association of Nigeria, large-scale farmers are mainly concentrated within the animal sub-sector (Finelib, 2019). In 2010, for instance, a study by Olawepo (2010) showed that for an average of 268 small-scale farmers in Nigeria, the annual profit is only N31,000 (88 USD). This annual profit is far less than 1 dollar per day. Each farmer produces an average of 3 tons of rice annually ($1000 per ton). The considerable difference between the quantity produced by the farmer and the final benefit the farmer receives shows a high level of inefficiency in the system. However, the impact of climate change on food and nutritional security and environmental sustainability is continuously gaining attention across Nigeria. The Southeast region is, however, complicated as it is also burdened with ecological issues, including soil erosion and water pollution.

Most farmers usually produce food crops such as yam, cassava, beans, and vegetables. It is common to see farmers who keep few animals within their homes and around the farmers. Farm areas sometimes are located within the houses. Still, in most cases, some farmers have their farmland situated at a distance where they have to travel long distances daily for farming activities. Farmers often receive farming education from the local extension agent under the National Agricultural Extension and Research Liaison Services (NAERLS) and the Agricultural Development Programme (ADP). Recently, there has been the emergence of agroecology groups in the Southeast region. The agroecology farmers organize to share knowledge and resources and are characterized by adopting sustainable farming practices. Apart from the agroecology farmers, there are also the "conventional" farmers. These farmers are the majority and are conventional farmers in the sense that they employ conventional farming practices such as dependency on external inputs such as fertilizers and insecticides. The so-called conventional farmers also belong to the FADAMA project, which seeks to increase agricultural productivity by supplying external inputs and seeds to the farmers – usually medium and largescale- while ignoring the smallholder farmers (Sennuga et al., 2023).

1.3.2 History of the agroecology group in the study area

The emergence of the agroecology group in southeast Nigeria represented a small part of the massive resistance to cases of land grabbing and exclusion of smallholder farmers in the ongoing Agricultural Transformation Agenda (ATA) of the federal republic of Nigeria (Nigeria Medium-Term National Development Plan [NM-NDP], 2021). Before the discovery of oil in Nigeria on January 15, 1956, by Shell British Petroleum, Agriculture had been the mainstay of the nation's economy. From 1952 to 1969, the agricultural sector accounted for, on average,

56.0% of the GDP and generated over 60% of the nation's export earnings (PWC, 2017). Nigeria was not only food self-sufficient per capita but could produce a surplus for export on a sustainable basis (Okotie, 2018). There were no records of big agribusinesses and farm corporations. Still, the local smallholder farmers were the main drivers of food production and national food security in that period (Okotie, 2018). With the discovery of oil, the agricultural sector generated less than 4% of export earnings, contributing less than 22% % to GDP, while crude oil generated over 80 percent of the nation's export value. From 2005, Nigeria's oil production began to decline. According to a Bloomberg report (2021), Nigeria's oil production fell from 2.5 million barrels per day in 2005 to 1.5 million in 2015 and is currently hovering around 1.14 million barrels per day as of 2021 (Nigeria National Petroleum Corporation, 2021).

With the decline in oil, successive governments saw the need to diversify the economy and return to agriculture. In 2015, the Muhammadu Buhari elected government launched the agricultural transformation agenda under the Economic Recovery Plan. The goal was to increase the national output and productivity and transform agriculture into a business for stakeholders and not a way of life (NM-NDP, 2021). With the increased government interest in agriculture for business, the Nigerian agricultural structure became characterized by rapid and heavy changes over the last 15 years due to neoliberal trends and the intensification of cash crop production (Bjornlund et al., 2020). Currently, there appears to be a dominance of cash crop agribusiness while food crop production by peasants continues to decline (Chete et al., 2021). The Nigerian Bureau of Statistics report shows that between the years 2015 to present, while crops produced for commercial purposes such as wheat, rice, cotton, and jute have increased, hunger and malnutrition have also increased within the same period (National Bureau of Statistics, 2021; UNICEF, 2020). Since 2015, a heavy expansion of rice production has occurred (Okonkwo et al., 2021). With the rice boom, the land on which rice is cultivated increased massively quickly. The land on which rice is grown rose from 1.31 million ha in 2005 to 3.14 million ha in 2021 (FAOSTAT, 2021). This sharp increase in area under cultivation corresponds to an over 200% increase. In Africa, Nigeria is currently the largest producer of rice, producing over 8 million metric tonnes. 2019, the country was ranked 14th among the world's largest rice producers (Eliazer et al., 2019). This agri-industrial agricultural transformation was supported by the World Bank-sponsored third national FADAMA development project (FADAMA III), which helped commercial crop production (World Bank, 2021). The concentration on the agri-industrial transformation has altered the production

environment for small-scale farming households, as many production inputs and services, such as seeds, extension services, land allocations, etc, now favour large agribusinesses.

In 2016, a team of researchers from the Centre for Agroecology in the United Kingdom embarked on an initiative to establish an agroecology group within the Umuimo community in the Southeastern region of Nigeria (Emeanaa et al., 2017). The primary objective of this endeavour was to provide support for the transition toward agroecology-based farming and food systems by implementing sustainable agroecological farming practices. Smallholder farmers in the area were offered training in these sustainable practices, and their participation was entirely voluntary. Those who received training subsequently formed an informal agroecology group. The research team set up a peer-to-peer network to facilitate communication and collaboration among the group's members, employing a registered smartphone application as a critical tool. In conjunction with in-person meetings and training sessions, this application served as a platform for knowledge sharing and collective action. This innovative approach effectively bridged the gap between scientific insights and traditional knowledge, enabling smallholder farmers to engage in sustainable food production.

One notable achievement of the agroecology group was its ability to harness various knowledge systems in novel ways, identifying science-based actions that enhanced the resilience of food systems and ecosystem services within the agricultural landscapes of the region, even in the face of impending climate change risks (Emeana, Trenchard, Dehnen-Schmutz, & Shaikh et al., 2018). Beyond knowledge production and sharing, the members of the agroecology group pooled their resources, engaged in the mutual utilization of land and labor, and established local markets and crop exchange mechanisms. These collaborative efforts exemplify their commitment to sustainable and community-oriented agriculture.

1.3.3 Land issues and ownership.

Regarding food security and socioeconomic dimensions, the agricultural transformation agenda has hampered the ability of smallholder farmers to participate in the food system. These have profound implications on livelihood strategy and consumption patterns. For instance, the dominance of agri-industrial production has been reported to impact access to land and productive resources (Liverpool-Tasie, Adjognon, and Reardon, 2016). According to Liverpool-Tasie et al. (2016), smallholder farmers are constrained from the food system due to

a lack of access to land and other productive resources. According to The Conversation (2021), a United Kingdom academic journal, grave inequality in land distribution exists. The disparity in land distribution is more pronounced in the rural rice-producing areas where over 80 per cent of the farmers are small-scale farmers but cultivate less than 50% of the whole arable land under cultivation (Emenyonu et al., 2017). Illegal land appropriation, patriarchal customs, and land grabbing underpin these inequalities. Because the land tenure system appropriates all lands to the government, the government, backed by powerful international actors, illegally appropriates lands to foreigners to the detriment of smallholder farmers:

> "*Farmers in Nigeria's Taraba State are being forced off lands they have farmed for generations to make way for US company Dominion Farms to establish a 30,000 ha rice plantation. The project is backed by the Nigerian government and the G8's New Alliance for Food Security and Nutrition in Africa* (Global Justice, 2015)*".*

Furthermore, although women are not legally prohibited from owning land in Nigeria, there is little gender equality in land ownership as women are not culturally allowed to inherit the land. When women purchase land, the title deeds are less secure than their male counterparts (Ngodoo, 2014).

Also, a study by Mgbenka & Mbah (2016) showed that the agricultural transformation agenda implemented in the Southeast led to a production exclusion of small-scale agricultural farmers. According to the authors, the rise of influential players in the food system made it difficult for small-scale farmers to access lands as lands became expensive; therefore, smallholder farmers often lacked access. The government's predominant focus on producing cash crops for export, notably rice, has fostered a protectionist food system framework. This approach has led to the prioritization of land allocation for cash crop cultivation, often at the expense of cultivating essential food crops such as vegetables, beans, and yam (Nigerian Organic Agriculture Network, 2018). Additionally, concerning this issue, there have been reported instances of land-grabbing, where impoverished villages and local smallholders have been compelled to relinquish their ancestral lands to make way for large-scale cash crop production (Emenyonu et al., 2017; Picco et al., 2016).

Moreover, the technology incorporated into the agricultural transformation agenda in the region necessitates a substantial capital investment. Consequently, only a select few larger-scale farmers possess the resources to fully leverage this technology, resulting in the concentration

of power over large farming operations and consolidation of agricultural control into fewer hands. As emphasized by Picco et al. (2016), the market structure in the region follows an oligopolistic pattern, with a small number of dominant actors wielding considerable influence within the commodity crop chains. This concentration of power translates into limited bargaining power for regional food producers.

1.4 Research design

This thesis employed an explanatory sequential design of mixed methods research to answer the question of how agroecology leads to food and nutrition security among smallholder farmers. From the research design presented in Figure 4, the study intends to uncover this linkage in three steps and through three stages of analysis.

1) Narrative review: In the first analysis, the study engaged in a narrative review whereby we engaged with the empirical literature on agroecology and food security to find the pathways through which agroecology leads to food and nutrition security. The study developed a theory/hypothesis from this analysis that was subsequently tested empirically.

2) Quantitative analysis: The second step was a quantitative analysis that involved testing if agroecology farmers are more food secure compared to their conventional counterparts. Also, the empirical pathways linking agroecology to food security and nutrition were tested.

3) Qualitative analysis: The third part was a thematic analysis of interviews with agroecology farmers. The goal at this stage was to understand those reproductive practices that lead to an improvement in food and nutritional Status. The reproductive activities that significantly affected food security from the quantitative analysis were highlighted here. The study tried to understand if the farmers could overcome the challenge of food insecurity and how they could do that. The diagrammatic representation of the research design is presented in Figure 4.

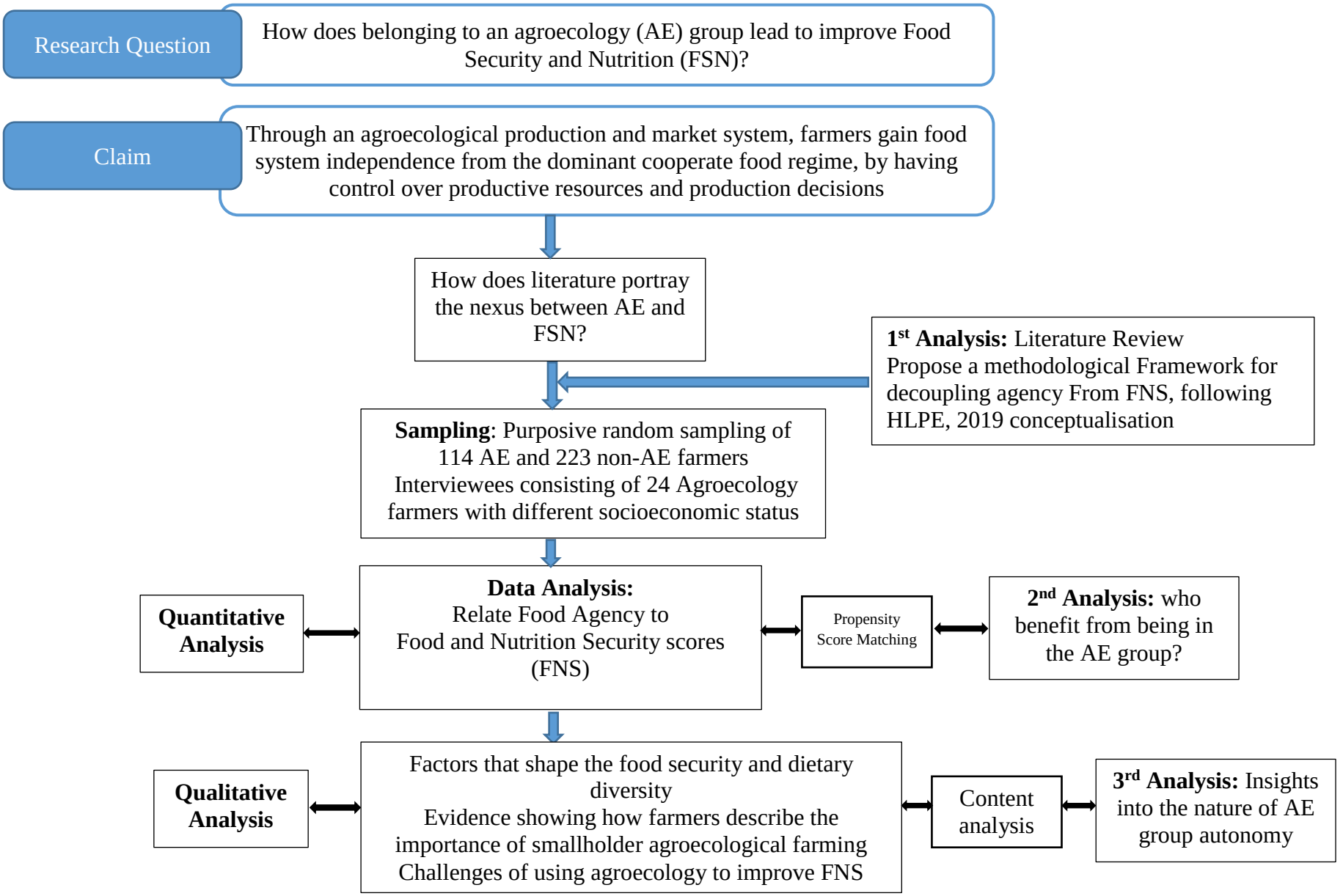

Figure 4: Evolution of the concept of Agroecology (Source: Author's)

1.4.1 Sampling Techniques and Sample Size

In this study, the definition of a smallholder farmer follows from FAO (2020). In this regard, a farmer is a smallholder when she manages a land area of less than 5 hectares. To capture only smallholder farm households, I asked a control question on land size at the start of each survey to determine the eligibility of the respondents for the survey. For the quantitative data, I employed cluster sampling, as the population for the study comprises mutually homogeneous yet internally heterogeneous groups of agroecology and conventional farmers. I obtained a list of conventional farmers from the Agricultural Development Program (ADP) regional headquarters and a list of agroecology farmers from the agroecology group facilitator. For the agroecology group, we surveyed 115 farmers. For the conventional farmers, I sampled 223 smallholder farm households. The study surveyed 337 respondents (114 agroecology farmers and 223 non-agroecology farmers). One respondent from the agroecology group was dropped as they declined to provide primary information necessary to be included in the study. I administered a structured questionnaire to the farmers. I employed trained enumerators who understood and spoke the local language of the study area to administer the questionnaires in person.

For the qualitative data collection, the sampling was first based on specific socioeconomic characteristics of the farmers that are common across the agroecology group. In general, the selection of the interviews followed this order:
First, the households have a farming activity as income or food source in the past, present, or both. Second, the households have access to land or had it in the past. Third, the households had participated in the FADAMA program. Second, to allow for varying perspectives within the group, sampling also included a spectrum of farmers with varying characteristics to compare each group's realities to those of their counterparts. I included farmers with farming as their primary occupation and those with off-farm income. I also included farmers who receive remittances from abroad or relatives in the city. I included farmers with varying means of land access, ranging from ownership to lease. I include farmers with different age ranges and educational levels. An overview of the 24 households interviewed is presented in Table 4 as follows:

Table 4: Overview of interviewees

Name*	Description	Education	Age (Years)	Farm size (Ha)
Chiamaka	Farming as a major occupation, off-farm income, and remittance from abroad, land ownership within the family, married	Primary	35	3
Chidinma	Farming as major occupation, off-farm income, land ownership by rent, single	Primary	24	1
Cynthia	Farming as major occupation, No off-farm income, land ownership by lease from AE group, Married	NFE	43	2
Arith	Farming as major occupation, off-farm income, land ownership by lease from AE group and from husband, Married	Primary	49	1.5
Ijoma	Farming as major occupation, off-farm income, land ownership by lease from AE group, Married	NFE	32	1
Joy	Farming as major occupation, off-farm income, land ownership by lease from AE group, Single	NFE	19	2
Joyce	Farming as minor occupation, Lecturing as major occupation, off-farm income, land ownership within the family, Married	University	29	7
Chinyere	Farming as minor occupation, civil service as a major occupation, off-farm income, land ownership within the family, Married	Primary	36	1
Nnennaya	Farming as major occupation, off-farm income, land ownership by lease from AE group, Married	NFE	27	1
Okechukwu	Farming as Major occupation, no off-farm income but with remittances from abroad, land ownership within the family, Married	Primary	34	1.5
Rose	Farming as minor occupation, Civil service as major occupation, off-farm income and remittances from abroad, land ownership within the family, Married	University	33	3.5
Ifeyighinwa	Farming as major occupation, off-farm income, land ownership by lease from AE group, MArried	Primary	43	2
Ezinne	Farming as major occupation, no off-farm income, land ownership by lease from AE group, Widow	Primary	51	1
Ngwobia	Farming as minor occupation, teaching as major occupation, off-farm income and remittances from abroad, land ownership by lease from AE group, single mother	Primary	29	2
Nnenna	Farming as minor occupation, teaching as major occupation, off-farm income, land ownership by lease from AE group, single mother	Primary	25	2

*NFE: No formal education, *Pseudo names were used instead of real names of interviewees*

Table 4: (Continued)

Ojiugo	Farming as major occupation, off-farm income, land ownership by lease from AE group, married	Primary	44	2
Uchime	Farming as major occupation, off-farm income, land ownership by lease from AE group, married	NFE	33	1.5
Charity	Farming as minor occupation, Lecturing as major occupation, off-farm income, land ownership within the family, Married	Post graduate	44	1
Okogbuo	Farming as major occupation, no off-farm income, land ownership by lease from AE group, Widow	NFE	65	1
Matilda	Farming as minor occupation, Lecturing as major occupation, off-farm income, land ownership within the family, Married	University	39	4
Nkechi	Farming as major occupation, no off-farm income, land ownership by lease from AE group, Married	Primary	48	1.5
Neche	Farming as major occupation, no off-farm income, land ownership by lease from AE group, Widow	NFE	63	3.5
Ifeoma	Farming as major occupation, no off-farm income, land ownership by lease from AE group, Married	Primary	42	1
Chineye	Farming as major occupation, no off-farm income, land ownership by lease from AE group, married	NFE	58	3

*NFE: No formal education. *Pseudo names were used instead of the real names of interviewees*

I conducted eight expert interviews to gain a deeper understanding of the agroecology group's mechanisms and the FADAMA project's structures. I conducted three expert interviews with the facilitators of the agroecology projects and five semi-structured interviews with stakeholders and policymakers from political institutions, women leaders from the women's organization, and agricultural extension officers. An overview of the expert interviews is presented in Table 5 as follows:

Table 5: Overview of expert interviews

Institution or actor	Description
Institutions and policymakers	
Agricultural Development Project	Umbrella body in charge of agricultural extension service in the study area
Catholoic Women Organisation	Women religious groups concerned with the welfare of women in the area
Ministry of agriculture and rural development	The organization's mission is to coordinate and manage the agricultural sector, facilitate agribusiness for increased food security, and promote agro-industrial development.
Ministry of women and youth development	It stimulates actions that will promote women's civic, political, social and economic participation.
FADAMA programme office	Help local farmers by promoting a green revolution strategy.
Agroecology facilitators	
Facilitator A	PhD holder and a former extension agent working with the National Agricultural Extension Research Institute
Facilitator B	Ph.D. candidate in agroecology.
Facilitator C	Pioneer member of the group, Male, in charge of registration and logistics

1.4.2 Data collection techniques

For the quantitative data collection, I used a detailed participant information sheet containing participants' consent forms to obtain consent from each respondent. I limited identifying information to the questionnaire number and the village's name. I used the household questionnaire to elicit data on individual and household demographic characteristics, asset ownership, access to services such as extension, markets, and credit, off-farm income generating, and activities networking and social capital.

The second segment of the questionnaire was designed to gather information related to the Food Insecurity Experience Scale and the Dietary Diversity Score. Agroecology was quantified through a dichotomous dummy variable, which took on values of 0 or 1, where 1 indicated farmers who were members of an agroecology group, while 0 denoted those who were not. Food security was assessed using the Food Insecurity Experience Scale, as outlined by the Food and Agriculture Organization (FAO, 2020). Over the past decade, the primary approach to measuring household food security has evolved to include the utilization of scales or scores that

rely on the firsthand experiences and perceptions of individuals affected by food insecurity. The utilization of the experience-based food security measurement scale offers several distinct advantages:

i) It stands as the sole method that directly measures our variable of interest, which is food insecurity, from the perspective of the individuals experiencing it.

ii) This approach allows for exploring and comprehending the causes and consequences of hunger and food insecurity.

iii) The method can be adapted for either household-level or individual-level analysis.

iv) Both the data collection process and subsequent analysis are relatively cost-effective and straightforward.

v) This measure encompasses both the physical and psychosocial dimensions of food insecurity.

The scale consists of eight questions, with each respondent's answers scored based on the specific question items to ascertain their level of food insecurity.

To incorporate the nutritional aspect into the Food Security and Nutrition (FSN) measurement, the study included the Dietary Diversity Scale (DDS) developed by Kissoly et al. (2020). The DDS has been extensively validated as an indicator of nutrient adequacy, malnutrition risk (Moursi et al., 2008; McDonald et al., 2015; Zhao et al., 2017), and socioeconomic status (Vhurumuku, 2014). The DDS comprises 12 questions, each corresponding to one of the 12 food groups typically consumed by household members. In the assessment, a value of "0" is assigned if individuals in the family did not consume a particular food group, and "1" is assigned if they did consume it. The raw score is derived by summing the affirmative responses to all the questions in the food security experience scale and the dietary diversity components. For clarity and reference, Section 1.4.3 provides a comprehensive overview of the variables used in the study, along with their respective definitions and descriptive statistics.

For the qualitative data, the study employed a qualitative research methodology in keeping with the methodological tradition of political ecology that requires sensitivity to context, social relations, and multiple views (Nyantakyi-Frimpong et al., 2016). In addition, using a qualitative approach will provide the opportunity to base the discussion on the firsthand experiences of the land managers (Okpara et al., 2019).” The interviews were conducted from June to September 2021 by a team comprising one of the authors and two research assistants who were members of the communities. These communities were selected because of the existence of a functional group in the communities. The interviews lasted between 40 and 70 minutes. I conducted the

interviews using an interview checklist for guidance. The interview questions were written in English and Igbo (the local language) to suit the language preferences of the respondents. The checklist included questions on socioeconomic characteristics, food security, dietary diversity, and farming practices. Questions were also included to assess whether the agroecological interventions have played any role in the experiences of food security and dietary diversity. The checklist also contained questions on motivation for joining the agroecology group and the household feeding strategy. I provided informed consent to all the participants who participated in the research. I audiotaped all the interviews with permission and then transcribed them for analysis. Interviews conducted in Ibo language were first transcribed verbatim in Ibo to maintain the fidelity of the narratives and subsequently translated into English. I shared our preliminary results with the agroecology farmers using four participants' feedback workshops to help ensure the credibility, accuracy, and validity of our qualitative summaries. All four feedback workshops took place at the village centre halls of the four selected communities. In the four workshops, I asked the participants to share their thoughts on the accuracy of the preliminary results and assess if I had appropriately reflected the experiences of the agroecology farmers.

1.4.3 Summary statistics of data for the study

The descriptive results of the empirical data collected are presented in this section. The results provide an overview and an understanding of the respondents and their socioeconomic dynamics. A comparison of the socioeconomic characteristics of agroecology and conventional farmers are contrasted. STATA 15 was used to generate descriptive statistics such as means, percentages, and standard deviations. The results generated (in this section) are also used as input for further analysis in the subsequent sections, for example, the propensity score matching of the farmers. The percentage distribution is based on the following frequency distributions: organic farmers (N = 114), conventional farmers (N = 223), and total respondents (N = 337).

1.4.3.1 Gender of the respondents

In the human-nature interactions in Agricultural Socio-Ecological systems, gender has emerged as crucial yet unexplored element that can improve our understanding of grappling with prevailing ecological challenges. Gender is used in this study as a social construct to represent the female sex or the male sex regarding cultural and social differences rather than biological differences. The majority of the members of the agroecology group are female. Our survey

showed that out of the 114 agroecology group members, about 83% are women (Figure 5). The greater percentage of women indicates that the women are more motivated to join the group. Perhaps this is because, in the study area mainly, women are primarily in charge of food provision and might tilt towards organizations that do not see food as a commodity of exchange but as an essential aspect of family care. Also, previous studies have alluded that women are more interested in nature conservation (Ajibola et al., 2020; Caissie & Halpenny, 2003). The preponderance of women in the group suggests laying credence to the fact that, compared to their male counterparts, literature has consistently found that females care more about environmental issues and engage in higher conservation behaviors than males. According to Bridgewater and Rotherham (2019), women have stronger attitudes toward protecting the environment hence are more likely to engage in pro-environmental behaviours. The distribution of the respondents as indicated in Figure 5 showed that, although there were more women in the total sample, the percentage difference in the group was higher than the percentage of women in the full sample and also in the conventional farmers.

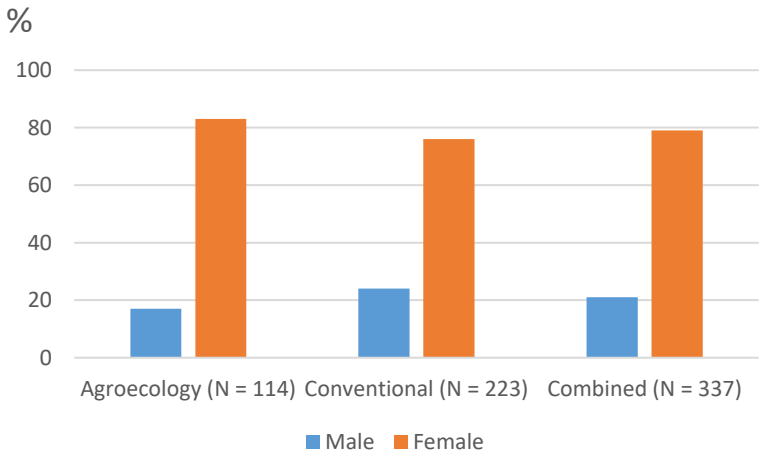

Figure 5: Distribution of the respondents based on gender (Source: Authours)

1.4.3.2 Group membership

Apart from the agroecology group, there are also many other farming groups in the area (Figure 6). It was also common for farmers to belong to two or more of the groups. This shows the intrinsic variations in the goals and benefits of the various groups. It was also observed that some of the agroecology farmers also belonged to other groups in the community. The mainstream farming group in the area was the FADAMA and the Agricultural Development Programme (ADP) group. The FADAMA is a World Bank-assisted agricultural programme

aimed at mechanization and supporting commercial agriculture in the area. FADAMA is a local indigenous word (Hausa language) that loosely translates to irrigable lowland.

Interestingly, about 2% of the agroecology farmers still belonged to the FADAMA group. However, they claimed that they only identified because their husbands were officials in the FADAMA group. The group's focus is to boost the production of low land commercially and at large-scale levels. The ADP, on the hand, is a programme in charge of agricultural extension services in the communities. Every farmer in the region is expected to belong to an ADP extension bloc to be reached by the government in case of any subsidy or benefit from the government or international donors. There are also market associations, mainly formed and organized by farmers. This is mostly among farmers who are into rice production I the area. This organization presents a platform whereby the farmers can quickly negotiate with the government, seed providers, processors, and other market intermediaries.

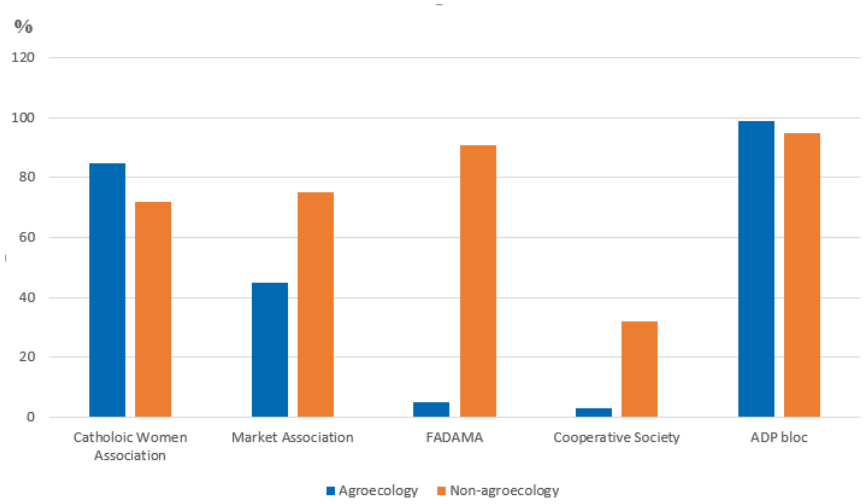

Figure 6: Distribution of the respondents based on group membership (Source: Authours)

1.4.3.3 Educational Status

Figure 7 shows that 48 agroecology members completed their primary education, and about 11 had tertiary education from the universities. This showed that the group is not only made up of uneducated farmers who might not have the potential to venture into other businesses or engage in commercial farming. Although formal education does not predetermine knowledge about agroecological practice, it is also important as the more educated person in the group provided most of the training on nutrition and dietetics. The educated members also took care of most of the paralegal and administrative tasks. In contrast with the conventional farmers, Figure 7 shows more graduates in the agroecology group than among the conventional farmers.

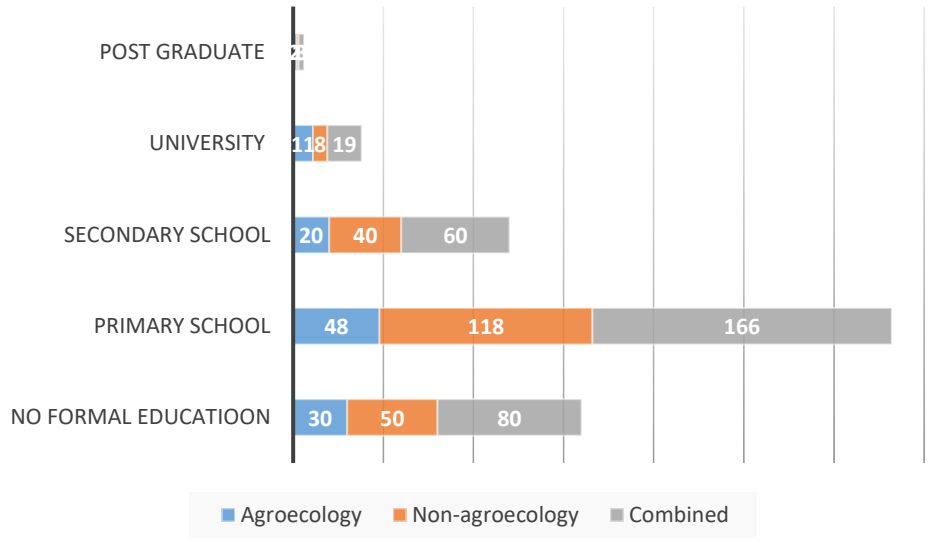

Figure 7: Educational status of the respondents
(Source: Authours)

1.4.3.4 Adoption of organic farming

The Food and Agricultural Organization of the United Nations (2022) defines organic agriculture as: "*a holistic production management system which promotes and enhances agroecosystem health, including biodiversity, biological cycles, and soil biological activity. It emphasizes the use of management practices in preference to using off-farm inputs, considering that regional conditions require locally adapted systems. This is accomplished by using, where possible, agronomic, biological, and mechanical methods, as opposed to using synthetic materials, to fulfil any specific function within the system*." (FAO, 2022). The distribution of the respondents based on the adoption of organic farming (Figure 8) showed that organic agriculture is still at the infant stage in the study area. This is in line with the submission made by Emeana *et al.* (2019), who reported that only about 10% of the farmers in the study area adopted organic farming. However, it can be from Figure 6 that it is common for farmers to engage in a combination of organic and inorganic farming. Study by Chukwuma, Onunka and Oranu (2016) found that farmers who engaged in a combination of organic and inorganic farming had higher output in vegetable farming. This also shows that most farmers are still employing the weak sustainability strategy in transitioning towards complete agroecology farming. The high cost of organic fertilizer Vis a Vis the availability of subsidized inorganic fertilizers might be one reason for this observed dynamics.

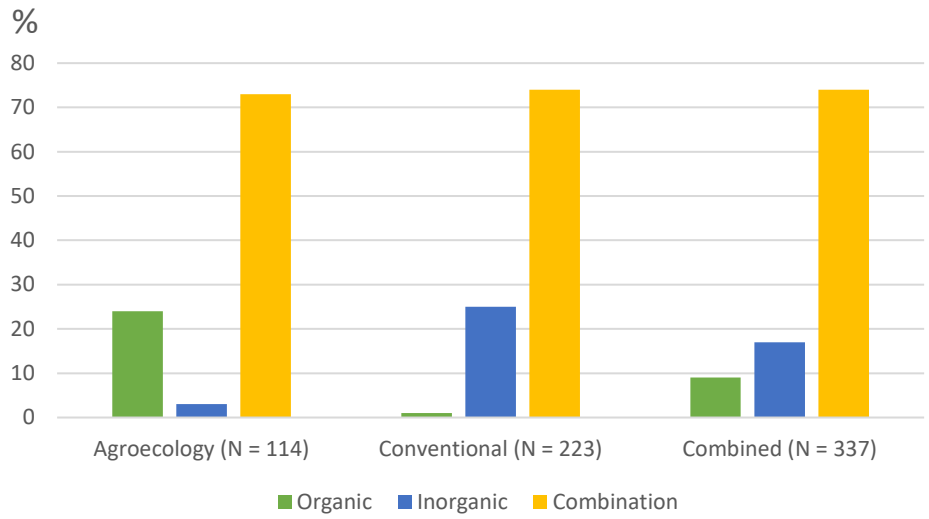

Figure 8: Distribution of the respondents based on level of Adoption of organic farming
Source: Authors

1.4.3.5 Sources of Credit

Credit is essential in successful agricultural ventures, even small-scale agribusinesses (Ume et al., 2020). The impact of credit constrict on performance cannot be over-emphasized. In the area, there are four sources of credit for the farmers, the deposit money banks, the microfinance banks, the agricultural banks and the informal credit lenders. Figure 8 shows that the agricultural banks and the informal sources are the farmers' primary credit sources. While the agricultural banks serviced most conventional farmers, most agroecology farmers sourced their credit informally. The informal source of credit is of different forms. However, in the agroecology group, an informal source of credit entails a contribution made by the organization's members from which members can access at little or no interest. For microfinance and Deposit Money banks (DMB), a high-interest rate is usually attached to the disbursed credits. The high interest rate makes it difficult for small-scale farmers to access this channel of credit source. The reason for the sharp difference between agroecology and non-agroecology farmers regarding the choice of credit source was unclear. Still, most of the agroecology farmers believed that they preferred the group's assistance in implementing the credit received, unlike in the Bank of Agriculture, where financial services and advice were not provided.

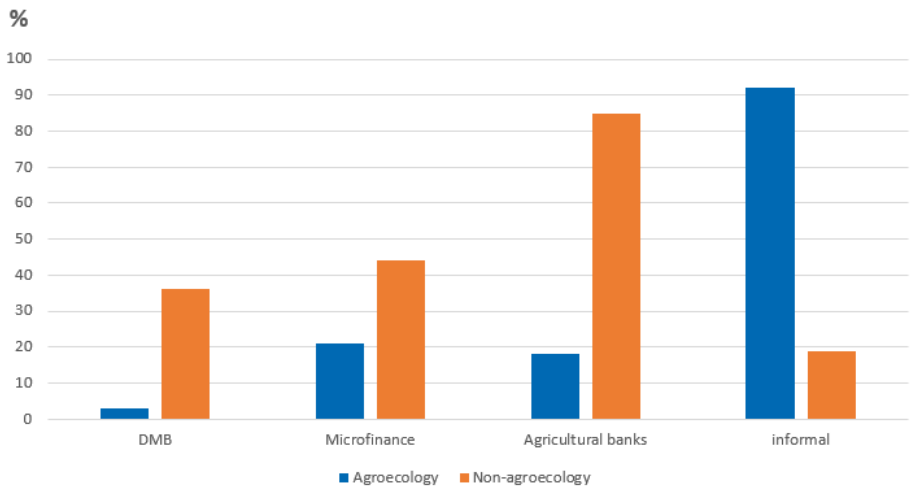

Figure 9: Distribution of the respondents based on Sources of credit
Source Authors

1.4.3.6 *Land Access*

Access to land is a very important yet complex phenomenon in the study area. The land tenure system bestowed all land ownership rights in the country on the government and its agencies. The goal was to ensure that farmers who wanted to engage in large-scale production had ease of land acquisition (Obayelu, 2017). Framers who, therefore, acquire land from the government can easily resell or lend it to others who could not afford or negotiate from the government. Over time, a land tenure process emerged. The land tenure process gives property ownership to legal entities, individuals, natural entities, and corporations, depending on their land usage. Therefore, four tenureship outside the state ownership emerged: free lending (borrowing), communal land tenure, private ownership, and tenancy or rented.

Figure 10 shows that most agroecology farmers access their land through free lending or borrowing. This process of access resulted from the willingness of the members of the group who were opportune to negotiate lands from the government or their communal land and share parts of the land with members of the group who could not access land. Also, most of the women cultivate on their husbands' lands.

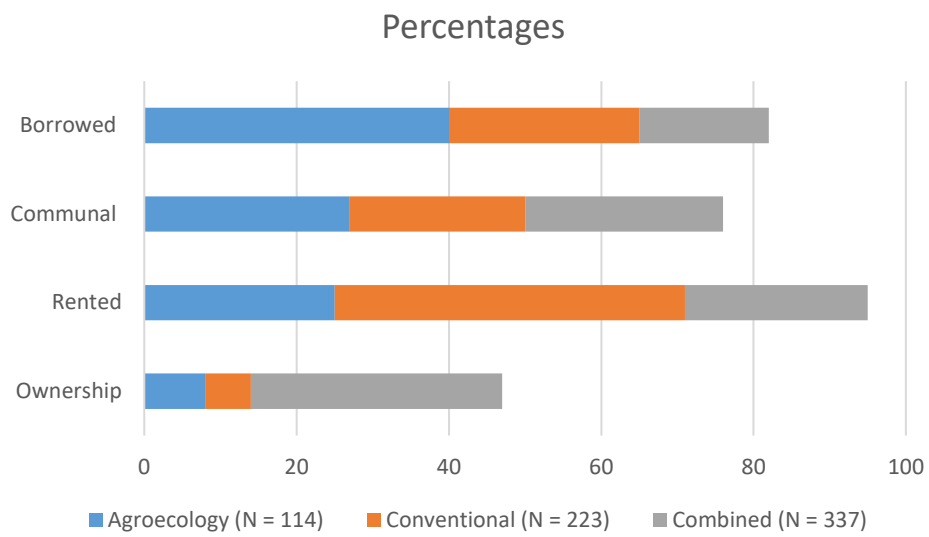

Figure 10: Distribution of the respondents based on the kind of access to land
Source: Authors

1.4.3.7 Land ownership

It is also essential to look at the distribution of the respondents based on land ownership. Here, the study considered only the farmers who own land. Figure 11 shows that the majority of the conventional farmer own their land through government assignments to them. Most of the agroecology own their land through purchase. Only about 4% received government assignments. The low percentage of land allocation from the government to the agroecology farmers might be related to the fact that the government assigns land to large rice producers who will cultivate food that the government needs.

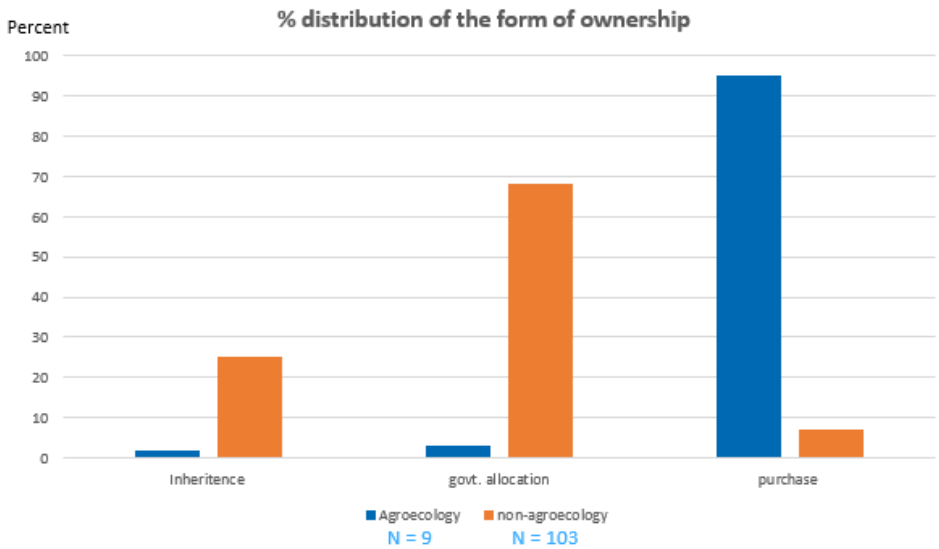

Figure 11: Distribution of respondents based on land ownership
source Authours

1.4.3.8 Kinds of crops produced

The study area is mainly agrarian communities with farmers planting staple food crops such as maize, yam, cassava, and rice. About 20% engage in mixed farming. For the agroecology farmers, our survey shows that 30% engaged in cultivating crops and keeping livestock, unlike conventional farmers, where only about 12% of the population engages in mixed farming. Figure 12 shows that cassava is the most common crop cultivated in the area for agroecology farmers, followed by maize. For non-agroecology farmers, cassava is the most commonly cultivated crop, followed by rice. Vegetable crop cultivation is more common among agroecology farmers than among conventional farmers.

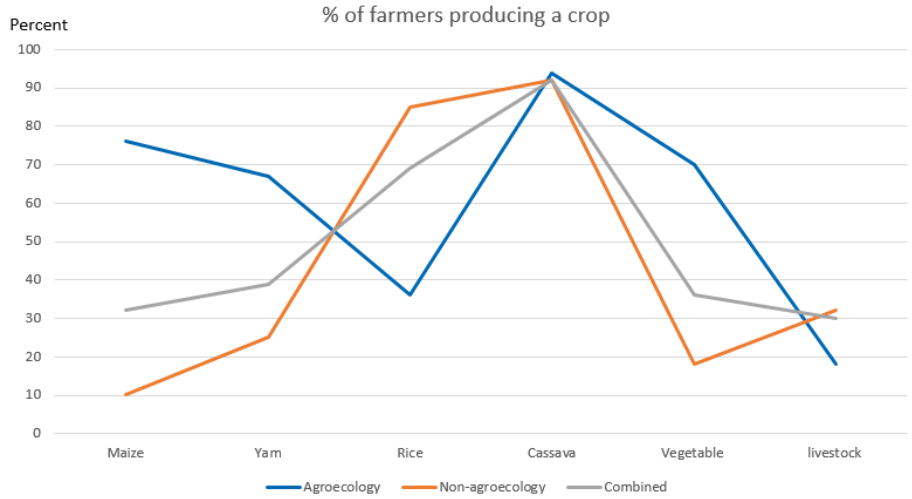

Figure 12: distribution of the respondents based on the types of crops cultivated
Source Authors

1.5 Summary of Results

This section summarises the results of the PhD thesis. The summary presented in this section encapsulates the results from the three analyses conducted and how each analysis relates to one another. As a first step in the PhD study, I reviewed research conducted in sub-Saharan Africa on the link between agroecology and nutrition. The narrative review was important to summarize and synthesize the arguments and ideas of existing knowledge around the research question and provide an entry point to join the conversation. The narrative literature review was an essential part of the research process and helped to establish a theoretical framework and focus or context for the research. Theories and hypotheses distilled from the review were empirically investigated using a two-phase explanatory sequential mixed method where

quantitative data was collected and analyzed first, then qualitative data was collected and analyzed based on the quantitative results. The qualitative data was used to explain the quantitative data and to gain insight into the lived experiences of the agroecology group members, thereby providing more robust inference and complete evidence.

1.5.1 *Narrative literature review: Framework linking agroecology to FNS*

Ume, C., Nuppenau, E., & Domptail, S. E. (2022). A feminist economics perspective on the agroecology-food and nutrition security nexus. *Environmental and Sustainability Indicators*, 16, 100212. https://doi.org/10.1016/j.indic.2022.100212

The importance of integrating agroecological practices and principles into food security programs is evident, and considerable research has investigated the link between agroecology and FSN. However, the literature review revealed mixed evidence thus far. For instance, two of the 19 empirical studies reviewed (about 11%) concluded that adopting agroecology might not be beneficial for farmers' food security. Mugwanya (2019), for instance, concluded that there is a danger that agroecology can lock farmers into a poverty trap and non-productive traditional agriculture. Generally, it was observed that all the studies that provided negative conclusions on the link between agroecology and FSN were the studies that conceptualized agroecology only as an agronomic practice, neglecting the social and political advantages that the adoption of agroecological approaches can offer. Studies such as Appropedia (2018) have called for investigations on the broader conceptualization of agroecology beyond the farming practices level. This study, therefore, provides a conceptual contribution in line with the demand to distil the full complexity of agroecology-FNS links in human-environment systems (Appropedia, 2018).

The comprehensive narrative review approach, through examining heterogeneity/variability of results in the literature, provides an objective account of what we know about the role of agroecology in the sub-Saharan Africa context, as well as significant trends and conclusions that can influence policymakers' decisions and future research. Apart from consolidating evidence on agroecology as a vector for an efficient production model for small-scale farming units, this review went beyond state-of-the-art to distil other essential pathways through which adopting agroecology practices can improve FSN among small-scale farmers. To my knowledge, this study might be the first to have conceptualised the different routes between agroecology and FNS. This study serves the ‘ground-truthing’ requirement for further studies

on agroecology-FNS conceptualization, especially in regions with deeply entrenched food system inequalities.

The study identified compelling evidence supporting two overarching pathways through which agroecology contributes to enhancing Food and Nutrition Security (FNS). These pathways have been categorized as the "physical reproduction" and "social reproduction" pathways. In this context, the physical reproduction pathway is centred around innovative and sustainable production practices that agroecology farmers employ to improve their food security and nutritional well-being.

The physical reproduction pathway can be further subdivided into three distinct sub-pathways, each characterized by the nature of the benefits derived from the innovative farming practices embraced by agroecology farmers:

1. Input Reduction Pathway: Within this pathway, agroecology farmers are dedicated to reducing their reliance on external inputs. This strategy serves as a means of curtailing production costs and optimizing the utilization of available resources through methods like recycling and conservation.
2. Climate Resilience Pathway: As climate change poses a significant threat to food security and nutrition in Africa, the climate resilience pathway encompasses farming activities designed to ensure the long-term stability and continuity of food production. These practices are vital for safeguarding food availability over time in the face of shifting climatic conditions.
3. Production Diversification Pathway: Agroecology farmers actively engage in various farming practices such as mixed farming, crop rotation, and cropping.

These practices have been observed to exert a positive and substantial impact on the dietary diversity of households (Kassie et al., 2020b; Moses Mosonsieyiri Kansanga et al., 2020). By optimizing the variety of crop and animal species, agroecology farmers not only secure food and nutrition but also contribute to the preservation of natural resources. These pathways collectively underscore how agroecological practices enable farmers to enhance food security and nutrition while simultaneously promoting ecological sustainability.

The social reproduction pathways identified in the study shed light on the intricate web of social relationships cultivated by agroecology farmers, both within their households and in broader society. These pathways encompass activities that shape social interactions within households

and communities, ultimately improving food and nutrition security. Central to these pathways is social capital, cultivated through networks that facilitate knowledge sharing among farmers and provide access to productive resources. Through peer-to-peer activities and grassroots movements, agroecology farmers actively participate in co-creating knowledge and disseminating indigenous wisdom (Kansanga et al., 2020). This knowledge-sharing process is vital for enhancing food and nutrition security.

Moreover, agroecology empowers many women farmers to unite and form women's groups and movements that amplify their voices and influence (Bezner Kerr, Hickey, et al., 2019). These collective efforts have significant implications for women's empowerment and their role in shaping food security. Beyond the African context, examples from places like India illustrate how marginalized women, historically oppressed due to factors like caste and landlessness, have come together to form self-help groups and collectives. These groups engage in collective farming practices, drawing upon indigenous traditional knowledge and practices to achieve independence and food security (Kangmennaang et al., 2017). These examples underscore the transformative potential of agroecology in fostering social cohesion and improving food security for marginalized communities.

It's important to note that while the study distinguishes between the physical and social reproduction pathways for analytical clarity, these pathways are inherently interconnected and mutually reinforcing. They form a cohesive and integrated approach that collectively enhances the production efficiency of smallholder farmers. While the physical reproduction pathways primarily pertain to farm-level practices and activities, they are intimately linked to the broader context of social reproduction beyond the agricultural landscape.

1.5.2 *Quantitative analysis: Pathways from Agroecology to FNS*

Ume C, Nuppenau E-A and Domptail SE (2023) Who profits from agroecology to secure food and nutrition? On access of women to markets and assets. *Frontiers in Sustainable Food Systems.* 7:1082944. doi: https://doi.org/10.3389/fsufs.2023.1082944

The study's second objective was to empirically analyse the conceptual framework determined in the first analysis. The literature review revealed many studies that empirically linked agroecology to food security and nutrition (Wezel *et al.*, 2014; Nyantakyi-Frimpong *et al.*, 2017; Bezner Kerr, Young, *et al.*, 2019). As highlighted above, empirical evidence on the link between agroecology and FSN is mixed. Hence, there is a need for further empirical evidence to establish coherence in the literature. The first part of this study provided empirical evidence

on the relationship between agroecology (as a group) and FSN. Previous studies did not control for potential endogeneity (factors that affect FSN might also affect being in the agroecology group). Pretty et al. (2003) investigated the effect of agroecology adoption (i.e. agroecology as a practice) on the food security of 200 farmers and concluded that failure to control for endogeneity would underestimate the effect of agroecology on FSN outcomes. I addressed the potential endogeneity problem using a propensity score matching approach. The result of the propensity score matching analysis in this study suggests a positive relationship exists between being in an agroecology group and being food and nutrition-secure. The result indicates that the action of the agroecology group in the study area has been effective in improving their members' nutrition and food security status.

Relatedly, while previous studies only investigated the relationship between agroecology and FSN, the channel of transmission or the mechanism through which agroecology influences FSN is largely understudied. This gap in literature is what the second part of this paper addressed. This study used an innovative quantile propensity score matching approach to empirically investigate how being in the agroecology group affects the smallholder farmers' food and nutrition security status. The multi-method propensity score approach provides a methodological contribution to exploring the full complexity of agroecology-FNS links in human-environment systems. The study investigated the nexus between agroecology and food security using four variables to represent the social dimensions of agroecology. The four variables include (1) time, (2) production diversity, (3) self-provisioning, and (4) Extension visits. These four variables were based on the result of the social reproduction pathways uncovered from our literature review (Objective 1).

Our matching technique highlights significant variables and reproduction goals critical in analyzing the established relationship. The study found that agroecology farmers who strategize their food security by orientating towards producing their own food (direct production entitlements) achieve better food security than non-agroecology farmers in the same category. However, the most food-secured group was the farmers who balanced between self-provisioning and market orientation. Yet, there is a difference between markets that support food production and markets that mainly support income generation. Farmers' choice to produce for food or cash will affect food security differently. The market used and co-developed by the agroecology group in southern Nigeria enables farmers to sell “real” surpluses of food (and not specific commodities) at a valuable price. Thus, women's production decisions can be directed

towards consumption first and foremost while enabling them to acquire cash for supplementary necessary food purchases. The food market that emerged from this group was vital as it helped deemphasize cash crop production as the panacea to improve food security. The agroecology food market was instrumental in promoting a more local rural market and engendering the production of food crops rather than cash crops.

The agroecology farmers also engage in food exchange in the market. The importance of the barter opportunities was that food exchange ensured the availability and access among participants. The literature on barter markets in rural Nigeria highlights this finding (Danlami, 2013; Fujishige & Yang, 2022). The exchange system was necessary for the women in the agroecology group as food exchange instead of cash exchange allowed them to maintain control over food, which would not have been the case if cash had been involved. Women's control over food is more assured than their control over money. Beyond achieving food availability and access, barter markets reduce waste as excess food can be easily disposed of without cash.

The study's findings concerning access to extension services reveal a noteworthy trend: Agroecology farmers with limited or no access to conventional extension agents tended to fare better in terms of food security and nutrition when compared to their conventional farming counterparts in similar circumstances. This counterintuitive result suggests that agroecology farmers benefit significantly from their engagement in constant peer-to-peer knowledge exchange. Sharing expertise and experiences within the agroecology community likely contributes to improved food and nutrition levels among its members. Furthermore, the study underscores the significance of non-farming dimensions in addressing food security and nutrition, particularly among smallholder women farmers who bear primary responsibility for household food provision. As exemplified by the collaborative and reciprocal activities among its practitioners, the social dimension of agroecology plays a vital role in enhancing food security and nutrition outcomes.

Based on these findings, the study comprehensively conceptualises agroecology as a complex socio-ecological system. This system encompasses not only agronomic practices but also social dynamics involving mutual exchange and co-creation activities. These activities mobilize local production resources such as land and labour, as well as inputs like seeds and knowledge. Consequently, agroecology transcends mere farming practices and extends its influence at both the household and societal levels. In essence, the study highlights the limitations of food

security programs and academic studies that solely view agroecological farm organizations through the lens of farming practices. It emphasizes the need to recognize the myriad innovative ways in which agroecological principles are woven into the fabric of rural communities, affecting food security and nutrition outcomes.

1.5.3 *Agroecology, gender, and autonomy for food security*

Ume C, Nuppenau E-A, Wahlen S, and Domptail SE (2023) How agroecology group empowered women smallholder to achieve food security. *Submitted to the journal of peasant studies*.

While some studies (Kassie et al., (2020); Kerr, 2005; Kerr, Hickey Lupafya, et al., 2019; Kabeer 1999) have started to integrate the gender-autonomy nexus in studies on food security, research on relationships between agroecological practices, autonomy, and food security is sparse. In the third analysis of this PhD dissertation, I examine how agroecology-farming approaches provide autonomy for women in a capitalist food system. In the previous paper, it was observed that the women mostly associate with the agroecology group. In this paper, I attempt to broaden the role of agroecology (both as a practice and as a group) into the social processes, drawing on the idea of feminist intersectionality. Rooted in a conceptual framework informed by feminist agroecology, I identified and examined how practising agroecological farming and belonging to an agroecology group boost the agency of smallholder female farmers in pursuing non-market reproductive goals that are critical in achieving food security. Extensive studies in agrarian communities indicate that agriculture is paramount in improving FNS outcomes (FAO, 2018; CGIAR, 2013). However, researchers argue that agroecology groups and the adoption of agroecological practices can create empowerment structures for women smallholder farmers, which can guarantee equity in the distribution of FNS benefits from farming (Boillat & Bottazzi, 2020; Emeana & Trenchard, 2018; Fuhrer, 2003). However, none of these studies empirically tested this argument, i.e., it is a maintained hypothesis. This gap in literature is what the third paper addressed.

The study identified three ways through which the agroecology group boosts the agency of women smallholders in achieving food security. These include Status and related decision-making power, Autonomy to function in a non-monetary economy, and the development of parallel food systems.

Women's status and decision-making power are essential indicators of the Women Empowerment in Agriculture Index (WEAI). It can play a far-reaching role in ensuring that the

family is food secured. According to the agroecology farmers, the reproductive goals and activities associated with agroecology, in terms of the application of organic manure, peer–to–peer activities, and local market participation, play vital roles in boosting their level of agency within the household and in the community. Many women interviewed previously had to depend on the government, extension agents, or their husbands for fertilizers, farming knowledge, or land, respectively. However, by adopting different agroecological practices and associating with the agroecology group, they do not need to depend on 'external agents' for these essential inputs. In terms of functioning in a non-monetary economy, the status and decision-making power of the women appear to be more pronounced and made possible when they operate within the reproductive sphere and non-monetary economy. When embedded in a monetary economy, the reproductive sphere and non-monetary economy represent a range of activities such as household work, caregiving, and food self-provisioning that do not have monetary value in the market but remain vital to food security (Jarva, 2016). As noted by Ijeoma, one of the agroecology women farmers, self-provisioning was crucial in overcoming market variability and inflation that resulted during and immediately after the COVID period.

The non-monetary economy that emerged because of the agroecology group and the adoption of agroecology practices is also reflected at other stages within the food system: production, processing, and marketing. In terms of production, some of the interviewers believed that the method of production employed by the agroecology farmers, which includes organic farming and reduced tillage, makes the agroecology farmers less reliant on fertilizers and tractors that the corporate food firms supply. In terms of marketing patterns, by producing organically, the agroecology farmers believed that they could develop a local marketing system less influenced by the dominant capitalistic marketing system.

In general, if food policy frameworks will integrate agency and sustainability as an essential and fundamental approach to food security (Clapp et al., 2022), this study suggests that efforts should be made to expand women's autonomy within the household and in society by acknowledging reproduction works as being necessary for food security. Emphasis on "women's autonomy" is essential, as women are often in charge of the food needs of the family. Men, on the other hand, are more often in charge and control over money and cash. Therefore, the commercialization of food will most likely shift the locus of control of food away from women, thereby reproducing inequalities that weaken women's control over food.

1.6 Discussion

The concept of agroecology has never been static, having no universally recognized boundaries. Interpretations and understanding arising from research, activism, and practice have always informed how our conceptualization and understanding of the different dimensions of agroecology have become more nuanced over time. Recently, transitioning to an agroecological farming system is now recognized as a vital indicator of progress towards agricultural sustainability and the potential to advance broader welfare outcomes such as women empowerment, no poverty and zero hunger (HLPE, 2019; FAO, 2019). Although there is a consensus among researchers, policymakers, and practitioners that there is a need for a more environmentally friendly system of agriculture capable of producing improved food and nutritional outcomes, there is still the need for additional research before solid conclusions can be reached on the instrumental value of agroecology (De Schutter, 2019). The present doctoral study contributes to the expanding body of literature on agroecology and its implications for food security by focusing on the case of Southeast Nigeria. It examines how the presence of agroecology groups and the adoption of agroecological practices independently and synergistically influence the experiences of food security and dietary diversity. Notably, while prior research in the field of agroecology and food security has commonly identified correlations, the elucidation of potential mechanisms underpinning these associations has, to the best of my knowledge, not been systematically explored until now.

The findings of this doctoral thesis underscore the pivotal role of agroecology, whether as an agricultural practice or through the collective efforts of farmers adopting these techniques, as an essential determinant of dietary diversity and food security, which is unsurprising. As farmers embrace alternative and innovative farming methods, they not only realize cost and time savings but also allocate these benefits toward their caregiving responsibilities and personal well-being. Furthermore, when they organize into cohesive groups, they gain access to an enhanced knowledge base on food and nutrition, extend mutual assistance, and cultivate the collective agency and capacity to assert their voices (Hoddinott & Haddad, 1995; Pereira, 2017). In the case of Southeast Nigeria, where the green revolution strategy for agricultural development has been widely subsidized and endorsed by the nation-state, with more significant gains for large and medium-scale farmers and lesser shifts in FSN for poorer households, the result of this PhD suggests that agroecological methods offer a worthwhile alternative for small farmers to improve FSN – however, one that would require political support to facilitate its widespread adoption and realization of its full potential.

The agency-related capability offered by agroecology as a group (and not only as a farming practice) serves as the foundational basis for the growing interest in 'food sovereignty' and related concepts such as the 'right to food' and the 'new politics of food' (Thompson, 2015). The term 'food sovereignty' was specifically coined to challenge development policies centered around 'food security,' which primarily framed food security as access to sufficient and healthy diets (Vía Campesina, 2011). Policies supporting the food security-oriented development approach operated on the assumption that food security could be achieved by ensuring that local markets supplied enough food, and that the income levels of the poor matched the provisions of these markets. The idea of food sovereignty, as advanced by Via Campesina, opposed these policies, emphasizing that such strategy for food security did not provide indigenous farmers the voice to shape the institutional structure of their food systems. Although an exhaustive discourse on food sovereignty is well beyond the purview of this PhD, the conceptualization of food sovereignty ultimately returns to the initial notion of agency as the political voice that enhances the capabilities of marginalized individuals, in this case, smallholder farmers, to actively participate in shaping the governance and institutions that govern their activities. As highlighted in this study, the group dynamics associated with the agroecology group expands the agency of smallholder farmers to achieve food security through (re)generating a diverse autonomous food system based on ecological sustainability and social justice. Moreover, our findings indicate that agroecological methods can be viable for small-scale farmers who see agroecology as supporting their autonomy, as they ensure they are producers rather than rural labourers on estates or small farms. As a result, agroecology, in conjunction with feminist participatory praxis, has also contributed to political formation, reducing dependency on government subsidies and inputs from corporations. The outcomes of this study are consistent with other research that highlights the connection between agroecology and food sovereignty, with a particular emphasis on the autonomy and solidarity of small-scale farmers (Dale, 2023; Vergara-Romero, Jimber-del-Río, & Márquez-Sánchez, 2022; Rosset, et al., 2011).

This thesis does not dispute the significance of enhanced income in improving food security. However, the research has asserted the necessity of a more nuanced examination of how subsistence farming and direct food entitlements play a pivotal role in cultivating the essential capabilities required to achieve food security. It is imperative for policymakers and other food policy specialists to recognize that an exclusive emphasis on income-based entitlements can have adverse effects on food security. Bringing this point to the forefront of food policy frameworks is one message of this thesis.

Finally, the success of sustainable and innovative farming practices (physical reproduction) often hinges on the social capital and knowledge networks (social reproduction) that farmers build within their communities. These social relationships facilitate the dissemination of information, the sharing of resources, and the collective adoption of agroecological techniques. Conversely, the strengthened social bonds and shared experiences that result from social reproduction activities can directly influence the adoption and success of physical reproduction strategies on the farm. In essence, the study underscores the interdependence and synergy between these pathways, emphasizing that the holistic approach of agroecology extends beyond the field and encompasses the social fabric of farming communities. This integrated approach ultimately contributes to improved production efficiency and enhanced food security among smallholder farmers.

1.7 Conclusion and Future Research

This PhD assessed the role of agroecology group in improving food and nutrition security among smallholder farmers in southeast Nigeria. The analyses began with a review of relevant literature on agroecology and food security in Africa published between 1996 and 2020, consolidating evidence that agroecology has contributed to food and nutrition security and developing a conceptual framework for thinking about the link between agroecology and FNS. The literature review was followed by empirical analysis to test the framework developed from the review process. Primary data were collected from smallholder farmers in the area. Based on the results obtained from the study, this section concludes and provides essential ideas that will give a better understanding and extend the debate on the agroecology-FNS nexus within the sub-Saharan Africa context.

1.7.1 Rethinking agroecology-FNS nexus

Agroecology literature in Africa needs to embrace the social dimension of agroecology. Agroecology is not only a practice; it encompasses the social and network structures necessary to give voice to marginalized persons in a community. In my discussion, I modify the conceptual framework from the high-level panel of experts in food and nutrition security (2019) to show how reproduction activities relate to FNS and highlight how research on Africa has, until now, failed to embrace agroecology in its social and political context. The study then discusses reproduction dynamics as another essential pathway for analyzing the link between agroecology and FNS. The study argues that the foundational (related) concepts of social

reproduction and agency for food security and nutrition may provide a better lens to unpack the agroecology-FNS nexus than the agronomic technical perspective or the neoclassical eternal attempts to solve hunger among the (cash) poor through market mechanisms (e.g., integration). The study call upon research to strengthen the analysis of agroecology as an innovation in a socio-ecological system rooted in a political ecology context.

1.7.2 Six-dimensional food security pillars

The definition of food security has changed and evolved over the past decades and has seen the introduction of the four commonly cited pillars: access, utilization, availability, and stability, all of which have been instrumental in shaping policy. Acknowledging the significance of autonomy and environmental sustainability in assessing food security, particularly in regions marked by profound gender disparities, this study aligns itself with the High-Level Panel of Experts in Food Security and Nutrition in advocating for the incorporation of agency and sustainability as integral dimensions in the measurement and analysis of food security. Given the widening disparities within food systems and an increasing awareness of the interconnectedness of ecological and food system dynamics, it becomes increasingly evident that both the practice of agroecology and the collective efforts of agroecological farmer groups can play a crucial role in mainstreaming these additional dimensions of food security. However, it is noteworthy that the empirical quantification and measurement of these two pillars—agency and sustainability—in the context of food security and nutrition remain fertile grounds for future research endeavours.

1.7.3 Need for a long-term and time-series assessment

Establishing casualties requires time-series investigations. In real-world assessments, it often proves challenging to study phenomena or interventions comprehensively across periods before, during, and after their occurrence due to the absence of complete time series data. Consequently, this limitation can impede the accurate inference of causality regarding the hypothesized mechanisms. Furthermore, certain phenomena are complex, involving multiple causes and intricate feedback loops. To advance our understanding, future studies should aim to unearth the precise causal mechanisms underpinning the functioning of agroecology groups using time-series data. Such causal determination would require a long-term observations of these mechanisms and their interactions, ultimately contributing to a deeper comprehension of the dynamics involved in agroecological practices.

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Chapter 2: Narrative literature review: Framework linking agroecology to FNS

Ume, C., Nuppenau, E., & Domptail, S. E. (2022). A feminist economics perspective on the agroecology-food and nutrition security nexus. Environmental and Sustainability Indicators, 16, 100212. https://doi.org/10.1016/j.indic.2022.100212

Environmental and Sustainability Indicators 16 (2022) 100212

Contents lists available at ScienceDirect

Environmental and Sustainability Indicators

journal homepage: www.sciencedirect.com/journal/environmental-and-sustainability-indicators

A feminist economics perspective on the agroecology-food and nutrition security nexus

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ARTICLE INFO

Keywords:
Agroecology
Physical reproduction
Social reproduction
Agency
Sub-saharan africa
Smallholder agriculture

ABSTRACT

This paper investigates how research documented and framed the agroecology-food and nutrition security (FNS)-nexus in Africa. Our first objective is to reveal the links research in Africa has established between agroecology and FNS. Our literature review of empirical studies located in African countries, published between 1996 and 2020, consolidates evidence that agroecology has contributed to food and nutrition security. Second, we question which pathways of influence of agroecology on FNS the selected papers chose to investigate. While neo-classical economics concentrates on production and on the level of embeddedness of the agricultural activity in the capitalist markets to solve the problem of FNS, feminist economics offers new perspectives by addressing both production and the reproduction processes necessary to support production. Our analysis of literature is structured around the feminist economics concepts of physical, household, and social reproduction, as well as agency. We show that activities of reproduction linked to agroecology at the level of households and territories are scarcely documented in the investigated papers, while the documentation of the contribution of agroecology to FNS via physical reproduction activities (e.g. soil fertility) dominates. We then propose a conceptual framework linking agroecology, reproduction activities, and FNS based and also illustrate the postulate that sustainable production practices such as agroecological practices are intrinsically linked to the social activities of farmers and cultural contexts in which farmers are embedded. Viewing agroecology both as a social and ecological process concomitantly will reveal numerous pathways between agroecology and food security and nutrition and agroecology's full value.

1. Introduction

Malnutrition currently affects the lives of 23% of rural and farming households in sub-Saharan Africa (HLPE, 2020). Green revolution approaches advanced by international agencies and governments to address malnutrition promoted industrial input-based intensification strategy. Industrial agriculture embeds farming activities more tightly in formal commercial markets thereby promoting the production and consumption of more calories (Fanzo, 2015). This strategy, which remains dominant in development and agricultural policies in sub-Saharan Africa, requires the full involvement of the farmers in the cash economy. Yet, industrial input-based intensification seems in part ineffective in changing the nutrition status of rural smallholder households (Deutsche Welle, 2020). Yet, the persistence of malnutrition among farming households may also be related to the specific economic and social context in sub-Saharan African agricultural regions. Around 80% of Africa's poor population derive their livelihoods from production-based entitlement and not market-based entitlements (Thompson, 2015). A large share of sub-Saharan smallholders has little land available for production (less than 5 ha), have little access to cash and credit (Giller, 2020), and are females. In addition, numerous economic activities possibly contributing to food and nutrition security still take place outside the market sphere in Africa (Nicholls and Altieri, 2018). Women are also the prime responsible persons for nutrition at the household level (Kassie et al., 2020). Agaisnt this background, investigating how else rural farming populations maintain themselves with alternative food systems is crucial for food security in Africa.

As an alternative to industrial farming (and to the prevalent low-input farming) methods, agroecology practices have emerged in Africa following a strong development in the rest of the world (particularly

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https://doi.org/10.1016/j.indic.2022.100212
Received 19 December 2021; Received in revised form 7 October 2022; Accepted 29 October 2022
Available online 1 November 2022

South and Central America, but also Asia and Europe). Agroecological practices consist of agricultural practices which mimic natural ecological processes in soils and agroecosystems to regenerate soils and increase production (Nichols et al., 2017). Yet, the word agroecology also is used to denominate an alternative food system based on systems thinking, which can secure food and nutrition (HLPE, 2019; FAO, 2019). According to FAO (2019), the term promotes more socially and environmentally sensitive agriculture by focusing not only on production practices but also on the economic and social context in which these practices are introduced, implemented, and passed on.

But does agroecology improve farmers' ability to reach food and nutrition security? We define food and nutrition security following the High-Level Panel of Experts in Food Security and Nutrition (2016) as dependent on access, stability, accessibility, and agency. These may all be influenced by agroecology. As stated by Silici (2014), the nexus between agroecology and food security makes no consensus, and the pathways through which agroecology leads to improved food and nutrition security among farmers are still unclear.

In this paper, we ask how research has addressed this nexus in sub-Saharan Arica. Thereby, we adopt a feminist economics perspective to reflect critically on the pathways through which agroecology in Africa is assumed to influence nutrition. Feminist economics criticizes neoclassical economics by showing how its models and methods are based on exclusive attention to masculine-associated topics in formal economics, focusing on production activities, and capitalist and cash-based exchanges. Feminist economics thus introduces concepts that allow for a fuller analysis of economic life, including topics such as family economics, care work, and unpaid work. It thereby highlights those economic exchanges essential for reproducing our societies and supporting production activities (Ferber et al., 2003). While of course, many of the reproduction activities are conducted by women in patriarchal cultures, feminist economics goes further than adopting a gender glance by looking at the structural elements in the socio-ecological system which lead to reproduction activities being ignored instead of nurtured, rather than looking at why women have (for instance) little power in agriculture. In our critical review, we thus consider both production and reproduction activities that influence food security, irrespective of whether such tasks are undertaken by men or women (Esther-Mirjam and van Staveren, 2019; Figart, 2015; Thomson, 2009). We especially, use the concept of reproduction under its three forms: ecological, household (economic), and social (political) to analyze the pathways the identified studies have chosen to investigate the agroecology-food and nutrition security nexus. We consider FNS as a productive goal of the household, linked to several other reproductive dimensions.

Our first objective in this paper is to assess whether agroecology practices have improved food and nutrition security in rural Africa. Second, we critically review the studies from a feminist economic perspective to identify how agroecology was framed in the studies reviewed and how they address the socio-economic context into which the agroecological practices take place in their analysis. We address these two questions by presenting a systematic literature review of studies conducted in sub-Saharan Africa on the link between agroecology and nutrition from 1996 to 2020. Our analysis thus uncovers which pathways of causalities between agroecology and FNS have been investigated in literature, and which pathways have not.

Our review shows that research and evidence depicting pathways through which agroecology fosters FNS are sparser than expected. Research efforts focused on investigating how agroecological production practices channeled important foods into household diets. The review shows in a second step that social and power structures around the introduction of agroecological practices at the level of households and territories are not well documented. These results are compared to evidence elsewhere in the world showing that agroecological agronomic innovations are often linked with components of the social system, such as nutritional well-being and the economic and social empowerment of the practicing persons. Finally, we propose a conceptual framework that integrates the concept of reproduction proposed by feminist economics in the analysis of pathways toward food and nutrition security as a guide for the development of relevant indicators.

Competitions among actors in a food system can institutionalize hegemonic structures that contribute to food insecurity (Khadse and Rosset, 2017). In capitalist competitions, economic and material capabilities of actors within the food system determine the winners and losers in production and market decisions (Kapstein, 2000).

2. Theoretical background: Feminist economics perspective

While hunger and food insecurity might be blind to identity, vulnerability to hunger and food insecurity varies considerably across demography (Kabeer et al., 2008). Feminist economics is of the opinion that economics does not take women's experiences into account in economic affairs as gender roles are hardly represented in the economy (Janina and Pürckhauer, 2016). While gender is the focal point of feminist economics perspectives, it is also embedded in a broader understanding of inequality of - class, race, ethnicity, power, food security, etc. Therefore, the feminist economics perspective draws our attention to forms of work that are essential in our daily life, much of which we take for granted when we place emphasis only on commercialization and competition. Feminist economics raises the "ethics" questions of why housework and care are not recognized as work in economics? Why there should be a difference in value between productive (paid) work and reproductive (unpaid) work? According to Janina and Pürckhauer (2016), such dichotomy invariably affects scientific findings.

2.1. The concept of reproduction in food security framework

Studies, especially in Europe and Latin America, have documented the social and political dimensions associated with Agroecology (Fanzo, 2015; Thompson, 2015; De Schutter, 2019). The reproduction process that engenders and sustains these sociopolitical dimensions influences household agency for food security and nutrition (Burchi and De Muro, 2012). In this section, we review the different framings of reproduction and agency in literature, and how they contribute to The different pillars of food and nutrition security. Thus, we look at agency for FSN, not as a different (fifth) pillar of food security as proposed by the HLPE, but as an outcome of social reproductive process that influences or boosts the availability, access, utilization, and stability of food.

According to Menon (2015), reproductive activities consist of unpaid work such as subsistence activities (evident especially in developing nations) which do not earn or only earn less in the market. Within the food system context, it is linked to the different activities that lead up to the conversion of crops and wages from farms into useable goods in the home, as well as different activities that support this conversion(Menon, 2015). Age-long classical political economy literature by Lefebvre (1973)presented reproduction as an ongoing iteration process of production by which a unit (family, society, system, etc.) simultaneously: i) puts back consumed material goods, ii) replaces the depreciated stock of production capital, and finally iii) recreates or reinforces the relations of production through the perpetuation of experience into the present. These three ongoing iteration processes give rise to the economic and social reproduction processes as described in Paltasingh and Lingam (2014).

2.1.1. Physical reproduction

According to Paltasingh and Lingam (2014), economic reproduction represents a cyclical or recurrent process of maintaining the production base. Aglietta (2015) on the other hand described economic reproduction as the process whereby societies or families constantly recreate the initial conditions essential for economic activity to take place. In Agriculture, economic reproduction in terms of reproduction of physical environment, most especially the soil, is important for continuous production. The process whereby the initial condition of the soil, which

forms the foundation of agriculture, is recycled or at least maintained forms the basis for sustained economic production in agriculture (White et al., 2012). This means that the effectiveness of farm production economics, to an extent, depends on the efficiency of the reproduction in landscape.

2.1.2. Social and household reproduction

Social reproduction, on the other hand, is conceptualized as the "perpetuation and re-creation of the main production system with relation to society taken on the whole" (Paltasingh and Lingam, 2014, p.51). Social reproduction, while subsuming power and social relations, also involves the daily maintenance of the labor force and investment of time, effort, and resources in human capital (Paltasingh and Lingam, 2014). In the classical Marxist feminism's conceptualization, social reproduction describes the unrecognized gender role of women within the broader social structures and the capitalist market economy through their activities within the households, in terms of childbearing and care (Marx, 1992). According to Silvius (2019), the extent to which this form of social reproduction (household reproduction) contributes to household income and overall wellbeing has been constantly undervalued and understudied, especially in accounting for food security and nutrition status. Wesley (2021) argued that households that see wealth beyond financial capital and include human, social, and cultural capital successfully ensure food stability over time and across generations by building on the non-food inputs in food security. Although these households do not trivialize the value of strong financial capital, they understand that wealth has to be reproduced or replenished for it to be sustained (Wesley, 2021). In other words, they put more emphasis on reproduction activities such as household education, diet, clean water, sanitation, health care, etc. that sustain the factors of production, and reproduce/sustain the financial capital of the household.

2.2. Reproduction and agency

At the societal level, Gore and LeBaron (2019) argued that food inequalities, labor exploitation, usurious debt bondage or indebtedness, modern slavery, etc., that exists within any food system or value chain are not random occurring problems but are designed and reproduced by the power of larger agribusiness firms to dictate the rules of business. Gore and LeBaron (2019) applied this conception of reproduction to analyze the gendered relation of *unfree labor* in cocoa value chain in Ghana. According to Harrod (2006), it is the differences between power holders and subjects of power, combined with differences in degrees of power and authority held that perpetuate or recycle different power and social relations. The loser (subjects of power) find it difficult to exit labor arrangements dictated by power holders thereby supplying "involuntary labor" as a condition to remain employed (Gore and LeBaron, 2019: p.575). Such social power relations have been defined by Fiske and Berdahl (2007) as the disproportionateness between two actors in their comparative ability to exercise power for resource acquisition or to define their desired food system.

Sen (2005) frames agency for food security as a set of empowerment indicators or conditions that enables smallholder farmers to exercise control over the prevailing socially reproduced status quo of their food environment. Thompson (2015), on the other hand, characterizes agency for food security into two dimensions namely: economic agency and non-economic or political agency. The author defined economic agency of rural households as their ability to take charge or exercise control over their livelihood independent of external economic agents. Such agency emanates from having relational access to assets, livelihood diversification, exercising control over income, and control over production decisions. The non-economic agency, on the other hand, includes all forms of capability developed through the expression of one's view which ultimately leads to influencing power relations, existing state of affairs, and inputs in social decision making. According to Thompson (2015; p.343) to a very large extent, "it is the non-economic agency that is most crucial for food availability and access … since it determines capability – what we can and cannot do", and it is strongly tied to longstanding literature on ethics and political economy (Sen, 2001). Sen (1992) argued that entitlements alone are insufficient in addressing food security issues but should encompass capabilities developed through organizations and networks channeled towards exerting pressure on the social reproduction process and struggle for power in society.

3. Methodology

Following Nandi, Nedumaran and Ravula (2021) we applied a systematic review methodology to assess the role of agroecology in achieving food security and dietary diversity among smallholder farmers in sub-Sahara Africa. We employed two diverse search approaches to ensure that we retrieved the highest number of potentially relevant studies (Ahmad et al., 2020). The two search strategies include the automated search strategy from Electronic Data Sources (EDS) and Snowballing Method. We thoroughly performed a search on two EDS, namely, Scopus, and Web of Science. Scopus and Web of Science were used as starting points because journals in these databases are stricter in the peer review process as they seek to publish high standard research papers. As 'agroecology' can be conceptualized in various ways — encompassing sustainable farming system, empowerment, freedom, right to food, and food sovereignty, we developed different search strings to capture the fullness of,the topic. In total, we used 18 keyword combinations including food security, dietary diversity, empower*, food*, agency, reproduc*, right to food* and agroecology. We integrated the search terms and adapted them to the individual EDS using the "AND" and "OR" logical expressions where possible. We performed different search rounds for the different EDS until we achieved the best keyword combinations. We based the best keyword combination on the search that returned the precise and appropriate articles relevant to the topic. A set of final selected search string combinations employed for the two EDS is presented in Supplementary materials. The automated search strategy from the electronic data sources was conducted on 07/01/2021 and successfully retrieved 2,359 results only. 1338 studies were retrieved from SCOPUS and 1021 were retrieved from Web of science. After our search of the different databases, we de-duplicated the identified articles using the offline SRA-de-duplicator (Rathbone et al., 2015) to ensure that we retained unique articles. After deduplication, we were left with 1338 unique citations. Once imported into the EndNote software, we employed inclusion and exclusion citation screening using predefined criteria as presented in Table 1. 15 papers focusing on the agroecological approach to food and nutrition security analysis were retained.

In addition to the automated EDS approach, we also performed a snowballing search. Here the 15 empirical studies retained from the automated EDS search were used as primary seeds or the start set of papers. We first performed a backward snowballing by looking at the reference list of the start papers and then followed by a forward snowballing by looking at the papers citing the study being examined. To guarantee relevance, we applied the same inclusion and exclusion criteria used in the automated EDS search. After the first backward and forward snowballing, new papers identified in the first iteration were included in the next iteration stage. We ended the process after the third iteration as no new primary papers were found at this stage. During the snowballing search, grey literature emanating from the stipulated search strings was also included. According to Booth et al. (2016: p.120) not including grey literature in systematic reviews might lead to "exaggerated estimates of effectiveness" and publication bias. Finally, from the snowballing process, we retrieved 332 papers. After applying the inclusion and exclusion criteria, 11 papers focusing on the subject of investigation were retained. In total, 26 papers (15 from automated EDS and 11 from snowballing search) were retained. In summary, only empirical literature, written in English and focusing on agroecology and

Table 1
Exclusion/inclusion criteria for selecting documents.

	Inclusion	Exclusion
Focal area	Agroecology, Agency, and Food sovereignty/security Literature-based in Africa	Non-Food security-related projects High-income countries
Language	English	Language other than English
Year	1996–2020	1996 and earlier
Keywords	Agroecology and food security will be included either in the abstract, keywords, or title	Agroecology and food security not in the abstract, keywords, or title.
Alternative keywords	Sustainable food system, Alternative food system, food sovereignty	–
Methodology	empirically grounded research	Not showing a clear research methodology and based on conceptual work
Type of article	both published and grey empirical literature were included	

Note: In summary, articles published in English and conducted in Africa were purposively chosen. Also, Literature retained were those published after the year 1996, as that was when alternative concepts to neoliberal policies such as food sovereignty, was advanced by Via Campesina and brought to the public debate at the 1996 world food summit.

food and nutrition security among smallholder farmers in sub-Saharan Africa were included. Peer-reviewed publications and grey literature that do not fall within this scope were excluded. The retained studies were selected for further review. The diagrammatic representation of the algorithm employed is presented in Fig. 1. It is important to indicate the potential limitation that might arise from excluding literature in other languages other than English.

Following Porter et al. (2014) we graded the selected articles from zero to five to differentiate empirically robust (high-quality publications) among those using less rigorous methodology. Five-star papers had clearly executed methodology that answers the research questions relevant to our study, and also had a large sample size; covering 200 subjects for surveys or 30 participants for in-depth interviews. Nineteen papers (0.01% of the initial search) had three stars and above. We assigned an identifier number 1 to 19 to each article, which, henceforth, we now use to refer to each paper individually. A list of all the 19 papers is found in supplementary material.

4. Result

In this section, we report the review findings. Our review provides evidence on the pathways from agroecology to FNS. We define these pathways as physical and social reproduction pathways. The physical reproduction pathways are framed as innovative or sustainable production practices through which agroecology farmers enhance their food security and nutrition status. We classify the physical reproduction pathway into three sub-pathways based on the nature of benefits derived from the innovative farming practice employed by agroecology farmers. The physical reproduction pathways include input reduction, production diversification, and climate resilience. Although we present the reproduction pathways separately, in reality, they are interdependent, integrating into diverse ways to improve smallholder farmers' production efficiency. While the physical reproduction pathways occur at the farm or field level, they are linked to social reproduction activities that take place beyond the landscape. These social reproduction pathways encompass activities that define social relations within the household and society at large. Results of the review showed that assessed literature linking agroecology to FSN in Africa focused mainly on the physical reproduction pathways through which agroecology farmers achieve food security and nutrition. Out of the 19 papers reviewed, only four highlighted the social reproduction pathways, which we indicated as "*Social reproduction*". A summary of the different pathways can be found in the supplementary material.

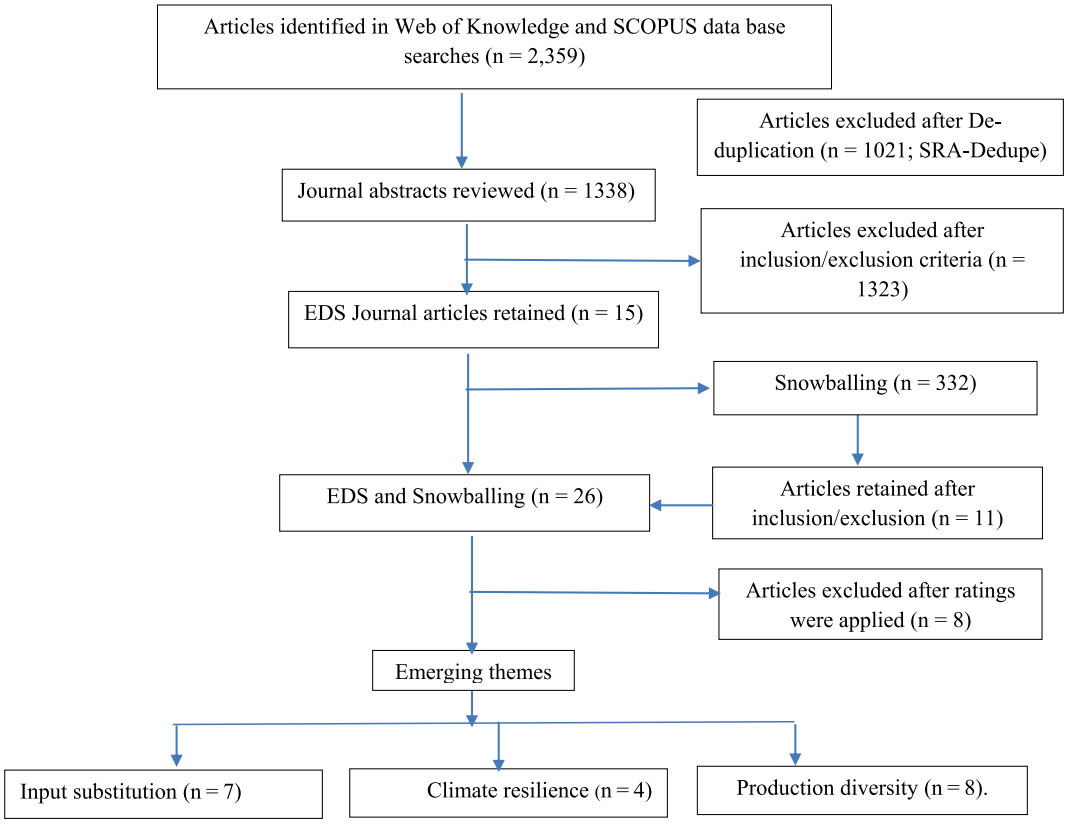

Fig. 1. Database search algorithm applied in citation screening.

4.1. Physical reproduction pathway

Physical reproduction in the landscape includes the innovative farming practices adopted by agroecology farmers to reduce the use of external inputs, conserve biodiversity, and build resilience to climate change. Our review identified seven papers on resource use efficiency, four on climate resilience, and eight on biodiversity conservation.

4.2. Resource use efficiency (Reduction in use of external input)

Literature on agroecology over the last two decades has provided substantial evidence on how agroecology farmers achieve efficiency and sustainable harvest without reliance on external inputs (Akpoti et al., 2021; Kassie et al., 2009, 2020; Kissoly et al., 2020; Ng'endo et al., 2015; Nyantakyi-Frimpong et al., 2016; Rogé et al., 2017). While some farmers gradually reduce the use of external inputs, others eliminate dependency on purchased inputs. The papers suggest that substituting or complete elimination of external inputs drives innovations and engenders better ways of producing appropriate and more nutritious foods. Most of the farmers were found to engage in organic farming, by reducing or eliminating the use of chemical fertilizers (Akpoti et al., 2021; Ng'endo et al., 2015). Some preserve and exchange seeds instead of depending on GMOs (Bezner Kerr, Kangmennaang, et al., 2019). To control pest infestations, agroecology farmers in Kenya, for instance, employ the use of Push-pull agricultural pest management which involves the planting of leguminous genus Desmodium that produces scents that repel common crop pests in the region (Kassie et al., 2020). In Burkina Faso, study by Akpoti et al. (2021) showed that farmers that adopted the agroecological approach of alternate wetting and drying techniques were able to save limited water and still achieved self-sufficiency in food production. The input reduction, therefore, appeared to be a strategy for reducing production cost as four of the assessed literature point to the fact that peasant farmers who engaged in this replacement strategy and reduction in input use, though they do not produce in large amounts, make more profits thereby achieving better food security and nutrition status (Kassie et al., 2009; Kissoly et al., 2020; Nyantakyi-Frimpong et al., 2016; Rogé et al., 2017). Study by Kassie et al. (2009) compared farmers that rely on recycling farm resources to those that rely on non-renewable resources in Ethiopia. The study particularly focuses on reduced tillage and chemical fertilizer use. Results of the study "revealed a clear superiority of reduced tillage over chemical fertilizers in enhancing crop productivity among small-scale farmers "(p.1).

4.2.1. Climate resilience

It is expected that climate change will strongly affect food security and nutrition in African as many nations in Sub-Sahara Africa rely on rain-fed agriculture, with little or no access to efficient market system. Empirical studies showed that agroecology farmers engage in climate-resilient crops and livestock (Bezner Kerr et al., 2018; Boillat and Bottazzi, 2020; Debray et al., 2019; Zazu and Manderson, 2020) production strategies that enable them to recover and maintain functioning in the time of adverse climate events. Studies such as Bezner Kerr et al. (2018) observed a strong correlation between the number of climate-proof practices adopted by farmers and the level of food security they experience. As earlier stated, the challenges of malnutrition in sub-Saharan Africa are associated with problems of environmental degradation heightened by climate change (FAO, 2019). Farming practices that will enhance the adaptive capacity of smallholder farmers will therefore enable them to overcome environmental shocks. As observed by Bezner Kerr et al. (2019) single climate-resilient practices are usually not enough, therefore, many agroecology farmers use a combination of multiple practices to build overall farming system resilience and ensure availability. Study by Ng'endo et al. (2015) showed that agroecology farmers employed diverse climate-smart agricultural practices such as green manure; organic farming and agroforestry in Malawi which helped build resilience among women agroecology farmers in the area.

4.2.2. Production diversity and biodiversity conservation

Through recycling of soil organic matter, and other soil conservation techniques, agroecology farmers maintain stability in food production by securing soil health in the long run. Through minimum or zero soil disturbances and bush fallowing, agroecology farmers retain perpetual soil cover which contributes to improved water and nutrient use (Moses Mosonsieyiri Kansanga et al., 2020). Agroecology farmers also engage in other farming practices including mixed farming, crop rotation, and mixed cropping which were found to have a positive and significant effect on the dietary diversity of households (Moses Mosonsieyiri Kansanga et al., 2020; Kassie et al., 2020). Through the optimization of the diversity of crop and animal species, agroecology farmers ensure food and nutrition security while preserving natural resources (Ng'endo et al., 2015). According to Wielgosz et al. (2014) effect of biodiversity conservation was also found to affect soil fertility levels. For instance, in Kenya and Tanzania, traditional mixed agroforestry farms were reported by (Moses Mosonsieyiri Kansanga et al., 2020) to improve soil nutrient levels that lead to improved productivity. Nyantakyi-Frimpong et al. (2016) also reported that agroecology farmers experience "higher yields, greater food security, and dietary diversity as a result of legume intercropping" (Nyantakyi-Frimpong et al., 2016: p.97).

4.3. Social reproduction pathway

The social reproduction pathways point to the social relations developed by agroecology farmers, within the household and the society at large. It deals with the improvement in food and nutrition security status as a result of social capital built through networks that facilitate knowledge sharing among farmers and access to productive resources. It also includes women empowerment goals that transform the social relations within the households, influencing how household food decisions are made, thereby impacting how food utilization within the household. Only four of the reviewed studies (Bezner Kerr, Kangmennaang, et al., 2019; Nyantakyi-Frimpong et al., 2017; Wielgosz et al., 2014) emphasized the social reproduction associated with agroecology which is currently evident in agroecological movements in Latin America such as Cuba and Brazil, however, still emerging in Africa.

Through peer-to-peer activities and movements, agroecology farmers engage in the co-creation of knowledge and indigenous knowledge dissimilation(Moses Mosonsieyiri Kansanga et al., 2020). The conventional ways of Agri-technology dissemination hardly benefit a large majority of the smallholder farmers due to high farmer-to-extension workers ratio in the developing nations, and neither are small-scale farmers capable of paying for independent advisory services. Agroecology farmers, therefore, leverage their social capital to build knowledge networks to enhance their farming practices (Emeana et al., 2018). Not only that these farming practices productive, but the social process involved is also critical as it is embedded in cultural and indigenous multidirectional and transgenerational process of knowledge transfer (Bezner Kerr et al., 2019a,b). Such process is fundamental to the idea of right to food, and its variations. Findings from Rogé et al. (2017) showed that the agroecology movement to protect indigenous people's right to feed themselves with dignity shields local farm households from corporate food regimes and vagaries of market that undermine the agency for self-sufficiency, which is essential for the temporal dimension of FSN. Also, agroecology farmers develop local agroecology markets (Kansanga et al., 2020).

The social structures underlying these markets help to preserve and perpetuate sustainable traditional, indigenous, and ecological practices required for transgenerational continuance of practices that brings about meaningful, economically adequate, and dignified food security in line with the customs of the people (Kansanga et al., 2020). Also, through agroecology, most women farmers come together to form women groups and movements that amplify their voices(Bezner Kerr, Hickey, et al., 2019). Outside Africa, in India for instance, the self-help group in Uttar Pradesh and the Tamil Nadu Women's Collective paints

the picture of how women who were oppressed as a result of their castes and landless status, engage in collective farming, employing indigenous traditional practices, thereby achieving independence and food security (Kangmennaang et al., 2017).

5. discussion

Our review has provided evidence for links between agroecology to food and nutrition security. Chronologically, in 2003 when scholars began to research this link, they focused on the perspectives of agricultural production and ecology. Few recent studies since 2015 have extended the scope of research to other pathways of causalities between agroecology and food and nutrition security, including that of social reproduction. To discuss the findings from the feminist economic perspective, we have incorporated the concepts of social and physical reproduction into an existing framework for understanding the link between agroecology and nutrition. Fig. 2 is a modified version of the research framework presented by the High-Level Panel of Experts (2019) for innovative approaches to achieving FSN. We introduce the concepts of physical and social reproduction operationalized at the scale of farming households by basic principles (e.g. resource cycling, social equity, household care) guiding decisions and enacted by practices (at the bottom of the figure, e.g. organization of farmers, zero tillage, permaculture). Through the enhancement of their physical and social reproduction, the farming households shape their economic and non-economic agency in general and in relation to food and nutrition security in particular. This agency directly facilitates both the production (availability and stability) and non-production (access and utilization) components of food security and nutrition.

Agroecological practices encompass sustainable farming methods such as organic agriculture, permaculture, and agroforestry. These are what Dalgaard et al. (2003); Nicholls and Altieri (2018); and Silici (2014) termed field-level agroecology. Reviewed literature shows that such agroecological farm practices ensure food availability by reducing the cost of production, overcoming climate impact, and ensuring food stability through agrobiodiversity conservation. Our review shows that research on agroecology at the field level in Africa is well developed. This is not surprising as most of the field-level agroecological practices are semblances of traditional farming practices associated with small-scale farming in rural areas of Africa. However, there appears to be a connection between the farming practices as part of a farming socio-ecological system where practices cannot be implemented independently from other social and economic dynamics at the farm and higher levels. Although the field level is of course straightforward and intuitive. Yet, it is also rooted in a perspective of farming as a technique of production, where problems – here environmental or nutrition problems can be addressed with technical improvements or innovations. As opposed, we understand farms as socio-ecological systems, in which

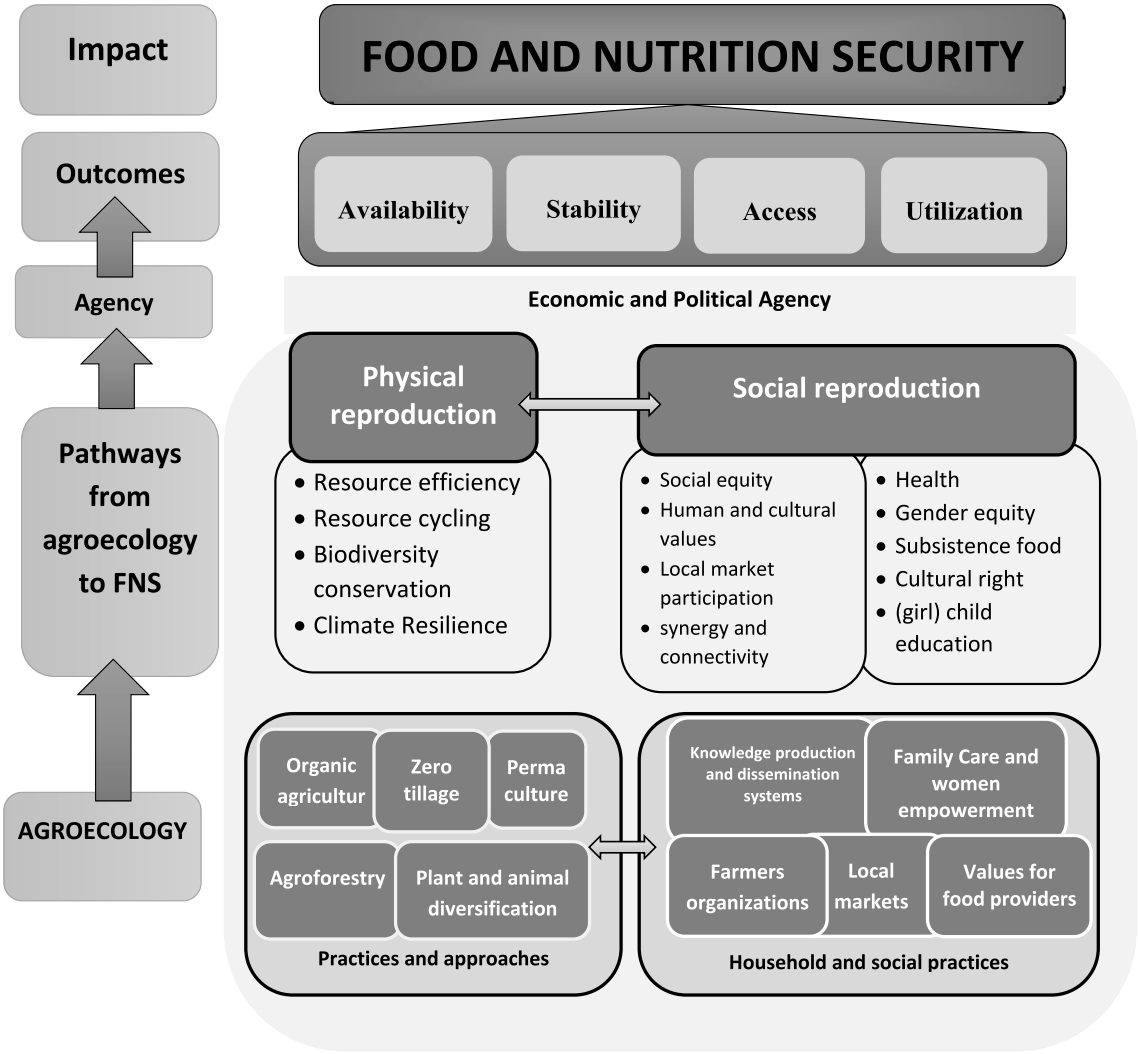

Fig. 2. Framework for understanding pathways from innovative agroecology to FNS at the household level.
Source: modified from HLPE (2019).

practices on a farm are also subject to and affect the social and economic elements of the household and higher-level system.

This perspective provides a background to understand the statement of Olivier de Schutter, the United Nations' former Special Rapporteur for Food, that without the social and political dimensions, agroecology is mere cooptation, lacking the full principles of agroecology (De Schutter, 2019). The following section develops evidence and arguments for the social reproduction pathway of causality.

According to Nandi et al. (2021) household decisions on food purchase, production and consumption are complex and connected. "The farm household decision to produce their food on-farm or purchase from the markets has important implications for their access to food, and they pose great complexity in assessing household nutrition" (Nandi et al., 2021, p.2). Majority of farm households in Africa are characterized by small-scale subsistence farming. Bezner Kerr, Young, et al.(2019) found in their analysis in Malawi that agroecology farmers who decide to produce what they want to consume experience higher levels of food security and dietary diversity. Substantial evidence from smallholder farm households in low-income societies in Latin America such as Cuba and Bolivia suggests that agroecology and non-agroecology farmer differ in their patterns and preferences for resource allocation for food and cash crops. Agroecology farming households tend to have a more significant concern for food availability at the household level, which trickles across to family members in terms of food availability (CGIAR, 2020).

Because small-scale farmers cultivate on a very little land, they cannot effectively compete with big agribusinesses in terms of access to productive resources and markets. Thus, we observe that agroecology farmers organize alternative market systems (O'Kane and Wijaya, 2015). Agroecology markets emerged as a territory less influenced by political-economic and market factors, as they are more concerned with food crop marketing rather than cash crops. Findings by (Matita et al., 2021): p.8) in rural Malawi suggest that "agroecology households that engage more with food markets are more likely to have more diversified diets". Although agroecological markets are constrained by the fact that most consumers in the developing nations lack the awareness of the agro-ecological quality of food, the development of farmers' markets and sales through networking has proved to be a very progressive way of linking agroecology farmers and consumers (Courtois and Subervie, 2014; De Schutter, 2010). A typical example is in Kenya where the farmers' market serves as a public and recurring assembly where local farmers exchange produce and also sell products directly to consumers because the consumers value the ecological efforts put towards producing the foods (Fischer and Qaim, 2012). The market is less rigidly regulated; hence the farmers decide their prices and also avoid warehousing, distributors & retailers, and international quality standards.

Outside the farmers' market, agroecology farmers are also involved in network sales (tapping into their peasant group networks to find willing buyers through referrals) and exchanging their produce with fellow agroecology farmers. Most times, agroecology farmers recommend the products of their fellow farmers to consumers who buy at the farm gate (Bezner Kerr et al., 2018). By creating alternative agroecological markets, farmers are enabled to access not just market opportunities but also relational and structural access to inputs that are driven by demand for agroecology produce.

Thus, farmers who adopt agroecology seem to adhere to more than a set of practices but rather to group-sharing practices and further informal institutions. In France, Latin America, and Nigeria (own observation) agroecology farmers' groups develop knowledge, and technologies, share resources (land, seeds) and create markets, which all contribute to maintaining the farmers in the socio-ecological landscape of producers in their countries. Agroecology appears thus as a vehicle of social reproduction. How agroecological practices in particular, as compared to other environmentally friendly innovations such as climate-smart agriculture, achieve this in Africa, is a very exciting path for research.

From a socioecological perspective, Ajao et al. (2010) assessed the impact of reproductive activities such as family management and childcare practices on the food and nutritional status of rural households Ile ife, Nigeria. They found that children with less childcare were significantly more likely to be stunted and food insecure. Reproductive activities such as childcare and family management have also been shown to reduce diseases and health challenges in households in China (Li et al., 2009), thereby freeing up man-hours that can be relocated to more quantity and quality food production. Agroecology farmers prioritize the traditional family caregiving by performing the essential roles of achieving household food and nutrition through selection, production, preparation, and ensuring that food is available for all family members.

Given that women constitute the majority of smallholder farmers in the developing nations, efforts in "de-marginalization" and empowering women farmers in making decisions that directly affect their lives, which is foundational in emerging agroecology movements, can be fundamental to eradicating hunger and food insecurity. Most of the agroecology movements in Asia and Latin America show that agroecology farmers are mostly comprised of women (Nicholls and Altieri, 2018; Vorgelegt et al., 2016). The practice of agroecology seems to empower women in the household to dedicate more resources to reproductive activities in wider sense - in other words, to maintain the household by constructing a healthy (adequate diet, care, and sanitation) home. How agroecology leads to such empowerment and a greater focus of farmers on household reproduction at the level of the household is not yet researched in southern Africa and is not clearly understood in general.

6. Conclusions

How is research on agroecology related to food and nutrition security is framed in research taking place in Africa? The paper opts for a feminist economics perspective to address this question for two reasons. First, food and nutrition are still among the few economic activities in Africa that largely take place within the household economy and not in the global economy. Second, marginalized actors (rural women) are often the main actors in rural food security. Feminist economics, with its consideration of both production and reproduction dynamics, appeared ideal to complement and rethink existing views on the causalities leading to food and nutrition security.

By employing a systematic literature review of empirical studies located in African countries, published between 1996 and 2020, we consolidate evidence on agroecology as a vector for an efficient production model for small-scale farming units. The results of our review show that the nexus between agroecology and FSN has been framed mainly from an agronomic perspective. On the contrary, impact of the adoption of agroecology practices on the household economy and their social reproduction is seldom investigated, despite being heavily documented in other parts of the world.

In our discussion, we modify the conceptual framework from high-level panel of experts in food and nutrition security (2019) to show how reproduction activities relate to FNS and highlight how research on Africa has until now failed to embrace agroecology in its social and political context. We then discuss reproduction dynamics as another essential pathway for analyzing the link between agroecology and FNS. We argue that the foundational (related) concepts of social reproduction and agency for food security and nutrition may provide a better lens to unpack the agroecology-FNS nexus than the agronomic technical perspective or the neoclassical eternal attempts to solve hunger among the (cash) poor through market mechanisms (e.g. integration). We call upon research to strengthen the analysis of agroecology as an innovation in a socio-ecological system rooted in a political ecology context. Further, in addition to documenting ecological sustainability, indicators to measure the effect of agroecology or any agricultural innovation at the household level, and especially on FNS, should be developed to capture the ability of the household to reproduce its members and to

reproduce itself in its social and political context.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Acknowledgements

Chukwuma Ume was supported by the German Academic Exchange Service

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.indic.2022.100212.

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SUPPLEMENTARY MATERIALS

Appendix A. Methodology for Choosing Empirical Studies

We employed two sets of search strings to obtain publications from the Web of Science data base and SCOPUS. As agroecology and food security can be conceptualized in a variety of ways, not just 'sustainable farming', there was a need to capture the entirety of the concept, and to understand agency for food security in various ways it is presented in literature, we used different keyword variations.

Table A1: Set of search strings, adapted to each of the EDS.

EDS	Search strings
Web of Science (WoS)	TI = ("Agroecology" OR "agro-ecology" OR "food sovereignty" OR "right to food" OR "agency" OR "empowerment" OR "capability" OR "sustainable agriculture" OR "sustainable farm*") AND TS = (nutrition OR hunger OR food secur* OR access OR "food avail* OR reproduc*" OR diet OR dietary divers* OR sustainable food system) and language: (English) refined by: web of science categories: (Agricultural Economics & Policy)
Scopus	TITLE (Agroecology OR agro-ecology OR food sovereignty OR right to food OR agency OR sustainable agriculture OR sustainable farm*) and TITLE-ABS-KEY (nutrition OR hunger OR food secur* OR access OR "food avail" OR diet OR dietary divers* OR sustainable food system OR reproduc*) AND (Limit-to (subjarea, "AGB")) AND (limit-to (LANG, "English"))

TI=Title. TS=Topic. WoS=Web of Science. AGB = Agricultural and Biological Science

Appendix B. Criteria for Ranking

Table B1: description of criteria for ranking selected articles

Star Rating	Assessment	Example
5*	- Survey covered a large amount of sample, with Questionnaires of 200 participants or more. For indepth interviews, up to 50 participants or more. The method employed aligns with the study at hand and the method was clearly executed and well justified. In addition, multiple methods used to ensure triangulation. - Choice of site was clearly stipulated and justified and findings can be scaled up - The outlook of the study clearly fits into or answered the core research questions to be investigated in this systematic literature review.	(Pretty et al., 2003)
4*	- Survey covered a large amount of sample, but with sample of less than 200 participants. For indepth interviews, less than 50 participants. The method employed aligns with the study at hand and the method was clearly executed and well justified. No clear indication of triangulation of findings. - Choice of site was clearly stipulated but not very well justified and findings can be scaled up - The theme covered by the study clearly fits into or answered the core research questions to be investigated.	(Nyandiga & Currea, 2017)
3*	- Survey covered a appropriate amount of sample but less than 200 participants. For indepth interviews, less than 50 participants. The method employed aligns with the study at hand and the method was clearly executed and well justified. No clear indication of triangulation of findings. - Choice of site was clearly stipulated but not very well justified and findings can be scaled up - The theme covered by the study closely fits into or answered the core research questions to be investigated.	(Mutea et al., 2020)

Adapted from Porter, Dessai and Tompkins, 2014

Appendix C. Sample of Article Characteristics scorecard

Table C1: Example of template for Recording Article Characteristics

Ref [1] JP	**[(Pretty et al 2003)]**
Title	**Reducing food poverty by increasing agricultural sustainability in developing countries**
Review rating	5 star.
Pathway covered	Physical reproduction of the landscape
Agency enabling indicator	Economic agency: Assets ownership and control
Overview	We examined the extent to which farmers have improved food production in recent years with low cost, locally available and environmentally sensitive practices and technologies. We analysed by survey during 1999–2000 208 projects in 52 developing countries, in which 8.98 million farmers have adopted these practices and technologies on 28.92 million hectares, representing 3.0% of the 960 million hectares of arable and permanent crops in Africa, Asia and Latin America. We found improvements in food production occurring through one or more of four mechanisms: (i) intensification of a single component of farm system; (ii) addition of a new productive element to a farm system; (iii) better use of water and land, so increasing cropping intensity; (iv) improvements in per hectare yields of staples through introduction of new regenerative elements into farm systems and new locally appropriate crop varieties and animal breeds. The 89 projects with reliable yield data show an average per project increase in per hectare food production of 93%. The weighted average increases across these projects were 37% per farm and 48% per hectare. In the 80 projects with small (<5 ha) farms where cereals were the main staples, the 4.42 million farms on 3.58 million hectares increased household food production by 1.71 t per year. We report on the practices and technologies that have led to these increases: increased water use efficiency, improvements to soil health and fertility, and pest control with minimal or zero-pesticide use. This research reveals promising advances in the adoption of practices and technologies that are likely to be more sustainable, with substantial benefits for the rural poor. With further explicit support, particularly through national policy reforms and better markets, these improvements in food security could spread to much larger numbers of farmers and rural people in the coming decades.
Methods:	**What methodological/empirical criteria does the paper meet?**
	Very large sample with 45 projects in Latin America, 63 in Asia and 100 in Africa, in which 8.98 million farmers. The questionnaires were self-completed, so were subject to potential bias. Triangulation was employed through checks with secondary data, critical review by external reviewers and experts, and interview sessions with selected respondents. The most common country representations in the dataset are India (23 projects/initiatives); Uganda (20); Kenya (17); Tanzania (10); China (8); Philippines (7); Malawi (6); Honduras, Peru, Brazil, Mexico, Burkina Faso and Ethiopia (5) and

	Bangladesh (4). Highest number of farmers comprise of 200,000 farmers in Chile. There is a cross-country analysis for more equitable action. Comparative descriptive analysis and content analysis were employed to compare the changes over time. All these points to the fact that the research project is empirical robust.
Scalability:	**Could the data/findings collected be scaled up?**
	Arguably the largest known survey of sustainable agricultural practices and technologies in developing countries. By taking a cross country analysis the lent themselves better to be scaled both up and down. The improvements were found across many rural and semi-urban areas hence provides evidence for scaling
Question:	**what are the pathways through which agroecology lead to food security and dietary diversity?**
Evidence	Recycling and reproducing the physical environment forms the core element of agroecology. One of the patwayd through which agroecology production improve productivity and enhances food security is by the preferentially use local renewable resources thereby ensuring the recycling of resource, nutrients and biomass. • water use efficiency (e.g: water harvesting, local alternate wetting and drying innovation, and community based water management) • improvements to soil health and fertilitythrough the use of legumes, green manures and cover crops, incorporation of plants with the capacity to release phosphate from the soil into rotations, use of composts and animal manures, adoption of zero-tillage, and use of inorganic fertilisers where needed, • pest control with minimal or zero-pesticide use (Pp. 224 – 226)
Full reference	Pretty, J. N., Morison, J. I. L. and Hine, R. E. (2003) 'Reducing food poverty by increasing agricultural sustainability in developing countries', Agriculture, Ecosystems & Environment, 95(1), pp. 217–234. doi: https://doi.org/10.1016/S0167-8809(02)00087-7.

Table **C2.** Identifiers and details of included literature

Identifier	Paper details
1.	Pretty, J. N., Morison, J. I. L., & Hine, R. E. (2003). Reducing food poverty by increasing agricultural sustainability in developing countries. Agriculture, Ecosystems & Environment, 95(1), 217–234. doi.org/10.1016/S0167-8809(02)00087-7
2.	Kassie, M., Zikhali, P., Pender, J., & Köhlin, G. (2009). Sustainable Agricultural Practices and Agricultural Productivity in Ethiopia: Does Agroecology Matter?. Working Papers In Economics. School of Business, Economics and Law at University of GothenburgRetrieved from https://ideas.repec.org/p/hhs/gunwpe/0406.html
3.	Wielgosz, B., Kato, E., & Ringler, C. (2014). Agroecology, household economics, and malaria in Uganda: Empirical correlations between agricultural and health outcomes. Malaria Journal, 13(1), 1–11. https://doi.org/10.1186/1475-2875-13-251
4.	Mary Ng'endo, Gudrun B. Keding, Shonil Bhagwat & Katja Kehlenbeck (2015) Variability of On-Farm Food Plant Diversity and Its Contribution to Food Security: A Case Study of Smallholder Farming Households in Western Kenya, Agroecology and Sustainable Food Systems, 39:10, 1071-1103, https://doi.org/10.1080/21683565.2015.1073206
5.	Nyantakyi-Frimpong, H., Mambulu, F. N., Bezner Kerr, R., Luginaah, I., & Lupafya, E. (2016). Agroecology and sustainable food systems: Participatory research to improve food security among HIV-affected households in northern Malawi. Social Science and Medicine, 164, 89–99. https://doi.org/10.1016/j.socscimed.2016.07.020
6.	Kangmennaang, J., Kerr, R. B., Lupafya, E., Dakishoni, L., Katundu, M., & Luginaah, I. (2017). Impact of a participatory agroecological development project on household wealth and food security in Malawi. Food Security, 9(3), 561–576. https://doi.org/10.1007/s12571-017-0669-z
7.	Rogé, P. et al. (2017) 'Perennial grain crops in the West Soudanian Savanna of Mali: perspectives from agroecology and gendered spaces', International Journal of Agricultural Sustainability. Taylor & Francis, 15(5), pp. 555–574. doi: 10.1080/14735903.2017.1372850.
8.	Nyantakyi-Frimpong, H., Kangmennaang, J., Bezner Kerr, R., Luginaah, I., Dakishoni, L., Lupafya, E., Katundu, M. (2017). Agroecology and healthy food systems in semi-humid tropical Africa: Participatory research with vulnerable farming households in Malawi. Acta Tropica, 175, 42–49. https://doi.org/https://doi.org/10.1016/j.actatropica.2016.10.022
9.	Bezner Kerr, R., Nyantakyi-Frimpong, H., Dakishoni, L., Lupafya, E., Shumba, L., Luginaah, I., & Snapp, S. S. (2018). Knowledge politics in participatory climate change adaptation research on agroecology in Malawi. Renewable Agriculture and Food Systems, 33(3), 238–251. https://doi.org/10.1017/S1742170518000017

10.	Debray, V., Wezel, A., Lambert-Derkimba, A., Roesch, K., Lieblein, G., & Francis, C. A. (2019). Agroecological practices for climate change adaptation in semiarid and subhumid Africa. Agroecology and Sustainable Food Systems, 43(4), 429–456. https://doi.org/10.1080/21683565.2018.1509166
11.	Bezner Kerr, R., Kangmennaang, J., Dakishoni, L., Nyantakyi-Frimpong, H., Lupafya, E., Shumba, L., Msachi, R., Boateng, G. O., Snapp, S. S., Chitaya, A., Maona, E., Gondwe, T., Nkhonjera, P., & Luginaah, I. (2019). Participatory agroecological research on climate change adaptation improves smallholder farmer household food security and dietary diversity in Malawi. Agriculture, Ecosystems & Environment, 279, 109–121. https://doi.org/https://doi.org/10.1016/j.agee.2019.04.004
12.	Bezner Kerr, R. et al. (2019) 'Repairing rifts or reproducing inequalities? Agroecology, food sovereignty, and gender justice in Malawi', The Journal of Peasant Studies. Routledge, 46(7), pp. 1499–1518. doi: 10.1080/03066150.2018.1547897
13.	Kansanga, M. M. et al. (2020) 'Beyond ecological synergies: examining the impact of participatory agroecology on social capital in smallholder farming communities', International Journal of Sustainable Development & World Ecology. Taylor & Francis, 27(1), pp. 1–14. doi: 10.1080/13504509.2019.1655811.
14.	Zazu, C., & Manderson, A. (2020). Agroecology and Climate Change Adaptation: Farmers' Experiences in the South African Lowveld. In African Handbook of Climate Change Adaptation (pp. 1-16.). https://doi.org/https://doi.org/10.1007/978-3-030-42091-8_181-1#DOI
15.	Boillat, S. and Bottazzi, P. (2020) 'Agroecology as a pathway to resilience justice: peasant movements and collective action in the Niayes coastal region of Senegal', International Journal of Sustainable Development & World Ecology. Taylor & Francis, 27(7), pp. 662–677. doi: 10.1080/13504509.2020.1758972.
16.	Kassie, M. *et al.* (2020) 'Women ' s empowerment boosts the gains in dietary diversity from agricultural technology adoption in rural Kenya', *Food Policy*. Elsevier, (November 2019), p. 101957. doi: 10.1016/j.foodpol.2020.101957.
17.	Kansanga, M. M., Kangmennaang, J., Bezner Kerr, R., Lupafya, E., Dakishoni, L., & Luginaah, I. (2020). Agroecology and household production diversity and dietary diversity: Evidence from a five-year agroecological intervention in rural Malawi. Social Science & Medicine, 113550. https://doi.org/https://doi.org/10.1016/j.socscimed.2020.113550
18.	Kissoly, L., Karki, S., & Grote, U. (2020). Diversity in Farm Production and Household Diets: Comparing Evidence From Smallholders in Kenya and Tanzania. Frontiers In Sustainable Food Systems, 4. doi: 10.3389/fsufs.2020.00077
19.	Akpoti, K., Dossou-Yovo, E., Zwart, S., & Kiepe, P. (2021). The potential for expansion of irrigated rice under alternate wetting and drying in Burkina Faso. Agricultural Water Management, 247, 106758. doi: 10.1016/j.agwat.2021.106758

Table **C3:** *Summary of literature on pathways from agroecology to FNS reviewed*

Author(s), year	Journal/book	Objectives of the Study and study area	Analytical approach	Key findings	Pathways elicited	Contribution to FSN
Pretty et al., (2003)	*Agriculture, Ecosystems & Environment*	Examine the extent to which farmers have improved food production in recent years through agroecological practices in **41 African countries**	Descriptive analysis of 208 projects among 8.98 million farmers and on 28.92 million hectares	Agroecology led to increased water use efficiency, improvements to soil health and fertility, and pest control with minimal or zero pesticide use.	**Input Reduction**	Improvement in soil health ensures stability in production over time. An overall increase in per hectare food production of 93%
Kassie et al (2009)	*Working Papers in Economics*	"Investigate the impact of agroecological practices on crop productivity, with a particular focus on reduced tillage" in **Ethiopia**	plot-level experiments	"Results revealed a clear superiority of reduced tillage over chemical fertilizers in enhancing crop productivity".	**Input reduction**	Increased availability at a reduced investment cost
Wielgosz et al (2014).	*Malaria Journal*	Explores linkages between agricultural management, malaria, and implications for improving community health outcomes in rural **Uganda**	Parametric multivariate Two-Limit Tobit model analysis of Uganda National Household Survey	home care correlates significantly with malaria incidences, nutrition, and consequently health status	**Social reproduction**	Collaboration among smallholder boosts health benefits from good nutrition

Mary et al (2015)	*Agroecology and Sustainable Food*	Do farm plant and livestock diversity affect food and nutrition security in Western **Kenya**	Plot experiment with 30 smallholder farms	Traditional mixed agroforestry farms contribute to food and nutrition security through household high on-farm plant and livestock diversity	**Production diversity**	Production diversity leads to availability and access to diverse foods which is necessary for better nutrition
Nyantakyi-Frimpong et al. (2016)	*Social Science and Medicine*	Whether and how participatory agroecological farming can improve food security and nutrition among HIV-affected households in northern **Malawi.**	Content analysis of in-depth interviews with 27 farmers in HIV-affected households in	Agroecological farming helped HIV-affected households, meet their food, dietary, labor and income needs whilst helping them to manage natural resources sustainably.	**Social reduction**	Exchange of food and non-material goods ensures participating households remain food secured in times of lack. (Networking among HIV patients provide a platform to share production knowledge)
Kangmennaang, et al (2017)	*Food Security*	Compare food security status of agroecology and non-agroecology farm households in **Malawi**	Household Food Insecurity Access Scale (HFIAS) and average treatment-effects using difference in difference methods	participating in agroecology programs led to a significant increase in household wealth ($\beta = 3.54$, $p = 0.01$) and a large reduction in food insecurity ($\beta = -3.21$, $p = 0.01$) through resource use	**Input reduction**	Efficiency in production led to increased production, hence availability of food

				efficiency, compared to non-participants. Farmers share knowledge on better and more efficient production techniques		
Rogé. et al. (2017).	*International Journal of Agricultural Sustainability*	Determine if agroecology practice of Perennial grain cultivation may improve food security and environmental performance in **Mali**.	Content analysis of interviews from 72 farmers across the sorghum-growing region of Mali.	Agroecology perennial grain cultivation led to "reduced labor, saving seed, resource sharing of customary land tenure and improving food security"	**Input reduction**	Households can access food from neighbors in times of need and also have available market to sell
Nyantakyi-Frimpong et al (2017).	*Acta Tropica*	"Can agroecology lead to improved food security and human health among vulnerable smallholder farmers in **semi-humid tropical Africa**?	Ordered logistic regression and average treatment effects models on 571 agroecology-adoption and 429 non-agroecology-adoption households.	Agroecology households reported optimal food security status and health as a result of crop diversification. Agroecology farmers were found to be12% more likely to be food secure (OR = 0.59, p = 0.05)	**Production diversity**	Households were able to produce food they need without depending on market availability
Bezner Kerr, et al. (2018)	*Renewable Agriculture and Food Systems*	Identify effective strategies to help rural communities build resilience to climatic risks in **Malawi.**	Participatory agroecology experiments with 425 farmers	Participatory agroecological approaches increased food security by influencing adaptation strategies used by	**Climate resilience**	Households were able to produce enough for family consumption using

				smallholder farmers. (Innovative production systems that lead to increased food production)		local irrigation and cover cropping
Debray, et al (2019)	*Agroecology and Sustainable Food Systems*	Assess which agroecological practices implemented in sub-Saharan Africa promote resilience and yield in **semiarid and subhumid Africa**	Content analysis of qualitative data	Small scale farmers employ combinations of agroecology practices that promote indirect adaptation by increasing resilience of cropping or livestock systems to climate change. (Organic livestock farming leads to nutrient cycling, a process by which nutrients are returned to the soil)	**Climate resilience**	Reduced cost of input as well ensures availability through increased yield
Bezner Kerr et al. (2019)	*Agriculture, Ecosystems & Environment*	Compare food security of agroecology and non-agroecology farm households in **Malawi**	Longitudinal mixed-effects models and content of analysis conservation	Participatory agroecology experimentation increased intercropping, legume diversification, and overall biodiversity. Reproduction of the soil through nitrogen fixation and green manure	**Production diversity**	Maintenance of soil biodiversity will ensure stability in crop yield

Bezner et al. (2019).	*The Journal of Peasant Studies*	"examines whether agroecology can be effectively used by smallholders to address food security" in **Malawi**	Participatory rural appraisal	Feminist concepts and social reproduction central to mobilizing agroecology to build social relations for food security. Household care ensures that food is channeled to the family and trickles down to every member of the family	**Social reproduction**	Food utilization is ensured as time is spent on cooking and nutritional activities
Kansanga et al. (2020),	*International Journal of Sustainable Development & World Ecology*	"Compare the social capital endowment of agroecology-practicing households (n = 514) and a control group of non-agroecology households (n = 400)" in **Malawi**	Difference-in-Difference (DID) on longitudinal data from a five-year participatory agroecology intervention	agroecology adoption builds Social capital improved livelihood. Households build networks through which they share knowledge and resources	**Social reproduction**	Networks developed by the agroecology farmers give them access to production input as they shared land and farm implements
Zazu & Manderson (2020)	*African Handbook of Climate Change Adaptation*	Assess the effect of agroecology on Climate Change Adaptation among farmers in **South African**	Case Study Evaluation Method	Smallholder farmers adapt to climate change through uptake of agroecology, and correlation between adaptation and food security	**Climate resilience**	Continuous yield leading to stability in the food supply. Climate resilience practices by smallholder farmers led to natural insurance against crop failure

						in the face of climate change
Boillat and Bottazzi 2020)	*International Journal of Sustainable Development & World Ecology*	"Examines the potential of agroecology to improve the adaptive capacity of smallholder farmers in the Niayes coastal region of **Senegal**"	knowledge co-production process with local farmer unions	Union actions promoting agroecology enhanced system thinking that build resilience	**Climate resilience**	Continuous yield leading to stability in food supply. Adaptation practices led to natural insurance against crop failure in the face of climate change
Kassie *et al.* (2020)	*Food Policy*	assess the moderating effect of women's empowerment on the relationship between agroecology practice and women's dietary diversity	Multiple treatment endogenous switching regression framework	Findings showed that individual and household welfare were enhanced through interventions that promote women's empowerment and agroecology technology adoption simultaneously rather than separately	**Input reduction**	Agroecology innovation led to an increase in milk and beef production which ensure availability. Nitrogen-fixing plants help naturally improve soil nutrient without chemical fertilizers

Kansanga, et al (2020)	*Social Science & Medicine*	Examine the impact of agroecology on production diversity and dietary diversity in **Malawi**	Difference-in-Difference and mediation techniques, using data from a five-year agroecological intervention among 514 agroecology-practicing farming households and 400 non-agroecology households.	Production diversity is directly associated with dietary diversity but the relationship is stronger for households practicing agroecology ($\beta = 0.19$, $p < 0.01$) compared to non-agroecology households ($\beta = 0.14$, $p < 0.01$).	**Production diversity**	Access to different food crops led to dietary diversity and consequent nutrition benefits
Kissoly, et al (2020)	*Frontiers in Sustainable Food Systems*	"Compares the influence of farm production diversity on household dietary diversity in rural and peri-urban settings in **Kenya and Tanzania**".	Descriptive and econometric analyses on 1212 households in Kenya and 899 households in Tanzania	results show that farm production diversity has a positive and significant influence on indicators of household dietary diversity. This influence was found to be more pronounced among households in rural areas.	**Production diversity**	Access to different food crops led to dietary diversity and consequent nutrition benefits
Akpoti et al., (2021)	*Agricultural Water Management*	Assess ways of improving irrigated rice farming under agroecology in **Burkina Faso**	Machine learning models (Random Forest and Maximum Entropy) and water balance model	Alternate wetting and drying technology have the potential of saving water, thereby minimizing cost and time	**Input reduction**	Improved rice production led to availability and enough for the farmers to sell. Natural irrigation

	reduced the cost of rice production without adversely affecting the environment

Source: Authors.

Chapter 3: Quantitative Analysis: Pathways of Influence from Agroecology to FSN

Ume C, Nuppenau E-A and Domptail SE (2023) Who profits from agroecology to secure food and nutrition? On access of women to markets and assets. Frontiers in Sustainable Food Systems. 7:1082944. doi: https://doi.org/10.3389/fsufs.2023.1082944

frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 27 July 2023
DOI 10.3389/fsufs.2023.1082944

OPEN ACCESS

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RECEIVED 16 November 2022
ACCEPTED 15 May 2023
PUBLISHED 27 July 2023

CITATION
Ume C, Nuppenau E-A and Domptail SE (2023) Who profits from agroecology to secure food and nutrition? On access of women to markets and assets.
Front. Sustain. Food Syst. 7:1082944.
doi: 10.3389/fsufs.2023.1082944

Who profits from agroecology to secure food and nutrition? On access of women to markets and assets

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In contrast to a large body of literature linking agroecology to food security through sustainable agronomic practices, research on how agroecology enhances smallholder farmers' access to productive resources, yet necessary for food security and nutrition, is sparse in Africa. Literature does not consider the fact that agroecology practices are often adopted *via* entering a group that provides corresponding knowledge, network and possibly markets. We investigate the case of an agroecology group operating parallel to the dominant agri-industrial food system in Southeast Nigeria. We ask: who are the agroecology farmers? Do they improve their food status in comparison to conventional smallholders operating in the commodity oriented agro-industrial system? Who appears to benefit most among agroecology farmers? To provide answers to these questions, we collected data from 334 smallholder farmers (comprising 111 agroecology farmers and 223 non-agroecology farmers) through a stratified cluster sampling process. Descriptive statistics of our data showed that women make up 89% of the agroecology farmers in the group. We found that in both the agroecology and the conventional groups, women farmers had little access to land, even lower ownership of land, little exposure to extension services, and no access to financial credits. Thus, the sample of female farmers we addressed consists of marginal persons who operate at the margins of the capital and input-based networks and agricultural production. In contrast to the expectation of conventional hypotheses, we show that on average, agroecology farmers had lower food insecurity experiences and higher observed dietary diversity scores. Exploring more detail within the agroecology group via a quantile semi-parametric propensity score matching, we further show that women left out of conventional extension services benefit more from being in the agroecology group. Similarly, the increase in food security and nutrition was highest among those farmers who balance self-provisioning and market as food sources compared to strategies pursued mainly by one of these two sources. To these farmers, mostly women, the agroecology group provides alternative to access important resources and knowledge that they ordinarily would not have accessed being in the capitalistic food system, and which enables them to reach their nutrition goals. Our study supports a conceptualization of agroecology as an interdependency between agroecological agronomic practices, reciprocity and autonomy-fostering social innovations.

KEYWORDS

agroecology, food security, agency, sustainability, social reproduction

1. Introduction

Agroecology (AE) has been portrayed as a practice and as a farm-social movement aimed at promoting sustainability, human well-being, and social cohesion among agrarian communities (Wezel and Jauneau, 2011). In contrast to the large body of literature linking agroecology to food security and nutrition through sustainable agronomic practices (Altieri et al., 2012; Kangmennaang et al., 2017; Khadse and Rosset, 2017), research on how agroecology enhances smallholder farmers' access to productive resources necessary for food security and nutrition is sparse in Africa. In this paper, we estimate the effect of agroecology (as a farm-social group) on the food security and nutrition of smallholder farmers. We argue that agroecological agronomic practices, just like any sustainable farming practices, on its own, might not be sufficient in "feeding the world," but that social and political structures matter. They include self-help activities organized in agroecology groups and which are coupled with agroecological practices. These are critical in achieving food security among the rural population who are marginalized from the dominant corporate food system. Our conceptualization of agroecology differs from other work in which sustainable farming practices are the dominant concept. We take a socio-ecological and political science perspective (De Schutter, 2010).

1.1. Agroecology and Food Security and Nutrition (FSN)

In many rural and agrarian communities in developing nations, households depend on farming as their main source of livelihood (Onyenekwe et al., 2023). Also, it is usually the women who are in charge of ensuring that the family is fed (Opata et al., 2020a). They are the major land managers, farmers, and food producers (Okpara et al., 2019), though access to land and titles are largely held by men. Recent studies, therefore, point to the fact that efforts in mainstreaming sustainable farming practices will provide food and nutrition benefits based on institutional change (Kassie et al., 2020). Such efforts need to provide empowerment, especially for women who are often marginalized in terms of lack of access to markets and other production assets. For example, Kassie et al. (2020) investigated how women's empowerment boosts the gains in nutrition from push-and-pull technology adoption among women farmers in rural Kenya. Their result showed that technology adoption and empowerment interventions are more impactful together if, for instance, aspects such as access to land are included in technology diffusion policies. This position suggests that social relations of production and structural transformation need to be taken into cognizance when analyzing the effect of sustainable farm-social movements practicing agroecology. This is necessary because such sustainable farm-social movements provide additional far-reaching social and economic benefits beyond the environmental benefits derived from the adoption of agroecological practices, especially to farmers who might not easily access land.

Several studies attempt to investigate the relationship between agroecology as a sustainable farming method and food security and nutrition looking for causes. However, these studies have produced mixed results, which may be influenced by the definition of agroecology adopted (as a practice or a social innovation) (Wezel et al., 2014; Nyantakyi-Frimpong et al., 2017; Bezner Kerr et al., 2019c; Guzmán Luna et al., 2022; Sintim et al., 2022). For example, a study conducted by Pretty et al. (2003) investigated 200 farm projects comprising 8 million farmers cultivating 28 million ha of land. They concluded that agroecology farming practices have a positive impact on the nutrition and food security of the farmers involved. Conversely, study by Rogé et al. (2017) showed that there was no difference between agroecology and non-agroecology farmers in terms of farm productivity. Mugwanya (2019) on the other hand concluded that there is a danger that agroecology can lock farmers into a poverty trap and non-productive traditional agriculture if social aspects are neglected. In contrast to the large literature linking agroecological practice to food security and nutrition through sustainable production practices (Altieri et al., 2012; Kangmennaang et al., 2017; Khadse and Rosset, 2017) associated with agroecology, research on how agroecology boost economic and political agency for food security and nutrition among smallholder farmers is sparse in Africa (Ume et al., 2022). The majority of literature on agroecology in Africa associates agroecology with agronomic practices at the farm level. A literature review (Ume et al., 2022) found only two studies highlighting the role of agroecology in strengthening the political and social agency of farmers (Nyantakyi-Frimpong et al., 2017; Bezner Kerr et al., 2019a). Specifically, Bezner Kerr et al. (2019a) investigated a 17 years group of smallholder farm households that practice agroecology (as practice and social formation) in northern Malawi and showed that agroecology as a tool in enhancing food security among smallholder farmers. Similarly, Nyantakyi-Frimpong et al. (2017) investigated the role of agroecology in improving food security among vulnerable farming households (households with women living with HIV and AIDS) in Malawi and reported that by forming a participatory agroecology group, these vulnerable women were able to engage in self-help activities which were instrumental in promoting their food and nutrition security status.

1.2. Objectives of the study

Using the case of an agroecology group which was initiated by a team from the Nigerian Agricultural Extension and Research Liaison Services (NAERLS) (Emeana et al., 2018) the study asks: who are the agroecology farmers? Do they improve their food status in comparison to conventional smallholders operating in the market-based agro-industrial system? Who appears to benefit most among agroecology farmers? Is agroecology a trap or a safety net?

This study adds to the current knowledge in three main ways. While the link between agroecology and improved food security and nutrition has been explored empirically as a social innovation, results do not permit to conclude on the benefits of agroecology. Often, agroecological practices have been assessed independently from the social context (often agroecological networks or groups) in which they are implemented (or not) (Ume et al., 2022). In this paper, we adopt the position that agroecological practices are adopted in a group of farmers and are inextricable to this social reality. Thus, their impact must be analyzed within that of the belonging to the agroecology group. We address this complex dimension of agricultural practices in social systems in this paper.

Second, previous studies did not take into account the potential confounding biases arising from the fact that inherent factors, not

related to adopting agroecology (such as the age of the farmer, gender, off-farm activities, and income, etc.) might also influence the food and nutrition security of farmers. A reference group or counterfactual would strengthen the findings (Jalan and Ravallion, 2003). We address these concerns by using the Propensity Score Matching (PSM) technique (Benedetto et al., 2018). The technique works as a quasi-experimental methodology by constructing an artificial control group of identical non-agroecology farmers, hence reducing the confounding biases. In our case, we compare an agroecological farmers group and neighboring conventional farmers as the reference.

Third, little has been done to empirically uncover the nature of the activities of the group that constitute the social group. These activities are important for food security and nutrition if we look at group-level and as well as individual variables. The necessary mechanisms through which the adoption of agroecological practices enhances food security remain unknown. Motivations and actions of being in a participatory agroecology group might lead to improved food security and nutrition only in a certain environment. For instance, agroecological knowledge has to be injected in the food system (Emeana et al., 2018). We claim that these mechanisms may lie precisely in the coupling between agroecological agronomic practices and reciprocity and autonomy-driven social structures.

The paper thus makes a substantial methodological contribution when centering the analysis on agroecology as a complex socio-ecological system constituted of an interdependency of agronomic practices and social reciprocal and co-creation activities by employing a quantile PSM that reflects the variations of impact across different variables of interest (peer-to-peer activities, gain in time use, self-provisioning, and production diversity). This approach shall ensure that we show a within-group effect, even if we do not generalize findings without reference to factors and reasons. We hypothesize that the adoption of agroecology practices is contingent on group formation and that the combination of both leads to higher food and nutrition benefits (as compared to the isolated promotion of agricultural practices). We aim to quantify the food security and nutrition benefits of agroecology as a social farm organization and to investigate how the benefits differ among farmers with varying socioeconomic statuses. Our focus in this study is smallholder farmers, who are often victims of food system marginalization and exclusion (Ume, 2023).

2. Methodology

2.1. Study area and characterization of smallholder farming in Southeast Nigeria

The study area is located in the Okigwe agricultural zone in the Southeastern geopolitical region of Nigeria (Figure 1). This study uses data collected in 2021 from a sample of rural farmers in southeastern Nigeria to assess the impact of agroecology on food security and dietary diversity. The group consists of farmers from villages targeted under the Research Extension Farmer Input Linkage Systems (REFILS), which is a research component of the regional agricultural extension service (Emeana et al., 2018). This program offered training to farmers in the use of agroecological farming practices. In this study, the definition of a smallholder farmer follows from Food and Agriculture Organization of the United Nations (2020).

Over 80% of farmers in Nigeria farm less than five hectares (Mgbenka and Mbah, 2016) and thus can be referred to as smallholder farmers (Food and Agriculture Organization of the United Nations, 2020). Smallholders produce over 98% of the food crops consumed in Nigeria - apart from wheat and contribute to about 99% of the total crop output (Mgbenka and Mbah, 2016). They thus play a dominant role in the agricultural sector of the economy. A typical farming community in Nigeria consists of smallholder farmers producing food (crop and animal), not just for family consumption but for commercial purposes as well. According to Adewumi and Omoresho (2002), it is the development of these farming communities that will, to a large extent, determine the progress of the agricultural sector.

Currently, Nigeria is the highest producer of cassava globally followed by Brazil (FAO, 2018), the highest producer of rice in Africa (FAO, 2019). All cassava and most of the rice are produced by small-scale farmers (Olawepo, 2010). This difference suggests low profitability of rice production for smallholders. Yet, national policies encourage strongly rice production among smallholders: inland rice production and availability are key elements of Nigeria's food security and stability strategies, especially for urban Nigeria. In addition to the lack of profit for state-demanded crops, farmers face environmental pressures. The impact of climate change on food and nutritional security and environmental sustainability is continuously gaining attention across Nigeria. The Southeast region also faces difficulties related to soil erosion and water pollution.

Most farmers engage in the production of food crops such as maize, vegetables, yam, cassava, and also poultry. Farmers also keep a few animals within their homes and around the farms. Fields may be located around the houses, but in most cases, are at distant locations, where farmers have to travel on foot. The National Agricultural Extension and Research Liaison Services (NAERLS) and the Agricultural Development Programme (ADP), through their local extension agents, are the prime source of knowledge and information on farming in the study area. The bulk of farmers consists of "conventional" farmers. Conventional farmers employ so-called conventional farming practices, such as significant external inputs in the form of fertilizers and insecticides, improved seeds and they produce cash crops. Most conventional farmers are members of the FADAMA project, a government project that seeks to increase agricultural productivity and the production of commodities such as rice and maize by supplying external inputs and seeds to the farmers at subsidized prices. In addition, to access markets, government-owned land, and other production assets, farmers must engage in rice production. This specialization in rice production goes hand in hand with the adoption of market-oriented strategies, whereby most of the rice is sold to rice companies, intermediaries, and bulk purchases from the urban areas. This usually takes place at the much large commodity markets.

Recently, several agroecology groups have emerged in the Southeast region. The agroecology farmers organize to share knowledge and resources and have adopted agroecological farming practices. While agroecology farmers remain a minority, in this study we try to understand which smallholders contribute to this recent burgeoning and why. Agroecology became popularized in the region of study in 2016 after an agroecology training was implemented in several villages through the Information Resource Centers (IRCs), under the Research Extension Farmer Input Linkage Systems (REFILS) in Nigeria (Emeana et al., 2018). Smallholder farmers were trained in sustainable and agroecological farming practices. Participation was voluntary and farmers who participated in this training formed an informal agroecology group. The

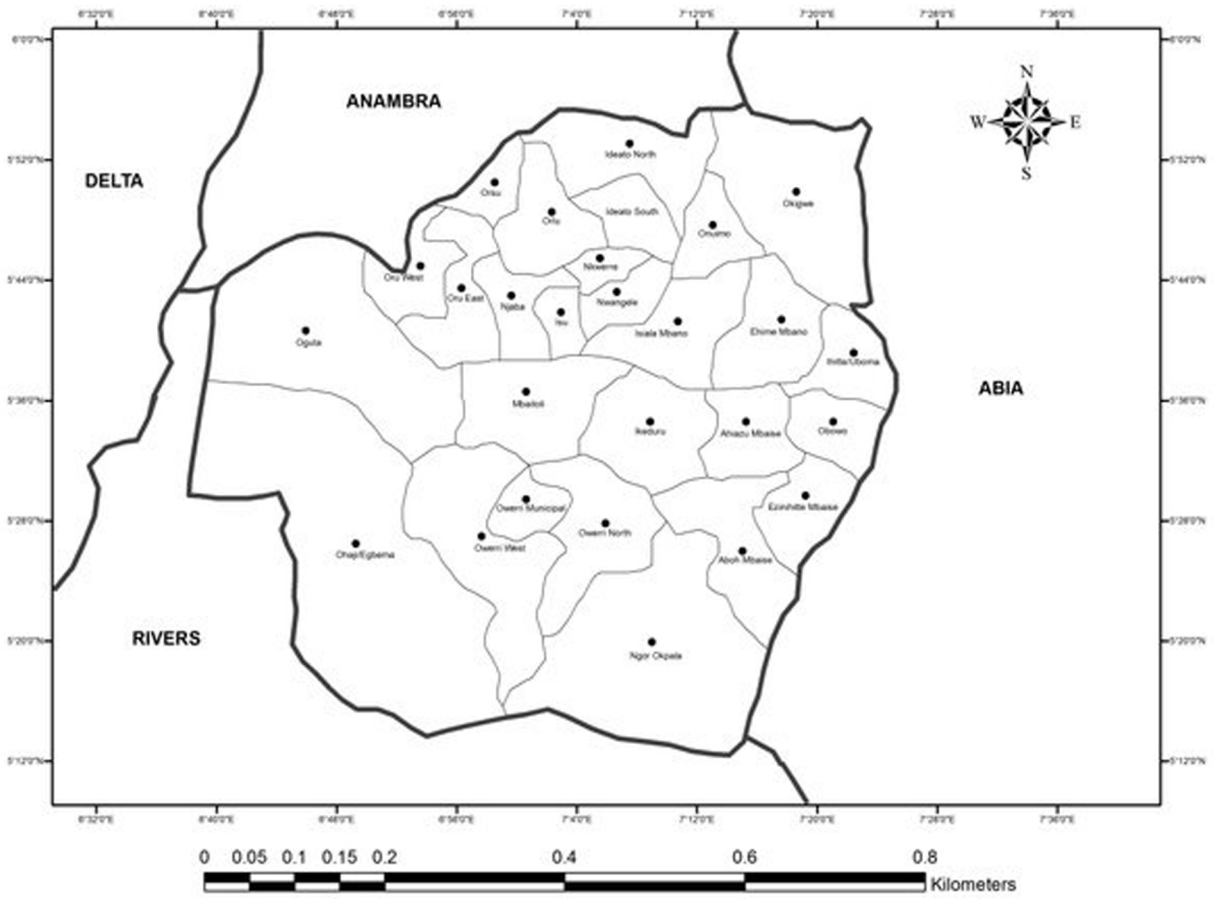

FIGURE 1
Map of the study area Source: (Uluocha et al., 2016).

team established a peer-to-peer network among the participating members (only small-scale farmers) through a registered smartphone application. Through this application and other peer-to-peer meetings and training, a stable group was formed. The group fostered knowledge-sharing and collective activities to produce food more sustainably. Agroecological practices in the group include crop choice for own food, bio-fertilizers, organic fertilization, biological pest control, natural pesticides, seed exchange, and other agroecological techniques and technologies. According to Emeana et al. (2018), the implementation of the agroecology project not only led to the adoption of sustainable farming techniques but also to social and economic changes in the production system. Apart from knowledge sharing, the farmers of the group pool their resources and share land and labor. They also support one another to be able to participate in the local "Ifewa" market (Market name changed for discretion) for consumers where they sell surpluses, and organize an internal crop exchange through a barter trading system.

2.2. Conceptual framework and hypotheses

For this study, agroecology farmers are those farmers who are a member of and identify with the established agroecology group. In other words, the term refers to the group, that is the social organization aimed at promoting a set of sustainable farming practices as well as exchanging knowledge and inputs among one another.

There is no single comprehensive economic theory on the behavior of agroecology households. We embed this research in theories on household reproduction which in our opinion frames best the ecological and social processes we observe in the agroecology group. We define household reproduction activities as investments in activities that ensure that household members are nourished. There are two ways through which the household reproduction goals can be achieved; first, by producing enough food for all household members, or, second, by purchasing this food (Fanzo, 2019). When markets are inefficient - by inefficiency we mean the inability of markets to incorporate social and environmental externalities, it becomes difficult for the agroecology farmers to reproduce or maintain their households by solely depending on productive or market activities that orient towards cash alone. The farmers are therefore constrained to ensure food security by depending on what they produce on their farms. The orientation towards self-provisioning, therefore, presents an alternative food security strategy for farmers who might not be able to benefit from commodity-oriented markets.

Similarly, in most rural households, women are in charge of food provisioning and the overall care of the household (Opata et al., 2020a). Domestic workloads make them time-poor with regard to

production or income-generating activities (Kassie et al., 2020). Ajao et al. (2010) assessed the impact of reproductive activities such as family management and childcare practices on the food and nutritional status of rural households and found that children with less childcare were significantly more likely to be stunted and food insecure. Li et al. (2009) showed that reproductive activities such as childcare and family management reduce diseases and health challenges in households.

Social reproduction is also central for agroecology farmers groups. Social reproduction as defined by Paltasingh and Lingam (2014) consists in "those practices that preserve and cultivate the ecological conditions necessary for the generational continuance (reproduction) of cultural practices that enable livelihoods that are meaningful, dignified, and economically adequate relative to the norms of the community" (Menser, 2018: p. 4). According to Menser (2018), the ecological conditions improve through the reproduction process, and the ecological and biological functions of soil fertility maintenance are achieved through physical reproduction which encompasses the knowledge accumulated over many generations which makes these sustainable modes of production possible. Most of the organic and agroecology markets and relationships exist because of the common production systems adopted by farmers of like-minds (Gliessman, 2016; De Schutter, 2019). The agroecological and other sustainable production models are therefore territorially rooted in social reproduction (O'Kane and Wijaya, 2015; Nasser et al., 2020).

2.3. Data collection

Both agroecology and conventional farmers constitute our sample: all agroecology farmers of the group were in the sample. The counterfactual sample of conventional farmers was chosen so as to be comparable in terms of the size of the land farmed. Only farms below 5 ha were included in the sample.

We employed cluster sampling, as the population for the study comprises mutually homogeneous, yet internally heterogeneous groups of agroecology and conventional farmers. We obtained a list of conventional farmers from the regional headquarters of the Agricultural Development Program (ADP) and a list of agroecology farmers from the agroecology group facilitator. For the agroecology group, we surveyed 111 farmers. For the conventional farmers, sampled 223 smallholder farm households. In total, we surveyed 334 respondents (comprising 111 agroecology farmers and 223 non-agroecology farmers). We administered a structured questionnaire to the farmers. We employed trained enumerators who understood and spoke the local language of the study area to administer the questionnaires in person.

We used a detailed participant information sheet containing participants' consent forms to obtain consent from each of the respondents. We limited identifying information obtained to the questionnaire number and the name of the village. We used the household questionnaire to elicit information on the demographic characteristics of the farmers such as their asses, off-farm income generating activities, access to services such as markets, extension agents, and credit, as well as social capital in terms of networking activities.

A second section of questions was used to collect data on food insecurity. Food insecurity is conceptualized in this study as a situation that exists when people do not have adequate physical or economic access to food (World Food Summit, 1996). The Food Insecurity Experience Scale (FIES) and Dietary Diversity Score (DDS). We measured the variable 'Agroecology membership' by employing the dummy of 0 and 1, where 1 represents farmers belonging to an agroecology group, and 0 otherwise. Food Insecurity Experience Scale has been proposed by the Food and Agricultural Organization for measuring food security at the individual and household level (Food and Agriculture Organization of the United Nations, 2020). A score or scale based on the experience and perception of the affected individuals has become the fundamental measure of household food security over the past decade. Due to the following advantages, the FIES measurement scale was used: (i) As the only method that directly measures our variable of interest which is food insecurity, as experienced by the farmers, it is the only method with scientific validity. (ii) The methods described above can be used to map and understand hunger and food insecurity's causes and consequences. (iii) The FIES can be employed for both individual and household analysis. Hence, making it appropriate for the measure of food insecurity among farmers. (iv) The process of data collection and analyzing the data is comparatively straightforward and inexpensive. (v) The FIES reflects both psychosocial and physical dimensions of food security. There are eight questions in the FIES so each of the farmers' answers was scored based on the total number of question items the farmers answers in affirmation.

To include the nutrition component in the FSN measure, we included the Dietary Diversity Scale (DDS: Kissoly et al., 2020). The DDS has been validated as an indicator of nutrient adequacy and malnutrition (Moursi et al., 2008; McDonald et al., 2015; Zhao et al., 2017) and socio-economic status (Vhurumuku, 2014). DDS consists of 12 questions representing 12 food groups consumed by members of the household of which values "0" or "1" are assigned when individuals in the family did not consume or did consume the food groups, respectively. A raw score is assigned by calculating the arithmetic sum of all the questions answered in affirmation by the respondents in both the food security experience scale and dietary diversity components. In Table 1, we provide the definition and descriptive statistics of the variables used in the study.

2.4. Econometric approach

We employed the propensity-score matching technique (Benedetto et al., 2018; Tang et al., 2019) to determine the causal effects of belonging to the agroecology group on food security and nutrition in a cross-sectional sample of smallholder farmers. The propensity-score matching has the advantage of balancing the distributions of observed control variables between a control group and a treatment group according to the similarity in their probability values (propensity scores) of belonging to the group. The approach allows estimating the mean impacts as it does not require a parametric model linking the propensity scores to outcome variables, hence, does not require the usual arbitrary assumptions about error distributions and functional forms (Jalan and Ravallion, 2001). We leverage this flexibility to further test for more potentially complex interaction effects as stipulated in the research questions.

We identified two groups: those farmers who are members of the agroecology group (given as $Ai = 1$, for farmer *i*) and those who are not members of the group ($A_i = 0$). The treated group (farmers who

TABLE 1 Definition and descriptive statistics of exogenous, outcomes, and control variables.

Variables	Description	Mean	Std dev.
Exogenous variable			
Agroecology	Farmer belong to agroecology group (1 = agroecology; 0 = Other)	0.33	-
Outcome variables			
Food security experience scale	Number of food insecurity experienced by households in the last 1 month	3.28	3.12
Dietary diversity	Number of food groups consumed by a farmer's household in the last 24 h out of 12 food groups	7.51	1.22
Socioeconomic characteristics			
Gender	Male = 1; female = 0	0.21	-
Age of the respondents	Main occupation of the farmer (1 = Farming; 0 = Other occupations)	38	20.12
Education status	Number of years spent in formal education	9	3.0.1
Marital Status	Single = 1, otherwise = 0		
Family size	Number of individuals in a household eating from the same pot	0.71	-
Farm size	Size of land under cultivation	2.21	2.52
Land ownership	Ownership = 1, Rented = 2, Communal = 3, Borrowed = 4	-	-
Farming experience	Number of years in farming	17.54	22.6
Tropical Livestock Unit	livestock from various species converted to a common unit	3.25	1.02
Off-farm income	Money gotten from non-farm undertakings, gifts, or cash transfers ('000 Naira)	110	51.01
Extension visits	Number of extension visits in the last farming season	3	4
No. of relatives	Number of close families the farmer can depend on at difficult times in a community	5.81	12,425
Access to development services			
Distance to market	Time taken to reach preferred selling point	50.2	9.22
County fixed effects			
Umuduru-Egbeaguru		0.29	-
Umuna		0.35	-
Okwe		0.14	-
Okwelle		0.20	-

Source: Authors.

belong to the agroecology group) are matched to the control group (farmers who are not members) based on the propensity scores given in Equation (1):

$$P(xi) = Prob(Ai = 1|xi)(0 < P(xi) < 1) \quad (1)$$

where, x_i = vector of the covariates. If Ai is independent over all farmers *i*, and the outcomes are not dependent on belonging, given x_i, then the outcomes are not also dependent on belonging given $P(x_i)$, meaning that it is exactly as it would have been if the assignment of who will belong or not belong to the group was done randomly. This is referred to as conditional independence (Benedetto et al., 2018). The propensity score matching uses a monotone function of $P(x)$ to select covariates for each of the observations that are treated. The implication will be that in estimated treatment effects, any observable heterogeneity will be addressed, as the exact matching on $P(x)$ will yield treated and control groups having the same distribution of the covariates.

To estimate the propensity scores for each observation in the agroecology group and the non-agroecology group samples, we employed the standard logit model. With the estimated propensity scores generated for each observation, $\hat{p}(x)$, we constructed matched-pairs based on how close the propensity scores are between the two groups. This is known as the nearest neighbor matching (Stuart, 2010). According to Jalan and Ravallion (2001), the nearest neighbor to the *ith* observation in the treatment group is defined as the non-group member that minimizes.

$[p(x_i) - p(x_j)]^2$ overall *j* among all the non-group members. $P(x_z)$ will be the predicted odds ratio for observation z, i.e., $p(xz) = \frac{\hat{P}(Xk)}{1 - \hat{p}(xk)}$.

Using the caliper values of 0.001, we accepted matches only if $[p(x_i) - p(x_j)]^2$ were less than the caliper value of 0.001. Therefore, if the gain in food security or nutrition *for* j_{th} farmer as a result of belonging to the group is given as ΔF_j, the mean impact will be estimated as:

$$\Delta Fj = \sum_{j=1}^{T} \omega j \left(ffj1 - \sum_{i=1}^{c} Wijfij0 \right) \quad (2)$$

f j1 = post-intervention food security indicator. *fij0* = outcome indicator of the jth treated matched to the *ith* non-treated. *T* is the total number of treatments. *C* = total number of non-treated farmers. ωj = sampling weights used to construct the mean impact estimator. *Wij* = weights applied in calculating the mean of the "any testable variable such as extension visits, own food production …" of the matched non-participants.

Based on kernel functions of the differences in scores, we use the nearest four neighbors estimator, meaning that we took into account the mean outcome measure of the closest four matched non-members as the counterfactual for each member.

The Logistic Regression Analysis (Logistic regression assumes categorical outcome variables, such as dichotomous outcomes, but logit does not directly model them) was used to generate the propensity scores, hence indicating variables that significantly motivate farmers to join the agroecology group. The LRA is an extension of the multiple regression and is employed when the dependent variable is a binary outcome assuming the form of 0 and 1. Therefore, for the Propensity Score Matching model, three (3) groups of variables were included. The first category of variables is the matching variables that will be used for the logit model. According to Tang et al. (2019), in the selection of variables for PSM, variables that are unrelated to the treatment variable but related to the outcome should always be included in a PSM model. These variables should be similar for both treatment and control groups to ensure matching. The inclusion of these variables will increase the precision of the estimated exposure effect without increasing bias. More recent studies also follow similar guidelines.

In an agricultural evaluation program, for instance, one can make predictions for a binary outcome as regards treatment and control groups (Pufahl and Weiss, 2009). Logistic regression assumes categorical outcome variables, such as dichotomous outcomes, but logit does not directly model the Y outcome. Due to simplicity and because it is the case most frequently encountered in practice, it relies on the probability associated with the values of Y, however, it is assumed that Y is dichotomous, meaning that it's the values of 1 for success or positive outcome, and 0, otherwise.

Conversely, in the context of regression analysis, we assume that $X_1,\ldots,Xn$, is set of predictors related to the outcome variable, Y and which provides information on Y. For mathematical and theoretical reasons, the model was based on natural logarithm whereby the logit function will be defined as the logarithm (ln) of the possibility (1) of being in the agroecology group. i.e.,

$$A_i = F\left(Y_i\right) = F\left\{\alpha + \Sigma_{i=}^{n} \beta_i X_i\right\} = \frac{1}{1 + e^{-(\propto + \Sigma \beta_i X_i)}} \quad (3)$$

In terms of the log of the odds ratio we rewrite the model as the likelihood that a farmer will be in the agroecology group (A_i) with respect to the likelihood that the farmer is not in the agroecology group (1 - A_i) as expounded (Otum Ume et al., 2020). The likelihood that a farmer is non-agroecology group member (1 - A_i) we define as:

$$\left(1 - A\right) = \frac{1}{1 + e^{Z_i}} \quad (4)$$

By means of Equations (3) and (4) the generate the odd ratio as:

$$\left(\frac{A_i}{1 - A_i}\right) = \frac{1 + e^{Z_i}}{1 + e^{-Z_i}} = e^{Z_i} \quad (5)$$

We take the natural log of the odd ratio from Equation (5) we get an expanded probability (Y) as:

$$Y_i = \ln\left(\frac{A_i}{1 - A_i}\right) = \ln e^{\left(\propto + \Sigma \beta_i X_i\right)} = \propto + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 \ldots\ldots\ldots \beta_n X_n + U \quad (6)$$

By introducing the error term is into the model we have Equation (7) as:

$$Y_i = \propto \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots . \beta_n X_n + \mu_i \quad (7)$$

The linearization of the logit model Equation (7) will give:

$$Y_i = \propto + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 x_4 \ldots . b_n x_n + U \quad (8)$$

where, A_i is the likelihood that i^{th} farmer will be in the agroecology group X_i, and X_i is the explanatory variable for the i^{th} farmer's, i = 1, 2, 3…n; *e* is the base of exponentials; β_i is the regression parameter estimates of the explanatory variables or the slope coefficient of the equation, α is the constant and, U is the error term.

3. Results

The result of the study emanates from the application of both descriptive and inferential analysis. The descriptive results are presented first, highlighting the socioeconomic characteristics of the agroecology farmers, and how that might enlighten our understanding of the make-up of the group and motivation for joining the group. The descriptive results also provided descriptive results showing the distribution of the agroecology farmers' food and nutrition status compared to the non-agroecology farmers. The descriptive statistics were followed by the econometric results that further reinforced the descriptive results, as well as providing information on which kinds of agroecology members that appears to benefit most among agroecology farmers.

3.1. Descriptive statistics

This section compares the socioeconomic characteristics of the agroecology farmers (STATA 15). The results generated (in this

section) are used as input for further analysis in the propensity score matching analysis. The percentage distribution is based on the sample size of 111 agroecology farmers, and 223 non-agroecology farmers. Our survey showed that the agroecology group is quite gendered as 83% of the 111 agroecology group members are women (Table 2). Almost half of the agroecology farmers (47%) earn less than 200 dollars from their farming activities in one planting season. In addition, 70% of agroecology farmers have farming as their major occupation. This point to the fact that farming is their major source of livelihood and food security. Table 2 showed that the majority of agroecology farmers access their land through free lending or borrowing. Further, the number of times extension agents visit the agroecology farmers was found to be very low (less than 2 times in a planting season) compared to the non-agroecology farmers (between 2 to 3 times in a planting season). The low level of extension visits indicated by the agroecology farmers might be a reflection of the fact that most of the extension agents prefer vising the large-scale farmers.

Finally, the descriptive statistics also suggest a negative relationship between being in the agroecology group and food insecurity experience (Figure 2): on average, the dietary diversity score of a farmer belonging to the agroecology group is higher (7.59) than for the farmer that is not a member of the agroecology group (5.70).

Figure 3 suggests a positive association between being in the agroecology group and cultivating more food crops. The figure shows that on average, an agroecology farmer produces approximately five different food groups while an average group member cultivates approximately three food groups. In terms of farm meetings, an agroecology group member attends an average of about 14 group meetings in a farming season (Figure 3B). These include activities such as field days and training on nutrition and dietetics. Figure 3C shows that non-agroecology group members are more market-oriented. An average group member consumed 86% of the food he or she produces while a non-agroecology group member consumes 48% of the crops produced. Finally, Figure 3D suggests a positive association between being in the agroecology group and the balance of time between paid and unpaid work. 81% of the agroecology group members against only 26% of non-agroecology members spent less than or equal to 12 h on paid and unpaid work in the last 24 h before recall.

TABLE 2 Socioeconomic characteristics of the agroecology farmers.

Variables	Agroecology Farmers (*n*=111)		Non-Agroecology farmers (*n*=223)	
	Freq.	(%)	Freq.	(%)
Gender				
Women	92	83	169	76
Men	18	17	54	24
Farming as major occupation				
Yes	79	70	152	56
No	32	30	98	44
Method of access to land				
Ownership	8	7	103	46
Rented	25	23	51	23
Communal	27	24	56	25
Borrowed	40	36	13	6
Number of extension visits (per planting season)				
<2	104	91	29	13
2–3	5	4	25	11
3–4	4	3	116	52
>4	2	1	54	24
Farm size (Ha)				
<1	105	93	145	65
1–2	5	6	54	24
2–3	1	1	11	5
>3	-	-	13	6
Farm income ($/planting season)				
<100	52	47	16	70
100–200	35	32	27	12
200–300	-	-	18	8
>400	24	21	22	10

Source: Authors.

3.2. Propensity score analysis

3.2.1. Relationship between agroecology and food and nutrition security

The estimated mean impacts of the agroecology group on food security and nutrition are given in Table 3. The average treatment effect indicates that being in the agroecology group significantly reduces food insecurity and increases dietary diversity. The result shows that food insecurity experience points amongst those in the agroecology group would be 0.45 points higher if they were not in the agroecology group. Dietary diversity will be 2.18 points lower if they were not in the agroecology group.

Before matching, the estimated average propensity score for farmers who were members of the group was 0.6315 with a standard deviation of 0.242, while the average propensity score for farmers who did not join the group was 0.2518, and a standard deviation of 0.126. Figure 4 presents the histograms of the propensity score estimates from the two groups.

After matching, we lost only four treatment observations, as we did not find a suitable match for them. The propensity score estimates after matching showed a negligible difference in the average propensity scores of the treatments and the resulting control group. The estimated average propensity score for the treatment group was 0.5182 with a standard deviation of 0.122, while the average propensity score of the treatment group was 0.509, and a standard deviation of 0.120. Figure 5 presents the histograms of the propensity score estimates from the treatment and control groups. Thus, we are assured that the two groups are comparable and our analysis shows the effect of belonging to the agroecology group rather than differences in resource endowments among farmers.

Once stratified based on 'time load' time-poor farmers in the agroecology group have better food security than time-poor farmers who do not belong to the agroecology group. In all the quantiles, the effect of agroecology on the dietary diversity of time-poor farmers is statistically significant. In terms of food security, we found significant

agroecology gains amongst the time-poorest two quintiles (first and second quantiles).

When we stratify the sample based on production diversity, our data showed a significant effect of production diversity on dietary diversity for all the quantiles, but we did not observe any significant effect of production diversity on food security. The difference in dietary diversity was pronounced for the farmers in the first quantile (highest production diversity?). Within the second, third, and fourth quantiles, we observed a statistically significant difference in dietary diversity between agroecology and non-agroecology farmers, however, in a declining magnitude. This shows that the dietary diversity impact is more pronounced among farmers producing relatively more crops than those producing fewer crops (Table 3).

Furthermore, we observed that food and nutrition security effects from belonging to the agroecology group tend to be larger and more significant in families who produce more of their own food. We found a similar pattern when we stratified instead by the strategy employed by the farmers to feed their households. However, we found an interesting case when we consider the first and third quantiles. The result shows that the impact of the agroecology group on food security tends to be larger and more significant for those in the first and third quantiles. The first quantile represents farmers whose 75% and above of their household food consumption comes from what they produce.

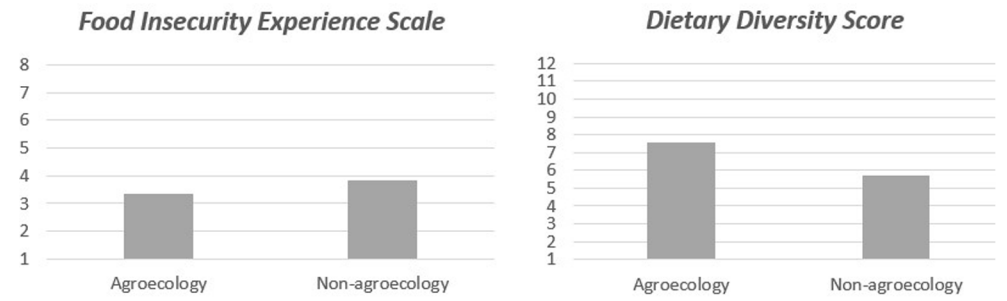

FIGURE 2
Average food security and dietary diversity among agroecology and conventional farmers. Food insecurity experience scale from 1 to 8; Dietary diversity scale from 1 to 12.
(Source: Authors).

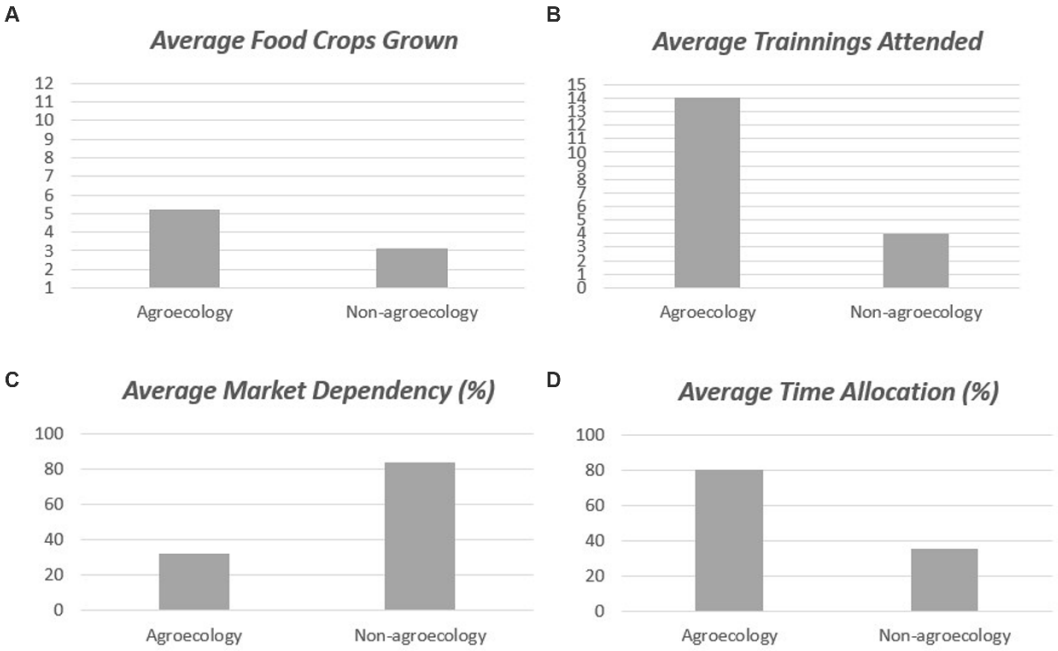

FIGURE 3
Distribution of agroecology and non-agroecology group members in terms of **(A)** the number of food crops cultivated by the farmer **(B)** the number of farming training attended **(C)** the average percentage of crops consumed that is bought from the market **(D)** Percentage of time allocated to reproductive activities.
(Source: Authors).

TABLE 3 Impact of Agroecology on Food Insecurity Experience (Scale 1 to 8) and Dietary Diversity (Scale 1–12).

	Food Security		Dietary diversity	
	Mean for agroecology farmers (Std. Dev)	Impact of agroecology (st. error)	Mean for agroecology farmers (Std. Dev)	Impact of agroecology (st. error)
Full sample	3.35 (0.12)	−0.4536* (0.22)	7.65 (1.33)	2.182* (0.28)
Stratified by Time (quantiles)				
1 (Smallest)	3.61 (0.042)	−3.025* (0.12)	7.02 (1.23)	2.813* (0.19)
2	3.37 (0.113)	−2.948* (0.04)	6.81 (1.01)	1.527 (0.11)
3	2.96 (0.231)	−2.367 (0.005)	6.33 (0.02)	1.085* (0.21)
4	2.43 (0.23)	−1.491 (0.22)	5.21 (0.11)	0.864* (0.05)
Stratified by the production diversity (quantiles)				
1 (highest)	3.51 (0.12)	−1.0457 (0.02)	8.68 (1.25)	2.2950* (0.05)
2	3.22 (0.02)	−0.1505 (0.18)	7.61 (0.52)	2.1694* (0.19)
3	2.51 (0.15)	0.5994 (0.21)	6.82 (0.91)	1.9186* (0.25)
4	2.01 (0.22)	2.1694 (0.09)	3.99 (1.32)	1.8919* (0.09)
Stratified by % of food consumed from self (quantiles)				
1 (Highest)	2.91 (0.01)	−0.8292* (0.12)	7.71 (0.21)	0.5131* (0.05)
2	3.73 (0.005)	−2.1235 (0.02)	6.52 (1.03)	0.3160* (0.09)
3	4.18 (0.21)	−1.8290* (0.15)	4.45 (1.21)	−1.6944 (0.21)
4	1.96 (0.30)	2.2076 (0.09)	5.29 (1.85)	−1.2923 (0.11)
Stratified by extension visits				
1 (Yes)	−2.2040* (0.02)	4.21 (0.21)	4.35 (1.02)	1.9894* (0.24)
2 (No)	−1.30 (0.10)	2.49 (0.11)	3.44 (0.55)	1.57 (0.32)

*Indicates significance at the 5% level or lower.
Source: Authors.

The third quantile represents farmers whose household consumption constitutes between 25 to 50% of their own food production. In addition, farmers within this third quantile have better dietary diversity and food security compared to the farmers in the rest of the quantiles. We could infer that although the strategy of own food production provides more gain for the agroecology farmers, those who balance their own food production and purchase from the market (3rd quantile) tend to have higher dietary diversity and reduced food insecurity, than those in the first quantile. Over 70% of the farmers, in this third quantile, engage in off-farm income-generating activities and receive income from relations or husbands who either are in other businesses or are abroad. The major occupation of the farmers in the first quantile is farming; hence, agriculture is their main source of livelihood.

Finally, the fourth quantile is constituted by farmers who purchase over 75% of their food from the market (irrespective of whether it is the agroecology or conventional market). The result shows that this set of farmers has higher food insecurity experience and lower dietary diversity compared to the rest of the quantile. Our data showed that 91% of the land under cultivation for the farmers in the 4th quantile is used in the production of rice. This is usually a result of the fact that they do not have their land (no private land right) and hence would produce according to the dictate of the processors or other landlords. Although rice can be said to be a food crop, in the study area, farmers engaged in rice production are engaged in contract farming, either with the government or with processing firms. Hence, most of their products are sold out and they receive cash in return. The 1st quantile, however, represents farmers whose major part of their land was used in the cultivation of vegetables, yam, cassava, and other food crops. Interestingly, the farmers in the 1st quantile representing the farmers that are engaged in self-provisioning have far higher production diversity compared to the farmers in the 4th quantile which reflects farmers highly commercialized.

Finally, after stratifying the sample based on (no) visits by extension agents in the last planting season, we found that farmers in the agroecology group had better food security and dietary diversity in both strata. However, the gain was more pronounced among the farmers who did not receive extension services. We therefore could infer that the peer-to-peer activities engaged by members of the group to improve their practices and increase their knowledge *de facto* replace formal extension visits and services.

3.2.2. Determinants for joining the group

In Table 4, we report the logit regression estimates where the binary outcome takes the value 1 if the farmer belongs to the agroecology group, and 0 otherwise. The determinants are made up of socioeconomic and household characteristics including proxies that we believe are seemingly plausible for explaining why farmers would be driven to join the agroecology group. The variables include gender, age, educational status, marital status, and family

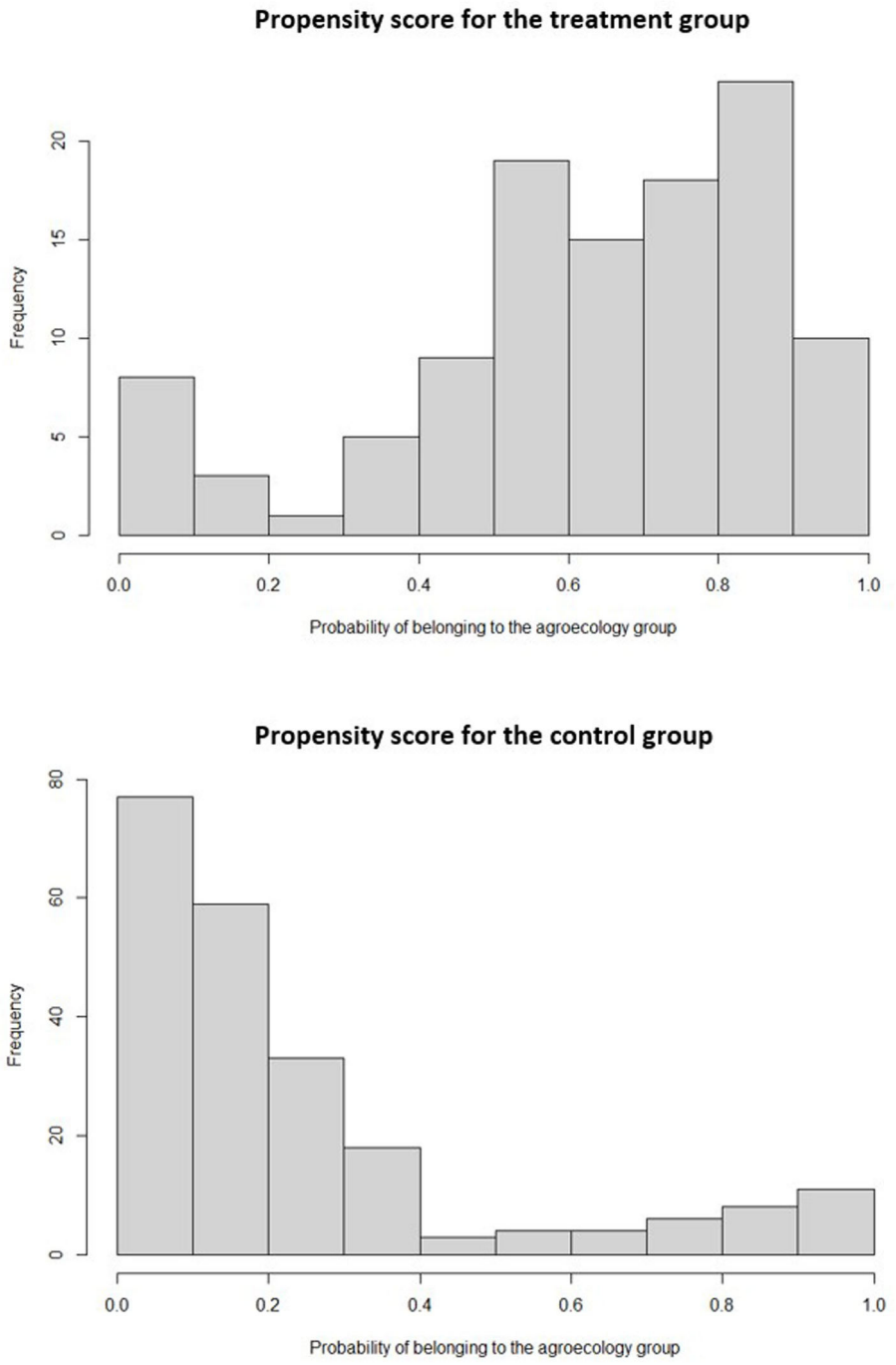

FIGURE 4
Histograms of the propensity score estimates from the two groups before matching.

size of the farmers. The variables were included as exploratory observation in the community as well as studies such as Emeana and Trenchard (2018) showed that the group mostly comprised family women with little formal educational training. Other included variables are the economic variables such as the number of relatives who are already members of the group, farm size, land ownership, and off-farm activities. Farmers who have alternative sources of income and assistance might not be motivated to join the group, compared to those who need assistance and a sense of identity. We also included extension visits, as most of the farmers who do not have access to extension agents might be more motivated to join the group. The location of the farmers within the community was also important as farmers closer to the community where meetings usually take place might be more motivated to join compared to those living far from the village center where meeting normally takes place.

We found no sign of correlation between farmers who are members of the group and their location (Table 4). This suggests that the location of the farmer does not determine their motivation to join or not to join the group. We saw a number of significant

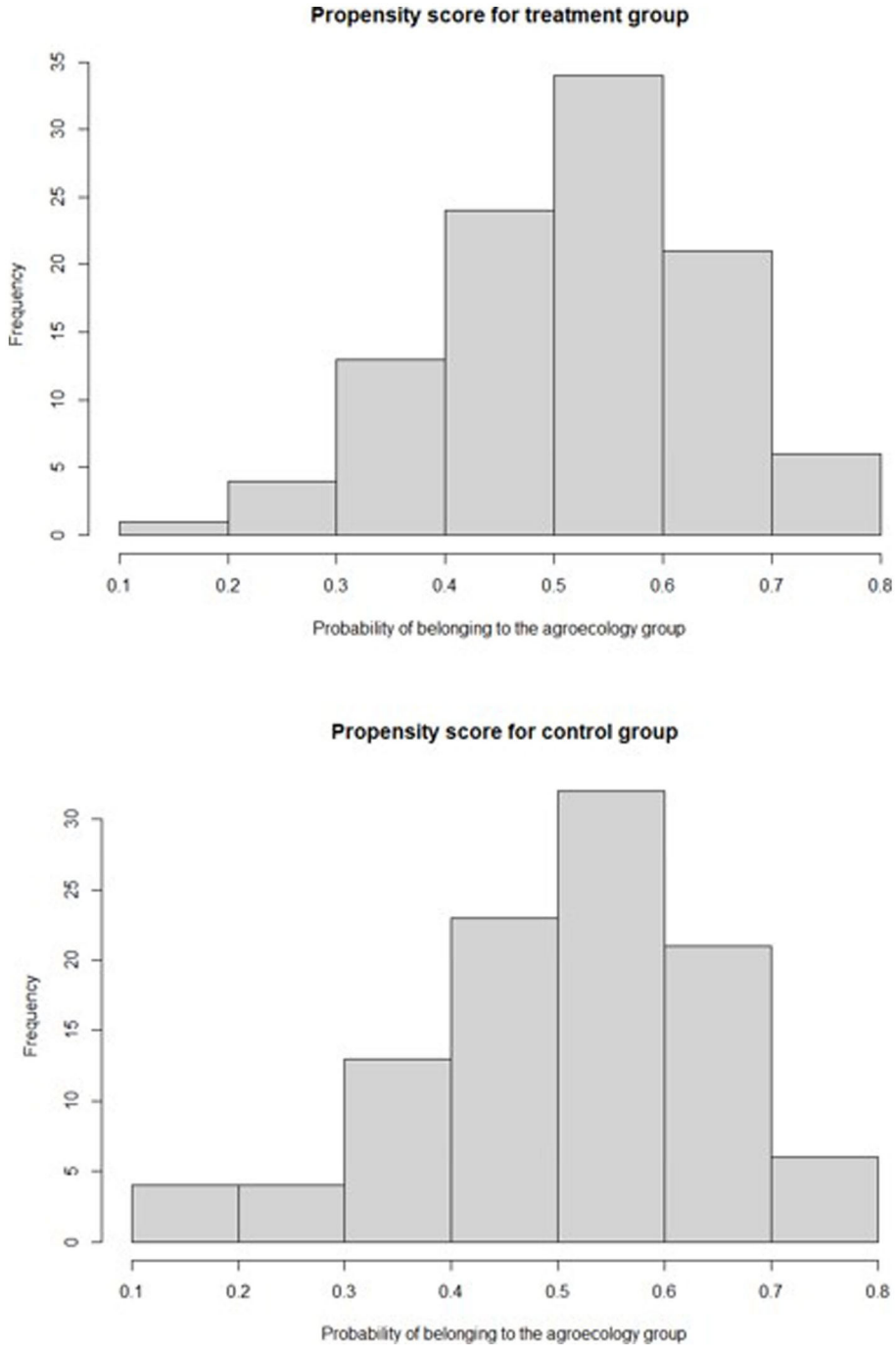

FIGURE 5
Histogram of propensity scores after matching.

variables that could explain the reasons for joining the group. Out of the ten variables tested, six were found to be significant explanatory variables. The result showed that women were more likely to join the group than their main counterparts. This confirms the idea that agroecology groups provide an empowerment platform for women and other historically marginalized stakeholders in the food system such as the caste and smallholder farmers (Oteros-Rozas et al., 2019; Zaremba et al., 2021). This is also not surprising as 83% of the group members were women. In addition, the entire leadership was women, suggesting that the group might have provided a safe origination for the women to air their views conveniently. Having more relatives made it more probable that a farmer will join the group. This is contrary to our expectation as we assumed that farmers who have relatives to rely on in times of need might be less interested in joining the group. However, our interview with the members of the group showed that most of them knew about the group through referrals from their friends and relatives. This might explain the positive correlation between being in the agroecology group and the number of relatives. Expectedly the greater the farm size, the less the probability of joining the

TABLE 4 Determinants of choosing to belong to the agroecology group.

	Coefficient	z-values	Std. Error
Gender	−0.7581**	−2.15	0.35
Age	−0.0085	−0.01	0.006
Educational status	−0.0457	10.31	0.14
Marital status	0.2412	0.66	0.36
Number of relatives	0.2778***	4.99	0.06
Family size	−0.0305**	−0.40	0.07
Farm size	−0.2097*	−1.77	0.11
Land ownership	−0.0317	−0.24	0.13
Ln (Off-farm activities)	−0.0779	−0.36	0.21
Extension visits	−0.2341***	−2.81	0.08
Location	−0.0895	−0.76	0.11

*, **, and *** denote sign. Levels of < 10%, < 5% and < 1%, respectively.
Source: Authors.

group. This finding is plausible and consistent with the *apriori* expectation that the group provides better benefits to landless farmers. By farming communally as well as sharing their lands, these farmers can attract farmers who are landless as they might be able to pull resources and benefit from economies of scale. Finally, farmers who had no access to extension agents have a higher probability of joining the group. This also justifies the hypothesis that the peer-to-peer activities and the training within the agroecology group can provide an alternative learning and knowledge acquisition platform for the agroecology farmers who might not have access to the traditional extension practices provided by the state.

4. Discussion

4.1. Agroecology as a safety net for marginalized farmers

Our findings have to be seen in the context of a discussion on strategies for combating food insecurity (Altieri et al., 2012; FAO, 2014; Nyantakyi-Frimpong et al., 2017). Several governments of developing nations address the problem of food insecurity by fostering the integration of farmers into formal value chains and the production of commodities for regional, national, or global markets. This strategy, which translates into greater support to large farms and commodity markets, also has the aim to generate revenues for the state. Since the advance of the green revolution and deployment of improved corporate-developed seeds and capitalized technology, smallholder farmers are depicted as anachronistic, backward, and inefficient (Jayne et al., 2016; Otsuka et al., 2016; Omotilewa et al., 2021). In practice, farmers with higher income generation potential are more likely to receive assistance and aid from governmental extension offices, subsidy schemes and credit opportunities than farmers with lower income generation potential. Yet, doubts upon the logic that food security in rural areas and among smallholders can be addressed by the focus on commercialization of the smallholder production are now casted (Collier, 2008).

In recent years, food sociologists have begun to realize that social organizations among small farmers have the potential to improve the food and nutrition security of smallholder farmers by enabling and nurturing reciprocal exchanges and supporting structures. The result is a welfare outcome that goes beyond financial individual benefit (Kangmennaang et al., 2017; Rahmadanih et al., 2018; Bezner Kerr et al., 2019b; Kehinde et al., 2021). The findings of the propensity score matching analysis reveal a relationship between being a member of the studied agroecology group and being food and nutrition secure as compared to the food status of conventional matched farmers in the same area. Of course, this result cannot be generalized easily, as the exact causal mechanisms are not revealed by PSM and the result could be case-dependent. Rather, in this study we use PSM as a method to test the efficacy of programs.

Nevertheless, our results suggest at least that the sum of the activities taking place within the agroecology group in the study area has been effective in improving the nutrition and food security status of its members. While the activities themselves might be case-specific, they are built on logics of reciprocity, providing access to resources without cash, co-creation, and sharing of free knowledge, that is principles of agency and empowerment (Emeana et al., 2018). Thus, our evidence strengthens the existing claims that agroecology in Sub-Saharan Africa also exists and manifests itself as a complex association of sustainable agronomic and social (organizational) innovations aimed and managing to improve food security and nutrition among smallholder farmers (Kangmennaang et al., 2017; Bezner Kerr et al., 2019a; Mdee et al., 2019; Kassie et al., 2020; Sachet et al., 2021).

Zooming onto the characteristics of the agroecology group members reveals that mostly marginalized smallholder farmers are more frequent in the agroecology group. Indeed, our logit regression model identified the following variables to be critical in predicting farmers joining the group: being a women, facing land shortage, and having no/little access to extension services. Female farmers were more likely to join the group than their male counterparts. This might be attributed to the fact that, apart from the sense of comradery in the group, the group presents a platform where women can be more empowered to make reproductive decisions, that is to achieve their aim of ensuring food security at the level of their household. This suggests that the association of agroecological practices restoring soil fertility associated with social reciprocal structures supporting the autonomy of women from the mainstream conventional farming system supports women in achieving food security. We can hypothesize further that it is through providing the farmers access to resources, ideas, support, human connection, and role models they do not get from the mainstream system that the agroecology group improves the food status of these women and their households.

In fact, women are the main actors in the agroecology group. This may not be surprising as in the study area, it is women who are in charge of food provision. They might likely tilt towards organizations that strengthen their ability to realize the non-monetary reproductive goals of family care. Our hypothesis rejoins with Peacock (2006)'s view that the non-monetary economy – in this case created by the agroecology group - has a socially or morally conscious philosophy that eliminates social exclusion. It works through the inclusion of the

unemployed and poor persons and gives them economic access and opportunities to goods and services. The agroecology group appears as a structure able to empower women in their role of food providers: Opata et al. (2020b) show that empowered women contribute to production decisions, income control, and access to resources which enables them to increase the quantity and quality and improve the fair distribution of food consumed in the home.

4.2. Key variables in the agroecology-food security nexus

Our matching technique highlights further particularly significant variables (reproduction goals) in analyzing the nexus between farm social organizations and food security and nutrition among smallholder farmers: market dependency, farm group meetings, production diversity, and time balance between production and household reproduction goals as we will see in the following sections.

In terms of production diversity, our findings showed that farmers who have higher production diversity have better food security and nutrition. Planting two or more crops on the same land simultaneously is one of the core principles of agroecology and farmers within the agroecology group largely adopted the mixed cropping techniques. Studies have shown that mixed cropping is associated with dietary diversity (PNAS, 2015) and food security (Usman and Callo-Concha, 2021). Mixed farming also has the benefit of fighting against diseases and weeds, hence enhancing production (Ngapo et al., 2021).

In terms of time balance, our result showed that the adoption of agroecological practices such as pull and push technology and zero tillage substantially reduce weeding and tillage time respectively, which are the most time-consuming cultural practices. These practices, thereby free up (wo)man-hours that can be relocated to non-farm or care activities (Kassie et al., 2020; Notenbaert et al., 2021).

Farm group activities such as peer-to-peer meetings and training on sustainable practices are important as it helps the farmer put knowledge into action for better food security and nutrition (Organic Farming Research Foundation, 2022). The more meetings are attended by the agroecology group members, the higher their food and nutrition security, according to our results. The gains observed among agroecology and non-agroecology farmers who had access to extension agents suggest that the interactions within the agroecology group provide an additional or even better knowledge base for the agroecology member. One may interpret that peer-to-peer meetings strengthen the adoption and application of agroecology principles and structures and increase productivity and food security (Faysse et al., 2012; Chen et al., 2015). Indeed, farmers consider other farmers their "best sources of information" (Organic Farming Research Foundation, 2022: p. 3). Yet, the importance of meetings in increasing food security may not relate to the fact that they foster peer-to-peer learning but rather to the content of the knowledge shared and in fact also co-developed within the group. The group delivers and creates agroecological knowledge, which is knowingly complex, place-based, adapted to diverse food crops and based on agroecological principles (Rahmadanih et al., 2018), far from the teachings of rice-supporting extension schemes. In addition, a higher attendance to meetings may mean that farmers contribute financially more often in the financial reciprocal credit system and thus benefit more when they indeed need it. They may also have better chances to access inputs (seeds, lands) and to cooperate with others to sell their product to the agroecological market. The additional benefits from these social networks among rural farmers, may explain the role of the attendance of peer to peer meetings on the food security and nutrition status of farmers (De Schutter, 2010; Tilzey, 2021). The next section deals with the market dependency variable.

4.3. Commercialization, subsistence, and adequate markets

Access to food is critical for food security. We show evidence that farmers who strategize their own food security goals through self-provisioning are better-off both in experiencing more food security as well as diversifying their diets compared to comparable farmers depending more extensively on food purchased from the market. As Edmondson et al. (2019) and Galhena et al. (2013) found in the United Kingdom and Sri Lanka respectively, prioritizing the production of food for subsistence as compared to producing crops for markets is essential in the FNS among farmers excluded from the mainstream farming and cash-based economic system. At the same time, our evidence shows that agroecology farmers sourcing their foods in about equal shares from own production and purchase improved their food security and dietary diversity most. Thus, while it does not contradict the commonly assumed view that (off-farm) income is essential in achieving food security (Bazezew et al., 2013; Gebreyesus, 2016; FAO, 2019; Dsouza et al., 2020), it does temperate this statement and highlights the complementary role of purchased foods, as opposed to being a main strategy. The production of own food remains key for women, who within households do not have access to cash, land and inputs and yet are responsible for food and reproduction in their families. In fact, the high food security result of agroecology farmers who source foods from farming and markets leads to suggest that agroecology in its agricultural and social practices as in the farmers group investigated may be able to reduce the tension between consuming and commercializing, in fact maybe even create a synergy among these two apparently contradictory activities. Fanzo (2015) suggests h that a fundamental tension exists between income-based entitlements and direct production entitlements. The fact that those who are able to balance best between self-consumption and purchased food in our sample are also the best fed ones is an evidence for this tension. Yet, our results also point to a successful manner of navigating it and suggest that agroecology can support this optimal balance between subsistence and commercialization.

Indeed, the question is which kinds of markets support both the production of food and the generation of income? Certainly, commodity markets sharpen the trade-off between food and income generation as commodities are often produced in monocultures and extracted from the local food system for more distant or urban markets. In the presence of only such markets, the distinction between production decisions and consumption decisions is lost as consumption decisions ultimately become production decisions (Fischer and Qaim, 2012; Opata et al., 2020b; Anderson and Maughan, 2021; Usman and Callo-Concha, 2021). Farmers need to choose to produce for food or for cash, which affects food security differently. As opposed, the market used and co-developed by the agroecology group in southern Nigeria enables farmers to sell "real" surpluses of food (and not specific commodities) to a valuable price. Thus,

production decisions that women make can be directed towards consumption first and foremost, while still enabling them to acquire cash for supplementary necessary food purchase. Ume (2023) has shown that such markets are possible when they are local markets that are organized by the farmers themselves and most times involve an exchange system that is not only driven by money. This is important as it will help to deemphasize cash crop production as the panacea to improve food security. Rather, we need to promote local rural markets and the production of food crops such that excess food crops can be produced and transacted in such markets.

5. Concluding comments

The paper empirically investigates which farmers participate in the emergence of AE in Southeastern Nigeria and how it supports them in ensuring their food security. It uses PSM to analyze the efficiency of belonging to one specific agroecology group – as a program- in improving the food security of the members. The reference population constitutes of comparable conventional farmers in the same area. Findings from the analysis show that the agroecology social group is an important farm organization that leads to the improvement of the food security status of smallholder farmers by 0.45 points and nutrition status by 2.1 points. Our findings further showed that the improvement in food security is greater if the group supports (and the farmers make use of) elements such as production diversity, peer-to-peer resource sharing, and local food markets. In terms of production diversity, our findings showed that farmers who engage in production diversity rather than monocropping will have better access and could also take advantage of the benefits of mixed cropping. In terms of time balance, our result showed that the adoption of agroecological practices such as pull and push technology and zero tillage substantially reduce weeding and tillage time respectively, which are the most time-consuming cultural practices. Farm group activities such as peer-to-peer meetings and training on sustainable practices helped the farmers put knowledge into action for better food security and nutrition. Finally, we showed that farmers who strategize their own food security goals through self-provisioning are better off both in experiencing more food security as well as diversifying their diets compared to comparable farmers depending more extensively on food purchased from the market.

Our approach shows the value of the social dimension of agroecology in addressing food security and nutrition, especially among smallholder women farmers who are responsible for food provision in the household. In this study therefore, we conceptualize agroecology as a complex socio-ecological system constituted of agronomic practices and social reciprocal and co-creation activities mobilizing local production and exchange of production factors (land, labor) and inputs (seeds, knowledge). Food security programs and academic studies that conceptualize agroecological farm organizations only from the lens of agroecology as a farming practice might disregard other innovative ways through which the farming practices associated with agroecology are embedded both at the household level and at the societal scale. Furthermore, acknowledging gendered responsibilities in achieving food security at the household level and the political, social, and economic conditions under which these household activities are conducted will improve research and the ability of programs to support and empower food careers towards this aim.

Finally, there are some limitations to the study. In studying real-life evaluations, it is difficult to investigate phenomena or interventions before during after due to the absence of time-series data. Thus, making it difficult to properly infer causality of the hypothesized mechanisms. For future studies, relevant information would be to uncover exact causal mechanisms and this could be investigated by a qualitative investigation.

Data availability statement

The datasets generated for this study can be found in the Figshare (https://figshare.com/s/d4efd3f5e3c9548752b3). DOI: 10.6084/m9.figshare.21076312.

Ethics statement

The studies involving human participants were reviewed and approved by Institute of Agricultural policy and Market research. The patients/participants provided their written informed consent to participate in this study.

Author contributions

CU carried out fieldwork in Nigeria and data analysis. E-AN and SD were involved in the conceptualization, framing, writing, and other intellectual contributions. All authors listed have given approval and consent for publication.

Funding

Financial support from the German Academic Exchange Service (DAAD) under the program Development-Related Postgraduate Courses (EPOS), contract number P1401273, is gratefully acknowledged. The fieldwork was partly funded by the Stiftung Fiat Panis, Germany.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Chapter 4: Agroecology, gender, and autonomy for food security

Ume C, Nuppenau E-A, Wahlen S, and Domptail SE (2023) How agroecology group empowered women smallholder to achieve food security. Submitted to the *journal of peasant studies.*

How building an agroecology food system empowered women smallholders to achieve food security

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ABSTRACT

The conceptual framing of food systems needs to integrate feminist contributions and autonomy as essential components of food security. Despite the increasing injustice and inequalities that characterize the food systems in many agrarian societies, asymmetric power relations within food systems are seldom considered in discourses of food security analyses. This study aims to understand the role agroecology as a social innovation can play in bridging food system inequalities in rural communities. Rooted in a conceptual framework informed by feminist theories of the intersectionality of gender and reproduction feminism, we identified and examined how practicing agroecological farming and belonging to an agroecology group boost the autonomy of smallholder women farmers in pursuing non-market reproductive goals that are critical in achieving food security. The study is based on face-to-face interviews with 24 women belonging to an agroecology group since 2016 in Southeast Nigeria and analyzed using qualitative thematic analysis. Our analysis showed that implementing agroecological practices shapes the broader social relations with other actors of the food systems. The new relations built through adopting agroecology practices allow agroecology farmers to develop an alternative food system independent of the dominant capitalistic structures, representing an essential sustainable farming practice that simultaneously improves women's autonomy within the dominant food system.

Keywords: Food security, autonomy, agroecology, reproduction, parallel food systems

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1.0 Introduction

Despite the increasing injustice and inequalities that characterize the food systems in many agrarian societies, power relation within food systems is rarely considered in food security analyses (Jacobi et al., 2021). According to Jacobi et al. (2021: p.1), asymmetric power relations within food systems arise from the "uneven capacity of different actors to influence the goals, processes, and outcomes of governance." The Food and Agricultural Organization 2020 report on food security and nutrition showed that most of the hungry and malnourished in developing nations are found in rural areas and among smallholder farmers who depend on agriculture for their livelihoods and food security (HLPE, 2020). Conversely, research to date has shown that it is these smallholder farmers that produce almost 70% of all food consumed. Despite progress in realizing the four pillars of food security, why is it that food insecurity and malnutrition persist among smallholder farmers who produce large proportion of food consumed in developing nations? The capitalistic and market-oriented model designed to meet the challenge of hunger in most developing economies poses threats to the socioeconomic well-being of peasants and rural farmers. According to Satgar & Cherry (2020), the divide between small-scale farmers and multinational corporations widened under the corporate food regime. We empirically investigate how agroecology might be instrumental in expanding the agency of women smallholder farmers at the household and societal levels to influence food security. Using a group of women smallholder agroecology farmers in Southeast Nigeria as a case study, we ask: how does adopting agroecological practices foster an alternative food system that can strengthen the agency of female smallholder farmers to achieve food and nutrition security?

Recognizing the increasingly asymmetric power relations in food systems, the High-Level Panel of Experts on Food Security and Nutrition (HLPE) highlighted the necessity of incorporating the dimension of "agency" as an additional pillar of food security (HLPE, 2019). HLPE (2019: p.16) defined agency as the "capacity of individuals or communities to define their desired food systems and nutritional outcomes, and to take action and make strategic life choices in securing them." Inherent in this definition is the need to bridge the power imbalances and persistent hunger among the least advantaged in society. From a system perspective, agency is recognized as the capacity of groups or individuals to control the food value chain and to exercise voice in the governance processes, including addressing the widening inequalities within the food system (Clapp et al.,

2022; Wald and Hill, 2016). The proponents of agency as being vital in bridging food system inequality are not necessarily against external interventions but to scrutinize what is being attempted through those interventions, for whom, and the emerging food systems being fostered in the process.

2.0 Theoretical framework

2.1 Food Security, Autonomy, and Intersectionality of Gender

Discussions about integrating agency in food security analysis usually embed autonomy and intersectionality of gender (Sinharoy, Waid, Ali, et al., 2019; Bloom, Wagman, Dunkle, et al., 2020). The concept of intersectionality of gender in food security analysis describes how gender, as a category of difference, can be used as a source of power and oppression to produce systems of inequality at individual or societal levels (Bohrer, 2019; Haq, 2013). Much of the literature applying a gender lens in investigating occasions of food insecurity has focused on ways in which gender inequities at the household and society levels constrain women's autonomy in exercising voice over their own life circumstances and their capabilities to control their own well-being (Njuki et al., 2016; Ume et al., 2022; Visser & Wangu, 2021). These insights from the agency-gender literature highlight the importance of "autonomy" of female farmers to participate in food systems on their own terms in ways that empower them to live without hunger or deprivation devoid of patriarchal structures and gender norms (Clapp et al., 2022). Liberalism's conception of autonomy is characterized by an agent's ability to self-govern, thus allowing them to choose which commitments and values to follow (Terzi, 2022). Using a capability approach, Amartya Sen and Martha Nussbaum argue that people should be able to choose the kind of life they want to live (Sen, 1993; Nussbaum, 2002). An autonomy-based approach advocates evaluating women's food security and social well-being based on their realistic opportunities to choose what they value.

Few empirical studies have examined gender relationships in food security and nutrition (Kassie et al., (2020); Kerr, 2005; Kerr, Hickey Lupafya, et al., 2019; Kabeer 1999). In their analysis of nutrition impacts of women's empowerment and agroecology adoption in rural Kenya, Kassie et al., (2020) suggest that women's empowerment will boost the dietary diversity gains they derive from adopting any agroecological technology, and gender-sensitive technology diffusion programs will be more impactful together in improving nutrition of women and their households. Kabeer

(1999) opined that inequalities within a household often reflect women's presence and lack of autonomy within the household. Investigating the Colombian food systems, Turner et al. (2022) argued that Afro-Colombian women in sustaining localized food systems increased food provisioning practices for the nourishment of the households while maintaining socio-cultural and ecological relationships. In a baseline study of women and men smallholder farmers in the Northern Region of Ghana using the WEAI+, Ragsdale et al., (2018) showed that the soybean production sector of the four Ghanaian districts is characterized by gender inequality as regards autonomy in production, which has negative consequences on the capacity of the women in making food decisions. While some of these studies have started to integrate the gender-autonomy nexus in studies about food security, research on relationships between agroecological practices, autonomy, and food security is sparse. In this paper, we examine whether agroecology can effectively address food Insecurity by investigating how agroecology-farming approaches provide autonomy for women in a capitalist food system. As a starting point, we offer a brief argumentation of the role of agroecology in fostering a more democratic parallel food system.

2.2 Agroecology and Reproduction Feminisms

The word 'agroecology' was first mentioned in Bensin (1928). Since then, the term has increasingly attracted the interest of policymakers, advocacy groups, and researchers from different disciplines. Alexander and Jauneau (2011) attributed this rise in popularity to the need for agriculture to respond to the many sustainability challenges, including food security, food system equality, and sustainable rural development. Over the years, due to the multidisciplinary/cross-disciplinary nature of the term "agroecology", diverse definitions and conceptualizations have emerged. Between 1928 and 2000, agroecology was conceptualized as a method of applying principles of ecology in climate and land management to increase farm production with reduced ecological consequences (Azzi, 1956; Bensin, 1928; Gliessman, 1998). In 2000, the 'food system component was added to the definition of agroecology. Here, agroecology as a concept is discussed beyond farm-level analysis and immediate biophysical impacts at the farm and field to include how all the elements of a food production-distribution-consumption system come together and interact with one another (Dalgaard et al., 2003; Francis et al., 2003; Clements & Shrestha, 2004; United States Department of Agriculture (USDA), 2007).

More recently, the social, economic, and political elements have been introduced. The concept goes beyond science and practices in the food system approach/scale of agroecology. Still, it aims at facilitating knowledge sharing and interactions between actors in practice, science, and movements (Wezel et al., 2009) and as science and politics (Rosset & Altieri, 2017). According to the Forum for Agroecology (2015), it is at this stage that agroecology as a movement differs from major sustainable agricultural concepts; Climate Smart Agriculture (CSA), Conservational Farming (CF), etc. As posited at the international symposium on agroecology in Nyéléni, Mali, agroecology must be fashioned within a food system that defends peasants and smallholders through local and short food supply chains that entrusts the policies and mechanisms of food production, distribution, and consumption back to the peasants and rural communities (Forum for Agroecology, 2015). According to Menon (2015), reproductive activities consist of unpaid work, such as subsistence activities (especially in developing nations) that do not earn or only earn less in the market. Within the food system context, reproductive activities are linked to the different activities that lead to the conversion of crops and wages from farms into usable goods in the home and various activities that support this conversion (Menon, 2015).

Although there is no single comprehensive household economic theory, several clear ideas on reproduction centered on the analyses of the decisions made by households and the criteria by which decision-makers within a home divide wealth between consumption by the family and sales to the market (Kangmennaang et al., 2017; Oteros-Rozas et al., 2019; Zaremba et al., 2021). In line with Ferguson (2016), we define the household's reproduction activities as investments in non-production activities that ensure that household members are nourished. On the other hand, the reproduction of social networks is at the center of agroecology farmers' groups. Social reproduction is comprised of "those practices that preserve and cultivate the ecological conditions necessary for the generational continuance (reproduction) of cultural practices that enable livelihoods that are meaningful, dignified, and economically adequate relative to the norms of the community" (Menser, 2018: p.4). According to Olivier De Schutter (2011), through household and social reproduction, farmers are able to achieve critical pillars of access, availability, stability, and utilization of food, which leads to food security and nutrition. However, there is limited empirical evidence to support these claims, nor is there evidence to show the potential of agroecology in enabling the agency of female farmers, for instance, in making food production decisions within

and outside the household. In this study, we broaden these arguments by incorporating the concept of agency and intersectionality of gender (Friedmann, 2016).

3.0 Materials and Methods

3.1 Case study

The southeastern geopolitical zone of Nigeria is among the six geopolitical regions in Nigeria. It consists of 5 states –Abia, Enugu, Anambra, Ebonyi, and Imo (Onyekuru et al., 2020). The region's climate is a tropical monsoon (Onyekuru et al., 2020). Igbo language is the primary language spoken among the people of the area. 'Pigeon' English is also common among the people. According to the National Population Commission (2022), the people of southeastern Nigeria are about 22 million. Agriculture is the main occupation of the people in the rural area; hence are primarily agrarian.

The study shares result from a subset of the findings involving 29 in-depth interviews with agroecology farmers in Southeast Nigeria. The emergence of the agroecology group represented a small part of massive resistance to cases of land grabbing and exclusion of smallholder farmers in the ongoing Agricultural Transformation Agenda (ATA) of the federal republic of Nigeria. The goal of the ATA was to increase the national output and productivity and transform agriculture into a business for stakeholders and not a way of life (NM-NDP, 2021). With the increased government interest in agriculture for business, the Nigerian agricultural structure became characterized by rapid and heavy changes over the last 15 years due to neoliberal trends and the intensification of cash crop production (Bjornlund et al., 2020). Currently, there appears to be a dominance of cash crop agribusiness while food crop production by peasants continues to decline (Chete et al., 2021).

Regarding food security and socioeconomic dimensions, the agricultural transformation agenda has hampered the ability of smallholder farmers to participate in the food system. For instance, the dominance of agri-industrial production has been reported to have implications for access to land and productive resources (Liverpool-Tasie et al., 2016). According to Liverpool-Tasie et al. (2016), smallholder farmers are constrained out of the food system due to a lack of access to land and other productive resources.

The study employed a purposive random sampling method to select the 29 respondents. The interviews were conducted from June to September 2021 by a team comprising one of the authors and two research assistants who were members of the communities. We designed the interview questions in English and Igbo (the local language) to suit the language preference of the respondents. The interviews lasted between 40 and 70 minutes. We also included questions to assess whether the agroecological interventions have played any role in the experiences of food security and dietary diversity. The checklist also contained questions on motivation for joining the agroecology group and the household feeding strategy. We provided informed consent to all the participants who participated in the research. We audiotaped all the interviews with permission and then transcribed for analysis. Interviews conducted in Igbo were transcribed verbatim in Igbo to maintain the fidelity of the narratives and subsequently translated into English. After four months of discussions, between June and September 2021, we also organized a feedback workshop with a group of agroecology farmers interviewed to validate already gathered data with the group members.

The sampling was first on specific socioeconomic characteristics of the farmers that are common across the agroecology group. In general, the selection of the interviews followed this order: First, the households have either a farming activity as income or food source in the past, present, or both. Second, the households have access to land or had in the past. Third, the households had participated in the FADAMA program. To allow for varying perspectives within the group, sampling also included a spectrum of farmers with varying characteristics to compare each group's realities to those of their counterparts. We included farmers who have farming as their primary occupation and those who have off-farm income as well. We also included farmers who receive remittances from abroad or relatives in the city. We included farmers with varying means of land access, ranging from ownership to lease. We had farmers with different age ranges and educational levels. An overview of the 24 households interviewed is presented in Appendix 1. Finally, we conducted several expert interviews to understand better the agroecology group's mechanisms and the FADAMA project's structures. We conducted three expert interviews with the facilitators of the agroecology projects and five semi-structured interviews with stakeholders and policymakers from political institutions, women leaders from the women's organization, and agricultural extension officers. The aim was to capture a balanced narrative of the perceptions of the role of

the agroecology group in improving the food security status of the farmers in the area. An overview of the expert interviews is presented in Appendix 2.

3.2 Method of analysis

The interview transcript analysis followed a 4-step thematic analysis proposed in Braun & Clarke (2022) 's guidebook for thematic analysis (TA). The first step involves familiarization and getting to know our data. At this stage, during and after transcription, we had a thorough overview of all the interviews. We read through the transcribed text, taking initial notes, and generally reading through the discussions to get familiar with the data. In the second step, we coded the data. The analysis involves highlighting segments of our transcription, such as sentences or phrases, and assigning codes (labels or words) that describe their content. The analysis relied on an Excel spreadsheet and MAX-QDA computer software following the procedure suggested by Harwood and Garry (2003). Depending on our literature review (Ume, Nuppenau, & Domptail, 2022), we deductively derived a predefined set of codes and organized the codes into broader categories (See: Harwood and Garry, 2003). The systematic literature review informed the interview process by providing dimensions around which we organized the interviews drawing on concepts of physical reproduction, social reproduction, and household reproduction. The codes retained for the analysis were constructed in an inter-subjective validation strategy. First, based on our literature review, we defined a set of deductive codes (the ones in black letters). Second, we applied this set of codes to two interviews from which we obtained additional inductive codes (these inductive codes are the ones in blue letters). A summary of the codes, the definition, and examples of interview quotes informing and validating the codes are presented in Appendix 3. Each of the 24 interviews was coded in Excel spreadsheet.

The coding process involved reviewing the transcripts and assigning the constructed codes to every statement matching these codes. At the same time, we observed any interesting statements that do not match any of the available codes. We assigned them new codes as we went through the text. These codes provide a condensed overview of the common meanings and main points that recur throughout the text.

The third step involved generating themes by reviewing the codes generated and identifying the patterns among the codes from which the themes will be developed. According to Terry et al. (2021), the themes are broader terms compared to codes. Themes describe multiple codes combined (Onwutuebe, 2019). During the theme formation, some of our codes that did not fit into any theme were discarded because they were vague or irrelevant. The themes and their corresponding codes are presented in Annex 3. In the final stage, we compared the emerging themes with the actual dataset. We made this comparison to ensure that the themes were useful and accurately represented the data. At this point, we adjusted some of them by splitting them into two different themes. When we are sure the theme accurately represents the data, we proceed to the result section by describing the themes in turns.

4.0 Results

4.1 A description of the 'Umuimo" Agroecology group

As stated by the group facilitators, the agroecology group aimed to support the transition toward agroecology-based farming by training farmers to apply different innovative sustainable agroecological farming practices. Participation was voluntary, and farmers in this training formed an informal agroecology group. Apart from agroecological farming, the agroecology farmers established a peer-to-peer network mainly of small-scale female farmers. The groups had a registered smartphone application for peer-to-peer activity among members. As a result of this application and other peer-to-peer meetings and training, the group members were able to produce and share knowledge, thus bridging scientific and traditional knowledge for more sustainable food production. In a 2019 study on the group, members of the group were reported to utilize knowledge systems in new ways by identifying science-based actions which have helped the smallholder farmers to build resilience for food systems and ecosystem services in agricultural landscapes of the region despite the future climate change risks (Emeana, Trenchard, Dehnen-Schmutz, & Shaikh et al., 2018). Apart from knowledge production, the farmers pool their resources, share land and labor, and develop local and crop exchange markets. The agroecology farmers also engage in a barter system of exchange in which group members directly exchange their food for other food they do not have.

A 2021 survey of the group members showed that the majority (83%) are women. 27% percent of the members have no formal education, 43% have a primary-level education, 2% have high school education qualification, 10% have a university education, and 18% have one form of postgraduate certificate or another. Apart from belonging to the agroecology group, some of the members belonged to other groups. For instance, 53% of the group members also belonged to a religious women's group, while 3% belonged to cooperative societies. The agroecology group differs from these other groups, as the common goal is that it bounds farmers with the common objective of transiting to agroecological farming. All the participants interviewed adopted organic farming techniques in soil fertility enhancement and pest control. Our qualitative interviews indicate that the farmers interviewed value reproductive and self-transcendence goals. The farmers believed that adopting agroecology creates a sense of unity and a platform for which women who have common goals and aspirations network to achieve their goals. According to the women interviewed, besides providing social interaction, companionship, and support for each other, adopting agroecology gives them the sense of association to help one another in need, cooperate to achieve goals of increasing food production sustainably, as well as sharing ideas and resources:

> "We are like sisters and brothers in this group; we need to look out for each other in this community. That is how our forefathers used to behave" (Chiamaka, 35 years).
> "family is the foundation of our tradition. I always make sure that my family is taken care of; they have to feed, go to school, and shelter" (Arith, 49, Primary).
> "I learned many things about farming from this group. If I discover new ways of farming, I will share with my fellow farmers, and when others discover anything new, they also share with everyone" (Ojiugo, 38, NFE).

Using case studies from the women interviewed, we present the emerging themes on how adopting agroecology practices and being in the agroecology group influences the status and related decision-making power of the women within the non-monetary and reproductive sphere of the economy, thereby fostering a parallel food system less influenced by capitalism.

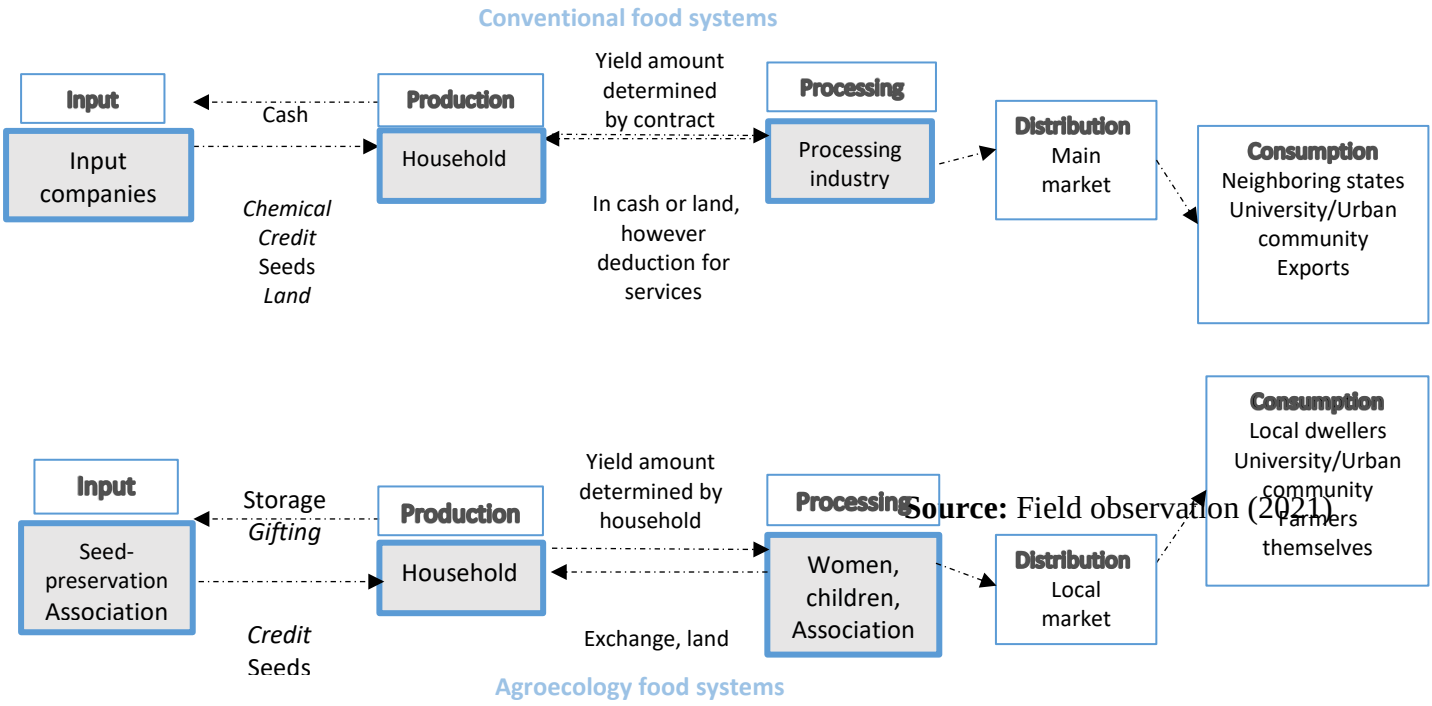
4.2 Parallel food systems

The principle of solidarity observed within the agroecology group due to adopting agroecology practices is also reflected at other stages within the food system, suggesting a parallel system different from the dominant capitalistic food system. The parallel systems could be analyzed at three stages: production, processing, and marketing patterns (Figure 1). In terms of production, some of the interviewers believed that the method of production employed by the agroecology

farmers, which includes organic farming and reduced tillage, makes the agroecology farmers less reliant on fertilizers and tractors that the cooperate food firms supply:

> "…before I use to give the FADAMA [government food organization] my land to farm, sometimes they will do the clearing and the tilling, but now I don't till again, I use the zero-tillage method, now I use my land myself, I don't give anybody my land to work for me" (Ijoma, 36, NFE)
>
> "Capital is no longer a problem for me now (since joining the agroecology group) because when it is my turn to receive the contributions (monthly contribution among the group members), I will always use it to buy the things I need on my farm or very important assets that we need in the house "(Niche, 63, NFE)
>
> "…when they give you fertilizers and give you seed and credit, what do you expect? They will want you to plant what they want." (Charity, 44, Postgraduate)

Figure 1: Conventional and agroecological food system patterns



Source: Field observation (2021)

This means that the agroecology group and producing agroecologically allows the farmers to run a parallel production system less influenced by cash crops and capitalistic contractual arrangements. Such arrangements are also observed at the processing stage (Figure 1). In terms of marketing patterns, by producing organically, the agroecology farmers believed that they could develop a local marketing system less influenced by the dominant capitalistic marketing system.

> "You have been to the IKPA market *[the local market where the agroecology farmers sell organic produce]*. That is where we now sell our produce, and people from

> different parts of the village come to us to buy because they know the value of what we produce" (Okechukwu, 34 Primary).
> "before joining this group, I used to use fertilizer, and I will produce and go to the main market to sell them. Before you reach the main market, your product will be spoiled and not good again, this Ikpa Market is closer to me, and I will be able to sell my goods" (Uchime, 33, NFE).
> "If you give the agents that buy the food from you, they will go to the main market and sell it for you, and when they come back, whatever they have to give you, that is what you will take, but now, I am the one in charge" (Okogbuo, 65, NFE).

Although the farmers produce organically and target customers who value organic foods, we observed low demand and patronage for organically grown foods. Contrasted with the past situation where they had to sell at the central market, the agroecology farmers opined that the emergence of the local market had increased awareness of their products and attracted more patronage. When asked about why she preferred selling at the local market, one of the interviewees responded:

> "I like the agroecology market because the people that come here to buy things know our produce. They know that it is good for their health, unlike in the main market where people see our products as bad products because they look at the appearance. The market (agroecology market) is very close to me, so I don't need to travel far away to the main market to sell my food." (Okogbuo, 65, NFE).

Non-monetary economy

Women's status and decision-making power in a household appears to be more pronounced and made possible when they function within the reproductive sphere and non-monetary economy. When embedded in a monetary economy, the reproductive space and non-monetary economy represent a range of activities such as household work, caregiving, and food self-provisioning that do not have an economic value in the market but remain vital to food security (Jarva, 2016). One pathway disrupted in the Agri-industrial food system is the dominance of capitalism and the associated commodification of food, where households are constrained to the market to achieve food security even as self-provisioning and family care is overlooked. As noted by Ijeoma, one of the agroecology women farmers, self-provisioning was essential in overcoming market variabilities and inflation that resulted during and immediately after the COVID period:

> "In this COVID-19 period, nobody was allowed to go to the market to sell or buy. We were only allowed to go to the market on Wednesdays and Saturdays from 12 noon to 4 pm. So people that used to sell and make money stayed at home because nobody wanted to go and catch the disease. I was the one providing food for the house, my

husband could not go out, and even with his money, we could not use it to buy anything during that time. Many people in this community I was the one that was helping them during the lockdown; nobody in this community was hungry. We exchanged food among ourselves and gave food to people who were not even members of this community. The head of our community told us that he wants to develop our market so that people will be exchanging food instead of using money" (Ijoma, 32, NFE)

Ijoma is a 32-year farmer in the community; she has no formal education but gained her understanding of agroecological practices from the group. She joined the agroecology group in 2017. She married with four children. Together with her husband, agriculture is their primary source of income. Before joining the group, the majority of the family's harvest went to the processing firms who provided inputs for them, and they struggled to feed their family, but since joining the group, they produce their own food; they also have different storage techniques and irrigation to use during the dry seasons and also sell.

Our interview responses showed that agroecology farmers consume more of what they produce instead of depending on the food market. Food grown on the farm has to be seen as an essential part of the farmers' life and not as a commodity meant for the market (Guzmán Luna et al., 2022). This food security strategy shows a feedback relationship between adopting agroecology and self-consumption. For instance, because the farmers depended more on what they produced, they strived to cultivate diverse crops and rare different livestock on their farms:

"the price of food in the market today is not what it will be tomorrow when you go; every day the price continues to rise; things are difficult in this country, so that is why I have to produce different crops and keep different animals in my farm so that I will always find food to feed my family." (Chidinma, 24, Primary)

Conversely, by adopting agroecological methods such as mixed cropping and mixed farming, they have different food to feed their household without depending on the market.

"We were encouraged to grow different things on the farm; there are always a lot of things on my farm, including fresh vegetables; when my children come back from school, they will always have food; if there is no food, my children will go to the farm and harvest vegetables and other things they will use to make soup. So there is no need to think about traveling to the market for food." (Nkechi, 48, Primary)

In some cases, they engage in exchange for produce among themselves. Through the solidarity in the agroecology group, the members engage in food aid and exchanges, ensuring that food is available even in times of scarcity.

> "My neighbor was able to provide my family and me with food because I also give them when they ask me" (Nkechi, 48, Primary)
>
> "We are like family in this group; when I need food or vegetable, and I don't have it on the farm, I can go to one of the colleagues, and if they have, they will give; if I have, I will also give them, we are like sisters from the highest person to the lowest person" (Charity, Postgraduate, 44)

In general, this narrative shows a different perspective on food security, which sees food as a value for household reproduction rather than a commodity for sale in the market.

4.3 Status and related decision-making power

Women's status and decision-making power are essential indicators of the Women's Empowerment in Agriculture Index (WEAI). According to the agroecology farmers, the reproductive goals and activities associated with agroecology, in terms of the application of organic manure, peer–to–peer activities, and local market participation, play critical roles in boosting their level of agency within the household and in the community. Many women interviewed previously had to depend on the government, extension agents, or their husbands for fertilizers, farming knowledge, or land, respectively. However, by adopting different agroecological practices and associating with the agroecology group, they do not need to depend on 'external agents' for these essential inputs.

> "Since I started following this group, I no longer use fertilizers that the government uses to provide for the people. Now that I am using organic manure, nobody demands my produce to repay anything; I will farm the way I want" (Ojiugo, 38, NFE).
> "…they [extension officers] do not come to me; they only come to me when my husband is around, he is the one that brings them, and I also learn from them when he is around". "In this group, I am no longer interested in them [extension service] because I always get the correct information that I need from the agroecology group" (Arith, 49, Primary).
> "Since I joined this group, my husband now allows me to decide on how food is prepared and shared, unlike when he was the one that always provided the money to buy food. When he comes back home, he will see food waiting for him; I don't ask him for money again to buy food" (Arith, 49, Primary).

This narrative suggests a fundamental change in women's societal autonomy after joining the agroecology group and a voice in intra-household farm production decisions and food allocation within the home. This change is induced through several processes, such as reducing their dependence on external inputs, exchange of land and food among the female farmers, and peer-to-

peer knowledge sharing through field days. Almost all the farmers interviewed spoke about their perceived dignity and the elevated status they experience due to taking control over the production process and decisions at home, on the farm, and in the community. One of the women recounted how because she no longer used her husband's land, she was able to channel most of the food produced into feeding the family, unlike before when her husband would sell most of the food they grew and give her only part of the proceeds to take care of the family:

> "One of the women in the group gave me part of her land to cultivate last year; from that land, I provided enough food for the family. I did not collect any money from my husband to buy food; still, everybody in the house fed well. It is not easy, but it is better for me since my family now has enough food. Oga [reverential name given to the head of the household] thought I was not serious as I told him that I didn't need money from him for food; from what I sold, I went ahead to offset the wages of our child's school teacher so that he will be less stressed about. My husband was so happy and, at the same time, amazed. Although I knew these things were just a fraction of what my husband brings to the family, he felt I gave him millions. Then I told him that he should be more relaxed now than when he was single because he did not marry a responsibility, but a helper. That day, Oga cooked the food we ate at the house and served me. This small support made many things right for me in the house. Because of that, my husband decided to give the land to me this year; I am the one taking care of the farm and everything in it. I do not need to ask him [her husband] for money to buy fertilizer or pay young men to come and till the soil for me. I use my compost from our animal farm and household waste. I also use the push-and-pull; before, I did not know anything about push-and-pull; in this group, we were taught how to use it, and it has been helping me a lot. Because of this, we always have food in the house, and my husband has all the time to concentrate on his work at the civil service center" (Ifeyighinwa, 43, Primary).
>
> *Ifeyighinwa is a 43-year farmer in the community; she has basic education, referred to as Primary school education. She is married and has three children, and her husband works with the state agriculture ministry. She described her husband as hardworking and responsible, ready to support her on her farm. For Arith, farming is a primary occupation and the main food source for her children, who are 15 years, 18 years, and 22 years old.*

In the study area, compared to men, women spend a more significant proportion of their time caring for their families and doing domestic work (Kassie et al., 2014; Opata et al., 2020). Expanding women's autonomy will have improved food security impact, e.g., through greater access to resources and control and the ability to make decisions and control what happens to the harvested crops. Thus, women's agency can improve empowerment for food and nutrition security for women and their family members. Besides, the woman's ability to provide enough food for her family was often a source of pride (Anugwa et al., 2020; Ngodoo, 2014).

5.0 Discussion and conclusion

In general, adopting agroecological practices and belonging to the agroecology group provides autonomy for female agroecology farmers in decision-making at two levels – at the household and the community or food system level. According to Sen (2005), famines do not happen in a democratic society that offers an equitable opportunity to exercise voice. At the household level, the ability of women to have a voice and make decisions on food is essential in ensuring food security within the household. At the community level, the capability to act can be enhanced through social movements and by engendering social and political activities capable of reducing barriers to self-actualization (Pattenden, 2018).

5.1 Autonomy and household decision making

Our analysis highlighted the role of adopting agroecological practices and belonging to the agroecology group in enabling the autonomy of female farmers for food security. Such independence begins with the improvement in the decision-making power of women within the non-monetary and reproductive sphere of the economy. At the household level, in many agrarian communities, farming activities and production roles are highly segregated based on gender (Lecoutere & Jassogne, 2016; Ngodoo, 2014). Emphasis on "women's autonomy" is essential, as women are often in charge of the family's food needs. Men, on the other hand, are more often in control of money and cash. Therefore, the commercialization of food will most likely shift the locus of control of food away from women, thereby reproducing inequalities that weaken women's control over food and food production decisions. It is very common for women to produce food crops, but when food crops are commercialized and exported, men tend to take over these types of food crops that women tend to specialize in. The implication is that the Male partners will dominate the control and decisions at the household level, and over time, this systematically leads to the exclusion of women in making critical decisions about food.

In most cases, to continue with the commercialized food system will entail that the women will not be able to participate in the food system on their terms but based on their husbands' decisions. The decision on what to produce and how land should be used is negotiated within the household, and most times, the male in the family predominately has greater access to land (Gafura, 2017). In

rare cases, even when the women legally own the farmland, in our interviews with such women, they still describe the farmland as if it belonged to the man. Therefore, enhanced autonomy of female farmers could benefit from agroecology groups that will provide alternative access to land and resources, as well as relevant farm training and education, especially among women who face gender-based inequities.

5.2 Autonomy and farming systems

At the community level, the agroecology farmers develop a parallel food system different from the dominant commercial system that forces the farmers to produce what the food processors or input suppliers want, as against what the farmers want. For the women to continue growing their crops without depending on external inputs such as chemical fertilizers and pesticides, they will have to employ alternative production methods that rely less on these external production inputs. The interview results in this study showed that the application of agroecology practices helped agroecology farmers maintain their soils and produce food in the long run. Applying the agroecological principle of soil maintenance increases soil fertility and food production even without synthetic fertilizers. Other practices, such as push and pull technology, are essential in improving nitrogen in the soil through the nitrogen-fixing bacteria at the root noodles of the desmodium plants used in the push and pull practice. This narrative corroborates prior findings in the literature (Bezner Kerr et al., 2019; Boillat & Bottazzi, 2020; Park & Maffii, 2017) that suggested that farmers using agroecological farming methods in different parts of Africa can produce sufficient food for the household without depending on external inputs. Adopting agroecology benefits the ecological food system's long-term viability. It creates a territory or space for like-minded farmers to organize into an agroecology group where they can have a voice and make decisions about their food systems. Efforts to address the power and inequality in the food system require that smallholder farmers have the autonomy to act without external influence or control. Our findings show that adopting Agroecological practices provides such independence at the community level. A level of autonomy within the food system gave rise to another food system parallel to the dominant food system. Such a parallel food system depicts what Jarosz (2008) described as an Alternative Food Network (AFN). The characteristics and attributes of the AFN include fair trade, spatial proximity between farmers and consumers, commitment to sustainable food production and consumption, community-supported agriculture (CSA), and the promotion of

local, organic, and premium specialty food. The parallel food system co-evolves with the conventional food system while attempting to change it from within by creating alternative economic spaces to develop different farming methods and value systems that de-emphasize capitalism and cash economy.

The above-discussed dimensions of the agroecology-autonomy-food system nexus provide a background for a better understanding of the four dimensions of food security – availability, access, utilization, and stability, from a more egalitarian perspective. Findings from this study support the idea within the literature on human development and capability approach to food security, which proposes that emphasis should be placed directly on the commodity of interest (food) and not on the money necessary to buy it (Burchardt & Vizard, 2011; Robeyns, 2016; Thompson, 2015). The autonomy approach to understanding food security places emphasis on non-material aspects of food security by incorporating smallholder farmers' rights to define their own food security goals. In this sense, food (in)security is mainly political, as an equitable distribution of power will give farmers equal opportunity (in terms of gender, literacy, race, or other factors outside the control of the female farmer) to participate in political life at home and in the community. According to Ribot & Peluso (2009), exclusion is the flipside of access, and factors that lead to exclusion are essential in understanding access to food. Ribot & Peluso (2009) defined exclusion as "the ways in which people are prevented from benefiting from things." In other words, when smallholder farmers do not have access to productive resources and are excluded from decision- and policy-making, many smallholders are prevented from benefiting from the system. Agroecology food system, therefore, presents an alternative food system that liberates women from the obligation to enter the cash/commercial system in which they are marginalized. Hence, we present the agroecology food system as a food system science concerned with designing agricultural systems based on ecological principles and applicable outside the cash-economy by mobilizing the local production and exchanging production factors (land, labor) and inputs (seeds, knowledge).

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Appendix 1

Overview of interviewees based on interviews conducted between June 2021 and September 2021 (own elaboration)

Name*	Description	Education	Age (Years)	Farm size (Ha)
Chiamaka	Farming as a major occupation, off-farm income, and remittance from abroad, land ownership within the family, married	Primary	35	3
Chidinma	Farming as major occupation, off-farm income, land ownership by rent, single	Primary	24	1
Cynthia	Farming as major occupation, No off-farm income, land ownership by lease from AE group, Married	NFE	43	2
Arith	Farming as major occupation, off-farm income, land ownership by lease from AE group and from husband, Married	Primary	49	1.5
Ijoma	Farming as major occupation, off-farm income, land ownership by lease from AE group, Married	NFE	32	1
Joy	Farming as major occupation, off-farm income, land ownership by lease from AE group, Single	NFE	19	2
Joyce	Farming as minor occupation, Lecturing as major occupation, off-farm income, land ownership within the family, Married	University	29	7
Chinyere	Farming as minor occupation, civil service as a major occupation, off-farm income, land ownership within the family, Married	Primary	36	1
Nnennaya	Farming as major occupation, off-farm income, land ownership by lease from AE group, Married	NFE	27	1
Okechukwu	Farming as Major occupation, no off-farm income but with remittances from abroad, land ownership within the family, Married	Primary	34	1.5
Rose	Farming as minor occupation, Civil service as major occupation, off-farm income and remittances from abroad, land ownership within the family, Married	University	33	3.5
Ifeyighinwa	Farming as major occupation, off-farm income, land ownership by lease from AE group, MArried	Primary	43	2
Ezinne	Farming as major occupation, no off-farm income, land ownership by lease from AE group, Widow	Primary	51	1

Ngwobia	Farming as minor occupation, teaching as major occupation, off-farm income and remittances from abroad, land ownership by lease from AE group, single mother	Primary	29	2
Nnenna	Farming as minor occupation, teaching as major occupation, off-farm income, land ownership by lease from AE group, single mother	Primary	25	2
Ojiugo	Farming as major occupation, off-farm income, land ownership by lease from AE group, married	Primary	44	2
Uchime	Farming as major occupation, off-farm income, land ownership by lease from AE group, married	NFE	33	1.5
Charity	Farming as minor occupation, Lecturing as major occupation, off-farm income, land ownership within the family, Married	Post graduate	44	1
Okogbuo	Farming as major occupation, no off-farm income, land ownership by lease from AE group, Widow	NFE	65	1
Matilda	Farming as minor occupation, Lecturing as major occupation, off-farm income, land ownership within the family, Married	University	39	4
Nkechi	Farming as major occupation, no off-farm income, land ownership by lease from AE group, Married	Primary	48	1.5
Neche	Farming as major occupation, no off-farm income, land ownership by lease from AE group, Widow	NFE	63	3.5
Ifeoma	Farming as major occupation, no off-farm income, land ownership by lease from AE group, Married	Primary	42	1
Chineye	Farming as major occupation, no off-farm income, land ownership by lease from AE group, married	NFE	58	3

*NFE: No formal education, *Pseudo names*

Appendix 2

Overview of expert interviews

Institution or actor	Description
Institutions and policymakers	
Agricultural Development Project	Umbrella body in charge of agricultural extension service in the study area
Catholoic Women Organisation	Women religious groups concerned with the welfare of women n the area
Ministry of agriculture and rural development	The organization's mission is to coordinate and manage the agricultural sector, facilitate agribusiness for increased food security, and promote agro-industrial development
Ministry of women and youth development	It stimulates actions that will promote civic, political, social and economic participation of women
FADAMA programme office	Help local farmers by promoting green revolution strategy
Agroecology facilitators	
Facilitator A	PhD holder and a former extension agent working with the national agricultural extension research institute
Facilitator B	Ph.D. candidate in agroecology.
Facilitator C	Pioneer member of the group, male, in charge of registration and logistics