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Prof. Dr. Andrea Knierim

Seeing through two lenses: Applying actor-centred and structural perspectives to understand farmer innovation and technological change

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Thomas Pircher
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Examination committee:

Head of the examination committee:	Prof. Dr Thilo Streck
Supervisor and reviewer:	Prof. Dr. Andrea Knierim
Co-reviewer:	Dr. Conny Almekinders
Additional examiner:	Prof. Dr. Georg Cadisch

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List of abbreviations

ADP	Agriculture Development Program
AIS	Agricultural Innovation System
AKADEP	Akwa Ibom State Agricultural Development Program
BASICS	Building an Economically Sustainable, Integrated Seed System for Cassava in Nigeria
BNARDA	Benue Agricultural and Rural Development Authority
CABDA	Community Area-Based Approach
CGIAR	Global research partnership for a food-secure future
CIAT	International Center for Tropical Agriculture
CIP	International Potato Center
CRS	Catholic Relief Service
DRC	Democratic Republic of the Congo
EaTSANE	Education and Training for Sustainable Agriculture and Nutrition in East Africa
FGD	Focus group discussions
GIS	Geographic Information System
GMO	Genetically modified organism
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFDC	International Fertilizer Development Center
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
ISP	Innovation support provider
ISS	Innovation Support Services
IUCN	International Union for Conservation of Nature
KALRO	Kenya Agricultural and Livestock Research
LGA	Local Government Area
MAAIF	Ministry of Agriculture, Animal Industry and Fishery
MEC	Means-Ends-Chain
MoEST	Ministry of Education, Science and Technology
NARO	National Agriculture and Food Research Organization
NASC	National Agricultural Seed Council
NGO	Non-governmental Organization
NRCRI	National Root Crop Research Institute
OFSP	Orange fleshed sweet potato
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RFN	Relatives/friends/neighbours
RTB/RT&B	Roots, Tubers and Bananas
SDG	Sustainable Development Goal
UN	United Nations
USD	US Dollar
VSE	Village seed entrepreneur
WTP	Willingness to pay
WUR	Wageningen University & Research

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Summary

Science and technology can make a major contribution to ending hunger, achieving food security and improving nutrition. Developing and spreading of innovations in agriculture and nutrition therefore is a main objective of international agricultural research. Despite decades of research, understanding the complex processes around technological change by small-scale farmers remains a challenge for researchers. Whereas behavioural approaches often neglect the influence of the wider innovation systems, approaches that focus on larger systemic challenges tend to downplay human agency. Research approaches that analytically differentiate structural and actor-centred perspectives and their interplay hold potential for more nuanced understanding of farmer innovation and technological change.

This thesis reviewed and explored the application of approaches that aim to understand farmer innovation and technological change through the interplay of two analytical lenses: actor-centred and structural. The three empirical research studies addressed different aspects of agriculture and nutrition, and included multiple study locations. Although each of the studies had its own objectives, they all relate to analytical dualism. In this regard, the study approaches separately focused on actor-centred and structural perspectives, and analysed how these influenced each other. Data collection and analysis in the empirical chapters followed these principles by developing and applying adapted conceptualisations of seed systems and agricultural innovation systems.

The systematic literature review in Chapter 2 provided an overview on methods for studying farmers' choices and demand for seed of roots, tuber and banana crops. The review identified 46 studies in which researchers studied various aspects and types of farmers' demand for seed of five crops in 18 countries. The qualitative analysis and categorization of the identified studies have led into a classification scheme. In one type of studies farmers expressed their preferences and choices through surveys or engagements in trials, auctions, choice experiments and interviews (explicit demand articulation). In another types of studies, researchers characterized farmers' use of varieties through determinants of adoption, current seed management practices or the functioning of their seed and farming systems (implicit demand articulation).

The study of the cassava seed system in Chapter 3 developed and applied a research approach that recognizes the interplay between farmer's demand for seed and the seed supply functions of the cassava seed system in Nigeria. The farmers maintained and gradually replaced a portfolio of varieties from multiple sources that reflected individual trait preferences. The national agriculture development program alone did not have the capacity to supply farmers with sufficient seed of desired varieties. Exchange between farmers and informal seed sellers contributed to the distribution of seed and new varieties. Informal seed sellers and decentralized seed multipliers have the potential to respond to farmers' heterogeneous demands. However, they would need continuous support from formal seed system actors to reach underserved markets.

The study of innovation and scaling in Kenya and Uganda in Chapter 4 analysed innovation processes in agriculture and nutrition through farmer-centred and structural perspectives. In an international research and development project, researchers introduced farmers to new agriculture and nutrition practices in action learning activities. The farmers selected, adapted and combined the promoted practices according to their individual preferences and needs. In addition to the researchers from the project, a wide range of innovation support providers encouraged farmers to develop innovations in farming, marketing, and nutrition. Promoting farmer innovation processes beyond the project sites and duration would require the engagement of multiple innovation support providers in creating an enabling environment for experimentation and demand articulation.

Analysing the empirical chapters with the overarching theoretical framework of the thesis highlights how structural conditions of seed systems and agricultural innovation systems influenced farmer innovation or technological change processes. The cases also illustrate how farmers reacted upon these conditions through social interactions. As a major finding, the analysis points out that the process of structural elaboration – how the agency of farmers influenced structural conditions - remains limited across the empirical chapters. This indicates a need to empower actors in articulating their demands for research and extension services and shaping their institutional environments.

Based on the general discussion, the thesis recommends (1) the use of interdisciplinary frameworks that combine different streams of research to study farmers innovation and technological change, (2) institutionalizing demand articulation in seed systems and agricultural innovation systems, (3) creating a shift of mindset from linear technology transfer towards technological change as a complex and interactional process. The thesis concludes by pointing out limitations of the study, and further research needs. These involve combining in-depth behavioural studies with comprehensive systems analysis, carrying longitudinal research for studying farmer innovation and technological change, and action research on structural elaboration processes to guide institutional change.

Zusammenfassung

Wissenschaft und Technologie können einen wichtigen Beitrag zur Beendigung des Hungers, zur Erreichung der Ernährungssicherheit und zur Verbesserung der Ernährung leisten. Die Entwicklung und Verbreitung von Innovationen in Landwirtschaft und Ernährung ist daher ein Hauptziel der internationalen Agrarforschung. Trotz jahrzehntelanger Forschung bleibt das Verständnis der komplexen Prozesse rund um den technologischen Wandel durch Kleinbauern eine Herausforderung für die Wissenschaft. Während verhaltensorientierte Ansätze häufig den Einfluss der umfassenderen Innovationssysteme vernachlässigen, neigen Ansätze zur Lösung von systemischen Herausforderungen, das menschliche Handeln herunterzuspielen. Forschungsansätze, die strukturelle und akteurszentrierte Perspektiven und deren Zusammenspiel analytisch differenzieren, haben Potenzial für ein differenzierteres Verständnis von bäuerlicher Innovation und technologischem Wandel.

In dieser Arbeit wurde die Anwendung von Ansätzen erforscht, die bäuerliche Innovation und technologischen Wandel durch das Zusammenspiel von zwei analytischen Linsen untersucht: einer handlungsbezogenen und einer strukturbezogenen. Die drei empirischen Forschungsarbeiten behandelten unterschiedliche Aspekte von Landwirtschaft und Ernährung und umfassten mehrere Untersuchungsstandorte. Obwohl jede der Studien ihre eigenen Ziele verfolgte, beziehen sie sich alle auf den analytischen Dualismus. In dieser Hinsicht konzentrierten sich die Studienansätze getrennt auf handlungsbezogene und strukturbezogene Perspektiven und analysierten, wie diese sich gegenseitig beeinflussen. Die Datenerhebung und -analyse in den empirischen Kapiteln folgte diesen Prinzipien, indem angepasste Konzeptualisierungen von Saatgutsystemen und landwirtschaftlichen Innovationssystemen entwickelt und angewendet wurden.

Die systematische Literaturrecherche in Kapitel 2 gab einen Überblick über Methoden zur Untersuchung von Auswahl und Bedarfen von Landwirten zu Saatgut von Wurzel-, Knollen- und Bananenkulturen. Dabei wurden 46 Studien ermittelt, in denen Forscher verschiedene Aspekte und Typen von Bedarfen der Landwirte nach Saatgut von fünf Kulturpflanzen in 18 Ländern untersucht haben. Die qualitative Analyse und Kategorisierung der identifizierten Studien hat zu einem Klassifizierungsschema verholfen. In einer Art von Studien drückten die Landwirte ihre Präferenzen und Entscheidungen durch Umfragen oder die Teilnahme an Versuchen, Auktionen, Choice-Experimenten und Interviews aus (explizite Bedarfsartikulation). In einer anderen Art von Studien charakterisierten die Forscher die Nutzung von Sorten anhand von Adoptionsfaktoren, aktuellen Saatgutmanagementpraktiken oder der Funktionsweise ihrer Saatgut- und Farmsysteme (implizite Bedarfsartikulation).

In der Studie über das Manioksaatgutsystem in Kapitel 3 wurde ein Forschungsansatz entwickelt und angewandt, der das Zusammenspiel zwischen dem Bedarf der Landwirte nach Saatgut und den Funktionen des Saatgutangebots des Manioksaatgutsystems in Nigeria aufzeigt. Die Landwirte unterhielten und ersetzten nach und nach ein Portfolio von Sorten aus verschiedenen Quellen, die individuelle Merkmalspräferenzen widerspiegelten. Das nationale Landwirtschaftsentwicklungsprogramm allein war nicht in der Lage, die Bauern mit

ausreichend Saatgut der gewünschten Sorten zu versorgen. Der Austausch zwischen Bauern und informellen Saatguthändlern trug zur Verbreitung von Saatgut und neuen Sorten bei. Informelle Saatguthändler und dezentrale Saatgutvermehrer haben das Potenzial, auf die heterogenen Bedarfe der Bauern zu reagieren. Sie bräuchten jedoch kontinuierliche Unterstützung durch die Akteure des formellen Saatgutsystems, um unzureichend versorgte Märkte zu erreichen.

In der Studie über Innovation und Skalierung in Kenia und Uganda in Kapitel 4 wurden Innovationsprozesse in der Landwirtschaft und Ernährung aus bäuerlicher und struktureller Perspektive analysiert. Im Rahmen eines internationalen Forschungs- und Entwicklungsprojekts stellten Forscher den Bauern im Rahmen von Action-Learning-Aktivitäten neue Landwirtschafts- und Ernährungspraktiken vor. Die Landwirte wählten, adaptierten und kombinierten die vorgestellten Praktiken nach ihren individuellen Präferenzen und Bedürfnissen. Darüber hinaus ermutigte ein breites Spektrum an Innovationsunterstützern die Landwirte, Innovationen in den Bereichen Landwirtschaft, Vermarktung und Ernährung zu entwickeln. Die Förderung bäuerlicher Innovationsprozesse über die Projektstandorte und -dauer hinaus würde das Engagement mehrerer Innovationsunterstützer zur Schaffung eines förderlichen Umfelds für bäuerliche Forschung und Bedarfsartikulation erfordern.

Die Analyse der empirischen Kapitel mit dem übergreifenden theoretischen Rahmen dieser Arbeit zeigt, wie die strukturellen Bedingungen der Saatgutsysteme und der landwirtschaftlichen Innovationssysteme bäuerlichen Innovations- oder technologische Veränderungsprozesse beeinflussten. Die Fälle veranschaulichen auch, wie die Landwirte auf diese Bedingungen durch soziale Interaktionen reagierten. Ein wichtiges Ergebnis der Analyse ist, dass der Prozess der strukturellen Umgestaltung - also die Art und Weise, wie die Landwirte die strukturellen Bedingungen beeinflussten - in allen empirischen Kapiteln eingeschränkt bleibt. Dies verdeutlicht, dass die Akteure in die Lage versetzt werden müssen, ihre Bedarfe an Forschungs- und Beratungsdienstleistungen zu artikulieren und ihr institutionelles Umfeld mitzugestalten.

Auf der Grundlage der übergreifenden Diskussion empfiehlt die Arbeit (1) die Verwendung interdisziplinärer Rahmenwerke, die verschiedene Forschungsstränge zur Untersuchung von Innovation und technologischem Wandel bei Landwirten kombinieren, (2) die Institutionalisierung der Bedarfsartikulation in Saatgut- und landwirtschaftlichen Innovationssystemen, (3) die Schaffung eines Mentalitätswandels vom linearen Technologietransfer hin zu technologischem Wandel als komplexem und interaktionalem Prozess. Die Arbeit schließt mit dem Hinweis der Grenzen der Studie und weiteren Forschungsbedarf. Dazu gehören die Verknüpfung eingehender Verhaltensstudien mit umfassenden Systemanalysen, die Durchführung von Langzeitstudien zur Untersuchung bäuerlicher Innovation und des technologischen Wandels sowie die Aktionsforschung zu strukturellen Umgestaltungsprozessen um institutionellen Wandel zu fördern.

Chapter 1

General Introduction

1 General Introduction

This introductory chapter starts with providing a background on the importance of and challenges in understanding farmer innovation and technological change. Based on a specified problem statement, the research objectives are defined. The theories and key concepts that will be used across all chapters of the thesis are introduced in an overarching conceptual framework. Finally, the study context and the methods applied in data collection and analysis in the following empirical chapters are described, and an outline of the thesis is provided.

1.1 Introduction

Hunger and malnutrition continue to affect millions of people worldwide, and are exacerbated by the COVID-19 pandemic and other crises (FAO, IFAD, UNICEF, WFP, & WHO, 2019). Small-scale food producers and family farmers require much greater support in infrastructure and technology for sustainable agriculture than currently to reach Sustainable Development Goals (SDGs), in particular SDG 2 on ending hunger, achieving food security and improved nutrition (UN, 2019a). The UN recognized the role of science and technology already since the 1960s and in 2015 formally positioned it as key means of implementation of the SDG through the Technology Facilitation Mechanism (UN, 2019b). In the Global South, improved farming technologies are widely considered as one essential ingredient to make small-scale farming systems more sustainable, productive and resilient to crisis. International research and development initiatives are therefore supporting the development and spread of innovation and technology in agriculture and nutrition, such as crop genetic improvement, mechanization, digitalization, and sustainable land management practices (e.g., CGIAR, 2021). Therefore, studies to understand the adoption of newly introduced technologies and its effects on farmers' livelihoods remain central to agricultural research and decision-making about new investments (Glover, Sumberg, & Andersson, 2016).

Glover et al. (2016) argue that the concept of technology adoption is widely used, but does not sufficiently capture the process of farmer innovation and technological change. Understanding the dynamical processes and interactions with a wide range of actors that influence farmers' technology use requires a systems perspective (e.g. Knickel, Brunori, Rand, & Proost, 2009). One conceptualization of such a perspective is farming systems, which are characterized as complex adaptive systems that undergo constant re-organisation to cope with unexpected events, and to adapt to changing agro-ecological, social and economic conditions (Darnhofer, Bellon, Dedieu, & Milestad, 2009; Hall & Clark, 2010; Spielman, Ekboir, & Davis, 2009). The concept emphasizes that farmers dynamically and flexibly respond to external conditions by re-configuring their farm structure, activities and objectives in order to increase sustainability and resilience (Darnhofer et al., 2009). This process is not limited to a farm level, but involves a wide range of other actors, such as input suppliers, processors, traders, researchers, extensionists, and civil society organizations

(Leeuwis & van den Ban, 2004; Röling, 2009). The focus of development-oriented agricultural research therefore shifted from a farming system to an agricultural innovation system perspective, which involves a wider set of stakeholders beyond the farm level (Darnhofer et al., 2009; Klerkx, Darnhofer, Gibbon, & Dedieu, 2012; Sanginga, Waters-Bayer, Kaaria, Njuki, & Wettasinha, 2012; Scoones, Thompson, & Chambers, 2009).

From an agricultural innovation system perspective, innovation is considered as a function between institutional and technical change (Röling, 2009), or a successful combination of technology (hardware), knowledge (software) and organizational or institutional conditions (orgware) (Leeuwis & van den Ban, 2004; Smits, 2002). As such, a systems perspective on technology use is particularly important for understanding institutional change needed to create an enabling environment for innovation. The behaviour of systems is determined by its structures, such as physical infrastructures, laws and culture, and interactions thereof. In particular, the relations between component structures constitute emergent features of a social system (Archer, 1995, p. 172). When placing focus on systems or structural perspectives to study technological change, such approaches tend to downplay the individual agency of actors, i.e to take action on their own behalf (de Haan & Rotmans, 2018; L. B. Fischer & Newig, 2016; Scoones et al., 2020). Also socio-technical system researchers call for more attention to the role of individuals and decision-making to bridge the divide between macro and micro level (Markard & Truffer, 2008; Upham, Bögel, & Dütschke, 2020).

A related aspect that is often omitted in systems literature is the (social) differentiation of actors and power relationships within actor groups (Avelino & Wittmayer, 2016). For example, agricultural innovation system and food system literature only scarcely reflects aspects of gender dynamics and social inclusion as it is overlooking different types of farmers (Badstue, Petesch, et al., 2018; B. Davis, Lipper, & Winters, 2022; Pyburn & Woodhill, 2014). This creates a major shortcoming as human agency and social differentiation are crucial for empowering individuals and communities through technology use, particularly in the highly variable context of African farming systems (Adam, Badstue, & Sindi, 2018; Badstue, Lopez, et al., 2018; Gassner et al., 2019). Understanding farmers socially differentiated technology use, while recognizing human agency, requires approaches that place farmer innovation and technological change in the centre of analysis. The actor-oriented approach by Long (1990) emphasizes the heterogeneity of actors, practices and social context (Tröger, 2019). In Long's actor-oriented sociology, "actors are capable (even within severely restricted social space) of formulating decisions, acting upon them, and innovating or experimenting" (Long, 1990, p. 8). Also Glover et al. (2019) suggest a framework for technological change that is actor-oriented, recognizes different kinds and loci of agency; and propose a more processual understanding of technology. In that framework, due attention is paid to actors' agency by explaining how and why a proposed change in technical inputs and practices may be appreciated and taken up in particular ways by different farmers.

1.2 Problem statement and research objectives

A recent analysis of initiatives that aimed at addressing complex sustainability challenges through co-production of research and practice pointed out that the analysed projects struggled to navigate tensions between agency and structure. While promoting agency posed the risk of failing to address the roots of sustainability problems, addressing big systemic challenges could disempower individual agency (Chambers et al., 2021). The interdependence between structure and agency was emphasized much earlier in social theories (e.g. Bourdieu, 1977; Giddens, 1984) as well as in more recent literature related to farmers' technology use (Engler, Poortvliet, & Klerkx, 2019; Feola & Binder, 2010; Kennedy & Liljeblad, 2016, p. 11; Klerkx, Darnhofer, et al., 2012). For example, literature on agricultural innovation systems highlights the self-organization character of innovation systems, in which systems and agency are mutually constitutive of each other; i.e. "innovation does not only involve adaptation to prevailing contextual conditions, but also the active influencing, redesign, or destruction of pre-existing conditions and institutional frameworks" (Klerkx, Schut, Leeuwis, & Kilelu, 2012, p. 54).

Meijer et al. (2015) proposed an analytical framework for studying the adoption of agricultural innovations by simultaneously taking account of both extrinsic (referring to structural conditions) and intrinsic factors (referring to farmers agency) and their interactions. Research efforts that pay attention to the mutually constitutive effects of structure and agency can lead to a more comprehensive understanding of innovation processes. However, they also carry the risk of conflating the interplay between these perspectives in its operationalization into research approaches. Margaret Archer (2003) argues that it is possible to unpick both perspectives analytically in order to investigate their internal causal dynamics. Hence, research approaches that analytically differentiate structural and actor-centred perspectives and their interplay may lead to a more nuanced understanding of farmer innovation and technological change.

Research approaches to study socially differentiated farmer innovation and technological change through an actor-centred perspective were applied across different agricultural technologies, such as seed (Addison & Schnurr, 2016; Tadesse, Almekinders, Schulte, & Struik, 2017; Urrea-Hernandez, Almekinders, & van Dam, 2016), soil fertility management (Knowler & Bradshaw, 2007; Pircher, Almekinders, & Kamanga, 2013) or agroforestry (Jerneck & Olsson, 2013). Farmer innovation and technological change were also studied on different scales and levels with structure-oriented systems perspectives (for an overview of studies and methods see Klerkx, Darnhofer, et al., 2012; Spielman et al., 2009). The importance to design and explore new research approaches that integrate structure and agency perspectives has been emphasized by scholars (de Haan & Rotmans, 2018; Feola & Binder, 2010; Markard & Truffer, 2008; Thompson & Scoones, 2009). However, there is still very little conceptual and methodological work that distinguishes the explanatory power of structural and actor-centred perspectives and builds on their interplay for understanding farmer innovation and technological change. To address this research gap, the overall objective of this thesis is

to contribute empirical evidence on explanatory power of approaches to study farmer innovation and technological change from structural and actor-centred perspectives, and their interplay

One aspect of small-scaling farming that receives much attention in international agricultural research is the use of new crop varieties that meet the food, nutrition and income needs of producers and consumers, respond to market demand, and provide resilience to environmental challenges (CtEH, 2022). To realize a widespread use of improved crop varieties with adapted breeding programs and more effective seed delivery channels, a better understanding of farmers' demand for seed is needed (McEwan et al., 2021; Thiele et al., 2020). However, it has been indicated that methods to study farmers' demands have weaknesses, in particular that the methods fall short in capturing farmers' demands in relation with seed systems as a whole and overlook the contextual and socially differentiated preferences (Almekinders et al., 2019). In order to identify reasons for these weaknesses and improve the application of these methods in the future, the first research objective of this thesis is

to understand what the application of existing research methods – from both actor-centred and structural perspectives – discloses about various aspects of farmers' demand for seed.

Based on the findings from the first research objective, an integrated approach to understand farmers' choices and demands for seed was developed and applied to understand the interaction of farmers' demand with the cassava seed system in Nigeria. The second research objective therefore is

to identify the interplay between farmers' demand for seed (actor-centred perspective) and the supply functions of the cassava seed system in Nigeria (structural perspective).

To widen the scope of this thesis beyond the topic of seed system research, a research approach with a similar orientation was developed and applied in a study on innovation and scaling of sustainable agriculture and nutrition practices in Kenya and Uganda. Differentiated analytical lenses with a focus on structure and agency were applied to understand the influence of farmers' motivations and structural conditions in the use innovations promoted by a research and development project. The analysis of farmer innovation processes through the interplay of these perspectives informed the design of a scaling strategy for the project. The third research objective therefore is

to identify the interplay between farmers' motivations for using agricultural and nutrition practices (actor-centred perspective) and the influence of the agricultural innovation systems in Kenya and Uganda (structural perspective).

1.3 Conceptual framework

The conceptual framework introduces the main theories, concepts and approaches that are applied in the following empirical chapters and the general discussion of this thesis.

1.3.1 Innovation, demand and scaling

The term “innovation” refers to the implementation of new concepts, ideas, inventions. As such, an innovation requires either to be put into active use or to be made available for use by other parties, firms, individuals or organisations (OECD/Eurostat, 2018). The definitions by the OECD/Eurostat (2018) distinguishes use of the term innovation for an activity and the outcome of the activity:

> *An innovation [the outcome] is a new or improved product or process (or combination thereof) that differs significantly from the unit’s previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process). Innovation activities include all developmental, financial and commercial activities undertaken by a firm that are intended to result in an innovation for the firm.”.*

In relation to agriculture, the term innovation has been described as “everything that is new for an individual; a community or something that someone has not yet known or received that may help in doing things better, making things easier or solving problems etc.” (Knierim et al., 2015). In relation to this definition, innovations can be distinguished in four forms: Product innovation (goods or services with improved characteristics or intended uses), process innovation (new or significantly improved production or delivery methods), market innovation (new marketing method, such as changes in product design or packaging, product placement, product promotion or pricing), and organisational innovation (new organisational method, collaboration organisation or external relations) (Inventta 2015 in Knierim et al., 2015).

Relating to product innovation, this thesis places its main focus on technologies in agriculture and nutrition as an outcome of a process that can be described as “technological change” (Glover et al., 2019). The authors stress that this process is often oversimplified as the decision to adopt or not, while the farmers’ responses to new technological opportunities are not sufficiently considered. Researchers have pointed out that human perceptions and the social nature of many choices are influenced by perceptions and values and by the activities of other members of the rural community (Darnhofer, Gibbon, & Dedieu, 2012a). Understanding farmers’ technological change hence requires insights into decision making processes, which can be influenced by intrinsic and extrinsic factors (Meijer et al., 2015). Farmers’ perceptions of technologies, their aspirations and livelihood aspirations were identified as main intrinsic drivers for technological change and need to be understood better to improve the targeting of technology development (Mausch et al., 2018).

To address underlying factors that gear farmers' technological change in the future, the concept of "demand" provides an entry point. Demand has been used differently by economists and sociologist (McMeekin, Tomlinson, Green, & Walsh, 2002). The economist view of demand refers to the quantity of a good that consumers are willing and able to purchase at various prices during a given period of time (O'Sullivan & Sheffrin, 2003). The sociologist view of demand has been used to describe demand as a driver of innovation processes. As such, the concept has evolved from "user needs", which refers to the quality of a product or properties of a service (Peine & Herrmann, 2012). These needs are not necessarily linked to already existing products and services, and can be latent, vague and potentially unlimited (Boon & Edler, 2018). By now, the term "need" has largely disappeared from innovation studies, but qualitative aspects and less defined needs or visions have been included in the use of the concept "demand" (Godin & Lane, 2013). For example, Boon (2008, p. 46) defines demand as "explicit, univocal statements of actors on how they regard (the future concerning) a technology […]". Such forms of demand are also referred to as "substantive demand" or "substantive needs" (Boon, 2008; Klerkx, de Grip, & Leeuwis, 2006; Leeuwis & van den Ban, 2004). In this thesis, demand is broadly used as less explicit needs of farmers regarding the use of seed and innovations in agriculture and nutrition.

In international agricultural research for development, researchers made substantial efforts to increase the widespread adoption of innovations, which is conceptualized as "scaling of innovations". These efforts have started already long time ago with rather linear perspectives of technology transfer, dissemination and adoption (Rogers, 1962), and recently highlighted systemic perspectives on scaling innovations that take into account complex interactions between biophysical, social, economic and institutional factors (Wigboldus et al., 2016). By building on the latter view, it was pointed out that successful scaling strategies need conceptual and methodological clarity (What should be scaled, where, when, how much, for whom, by whom, and why?) and create transformation process towards sustainable systems change (Woltering, Fehlenberg, Gerard, Ubels, & Cooley, 2019). Recent studies propose an agenda for the science of scaling that includes (1) developing systematic approaches that highlight conditions and dynamics that affect innovation and scaling processes; (2) creating scaling strategies that nurture efficient and responsible scaling with new approaches, concepts and tools, and (3) creating a conducive environment for scaling innovation (Schut, Leeuwis, & Thiele, 2020).

1.3.2 Structural perspectives and system thinking in agriculture and nutrition

In general, systems consist of components, relationships and attributes (Carlsson, Jacobsson, Holmen, & Rickne, 2002). The components make up the operating parts of a system and include individuals, organisations, and technological artifacts. These elements can be of similar type (e.g. humans in human societies) or different types (e.g. animal and plants in an ecosystem) (Knierim, Laschewski, & Boyarintseva, 2018). The links between the components define their relationships, which lead to interactions. The interactions in systems go beyond linear cause-effect relationships but entail complex interactions among multiple components, which are called feedback loops (Morecroft, 2010). The greater the extent of interaction among the components of a system, the more dynamic the overall system becomes (Carlsson et al., 2002). The properties that emerge from those interactions are attributes of a systems. These attributes of systems can be properties its components do not have on their own – "the system is more than the sum of its parts". To separate a system from the system environment and from larger systems which it is part of, the definition of boundaries is necessary.

The use of systems concepts for analysis varies across different strands of systems thinking that have evolved over time (Ison, 2017; Leeuwis & Wigboldus, 2017; Reynolds & Howell, 2010). These perspectives represent different ways of thinking about natural and social systems and how they can be influenced (see Table 1.1). A well-established distinction among systems approaches is into "hard" and "soft" system thinking (Ison, 2017; Reynolds & Howell, 2010). Hard system thinking considers systems as entities or structures that exist in the "real world" (ontologies). Such approaches are largely used in 'hard' sciences, i.e. based on data from physical, chemical, physiological and ecological processes, and can be usefully applied to natural systems (Darnhofer et al., 2012a). Soft systems thinking considers systems as social constructs and are used as heuristic devices (epistemologies). In this view, systems are artefacts - they do not exist in reality but are constructed for a particular purpose to study (Checkland, 2000). As such, the researcher and other stakeholders with their perceptions and worldviews are central. They decide on the boundaries of the system at focus, and the components and attributes to analyse.

Table 1.1. Different ways of thinking about natural and social systems (adapted from Leeuwis & Wigboldus, 2017, p. 322)

Type of systems thinking (origin and/or literature sources)	**Key metaphor**	**Assumption depicting how systems are seen**	**Key change strategy implied**
Hard system thinking *(scientific management, Taylor, 1947)*	Machines	Interactions in natural and social systems can be known and predicted	Engineer and optimize towards a given goal
Functionalist systems thinking (*human relations management, Roethlisberger and Dickson, 1961; structural functionalism, Parsons, 1951)*	Organisms	Systems are functional wholes, depending on relations between components and environment	Re-balance and adapt in a changing environment
Soft systems thinking (*Churchman, 1979; Checkland, 1981)*	Meanings	Systems consist of people with different worldviews and boundary definitions	Foster dialogue, learning and agreement among actors
Cognitive/autopoietic systems thinking *(Luhmann, 1984; Maturana and Varela, 1984)*	Psychic prisons	Biological and social systems tend to perceive the world through their own logic and be blind to others	Shock therapy by creating a crisis
Political/critical systems thinking *(Jackson, 1985; Ulrich, 1988)*	Arenas of struggle	Systems are characterized by power structures that constrain system change	Coalition building, competition and negotiation
Social/institutional systems thinking *(Giddens, 1984; North, 1990)*	Rules	Formal and informal rules are produced and reproduced in interaction, resulting in certain orders	Change rules and incentive structures

The concept of systems (thinking) has been used in agriculture and nutrition for long time to emphasize a holistic perspective on farming and the broader environment where these activities are embedded. The systems concept has been prominently applied in socio-technical systems (Geels, 2002, 2004), farming systems research (Darnhofer, Gibbon, & Dedieu, 2012b), food system conceptualizations (Ericksen, 2008; HLPE, 2017; Ingram, 2011), agricultural innovation systems (Hall, Janssen, Pehu, & Rajalahti, 2006; Klerkx, Schut, et al., 2012), and seed systems (Almekinders, Louwaars, & de Bruijn, 1994; Christinck et al., 2018). Despite the frequent and intensive use, the common epistemology of these system concepts is still often used implicitly and systems researchers do not necessarily have a shared understanding of how these systems function (Darnhofer et al., 2012b; Leeuwis & Wigboldus, 2017). Therefore, the use of system concepts requires to define its components, boundaries, and the interactions between components depending on context, level, and purpose of application in which an individual or a group has an interest (Ison, 2017).

In agricultural innovation systems, there are three different strands of thinking on how a system can be interpreted: an infrastructural view, a process view, and a functionalist view (Klerkx, Darnhofer, et al., 2012). To conceptualize the cassava seed system in Nigeria (Chapter 3), a functional systems perspective was chosen to explain the overall functioning of a system by the functioning of sub-systems and their interactions (Parsons, 1951). This kind of systems thinking draws upon a biological analogy, in which a living body (the systems as a whole) cannot function well if its organs and their interactions (sub-systems) are not performing its basic functions. Functionalist systems approaches tend to focus mainly on the macro level of a system. Therefore, individual action is to be explained in terms of system functioning, and thus considered rather static and passive (Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007). Building on the functionalist perspective, a structural-functional analysis combines the analysis of structures, i.e. the components that make up the system (actors, networks and institutions), and functions, i.e. how these elements work in support of the overall system performance (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2005; Schiller, Klerkx, Poortvliet, & Godek, 2020).

To analyse the agricultural innovation systems in Kenya and Uganda and understand interactions and activities of actors involved in an innovation process (Chapter 4), the thesis adopted a procedural system perspective. As such, innovation systems are considered self-organizing constellations of actors that are connected with the purpose of developing a certain novelty (Klerkx, Darnhofer, et al., 2012). This perspective has been applied to understand innovation systems by characterizing its actors' activities and the roles they have in the different phases in innovation processes (Kernecker, Busse, & Knierim, 2021; Koutsouris & Zarokosta, 2020). Actors can take a role of innovation support providers that perform activities as innovation support services (Faure et al., 2019; Koutsouris & Zarokosta, 2020; Mathe et al., 2016; Ndah, Knierim, Koutsouris, & Faure, 2018). These can include activities of the following criteria (1) awareness and exchange of knowledge, (2) advisory, consultancy and backstopping, (3) demand articulation, (4) networks, facilitation and brokerage, (5) Capacity building, (6) enhancing/supporting access to resources, (7) institutional support for niche innovation and scaling mechanisms stimulation (Faure et al., 2019).

1.3.3 Actor-centred approaches and the influence of human agency in decision making

While systemic perspectives reveal the inherent complexity of system interactions around technological change, they are criticized for diminishing the role of individual agency to interpret rules and arrangements resulting from these (Scoones et al., 2020). The relevance of actor-centred approaches to explain decision-making has been emphasized, particularly in relation to user acceptance and diffusion of technological innovations (Upham et al., 2020). To encounter the image of farmers as passive recipients of technological innovations, in the 1970s and 1980s a range approaches were put forward that place farmers at the centre of the innovation process and recognize the value of local knowledge (Scoones et al., 2009). By challenging the notion of 'technology transfer', actor-centred perspectives recognize innovation processes of packaging, unpacking, and a situated reconfiguration to adapt technologies to site-specific conditions (Glover, Jean-Philippe, & Maat, 2017). For example, the conceptual framework of 'agriculture as a performance' by Richards (1993; 1989) highlights the real-time technology adaptation of farmers to react to changing agro-ecological and socio-cultural conditions. Like a musical or theatrical endeavour, small-scale farming is described as a performance that is situated in a particular time and place, and shaped by its surrounding socio-cultural and ecological context. Long (1990, 2001) likewise advocates an actor-oriented analysis which stresses the interplay between internal (perceived experience of events and behaviour) and external factors (structural circumstances, culture, and context). As such, the actor-oriented approach explains individual choices and practices as a constant re-working of existing cultural repertoires, learned behaviour and the ways in which people improvise and experiment as a response to their structural circumstances and cultural context. By placing people in the centre of analysis, these approaches recognise different kinds and loci of agency in technological change processes.

Agency is defined as the ability to take action, i.e. "'make a difference' to a pre-existing state of affairs or course of events" (Giddens, 1984, p. 14). In this, Giddens emphasizes the capacity of "doing things", instead of "intentions to do things". This results in consequences that are either intended or unintended. Unintended consequences and the reflection of those directly influence further conditions of action. Understanding a situation thus requires explaining "why individuals are motivated to engage in regularized social practices across time and space, and what consequences ensue". This implies that at any phase of a sequence of events the individual could have acted differently (ibid, p.9). Long's (2001) actor-oriented approach points out the notion of social heterogeneity, which refers to different social responses to similar contextual conditions. Giving explanatory primacy to agency therefore allows to identify socially differentiated patterns of technological change. Building on actor-centric perspectives, different aspirations (e.g. Mausch et al., 2018), attitudes (e.g. Bögel et al., 2018), convictions (e.g. Preissel, Zander, & Knierim, 2017) and perceptions (e.g. Urrea-Hernandez et al., 2016) have been used to explain the adoption behaviour of users). Also in gender studies, women and men farmers' individual capacity of innovate has been studied through personality traits (e.g. self-motivation, commitment, or altruism) and their self-perceived agency (Badstue, Lopez, et al., 2018). For a structured overview of behavioural studies (actor-centred approaches) on the farmers' technology adoption processes, see Dessart, Barreiro-Hurlé, & Van Bavel (2019).

In one of most influential frameworks for the diffusion of new technologies, Rogers (1962) regarded adoption largely as a process of individual decision-making. As such, he differentiated – and later revised - the adoption or rejection of an innovation in five different stages that are influenced by external information: (1) knowledge (2) persuasion (3) decision (4) implementation and (5) confirmation (Rogers, 1995). Building on the work of Rogers, many researchers have been studying individual decision-making in technological change with behavioural and psychological theories and models (Leeuwis & Aarts, 2021). This has resulted in a range of socio-psychological approaches. Most popular approaches include the theory of planned behaviour (Ajzen, 1991), the theory of reasoned action (Fishbein & Ajzen, 2009), the technology acceptance model (F. D. . Davis, Bagozzi, & Warshaw, 1989), the social cognitive theory (Bandura, 2001), and the prospect theory (Tversky & Kahneman, 1992). For a detailed history and recent overview of social psychological approaches to understand adoption behaviour, see Burton (2004) and Taherdoost (2018). By highlighting the motivation of end-users to (not) use an innovation, behavioural and socio-psychological approaches play an important role to understand the demand-side of new technological developments (Bögel et al., 2018; Bögel & Upham, 2018; Breidert, Hahsler, & Reutterer, 2006).

1.3.4 The interplay between structures and agency

After the introduction of structural / systems perspectives and actor-centred, agency-focused approaches above, this section will point out their interdependence and refer to attempts of integrating these approaches. In relation to technological change, the central question is: what drives human behaviour and where do preferences come from? (Clark, 1998). Giving primacy to agency or structure implies to fundamentally different conceptions of how end-users engage in technological change. While a sole focus on agency would results in an image of an "individual with extensive freedom to make choices", a sole focus on structures would create an image of a "faceless automata following iron rules or given roles/functions" (Geels, 2004). Building on one or another of these two conceptualizations, impacts on how to engage with end-users in research and development projects.

The structure-agency dilemma has been addressed in social theories of Giddens (1984) and Bourdieu (1977), which conceptualized the relationships between structure and agency without giving primacy to either. In these theories, actors are embedded in structures, which configure their preferences, motivations, and social actions. Giddens' "Structuration Theory" defined the "duality of agency and structure", in which the nature of structure is both medium and outcome the actions. Similarly, Bourdieu's aimed to reconcile the imbalance between structure and agency in his “Theory of Practice”. In this theory, the agent is socialized by internalizing external structures into the “habitus”, while the actions of the agent are externalized into the social relationships in the “field”. Both theories stress that actors are taking decisions and acting upon them within the scope of existing structures, while they restructure these systems at the same time.

The work of Giddens on structuration was criticized for its relatively abstract nature and thus neglecting epistemology and methodology (Stones, 2005). A major aspect in this critique was the fallacy of conflation, which points out a failure to incorporate temporality into social theory properly (Archer, 1995, p. 79). Archer (1995, p. 80) argues that “an adequate theoretical stance is one which acknowledges the interplay between structure and agency, then this has to be predicated upon some autonomy and independence being assigned to each”. Instead of Giddens “duality”, she proposed “analytical dualism” between structure and agency to trace out the respective roles played by structure and agency in sequences stretching over time. Hence, the two are kept apart to the extent that they can be discussed separately. This analytical – rather than philosophical – separation allows to study linkages and interconnections between: (1) structural conditions, with their emergent causal powers and properties; (2) social interaction between agents on the basis of these conditions; (3) and subsequent structural changes or reproductions arising from the latter (Stones, 2005, p. 53).

The implicit temporality in the interplay between structure and agency, has been defined in an Archer’s “Morphogenetic Approach”. In this, the flow of morphogenetic cycle is broken down into three re-occurring phases: Structural conditioning at a certain point of time (T^1), social interaction (in the period from T^2 to T^3) and structural elaboration in a final phase (T^4). To oppose deterministic views of structures or agency, the approach inscribes that structures in existence at T^1 are emergent outcomes resulting from the past actions of agents (Figure 1.1). Culture is seen as being (re-)produced as a result of its interactions with agents and therefore seen similar to structure. Emergent properties of these structures can exercise influences that are mediated by people who act or interact in response to the situation they face. Archer (2003) describes this social interaction process (T^2 – T^3) as an internal conversation, i.e. a reflexive deliberation how agents mediate between themselves and structure. The outcome of this process is either morphogenesis (transformation) or morphostasis (reproduction) at T^4. Whereas morphogenesis refers to elaborating or changing a system’s given form, state, or structure, morphostasis refers to preserving a system’s given form, organisation or state (Archer, 1995, p. 75). The model provides a useful representation of structural impositions (T^1) and human decision-making in farmer innovation and technological change (T^2 to T^3) and how these processes lead to changes in the wider seed / innovation systems or not (T^4).

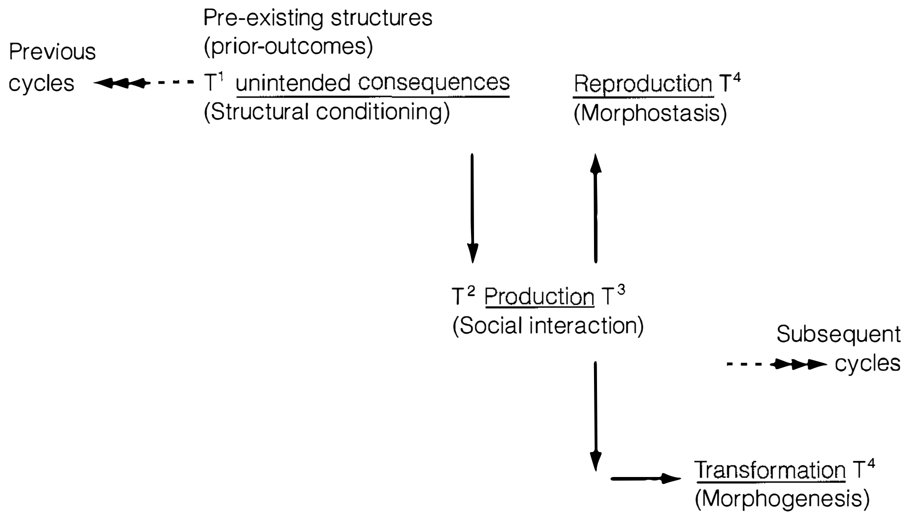

Figure 1.1. Transformational Model of Social Action and the morphogenetic/static cycle (source: Archer, 1998, p. 376)

1.4 Methodology

The empirical chapters of this thesis are comprised from three studies that addressed different research topics in the field of agriculture and nutrition across multiple study locations. Since each of the studies had its own justification and expectations towards the respective projects, the study designs vary in their methodology but complement each other towards the broader approach of this thesis. In this regard, all three empirical studies applied an approach that distinguished structural and actor-centred perspectives in data collection and analysis. This section provides an overview of the different study contexts, and methods for data collection and analysis. Further details on each study are described in the respective chapters.

1.4.1 Description of the study context

The study on farmers' demand for seed of RT&B crops (Chapter 2) was carried out as part of the global research partnership for a food-secure future (CGIAR) Research program on Roots, Tubers and Bananas (RTB) under "Cluster 2.1 - Quality seeds & access to improved varieties" (RTB, 2022). Five international agricultural research organizations contributed to the work of the cluster: International Potato Center (CIP), International Institute of Tropical Agriculture (IITA), Alliance of Bioversity International and CIAT, University of Florida (UF), and Wageningen University & Research (WUR). Their activities aimed to improve the economic sustainability of RT&B seed systems in providing quality seed of demanded varieties. To understand the dynamics of and intervene in seed systems, the team of researchers developed a suite of diagnostic and analytical methodologies, approaches and technologies (Andrade-Piedra et al., 2020).

Methods and approaches that can be used to better understand farmers' demand for seed has been a central issue in the work of the cluster. The systematic literature review on methods therefore aimed to develop the toolbox further by identifying a range of methods –

or a combination of methods - with potential to apply in the work of the CGIAR in seed system research. For that purpose, the study team developed a framework for a systematic literature review and involved the partner organisations in the RTB Cluster CC2.1 in the initial literature search and framing of data collection (see Section 1.4.2) in May 2018. The scientific backgrounds of the multi-disciplinary group in the Cluster CC2.1 included economics, plant pathology, agronomy, and rural sociology. This diversity of team members has resulted into a wide scope of approaches to understand farmers demand for RT&B crops (with no geographical limitation) that have been reviewed from December 2019 until August 2020.

The study on the cassava seed system in Nigeria (Chapter 3) was carried out under the project "Building an Economically Sustainable, Integrated Seed System for Cassava in Nigeria" (BASICS). The BASICS project, funded by the Bill and Melinda Gates Foundation, has been implemented from 2016 until 2020 (BASICS, 2022). The RTB Research Program coordinated the project and implemented it in collaboration with the International Institute of Tropical Agriculture (IITA), the National Root Crop Research Institute (NRCRI), and Catholic Relief Service (CRS). The BASICS project aimed to build a sustainable seed system for Nigeria via developing a network of seed entrepreneurs engaged in commercial sale of cassava planting material. The main activity of the project was to develop a cassava seed value chain from breeder seed to sellers of certified commercial seed. One component of the project was to facilitate the establishment of a network of decentralized stem multipliers, called village seed entrepreneurs (VSEs), in Nigeria's South-South, South-East, and North-Central regions. The VSEs had access to early-generation cassava seed from foundation seed producers, which they multiplied and sold to farmers in their vicinity.

In order to further shape the VSE model, there was a concrete need to understand farmers' demand for cassava seed, the supply side of the seed system and interactions between those better. The partner organisations formed a research team and held a workshop with seed system stakeholders to get a general understanding of the cassava seed system in Nigeria and to define the scope of the study in November 2017 (Almekinders, Pircher, & Obisesan, 2017). Results of the workshop have guided the design of a field study on farmers' demand for seed from August until December 2017 and a study on the supply side functions of the cassava seed system from May until June 2018. The study sites were selected to represent three major different cultural and agro-ecological zones (Figure 1.2): Umuohuodi (Umuapu Ohaji/Egbema local government area [LGA], Imo State, South East Zone); Ibiaku Ntok Okpo (Ikono LGA, Akwa Ibom State, South-South Zone); and Ashina (Gwer East LGA, Benue State, North Central Zone). The criteria for site selection were the presence of small to large farms and areas where cassava was a major crop in farming systems. The partner organisations and seed system stakeholders jointly interpreted the study findings in a final workshop in August 2018 (Stuart et al., 2018).

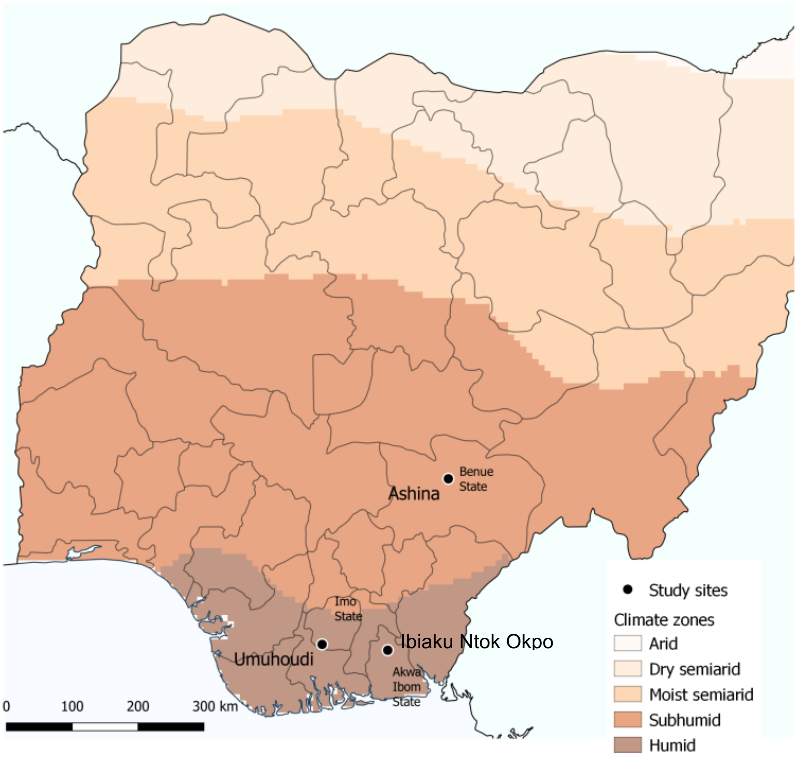

Figure 1.2. Map of Nigeria's agro-ecological zones with three study sites. (Produced with QGIS 3.4 using GIS data from HarvestChoice, 2015)

The study on farmer-centred and structure perspectives on innovation and scaling (Chapter 4) was carried out as part of the project “Education and Training for Sustainable Agriculture and Nutrition in East Africa” (EaTSANE, 2022). The EaTSANE project was implemented as part of the LEAP-Agri Program (LEAP-Agri, 2022) and has been implemented by an international consortium with partners from Germany, the Netherlands, Uganda and Kenya from 2018 until 2022. The EaTSANE project aimed to create more sustainable farming practices and improve diets by diversifying the food system. Specific objectives were (i) identifying and promoting improved farming practices for healthier soils and production of diverse, nutritious crops; (ii) improving access of value chain actors to inputs and services, their links and reducing food losses through improved handling and processing practices; and (iii) enhancing consumers’ food culture, resulting in healthier diets and more equitable distribution of food in households. To address the objectives of the project, three interlinked applied research work packages facilitated research with farming communities through participatory action learning approaches. The research findings were included into communication and dissemination products that targeted the wider public and facilitates policy dialogue.

The field study was carried out to inform a strategy for scaling research findings and learnings from participatory action learning activities in the final phase of the EaTSANE project. In particular, there was a need to identify and engage key actors in the agricultural innovation systems of the project sites. An interdisciplinary study team with members from the different work packages and with scientific backgrounds in nutrition, agronomy and economic sciences was formed. In February and March 2020, the study team reverted to farming communities at Kapchorwa District, Uganda, and the Teso South Sub-County, Kenya, where the EaTSANE project team carried out participatory action learning activities with farmers in the past 12 months (Figure 1.3). Kapchorwa district is located on the slopes of Mount Elgon in the eastern part of Uganda bordering Kenya with altitudes ranging from 1000 to 3000 meters above sea level. Due to the altitude gradient of the study area, temperature and rainfall vary across the district. Teso South Sub-County is one of the sub-counties that form Busia County, located along the Kenya-Uganda border. To capture geographical variations, the study team selected four villages for each study site (Olupe, Obekai, Achurut, and Palikite in Teso South Sub-County, Kenya; and Molok, Kiringet, Seron, and Kapndaroi in Kapchorwa District, Uganda). In the final phase of the field work, the identified stakeholders of the agricultural innovation systems discussed the study findings and derived practical implications in two workshops (Goss et al., 2020; Nertinger, Aliso, Pircher, & Hilger, 2020).

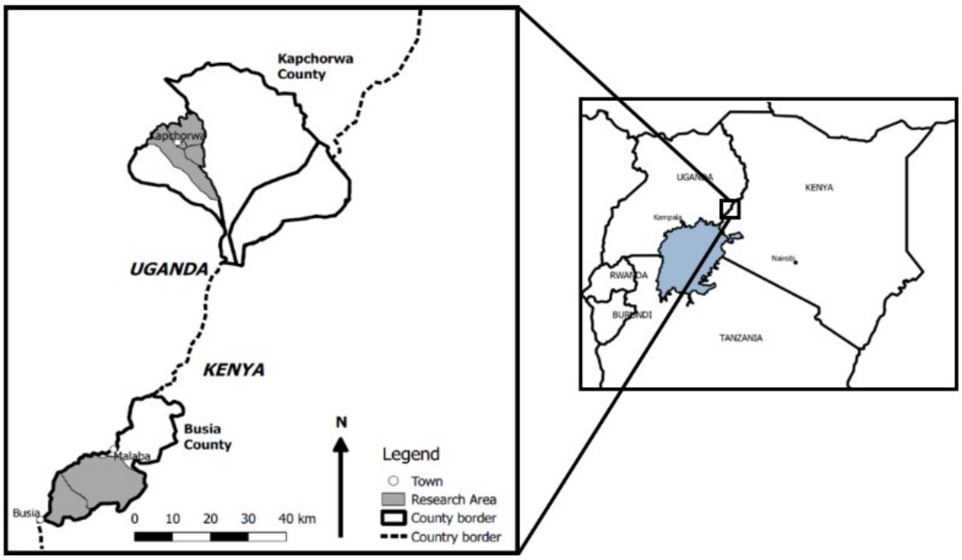

Figure 1.3. Map of the two research areas in Teso South, Kenya and Kapchorwa, Uganda (S. Fischer, 2021).

1.4.2 Data collection and analysis

The first empirical study, presented in Chapter 3, aimed to capture and categorize literature on methods for understanding farmers' demand for seed of RT&B crops. Data collection followed three lines of enquiry: an exploratory literature search, a consultation with an expert panel and a structured literature search in the SCOPUS database. After an initial, exploratory literature search, experts from the CGIAR RTB Cluster CC2.1 were consulted to share literature references from their fields of work. The provided literature sources guided the development of search terms for a structured literature search in the bibliometric database SCOPUS (https://www.scopus.com). A stepwise exclusion of studies, according to PRISMA guidelines (Moher, Liberati, Tetzlaff, & Altman, 2009), led to 46 studies that were further analysed. The qualitative data analysis software MaxQDA was applied to code the content and categorize the full text documents. Based on coding of the applied research methods, aspects of demand addressed and objectives, a classification scheme was developed in an iterative process that followed a grounded theory approach (Corbin & Strauss, 1990).

The empirical chapters based on field work in Nigeria (Chapter 3), Kenya and Uganda (Chapter 4) applied the principles of analytical dualism, which maintains the differentiation between structure and agency through temporality in social analysis (Archer, 1995). The data collection and analysis therefore put separate emphasis (methodological bracketing) in either the systems in focus (structural perspective), and the agency of actors that are part of these systems (actor-centred perspective). Data collection and analysis of the structural perspective has been applied according to the conceptualization of the systems in focus in the respective chapters. The studies of farmers' seed choices and demand, and innovation processes in agriculture and nutrition, were guided by a realist evaluation methodology (Pawson & Tilley, 1997). In this, data collection and analysis are based on an experimental observation, i.e., identifying actual practices (outcomes) and finding out about the cognitive and behavioural mechanisms that contributed to change in a specific context. Interviews with farmers contributed to theory building by testing hypotheses about reasons or causalities ("what works for whom; how and in what circumstances?").

The study of the cassava seed system in Nigeria (Chapter 3) identified key actors and analysed their activities and roles in performing seed system functions. Data were collected through individual interviews of eight key experts from formal institutions and informal seed sellers in the cassava seed system, and from workshop discussions. Whereas the representatives of the formal institutions were interviewed on a national level, informal seed sellers were interviewed in the three study sites. In a qualitative content analysis (Bengtsson, 2016; Mayring, 2014) most-discussed topics and most-prominent issues that were mentioned by respondents were related to the outlined seed system functions, aspects of demand, and seed system interactions. A final workshop with stakeholders served to validate the findings on the structure and functioning of the cassava seed system. Data on small-scale farmers' use and sourcing practices of cassava seed were collected through focus group discussions (FGDs) (Krueger & Casey, 2015; Morgan, 1997) and individual interviews. A categorization of different types of cassava farmers in the study area was established and guided the purposeful selection of farmers in the three study sites. To understand the variations and dynamics of demand between and within study sites, a small N/exploratory case study method (Andrade-Piedra et al., 2020) has been applied. The structured questions from surveys were collated in a spreadsheet and analysed with Microsoft Excel® for descriptive statistics.

The study of farmer-centred and structure perspectives on innovation and scaling (Chapter 4) collected data about the agricultural innovation systems and the existing Innovation Support Services (ISS) from farmer innovators that participated in the EaTSANE project. The study team carried out FGDs (Krueger & Casey, 2015; Morgan, 1997) in the selected study sites in Kapchorwa, Uganda and Teso South, Kenya. After identifying innovations in farming, marketing, and nutrition that the farmers had developed during the last 12 months, the farmer-research teams co-produced Venn diagrams (Theis & Grady, 1991) to map influencing actors and institutions, and characterize the interactions in each of the villages. As such, the maps described the innovation support providers (ISPs) and ISS from the farmers' perspective. To verify the actor maps, the study team carried out open interviews with key ISPs in Kenya and Uganda, and held workshops with representatives of the farmer groups and ISPs in both study locations (see workshop reports Goss et al., 2020; Nertinger et al., 2020). For the actor-centred analysis, the study team identified motivations to develop and use innovations during FGDs. The collected data were audio-recorded, transcribed, and then categorized using qualitative content analysis (Bengtsson, 2016; Mayring, 2014).

1.5 Outline of the thesis

This thesis is organized as a cumulative thesis, where each chapter consist of a journal article with the exception of the introduction (Chapter 1) and a general discussion (Chapter 5). The first empirical chapter (Chapter 2) provides a systematic literature review of methods that researchers applied to study farmers' demand for seed of RT&B crops. A particular focus of the literature review is placed on the epistemological perspectives to draw conclusions on different aspects of demand. The second empirical chapter (Chapter 3) studies specific aspects of farmers' demand for seed, as identified in Chapter 2, in a case study on the cassava seed system in Nigeria. The interaction between actor-centred and structural perspectives builds the basis for drawing conclusions on how responsive the seed system is to farmers demands. The third empirical chapter (Chapter 4) applies an adapted framework to study innovation in sustainable agriculture and nutrition in Kenya and Uganda. A differentiated analysis of actor-centred and structural perspectives depicts multiple influences on innovation processes and informs the design of scaling strategies. The general discussion and conclusion (Chapter 5) summarizes and discusses the findings of all empirical chapters with the theoretical framework, draws policy implications, and identifies limitations and further research needs.

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Chapter 2

Making sense of farmers' demand for seed of root, tuber and banana crops: a systematic review of methods

Thomas Pircher and Conny J. M. Almekinders

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2 Making sense of farmers' demand for seed of root, tuber and banana crops: a systematic review of methods

2.1 Abstract

A demand-driven approach is becoming increasingly central in the efforts to improve agricultural research and development. However, the question of how exactly demand is studied usually remains unstated and is rarely discussed. We therefore carried out a systematic review in order to better understand how farmers' demand for seed in root, tuber and banana seed systems is studied. The review is based on data from a consultation with an expert panel and a structured literature search in the SCOPUS database. Screening the gathered articles resulted in 46 studies on a global scale fitting the scope of our investigation. Through qualitative analysis and categorization of these studies, we developed a classification scheme according to the types of approaches applied in the retained studies. One group of studies explicitly articulates farmers' preferences and choices through surveys or engagements in trials, auctions, choice experiments and interviews. Other studies implicitly articulate farmers' demand by characterising their current use of varieties and seed. We discuss opportunities and limitations in the use of each type of study and we reflect on the body of available literature as a whole. Our conclusion is that a framework is necessary that purposefully combines the existing different methods and that it is necessary to involve stakeholders in a process where demand is articulated. Together, these two steps would characterise existing demands in a more effective and precise way, thus providing better guidance to decision-makers in their reactions pertaining to seed systems.

2.2 Introduction

2.2.1 Understanding farmers' demand for the seed of RTB crops

Seeds[1] of adapted crop varieties with more productive and nutritious traits are a fundamental requirement to increase food security and strengthen the resilience of smallholder farmers (McGuire & Sperling, 2011; Savary et al., 2020). Well-functioning seed systems are essential to ensure that high-quality seed of such varieties is available and accessible to farmers (Almekinders et al., 1994; Louwaars & De Boef, 2012; McGuire & Sperling, 2016). A central aspect of seed system improvement is to become more responsive, and proactive to the needs of different user-groups for better seeds and to promote demand-driven innovation in breeding programmes and seed systems. Demand-driven research and development approaches have become central since Farmer First thinking, inspired by people such as Robert Chambers (1989), became mainstream. The need

[1] In this article we use the term seed in its *true* botanical meaning, as well as in reference to planting material of vegetatively propagated crops.

for truly demand-driven approaches is prominently and frequently referred to in the current discussions about how to transform the agricultural research and development approach within the CGIAR (CGIAR, 2020). However, how exactly farmers’ technology demand is defined and, consequently, how it is studied, remains usually unstated and is rarely discussed. This study reports the results of a systematic literature review that explores and analyses scientific publications addressing farmers' demand for seed.

Farmers’ demand for seed is an expression that is readily used in seed system studies without specific definition or discussion of the concept. In plant breeding, farmers' demand has been addressed through participatory approaches (e.g. Almekinders & Elings, 2001; Ceccarelli & Grando, 2007, 2019; Sperling et al., 2001; Weltzien et al., 2003), and more specifically by John Witcombe (Witcombe et al. 2005; Witcombe and Yadavendra 2014) who argued for client-driven plant breeding. Some other examples of studying demand for seed include estimating the required volumes or quantities of seed to prevent over or under stocking by suppliers (e.g. Spielman & Mekonnen, 2013), identifying preferred variety traits, and the prices farmers are willing to pay for seed. The last type of assessment, willingness to pay (WTP) studies, includes a variety of approaches, reviewed by Breidert et al. (2006). Some are using WTP as a proxy for willingness to adopt (Olum et al., 2019). In this review, we are interested in discovering how demand for the seed of root, tuber and banana (RTB) crops has been studied.

Many crops are reproduced vegetatively, through roots, tubers, stems, suckers and vines. These plant parts can be multiplied easily by farmers themselves while remaining genetically *true to type*. The bulky and perishable nature of RTB planting material is a major reason why a majority of farmers multiply these seeds themselves or share, swap or trade them with neighbours, friends and relatives rather than buying them and/or transporting over longer distances (McGuire & Sperling, 2016). A disadvantage of continued clonal reproduction is that viruses and other pathogens can easily accumulate in vegetative material over time, resulting in yield losses (Okonya et al., 2019; Thomas-Sharma et al., 2016, 2017). These vegetatively propagated crops play an important role in providing food and income for more than 300 million people worldwide (RTB, 2018). Despite their importance, these seed systems have received comparatively little attention from research and development (Almekinders et al., 2019b). They are mostly informal and there is little understanding of farmers’ demand for such seed from formal sources (Almekinders et al., 2019b).

2.2.2 The concept of *demand* and its articulation

The core of this literature review is the concept of *demand*, the definition of which varies across different fields of science. Interdisciplinary dialogues among economists and sociologists contributed to bringing new perspectives to study the role of demand in innovation processes (McMeekin et al., 2002). In economic terms, *demand* is defined as the quantity of a good that consumers are willing and able to purchase at various prices during a given period of time (O’Sullivan & Sheffrin, 2003) and this can be plotted on a demand curve. A demand equation is a mathematical expression that relates the quantity of a demanded good to a set of factors that affect both the willingness and ability of a consumer to purchase it. These factors also include characteristics that are not directly related to the price of the product. In the case of seed, aspects such as seed quality, taste preferences, market for produce, and the socio-economic attributes of the consumer affect farmers' demand. For example, when farmers' cash income increases, their demand for seed may rise.

From a sociological perspective, *demand*, on the other hand, is studied in relation to innovation and stems from the concept of *user needs*, which is meant to address societal and political needs with innovation. User needs refer to the quality or properties of a product or service, whereas *demand* in an economic sense refers to the quantity (Peine & Herrmann, 2012). In case needs are not met by already existing products and services, their nature is latent, vague and potentially unlimited and therefore difficult to capture (Boon & Edler, 2018). Earlier efforts in understanding these less well-defined needs have actually led to successful technological innovation projects (Teubal & Twiss, 1979; von Hippel, 1976, 1977). However, Mowery & Rosenberg (1979) criticised the concept of user needs as elusive and incapable to drive research if not clearly separated from demand. In response to this critique, the *need-pull* model for technological innovation was subsequently labelled as *demand-pull* and later-on was integrated into multidimensional models. The term *need* subsequently disappeared from the literature on user innovation and was replaced by the term *demand*, which is now used in economic theory and models (Godin & Lane, 2013).

Despite the disappearance of the term *need* in innovation studies and the emphasis on the use of *demand* in its economic sense, the concept *demand* continues to include less-defined needs or visions of a technology or service. Earlier studies conceptualized and described this type of demand: Boon (2008, p. 46) defines demand as "explicit, univocal statements of actors on how they regard (the future concerning) a technology and which issues regarding this technology should be included or addressed by other stakeholders". This form of demand is also referred to as *substantive demand* or *substantive needs* (Boon, 2008; Klerkx et al., 2006; Leeuwis & van den Ban, 2004). Sumberg & Reece (2004) coined the term *incipient demand* for agricultural innovations that are latent demands for a not-yet existing product that is expected to exist in the future, which can be treated similarly to *substantive demand*. Bentley et al. (2007) studied farmers' implicit demands for farm technology that reflect "problems that the people themselves do not recognise (they will not demand control of potato viruses if they do not know that viruses exist), or for techniques which they have not imagined (e.g. they did not demand metal ploughs until they saw them)". All these conceptualizations refer to a latent form of demand that is not clearly defined and therefore difficult to articulate.

Alongside different forms of demand for seed, we recognise different *aspects* of demand. Tripp (2000) presented different types of demand for seed of grain and legume crops in sub-Saharan Africa on the basis of motivations of farmers to acquire seed. Based on that concept and recent literature of RTB seed systems (Almekinders, 2019b), we distinguish the following aspects of demand that are relevant for seed of RTB crops: *Varietal traits* which are defined by the genetic code of seed that is expressed in multiple traits, such as yield, disease resistance, culinary preferences of consumers, and marketability for produce; the physical *quality of seed* which is influenced by transport and storage of vegetative propagation material as well as the process of multiplication, i.e. presence of absence of diseases (Thomas-Sharma et al., 2016, 2017); the *quantity of seed which* refers to the amounts of seed that farmers are requesting from the market or other sources; and, *seed sourcing* characteristics which are defined by seed transactions and trade relationships how farmers access seed. Following scholars of the innovation studies field (Boon, 2008; Boon et al., 2011; Boon & Edler, 2018; Kilelu et al., 2014; Klerkx et al., 2006; Klerkx & Leeuwis, 2008), we use the concept *demand articulation* to refer to approaches or methods that researchers use to enable stakeholders to express their preferences or choices. To study substantive or implicit demands, the research methods need to discover and explore the as-of-yet unarticulated demands of farmers. This can be done in a process of a creative learning that includes discussions between different stakeholders, both insiders and outsiders (Bentley et al., 2007; Leeuwis & van den Ban, 2004). In order to understand this *demand articulation process* better, we reviewed scientific studies that describe which methods researchers used to make different forms and aspects of farmers demand for RTB seed explicit.

2.3 Materials and Methods

2.3.1 Data collection

We followed three lines of enquiry in this review to identify relevant studies: an exploratory literature search, a consultation with an expert panel and a structured literature search in the SCOPUS database (https://www.scopus.com). When defining the scope of this study, i.e. farmers' demand for seed, we conducted an exploratory search in bibliometric databases Google Scholar (https://scholar.google.com) and SCOPUS. To further define the scope of our database, we set up a structured expert consultation, inviting the 35 participants of the annual meetings of the CGIAR RTB CC2.1 Working Group in 2017 and 2018. The participants of these meetings have backgrounds in different scientific disciplines including economics, plant pathology, agronomy, and rural sociology.

We contacted the panel of experts via email (on 15/05/2018) and asked for literature references, either scientific articles or other types of study, based on the following criteria:

- studies on potato, sweet potato, cassava, yam and banana and other RTB crops;
- studies that combine RTB crops with one or more non-RTB crops;
- studies that consider farmers' preferences or motivations for using quality planting material (e.g. clean seed over degenerated seed), and;
- willingness to pay and choice game studies.

In our request, we excluded adoption studies and studies of participatory plant breeding and variety selection (PPB and PVS) that focus on farmers trait preferences as we were well aware of existing literature reporting on these types of studies. In addition, we asked the panel to provide links to colleagues who might be aware of studies within the defined scope. Six weeks later (25/06/2018) we sent a reminder email to all participants. In the next step, we contacted each person individually (up to two times) to follow-up on the identification of literature sources and links to colleagues. The inquiry resulted in 54 unique literature references and nine links to colleagues outside the selected expert panel. We contacted the referred experts and followed up with each one individually, but this did not lead to the identification of any new literature references.

After the first qualitative screening of Abstracts, Conclusions, and if necessary the Results sections of the 54 study reports, we selected 23 reports (15 unpublished project reports, working papers and dissertations, and 8 peer reviewed articles) for further review, based on the following criteria:

- the studies were based on empirical data;
- the studies had a focus on one or more RTB crops;
- farmer demand for planting material was a substantial component of the study, and;
- the methodology which was used to understand farmer demand, was presented in the study.

In the next step, we conducted a structured literature search in the bibliometric database SCOPUS. Informed by key words and concepts that were mentioned in the abstracts of the study reports from the panel of experts, we searched in SCOPUS for additional articles. The following search query was constructed based on the search terms in Table 2.11:

TITLE-ABS-KEY ((farmer OR smallholder*) AND (acqui* OR sourc* OR demand OR "willingness to pay" OR willingness-to-pay OR "choice experiment" OR "contingent valuation" OR "use") AND (banana* OR cassava* OR *potato* OR yam*) AND ("planting material" OR "propagation material" OR seed OR stem* OR plantlet* OR sucker* OR vine* OR "variet*")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))*

Table 2.1. Identified keywords and their translation into search terms for literature search in SCOPUS.

Keywords	Search terms
Smallholder farmers	*farmer*, smallholder**
Type of study to understand demand	*acqui*, sourc*, demand, 'willingness to pay', willingness-to-pay, 'choice experiment', 'contingent valuation', 'use'*
RTB crops	*banana*, cassava*, *potato*, yam*,*
Planting material	*'planting material', 'propagation material', seed, stem*, plantlet*, sucker*, vine*, variet**

Limited to the document type 'article' and English language, the query resulted in 444 articles (09/12/2019). We exported bibliographic information (including abstracts) from the search results in a CSV-file for screening the results according to the defined inclusion criteria listed earlier. Screening the abstracts and key words of these articles for relevance, we arrived at 70 articles. We were able to download 68 full texts from SCOPUS, publishers' websites and Research Gate (two articles were not accessible on the journal websites thus not considered in the literature review). The collection from SCOPUS found 5 papers that duplicated the 23 studies identified by the experts. After removing the duplicates, we were left with 86 documents in total (expert panel and SCOPUS search combined) that we reviewed in full-text. In that stage of review, we excluded 40 studies because they did not or not sufficiently address farmers' demand, as defined in this study. This led to a selection of 46 studies that were further analysed.

2.3.2 Data analysis

In a first step of analysis, we coded the identified studies and analysed their content. We used the qualitative data analysis software *MaxQDA Standard 2018 (release 18.2.0)* to assist with the analysis of the 46 full text studies, which included coding the content and categorising the downloaded documents. The following criteria were used to stratify and aggregate content for further analysis:

- the species of RTB crops, since the crop species has implications for the characteristics of planting material and how the seed system is organised;
- the country/countries in which the studies were applied in order to get insights on the regional coverage of studies;
- research methods, including data collection, stakeholder engagement and data analysis, which is a key aspect of our objectives in this review;
- aspects of demand to understand the relationship between the nature of demand and research methods used, and;
- claims made, and objectives addressed, in regard to farmers' demand for seed, which helped us to understand how the identified studies intended, and actually contributed, to articulating demand.

Based on coding the study content (objectives, main emphasis on the presented data, and conclusions of the study), we identified three main categories of studies. In an iterative process, we subsequently reviewed the studies in each category again to develop sub-categories of the classification scheme according to the research approaches used (Figure 2.2). While consolidating the (sub-)categories of the scheme, we assigned each study to a respective sub-category. In cases when a study covered multiple categories or methodological groups it was assigned to the one that was most prominently represented in the content of the study.

2.4 Results

2.4.1 General characteristics of the identified literature

We identified 46 literature sources that describe studies on farmers' demand for RTB seed. The majority (n=40) were articles published in peer-reviewed journals. We also included project reports (n= 4), one baseline study and one MSc thesis that we received from our inquiry to the panel of experts. All the identified literature was published between 2003 and 2019 without a visible trend of increasing or decreasing numbers in this period (data not presented).

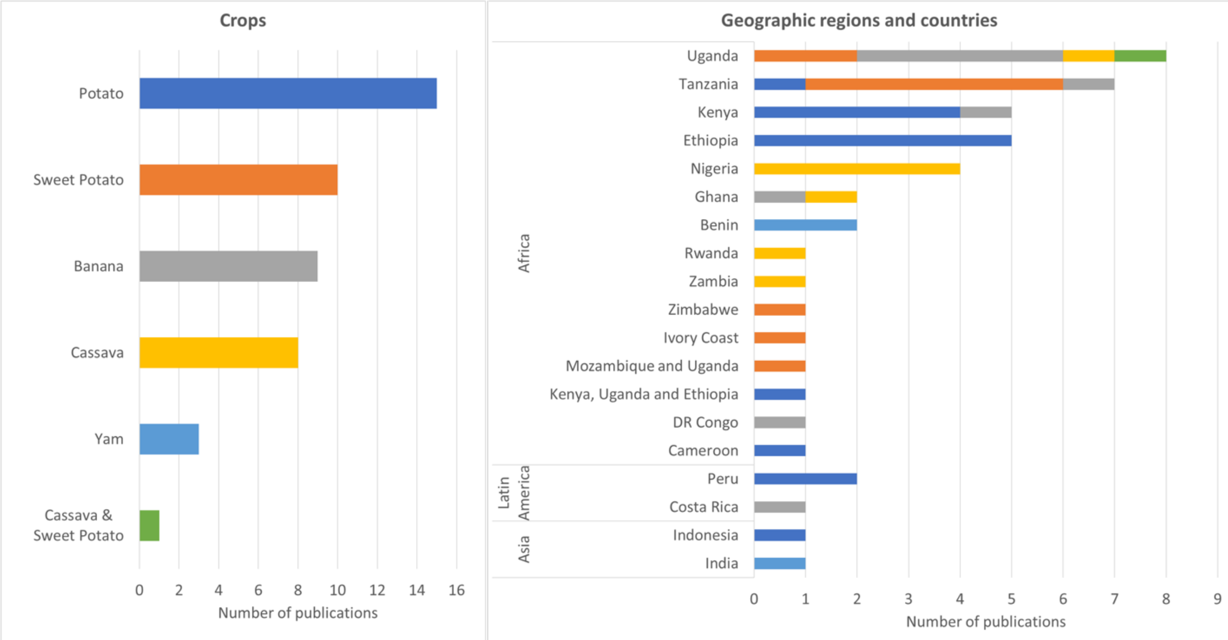

Figure 2.1. Characterization of selected articles (n=46) by RTB crops studied and regions and countries where studies were conducted, the colours representing the crops in the figure on the left correspond with the colours in the figure on the right

The most researched RTB crops for farmers' seed demand were potato and sweet potato (Figure 2.1). The majority of studies (n= 41) were carried out in countries across Africa; we identified only three studies in Latin America and two in Asia. Our literature search did not find any articles relating to Europe and North America.

2.4.2 Types of studies to understand farmers' demand.

When clustering the different literature sources, we arrived at different types of studies, which we used as categories and sub-categories (Figure 2.2).

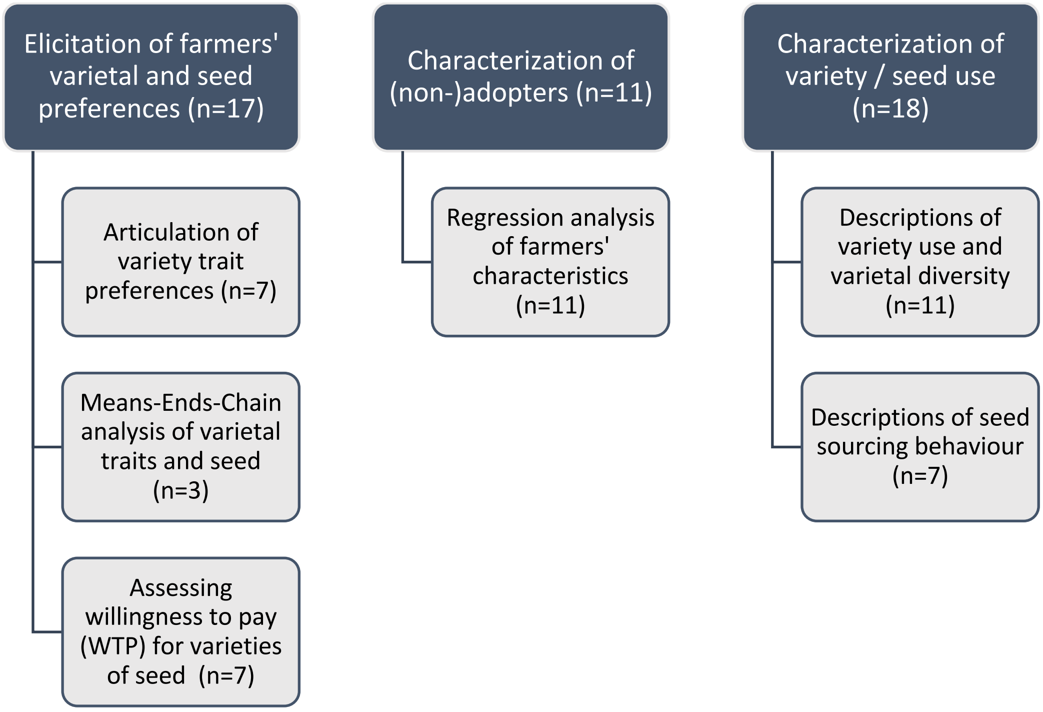

Figure 2.2 Classification scheme of selected studies on farmers' demand for seed of RTB crops in different categories and sub-categories.

2.4.2.1 Elicitation of farmers' varietal and seed preferences (n=17)

We categorised 17 documents that reported studies that aimed to elicit farmers' preferences for varieties and their traits. We found three groups of research approaches that were used to do so: articulation of trait preferences, Means-End-Chain analysis and willingness to pay (WTP) studies.

Articulation of variety trait preferences (n=7, Table 2.2): We did not explicitly search for trait elicitation studies in this review, i.e. the term was not used in our request to the expert panel and neither in our SCOPUS search string. Yet as we reviewed the studies in our results, we found that some of them captured the variety preferences of farmers, consumers or processors. In this way they facilitated the articulation of farmers' demand for specific varietal attributes of RTB crops. The identified studies included banana, cassava, potato, sweet potato, and yam in Ethiopia, Ghana, India, Ivory Coast, Nigeria and Uganda. The research approaches varied. In four studies, farmers actively engaged in evaluating varieties in farmer and/or researcher managed trials (Dibi et al., 2017; Dzomeku et al., 2008; Kolech et al., 2019; Dixon et al., 2008). The other three studies elicited farmers' preferences by using pictures in combination with survey questions (Edmeades, 2007), focus group discussions (FGDs) in combination with individual ranking of attributes on charts (Sivakumar, Nedunchezhiyan, Paramaguru, & Ray, 2009) or with surveys (Kolech et al., 2019). Teeken et al. (2018) studied farmers' trait preferences by asking farmers about each variety that they were growing what particular traits motivated them to cultivate it. In three studies, researchers also carried out sensory tests in which farmers expressed their taste preferences (Dibi et al., 2017; Dixon et al., 2008; Edmeades, 2007). The studies in this sub-category aimed to inform breeding programmes and in some cases did feed directly into a process of variety release (Dibi et al., 2017; Dixon et al., 2008). In addition to studying farmers' trait preferences, Edmeades (2007) included farmers' selling behaviour in a hedonic price model to draw conclusions on whether variety improvement will pay off at the market level.

Table 2.2. Identified literature articulating trait preferences through trials and/or with surveys and focus group discussions (FGDs).

Reference	Country and crop	General focus of study	Aspect of demand	Research methods to understand demand
Dibi et al. (2017)	Ivory Coast, sweet potato	Evaluated 6 varieties with women farmer groups to recommend the most appreciated and best performing one for release. All traits relevant to the women were assessed.	Varietal traits	Farmer managed plots (n=8); participatory assessment of crop characteristics and consumer preferences (sensory evaluation) of 6 varieties
Dixon et al. (2008)	Nigeria, cassava	Reported on a fast track evaluation of 40 cassava cultivars that resulted in the release of 17 cassava mosaic disease -resistant cultivars.	Varietal traits	Over 150 farmers- and/or researcher-managed trials in two growing seasons; participatory assessment of crop characteristics and farmers' consumer preferences
Dzomeku et al. (2008)	Ghana banana,	Evaluated new hybrid varieties on-farm and assessed their food qualities and consumer acceptability. The study emphasises that peoples' food habits must be considered when introducing new varieties.	Varietal traits	A total of 500 farmers in two districts were involved in on-farm testing of 4 new hybrid varieties alongside with landraces on-farm, using individual survey interviews and FGDs.
Edmeades (2007)	Uganda, banana	Explored the economic trade-offs between banana fruit size, bunch size and fruit quality at the farm gate. The study potentially informs about the economic value of an improved trait in cultivar development.	Varietal traits	Survey data (n=540) analysed with econometric model; Farmers ranked varietal attributes based on photos.
Kolech et al. (2019)	Ethiopia, potato	Studied which potato traits farmers consider most important, and characterised the diversity to inform breeding programs. Found variations in agro-ecological zones, cropping seasons and market access.	Varietal traits	Farmer survey (n=321 in six districts) and FGDs. Participatory variety selection scheme to test 9 local and 3 new varieties; Two (gender separated) farmers' groups ranked varietal traits in different growing stages.
Sivakumar et al. (2009)	India, yam	Identified farmers' varietal preferences and found that these are different in commercial production systems and subsistence ones. Their purpose was to redefine breeding objectives.	Varietal traits	Observational methods and key informant interviews; ranking exercise (n=30) of varietal production attributes (displayed on charts) and sensory evaluation.
Teeken et al. (2018)	Nigeria, cassava	Examined trait and varietal preferences of men and women cassava farmers and processors. They aimed to inform priority setting in gender responsive breeding programmes.	Varietal traits	Mixed methods (150 semi-structured interviews and 16 FGDs in 8 communities). Farmers ranked traits that motivated them to cultivate different cassava varieties.

Means-Ends-Chain (MEC) analysis of varietal traits and seed (n=3, Table 2.3): Studies that used a MEC analysis aimed to better understand which traits of seeds or varieties farmers consider and the underlying motivations for preferring certain traits. The identified studies were all three from 2016 and later, done with potato in Peru, Kenya and Tanzania. Urrea-Hernandez et al. (2016) studied farmers' use of seed potato varieties in Peru with this method and paid attention to the attributes of seed tubers that farmers used to recognise seed of their preferred quality. The study compared farmers' perceptions of quality with those of formal experts in the seed system. Okello et al. (2018) carried out a MEC study as goal priming to find out why farmers invested in the seed of a new potato variety that was superior in quality than those available locally. Okello et al. (2019) applied MEC analysis to farmers use of quality (certified) seed by using disaggregated data for men/women and users/non-users of certified seed.

Table 2.3. Identified literature on the Means-Ends-Chain analysis.

Reference	Country and crop	General focus of study	Aspect of demand	Research methods to understand demand
Okello et al. (2018)	Tanzania, potato	Studied the motivations of farmers in an auction that used vouchers, invested in quality seed of a new potato variety. They found that farmers expect to attain particular benefits that lead to reaching their personal life goals.	Varietal traits	Means-End-Chains methodology (n=45), disaggregated by gender
Okello et al. (2019)	Kenya, potato	Investigated what motivates smallholder farmers to invest in certified potato seed (or not). It found that all farmers are driven by life goals (having a good and happy life) for which profit-making is a means, rather than an end.	Quality of seed	Means-End-Chains methodology, disaggregated by gender and users / non-users of certified seed (n= 96).
Urrea-Hernandez et al. (2016)	Peru, potato	Studied farmers' variety use and compared their perceptions with those of formal experts. It found that farmers pay attention to seed tuber traits that researchers hardly consider.	Varietal traits and quality of seed	Means-End-Chains methodology (n=34)

Willingness to pay (WTP) for varieties or seed (n=7, Table 2.4): WTP studies were used to understand farmers' demand by relating it to the price that farmers are willing to pay for it. We identified WTP studies on orange fleshed sweet potato (OFSP) and potato in Indonesia, Kenya, Mozambique, Peru, Tanzania and Uganda, and one on banana in Costa Rica. The studies' approach to assessing farmers' WTP differed strongly. The studies reported by Arimond et al. (2010) and Labarta (2009) engaged farmers in a real choice experiment, in which farmers were given a small amount of money to spend (or not) in the study. The farmers could choose to buy one of the varieties – offered by the researchers– or opt not to buy. Labarta (2009) applied a mixed logit model to estimate farmers' marginal WTP and to evaluate the determinants of farmers' WTP for vines. Involving farmers in real-choice-experiments resulted in a so-called revealed preference for RTB planting materials.

Table 2.4. Identified literature assessing willingness to pay (WTP) for varieties and seed.

Reference	Country and crop	General focus of study	Aspect of demand	Research methods to understand demand
Aguilar & Kohlmann, (2006)	Costa Rica, banana (transgen.)	Studied farm managers' willingness to adopt a hypothetical transgenic banana.	Varietal traits	Survey with consumers (n=101) and farm managers (n=19); probit regression
Arimond et al., (2010)*	Mozambique and Uganda, sweet potato	Determined how smallholders' WTP for varying quantities of disease-free planting material of different sweet potato varieties.	Varietal traits and quantity of seed	Real choice experiment
Buijs et al. (2005)	Peru, potato	Identified farmers' WTP for a hypothetical variety as well as the opportunities to release GMO potatoes in the region.	Varietal traits	Survey (n=500), descriptive statistics
Fuglie et al. (2006)	Indonesia, potato	Calculated a seed price at which the present value of added benefits from using a seed source would equal the added seed cost.	Quality of seed	Survey (n=182) and calculation of demand equation
Kaguongo et al. (2014)	Kenya, potato	Established the status of the seed potato industry and evaluated the use of high-quality seed. Identified WTP for clean / certified seed and the explanatory variables for paying for different types of seed.	Quality of seed	Survey (n=1300) with contingent valuation method and econometric analysis
Labarta (2009)*	Mozambique, sweet potato	Determined smallholders' WTP for sweet potato varieties and disease-free planting material.	Varietal traits	Real choice experiment and survey (n=121), mixed logit model
Mwiti (2015)	Tanzania, sweet potato	Identified WTP for certain sweet potato varieties and factors that affect willingness to pay.	Varietal traits	Survey (n=732) with contingent valuation method and econometric analysis

***** Both studies were based on Reaching End Users (REU) project and appear to overlap. While Arimond et al. (2010) summarized two WTP studies in Mozambique and Uganda, Labarta (2009) is a more detailed report of the study in Mozambique.

The other identified studies used surveys to assess so-called stated preference: they asked farmers if they were willing to adopt a hypothetical variety or seed and/or how much they would be willing to pay for it (contingent valuation method). Researchers asked farmers the maximum amount they would pay for certified seed, clean seed, positively selected seed or farmer seed, respectively (Kaguongo et al., 2014), for different sweet potato varieties (Mwiti, 2015) or for hypothetical, transgenic, insect-resistant potato variety (Buijs et al., 2005) or for a transgenic banana variety that reduced pest management costs (Aguilar & Kohlmann, 2006). Buijs et al. (2005) complemented the WTP study with a study on the conditions for deployment of genetically engineered potatoes in the region. Kaguongo et al. (2014) analysed the results with an econometric approach to identify variety and farmer specific factors that affect WTP. Fuglie et al. (2006) used farmers yield data to calculate the value of seed and considered this the potential WTP. The authors found that the calculated seed value was higher than the actual price of potato seed in the market.

The results from these WTP studies led to quite varied claims: farmers were willing to adopt GMO banana that would reduce pesticide costs at a WTP of USD 500-999 per ha (Aguilar & Kohlmann, 2006). Buijs et al*.* (2005) calculated that if farmers were to pay a 25% premium price for the insect resistant potato variety, then they would increase their profits. Farmers' WTP indicated a market for decentralised vine multipliers (Labarta, 2009). Fuglie et al. (2006) raised the expectation that seed sector investment could make quality seed available to farmers and benefit them by increasing productivity. Farmers apparently were aware of the value of higher quality seed (Kaguongo et al., 2014). Farmers' WTP was influenced by gender, age, distance to the nearest road and education (Mwiti, 2015).

2.4.2.2 Characterization of (non-)adopters (n=11)

Another type of study we found are adoption studies (n=11, Table 2.5), although we had not initially aimed to include them in this review, i.e. the term *adoption* was not included in the SCOPUS search string. We kept the studies because some of them provided information on farmers' acceptance of, and preference for varieties, albeit indirectly. Eight studies in this category focused on the adoption of improved varieties in all five main RTB crops in Africa (Abebe et al., 2013; Afolami et al., 2015; Deffo & Demo, 2003; Edmeades et al., 2007; Nigussie et al., 2016; Tarawali et al., 2012). In addition, we identified studies on the adoption of planting material from rapid, disease-free propagation methods, such as tissue-culture bananas in Kenya (Wanyama et al., 2016) and tissue-culture sweet potatoes in Zimbabwe (Mutandwa et al., 2008), certified seed potatoes marketed by a private seed company in Kenya (Okello et al., 2016). While the majority of studies focused on the adoption of certain varieties, four of the identified studies (Abebe et al., 2013; Edmeades & Smale, 2006; Okello et al., 2016; Wanyama et al., 2016) also studied the intensity of adoption; the amount of seed and area of land that adopting farmers used for cultivation.

The majority of the studies are based on surveys and use regression analyses (linear regression, logistic regression, probit regression) to relate farmer characteristics with the adoption and non-adoption of improved varieties and seeds. On this basis the studies indirectly provided insights into the conditions under which farmers are willing to adopt a particular variety or type of seed. The results included socio-economic characteristics, geographical factors and access to advisory services as influences on adoption. Out of adoption and non-adoption, it was possible to distil information on farmers' preferences for particular varieties, seeds and their traits. Since the studies assessed farmers' revealed preferences, these studies cannot be used to understand the demand for varieties that farmers do not yet know or cultivate. In contrast, Deffo & Demo (2003) did not assess household characteristics, but analysed the adoption progress and farmers' reasons for (non-)adoption of four new potato varieties by applying descriptive statistics to survey data. Two studies by Edmeades and colleagues (Edmeades et al., 2008; Edmeades & Smale, 2006) used novel modelling approaches by using the survey data to, respectively, characterise the households likely to adopt transgenic banana in Uganda and estimate the demand for banana variety traits.

Table 2.5. Identified literature on the characterization of (non-)adopters via regression analyses of farmers' characteristics.

Reference	Country and crop	General focus of study	Aspect of demand	Research methods to understand demand
Afolami et al. (2015)	Nigeria, cassava	Identified the determinants of adoption and studied the effects of adoption of improved varieties on the welfare of households. Found that the adoption of improved varieties is pro-poor in nature.	Varietal traits	Survey (n=312 in 2 states); logistic regression
Abebe et al., (2013)	Ethiopia, potato	Identified the determinants of adoption in relation to farmers' engagement with the agricultural knowledge and innovation system and their preferences for local varieties. Also studied the intensity of adoption.	Varietal traits and quantity of seed	Survey (n=346), ordered probit model and treatment effect (Heckman sample selection) model
Deffo & Demo (2003)	Cameroon, potato	Explored the extent of adoption, and related constraints, of two improved potato varieties. Found that adoption was constrained by the cultivars' susceptibility to bacteria wilt and a lack of technical assistance.	Varietal traits	Survey (n=297); descriptive statistics
Edmeades et al. (2007)	Tanzania, banana	Identified the determinants of adoption for new banana varieties and made predictions of the impact on farms adopting these varieties.	Varietal traits	Survey (n=260); linear regression
Edmeades & Smale (2006)	Uganda, banana	Characterised agricultural households in Uganda that are likely to influence the adoption of transgenic varieties and illustrated the sensitivity of farmer demand.	Varietal traits, quantity of seed	Survey (n=540); modelling agricultural household model
Edmeades et al. (2008)	Uganda, banana	Modelled farmers' varietal choices and estimated the intensity of cultivating a variety in case of adoption. Drew implications for the social and economic impacts of crop improvement.	Varietal traits	Survey (n=540); Modelling varietal choices and demand
Mutandwa et al. (2008)	Zimbabwe, sweet potato	Identified the factors that affect adoption and the impact of using tissue-cultured materials on productivity and incomes.	Quality of seed	Survey (n=133) and semi-structured interviews with stakeholders; logistic regression model
Nigussie et al. (2016)	Ethiopia, potato	Identified the determinants of adoption of improved varieties (e.g. cooperative membership, age, use of fertiliser).	Varietal traits	Survey (n=158); logistic regression
Okello et al. (2016)	Kenya, sweet potato	Identified the factors determining the decision to use certified seed potatoes and intensity of use. They concluded that poverty impedes the decision to adopt, and thus benefit from, certified seed.	Quality of seed, quantity of seed	Survey (n=408); probit regression

Tarawali et al. (2012)	Nigeria, cassava	Identified determinants of adoption of improved varieties (e.g. improved crop management practices, gender, cassava yield and farming experience).	Varietal traits	Survey (n=68 in 8 states); probit model
Wanyama et al. (2016)	Kenya, banana	Identified determinants of adoption and the intensity of use of tissue culture bananas (e.g. the availability of seed, income, location, family size, farm size).	Quality of seed, quantity of seed	Survey (n=330 in 4 counties); double hurdle regression model

2.4.2.3 Characterization of variety / seed use (n=19)

The largest group of studies characterises how farmers use varieties and seed within their farming contexts, in which RTB crops predominantly involved informal seed systems. We distinguished two subcategories: one focusing more on the use of varieties and diversity and the other one on how farmers source and use seed.

Descriptions of variety use and varietal diversity (n=11, Table 2.6): These studies characterised the farmers' variety use and management to adapt to a context of history, agro-ecology, markets, and culture. The studies were generally motivated by wanting to understand the reasons why farmers continue to use certain (local) varieties and the dynamics in maintaining and managing variety diversity.

The identified studies provided empirical evidence on the influence of historical change of cassava farming in Ghana (Manu-Aduening et al., 2005), socio-cultural practices around yam in Benin (Zannou et al., 2004, 2007), farmers' resource endowments and associated farming practices for potato in Ethiopia (Tadesse et al., 2017), the constraints faced by farmers in cassava root production in Rwanda (Nduwumuremyi et al., 2016), variations in agro-ecologies, cropping systems and market outlets for potatoes in Ethiopia (Kolech et al., 2015), culinary preferences for cassava roots and leaves in Zambia (Chiwona-Karltun et al., 2015), the taste and market value of bananas in DR Congo (Adheka et al., 2018), and farmers' traditional and cultural preferences for using in different types of bananas in Uganda (Kilwinger et al., 2019; Nakabonge et al., 2018).

The studies used a mix of methods to collect the data: FGDs, open interviews, key informant interviews, surveys and transect walks. The results were mostly descriptive statistics combined with qualitative descriptions of use patterns. Kolech et al. (2015) also analysed the correlations between predominant varieties grown and the traits that farmers stated as important to them. Chiwona-Karltun et al. (2015) used chemical analyses of cassava root samples in addition to interviews to explain farmers' varietal preferences. While two of these articles aimed to explain why farmers are (not) adopting improved varieties that were being promoted in the study areas (Tadesse et al., 2017; Zawedde et al., 2014), the other nine studies informed how the interests of farmers in seed and varieties can be supported, e.g. with adapted breeding or diversity conservation programmes. The studies addressed varietal traits / genetic quality and, in two cases (Adheka et al., 2018; Kilwinger et al., 2019), additionally the quality of seed and associated seed management practices in order to explain varietal diversity.

Table 2.6. Identified literature describing variety use and varietal diversity.

Reference	Country and crop	General focus of study	Aspect of demand	Research methods to understand demand
Adheka et al. (2018)	DRC, banana	Assessed the diversity of varieties across one province to provide knowledge on genetic diversity and geographical spread. It found that farmers select cultivars mostly because of their taste and market value, and less because of high yield.	Varietal traits, quality of seed	Group discussions in 75 villages; survey (n=750) across all the villages; descriptive statistics
Chiwona-Karltun et al. (2015)	Zambia, cassava	Investigated the prevailing varietal preferences for leaves and roots, based on the utilization as well as the biochemical composition of local and recently improved varieties.	Varietal traits	Interviews with farmers and researchers, (n is undefined) chemical analysis of root samples
Kilwinger et al. (2019)	Uganda, banana	Studied seed management and replacement by exploring farmers' production objectives in relation to varietal diversity, in order to understand the demand for banana planting materials, and gain insights into farmers' evaluation of planting materials and their quality criteria.	Varietal traits, quality of seed	Focus group discussions (n=4) and semi-structured interviews (n=23) in 5 villages in 2 sub-counties, descriptive statistics and qualitative data analysis
Kolech et al. (2015)	Ethiopia, potato	Documented farmers' decision-making processes and the external factors that influence variety diversity. The authors called for greater consideration of variations in agro-ecologies, cropping systems and market outlets in order to develop varieties that meet farmers' needs.	Varietal traits	Mixed methods; survey (n=60, in 6 districts), key informant interviews, FGDs, field observations; correlations, descriptive statistics and qualitative data analysis
Manu-Aduening et al. (2005)	Ghana, cassava	Explored the dynamics of farmers acquiring and abandoning landraces over time; and the extent to which they use seedlings for propagation. Due to the slow evolution of landraces and the low adoption of improved varieties in the communities, participatory breeding programs were established.	Varietal traits	Mixed methods; (n=300), key informant interviews, FGDs; descriptive statistics, statistical and qualitative data analysis
Nakabonge et al. (2018)	Uganda, cassava	Explored how on-farm conservation of cassava germplasm is influenced by farmers' traditional and cultural preferences (e.g. culinary attributes, storability in the ground, early maturity and cooking quality) of particular varieties.	Varietal traits	Survey (n=384) in 6 agro-ecological zones, descriptive statistics.
Nduwumuremyi et al., (2016)	Rwanda, cassava	Identified the main constraints on cassava production, the traits preferred by farmers, the effects of late bulking cultivars, losses due to post-harvest physiological deterioration, and factors affecting the	Varietal traits	FGDs with farmers and district officials; and semi-structured interviews with farmers, traders and processors

		adoption of new genotypes. Informed breeding programs.		(n=180); descriptive statistics
Tadesse et al. (2017)	Ethiopia, potato	Tried to find explanations for the low adoption of improved potato cultivars through exploring potato growing practices and their influence on farmer's choice of varieties in different wealth groups.	Varietal traits	Survey (n=47, disaggregated wealth groups) and in-depth interviews; descriptive statistics
Zannou et al. (2004)	Benin, yam (and cowpea)	Analysed the importance of varieties and the influence of the socio-cultural and local economic contexts on maintaining diversity. The processes of loss and displacement of some local varieties are described and the need for conservation is addressed.	Varietal traits	Mixed methods; survey (n=40), key informant interviews, FGDs; statistical and qualitative data analysis
Zannou et al. (2007)	Benin, yam (and cowpea)	Elaborated on the cultural significance of the studied crops in maintaining genetic diversity. The study shows that the management of on-farm genetic resources is a socially and culturally constructed system.	Varietal traits	Survey (n=521), participatory characterization of planting material; statistical analysis and descriptive statistics
Zawedde et al. (2014)	Uganda, sweet potato	Assessed how the adoption of new cultivars and other factors influenced varietal diversity. Farmers' criteria for variety selection varied with a range of factors (e.g. age, gender) that need to be considered for setting breeding priorities and for diversity conservation.	Varietal traits	Survey (n=102), statistical analysis and descriptive statistics

Descriptions of seed sourcing behaviour (n=7, Table 2.7): Compared to the previous group of studies, this group had a stronger focus on understanding farmers' seed sourcing practices and their relationships with other actors in the seed system. The aspects of demand that were studied related either to the quantity or the quality of seed. Like the former group of studies, these used a mix of quantitative and qualitative methods, i.e. surveys, complemented with FGDs and/or key informant interviews.

The five studies in this group provided general descriptions of the varietal choices of farmers and their seed sourcing strategies. These studies aimed to understand potential entry points for (project facilitated) decentralised seed multipliers and seed marketing of sweet potato in Tanzania (Adam et al., 2018, Badstue & Adam, 2011; Sindi, n.d.; Sindi & Wambugu, 2012) and cassava and sweet potato in Uganda (Nangoti et al., 2004). In addition to characterising farmers' seed sourcing behaviour, Adam et al. (2018) and Badstue & Adam (2011) reported on the types of sweet potato vine transactions that occur among farmers and the roles that social relations and gender aspects play in this process. Kirimi Sindi (n.d.) complemented their findings by comparing the costs of production with farmers' willingness to pay, in order to estimate the potential for decentralised seed multipliers in the study areas.

Two other studies looked into the collective demand for seed in seed systems. Gildemacher et al. (2009) studied farmers' seed management and replacement in Kenya, Uganda and

Ethiopia with a survey. Based on this information they developed a model to calculate the demand for clean planting material in the potato seed systems in these countries. Kaguongo, Nganga, & Landeo (2009) assessed farmers' production practices and the potato seed system in Kenya in a large-scale survey to estimate the demand and supply of clean and certified seed potatoes and farmers' willingness to pay. Both studies informed seed system development (production, storage, marketing and distribution) in order to better address farmers' demand for quality seed.

Table 2.7. Identified literature describing seed sourcing behaviour.

Reference	Country and crop	General focus of study	Aspect of demand	Research methods to understand demand
Adam et al. (2018)	Tanzania, sweet potato	Studied farmers' sources of planting material; factors that influence their sourcing of planting materials from outside their own farms and the types of transactions and social relations involved in farmers' acquisition and distribution.	Seed sourcing	Survey (n=621 in 9 districts), key informant interviews (n=28) and FGDs (n=6); logistic regression and qualitative data analysis
Badstue & Adam (2011) Project report (unpublished)	Tanzania, sweet potato	Assessed the role of women in the management of sweet potato vines. This paper provides specific inputs into the discussion around the issues of gender and local knowledge in relation to seed system interventions.	Quality of seed, seed sourcing	Semi-structured interviews with women (n=29) and observation in contrasting sites in the Lake Zone; qualitative data analysis
Gildemacher et al. (2009)	Kenya, Uganda and Ethiopia, potato	Analysed farmers' seed management and pest management practices and calculated the demand for clean planting material. Discussed opportunities for seed system improvement.	Quality of seed, quantity of seed, seed sourcing	Disease analysis of potato fields and seed, surveys (n=251 in Kenya, n=144 in Uganda, n=220 in Ethiopia)
Kaguongo et al. (2009) Project report (unpublished)	Kenya, potato	Evaluated farmers' practices and their awareness of the importance of clean / certified seed. Estimated the demand and supply of clean / certified seed. Highlighted opportunities to improve the seed value chain.	Quality of seed, quantity of seed, seed sourcing	Survey (n=1300); descriptive statistics and regression
Nangoti et al., (2004)	Uganda, cassava and sweet potato	Described seed sourcing behaviour, varietal preferences, and seed management for a range of crops. Discussed how interventions can address various aspects of seed demand.	Varietal traits, seed sourcing	Survey (n=80), key informant interviews and focus group discussions
Sindi (n.d.) Project report (unpublished)	Tanzania, sweet potato	Characterised sources of seed, farmers' varietal preferences and compared the costs of production against farmers' willingness to pay, as an input to project design. The study concluded that vine production is commercially viable.	Varietal traits / genetic quality, seed sourcing	Survey (n=216); descriptive statistics

Sindi & Wambugu (2012), Baseline study (unpublished)	Tanzania, sweet potato	Described farming practices, farmers' preferred varieties and traits, and sourcing behaviour for vines and the challenges associated with seed of sweet potato. They conclude that there is a potential for decentralised seed multipliers in the study areas.	Varietal traits, seed sourcing	Survey (n=621 in 9 districts); descriptive statistics

2.5 Discussion

2.5.1 Scope and types of identified studies

Our approach of engaging a panel of experts, enabled us to identify a wide range of studies that examine farmers' demand for RTB seed in one way or another. It was also helpful in formulating the search terms that could capture papers that fell within the desired scope of this research. The combination of the literature identified by the experts and our search covered a range of different scientific disciplines that addressed multiple aspects of demand for varieties and seeds. Overall, the number of studies is moderate: 46 studies over a period of 16 years on five RTB crops that have global importance for food security in developing countries. We are aware that we may have missed some publications in our literature search, and not all studies may have been published, but consultation with our panel confirmed that we had not overlooked initiatives that would change our results radically.

The iterative process of categorising these studies helped us to develop a classification scheme that identifies three main categories of studies (see Figure 2.2). (i) Studies that articulate farmers' variety and seed preferences by actively engaging farmers. (ii) Studies that characterise (non-) adopters and identify determinants of farmers, households or farms that can be used to identify user groups that either opt for the adoption, or rejection, of particular varieties or types of seed. (iii) Studies that characterise farmers' varietal and seed use and sourcing behaviour to provide a contextualised or systemic characterization of farmers' demand for seed or varieties. We consider the first category as *explicit demand articulation* and the other two as *implicit demand articulation*, as discussed below.

2.5.2 Explicit demand articulation

In the studies that we categorised under *Elicitation of farmers' variety and seed preferences*, farmers were explicitly asked by researchers to express their interests in, and preferences for, varieties, varietal traits or types of seed. In general, these approaches show an important limitation concerning novel technologies, such as a hypothetical variety with traits farmers have never heard of (i.e. biofortified varieties, GMO seeds), which do not have pre-defined markets, or which farmers have not yet been able to evaluate over a number of seasons in their own fields (Misiko, 2013). In such a situation, it is doubtful that researchers will be able to define farmers' demand through surveying techniques (Orihata & Watanabe, 2000). In some studies, researchers engaged with farmers through participation in the evaluation of field trials, auctions or choice experiments, sometimes even including taste tests. These approaches allowed farmers to familiarise themselves to some extent with the new varieties or seed and compare them, but they still have some serious limitations. The influence of the specific context of farmers that shapes their real-life preferences and trade-offs remain outside the trial evaluations and therefore may be hidden (Almekinders et al., 2019a). The MEC approach may yield additional insights because of its openness, but does not pull in trade-offs with other livelihood activities. We might better understand the motivations and preferences of farmers through doing so, but we cannot characterise their demand and choices for seed beyond the experimental context.

2.5.3 Implicit demand articulation

We consider the second two groups of studies as being implicit forms of demand elicitation. Researchers studied farmers' adoption behaviour, seed management practices or the functioning of seed systems without directly asking farmers to express their preference for particular variety traits or demand for seed. These studies could, however, be used to distil particular aspects of demand through interpreting the findings.

The results of adoption studies mostly characterise the (non-)adopters *ex-post*, and relate this with characteristics such as age, gender, size of the farm and access to extension service. This information helps us to better understand the types of farmers that have an interest in certain varieties or types or seed. However, the majority of the studies in this category did not factor in how farmers used the specified type of seed or variety, e.g. the area of land they allocated to plant a new variety. Moreover, most of these studies did not pay specific attention to the traits that made varieties or seeds attractive or not. Thus, these studies do not create a deeper understanding of the reasons for, and conditions that influence, non-adoption: is it the variety, the availability or access of seed of the variety or the choice of the farmer? The simplified perspective of adoption is also reflected in the argument of Glover et al. (2019) and Sumberg (2016) that adoption data do not sufficiently explain the underlying process of farmers' technological change.

The final category of studies characterise how farmers currently use varieties and seeds. Studies that describe variety use and varietal diversity create a better understanding of how the dynamics of farming systems result in farmers' choices of varieties along with other technological choices. Descriptions of farmers' seed sourcing practices can lead to the identification of constraints and opportunities for farmers to access seed and new germplasm, and provide entry points for seed delivery programs to reach farmers with seed of improved varieties. While neither of the latter two types of studies directly inform us about farmers' demand for seed, they can be used to derive farmers' demand by interpreting their motivations for their current varietal choices and their seed sourcing practices. Representing farmers actual use of varieties and seeds, the results of these are generally very reliable and have a high external validity (see Breidert et al., 2006). The limitation of these approaches is that they do not necessarily point to constraints and potential improvements in seed or variety use. They can also not be used to study farmers' future demands for seed or their demand for varieties or types of seed that they do not know.

2.6 Conclusions

Our review has yielded a range of studies and approaches that all study aspects of farmers' demand for varieties and seeds. Each of them has its disciplinary angle and interpretation, and, consequently, its strengths and weaknesses. Yet it is worth asking whether and how the findings of these studies are being acted upon? Some studies were meant as baseline studies to inform project design and implementation or to inform breeding programs about farmers' preferences. However, the reasons why a large number of the studies were carried out remain unclear. Given the need for demand-driven innovation in seed systems, we consider the research we identified to be limited, and too diverse in set-up and approaches to be able to systematically inform breeders, seed suppliers and other actors who play a role in supporting seed system development.

While most studies aim to understand seed demand from the perspective of farmers, we should also consider the supply side. Both show a high degree of variability and unpredictability, co-evolving in a process that includes multiple stakeholders from the demand and supply sides (Bentley et al., 2007). We recognise that the identified methods study farmers' demands of the *here and now*, whereas breeding programs and seed system interventions have to address future demands that can be influenced by market fluctuations, climate change and crisis situations. Due to these dynamics and unpredictability of demands over time and space, it is unlikely that a single method of demand articulation can provide a satisfactory basis for making seed systems more responsive to demand.

The conceptualization of demand and the classification scheme of methods for its articulation form a foundation for dealing with the multiple types and aspects of demand for RTB seed. Our classification scheme may guide researchers and development practitioners in reflecting on the methods they use or can use to study specific types and aspects of demand. Making the differences between these methods visible and considering their limitations is a first step in recognising the complexity of understanding farmers' demand. As a next step, we call for a comprehensive framework that purposefully combines these methods in order to understand the multiple demands of farmers, taking into account their real-life preferences and trade-offs. Using such a framework and involving farmers and other stakeholders in a demand articulation process would characterise existing demands in a more effective and precise way, thus providing better guidance to decision-makers in their reactions pertaining to seed systems.

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Chapter 3

How responsive is Nigeria's cassava seed system to farmers' demand? Exploring supply and demand interactions in three farming communities

Thomas Pircher, Esmé Rosa Stuart, Conny J. M. Almekinders, David Obisesan, Hemant Nitturkar, Godwin Asumugha, Emmanuel Azaino, and Andrea Knierim

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3 How responsive is Nigeria's cassava seed system to farmers' demand? Exploring supply and demand interactions in three farming communities

3.1 Abstract

Based on a concept for demand-orientation in seed systems, we characterized Nigeria's cassava (*Manihot esculenta*) seed system from national to local level and farmers' demand in three study sites. Interviews with seed-system actors explained their roles for supply-side functions. Focus group discussions and a survey described multiple aspects of farmers' demand. Our findings show that the national agriculture development program alone did not have the capacity to supply farmers with sufficient seed of desired varieties. Seed exchange between farmers and informal seed sellers contributed to the distribution of seed and new varieties. The presence of seed sellers and farmers' demand for cassava seed varied between the three study sites, farmer types and gender. We conclude that informal seed sellers and village seed entrepreneurs have a potential to respond to farmer's heterogeneous demands. However, without recurrent demand for specialized seed production or continuous support from the formal system, they do not reach underserved markets.

3.2 Introduction

Using better varieties and higher quality seed[2] in farmers' fields is one pathway to enhance agricultural productivity and the quality of food. Root, tuber, and banana (RT&B) crops make a particular case. As some of the most important staple crops in the world's poorest regions, they play an important role in food security in the global South (RTB 2021). Because of their vegetative propagation via stems, roots, tubers, or suckers, their seed is managed differently from "true" seed crops. High potential for re-use by farmers, low profitability margins, bulkiness in handling and transport, and quick perishability of the planting material make them unattractive for commercial breeding and private sector seed programs (Bentley *et al.* 2018, Almekinders *et al.* 2019). International crop improvement programs, in collaboration with national agricultural research institutes, in many African countries, have contributed to breeding, release and spread of improved varieties and distribution schemes for clean planting material of an improved physiological quality. These efforts were informed by research on farmers' varietal preferences and aimed to provide farmers with better adapted and more nutritious varieties (Alene *et al.* 2015). Despite large investments across several decades, the public sector has not been able to meet the expected rates of varietal

[2] In this article we use the term "seed" not only in its "true" botanical meaning, but also in reference to planting material of vegetatively propagated crops. These include stems, roots, tubers, and suckers.

adoption, turnover and use of quality seed in RT&B crops (Walker and Alwang 2015, Spielman and Smale 2017).

There is a range of reasons why the supply of improved varieties and quality seed of RT&B crops do not meet farmers' demand and the uptake remains limited, and they vary across crops and context. Two recent studies presented further explanation. Thiele et al. (2020) analysed cases of multiple RT&B crops in Africa and concluded that varietal change was limited because of insufficient priority given to consumer-preferred traits by breeding programs. The authors indicated that more research was needed to understand the impact of gender differences in consumption preferences and the extent to which informal seed systems contributed to the slow uptake. McEwan et al. (2021) presented findings from an interdisciplinary group of CGIAR scientists on seed systems. The authors identified four major gaps in seed system research, which included understanding farmers' demand and their seed acquisition behaviour, identifying effective seed delivery channels, ensuring seed health, and identifying effective policies and regulations. The indicated knowledge gaps in seed system research of both studies call for a better understanding of the demand side as well as the supply side to design seed system interventions that make better adapted seed available to different types of farmers.

The supply side of RT&B seed systems is often characterized by a large variability of formal and informal actors and dynamic interactions among them. While breeding programs, seed certification schemes and early generation seed production are mostly operated by the public sector, informal seed traders often play a central role in seed delivery to farmers (Sperling *et al.* 2020b). A similarly important contribution to the supply of improved germplasm are farmer seed networks (Coomes 2010, Coomes *et al.* 2015). Because of the largely informal trade, sharing and re-use of RT&B seed, farmers' demand for seed cannot easily be measured by plotting a demand curve of certain varieties and types of seed. Studying farmers' demand requires an approach that goes beyond the economic concept of demand and includes also not clearly defined needs of farmers (Pircher and Almekinders 2021).

Understanding to what extent seed systems are able to respond to different types of farmers' demand, requires not only an analysis of demand and supply but also the mutual shaping of both sides. Literature that addresses both the supply side and demand side of RT&B seed systems consists of few empirical studies only (Nangoti *et al.* 2004, Gildemacher *et al.* 2009, Adam *et al.* 2018, Bentley *et al.* 2018, Almekinders *et al.* 2019). Some of these studies analysed the role of various seed system actors and to what extent farmers' demand was met in these seed systems. However, in none of these studies the supply-demand interactions were presented in sufficient detail to draw conclusions about the underlying dynamics in demand and supply that make seed systems responsive to farmers' demand. To address this knowledge gap, we carried out a study on the cassava (*Manihot esculenta*) seed system in Nigeria.

Nigeria's cassava seed system has been influenced by large-scale interventions from research and development in breeding, seed multiplication and distribution in the past 50 years (Alene *et al.* 2015, Oparinde *et al.* 2016). Despite these efforts, most farmers sourced seed from friends, relatives and neighbours, and informal stem trade remained a common form of seed acquisition (Almekinders *et al.* 2017, Wossen *et al.* 2017). Yet, the informal sector is not considered very effective or efficient; the cassava seed system needs to better address farmers' demand for varietal traits and improve distribution schemes to reach farmers better (Bentley *et al.* 2017). Therefore, the objective of our study was to characterize the functioning of the seed system from a national to a local level as well as different aspects of farmers' demand. The following questions guided our research: Who are key actors across key functions of the cassava seed system? How do these actors interact to make adapted seed available and accessible to farmers? What demands for cassava seed do farmers have? How are these demands addressed by the supply side of the system?

3.3 Conceptual framework to study demand and supply in seed systems

In our analysis, we consider farmers' demand for seed as an outcome of the interplay between demand and supply-side in a co-evolutionary process (Dijk and Yarime 2010, Saviotti and Pyka 2013). To capture the mutual influence between both sides of this interplay, we build on analytical dualism between agency and structure (Archer 1995). Farmers' choices and decision making for farming technologies, such as seed, can be explained by behavioural factors that are shaped largely by agency (Crane *et al.* 2011, Dessart *et al.* 2019). To describe farmers' demand, i.e., their preferences for specific varieties and types of seed, we take into account the various aspects of demand that were conceptualized in Pircher and Almekinders 2021: (i) varietal traits, (ii) quality of seed, (iii) seed sourcing, and (iv) quantity of seed. These preferences and choices are not only driven by farmers' agency alone, but influenced by structures that are also described as systems, regimes or rules of the game (Geels 2004). We studied these structures with a systems approach. The use of systems concepts for analysis, and thus their explanatory power, varies strongly with different perspectives for systems thinking that have evolved across time (Reynolds and Howell 2010, Ison 2017). In agricultural innovation systems, there are three different strands of thinking on how a system can be interpreted: an infrastructural view, a process view, and a functionalist view (Klerkx *et al.* 2012). In this study, we are taking a functionalist systems perspective, which explains the overall functioning of a system by the functioning of sub-systems and their interactions.

Seed systems can operate on different geographical scales and levels (e.g., local, national, international) (Almekinders *et al.* 1994), consist of formal and informal sectors (McGuire and Sperling 2016), and other interacting sub-systems like project-based seed systems (Gibson 2013, Rachkara *et al.* 2017). Drawing upon the work of Checkland (1981) and Banathy (1997), Christinck et al. (2018a) conceptualized seed systems as human activity systems, which are established and maintained by human actors. They highlight that human activity systems can be defined at three levels: *(1) the collective purpose it serves; (2) the individual* *purposes of its members; and (3) the relations with and contributions to the larger environment, in which it is embedded*. While the various actors in the system have individual goals (e.g., creating profit with seed trade), the collective purpose of a seed system is to ensure that sufficient seed (in quality and quantity) that farmers and their market partners require is available at the right time and place at an affordable price (Christinck *et al.* 2018a).

In our model of a seed system, we consider the following functions that lead to the collective purpose: (i) provision of a legal framework, (ii) variety development, (iii) seed multiplication, (iv) seed dissemination and exchange, and (v) crop production and use (adapted from Christinck *et al.* 2018b). Seed system actors carry out activities that contribute to these functions, thus to the collective purpose. The boundaries of seed systems are surrounded by a "larger environment" that includes agroecological conditions, genetic resources, markets for produce, as well as a political and a socio-cultural context for farming. This environment can change across time and dynamically influence the goals and activities of actors, and their interactions in the system (Christinck *et al.* 2018b).

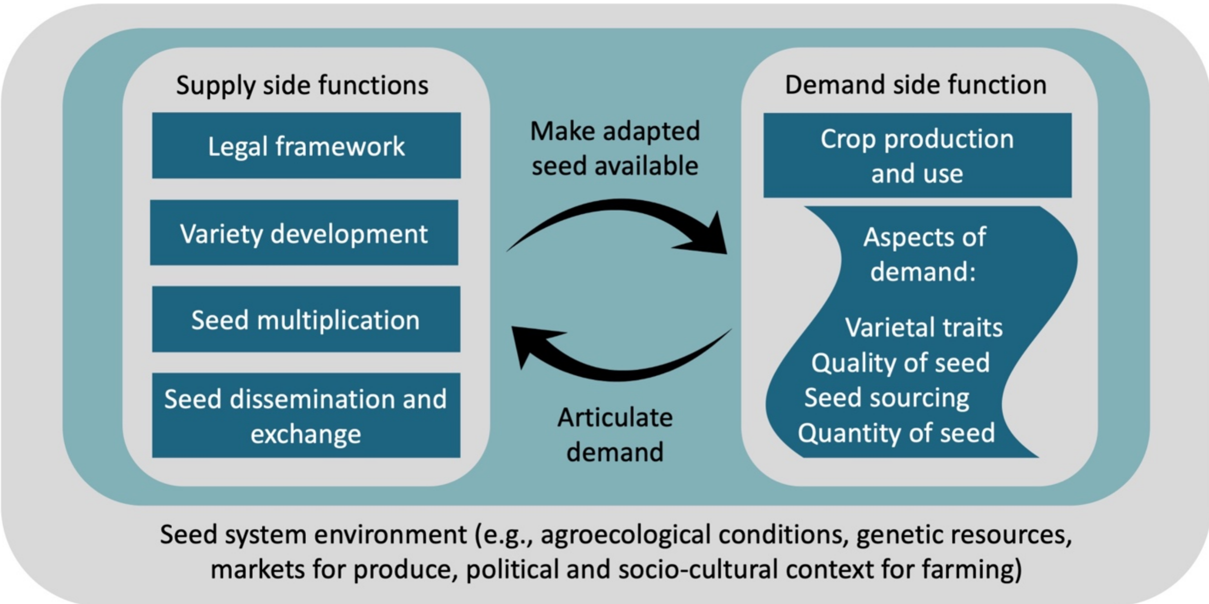

Figure 3.1. Model to study supply, demand and its interactions in RT&B seed systems (based on five seed system functions by Christinck (2018b))

A well-functioning seed system provides farmers with seed that is free of diseases, helps them adapt to local and global challenges, such as climate change, and creates enabling conditions for disadvantaged social groups, such as women, youth and ethnic minorities (Andrade-Piedra *et al.* 2020). To address these diverse needs of farmers better, researchers have emphasized the importance of demand-orientation in seed systems and outlined strategies for demand-driven breeding and seed system development (Ceccarelli and Grando 2007, Witcombe and Yadavendra 2014, Rubyogo *et al.* 2016, CGIAR 2020). Following these perspectives, we consider demand-driven seed systems as systems in which farmers' demand interacts with the supply side of seed systems in two ways. Firstly, the supply side of the seed system aims to provide seed that meets farmers' demand. Secondly, the articulation of farmers' demand acts as a driver for the supply side of the seed system. This could be through farmers' feedback in the breeding process with participatory plant breeding and variety selection schemes (e.g., Almekinders and Elings 2001, Sperling *et al.* 2001, Ceccarelli and Grando 2007). As such, providing the "right" seed to farmers is not only a static outcome but part of a process that consists of a dynamic interplay between demand and supply in a system (see Figure 3.1).

3.4 Materials and methods

3.4.1 Description of the study sites

To present some cases that show a variation in the functioning of cassava seed systems in Nigeria, we selected three study sites that represent three major different cultural and agro-ecological zones (see Figure 2): Umuohuodi (Umuapu Ohaji/Egbema local government area [LGA], Imo State, South East Zone); Ibiaku Ntok Okpo[3] (Ikono LGA, Akwa Ibom State, South-South Zone); and Ashina (Gwer East LGA, Benue State, North Central Zone). The criteria for site selection were the presence of small to large farms and areas where cassava was a major crop in farming systems. Below, we describe the three study sites, which build the agro-ecological, socio-cultural, market and policy environment of the selected cassava seed systems on a local level.

In **Ibiaku Ntok Okpo** (located in Akwa Ibom State), the vegetation is predominantly lowland rainforest. The most important food crops are cassava, yam (*Dioscorea rotundata*), maize (*Zea mays*), rice (*Oryza sativa*), and cocoyam (*Colocasia esculenta*). The growing season for cassava corresponds with the rainy season (March–October). Cassava roots are processed into *gari* (granular flour made by roasting fermented cassava) and *fufu* (fermented wet cassava paste) for home consumption; local markets exist for gari and raw cassava roots. Land fragmentation results in relatively small farm sizes compared with the other study sites and are seen as a challenge to cassava farming. In **Umuohuodi** (located in Imo State), the vegetation is humid tropical rainforest. Cassava is the most important staple crop next to plantain and banana (*Musa* spp.). It is typically grown in the rainy season (March/April–October) and processed into *gari, fufu* and *tapioca* (a form of processed root for starch production) for home consumption and sale to traders on the nearby market. Large areas of land are available and mostly communally owned. Personally owned lands exist to a limited extent and are used for cassava cultivation, too.

[3] The sample included farmers from different villages in the community Ibiaku Ntok Okpo, namely Ikot Akpan Udo, Ibiaku Ata, Itak Ikotakpandem, Ikot Ofiong, Ibiaku Ikot Edet, Ikot Ukana, Nkara Obio and Nung Ukim.

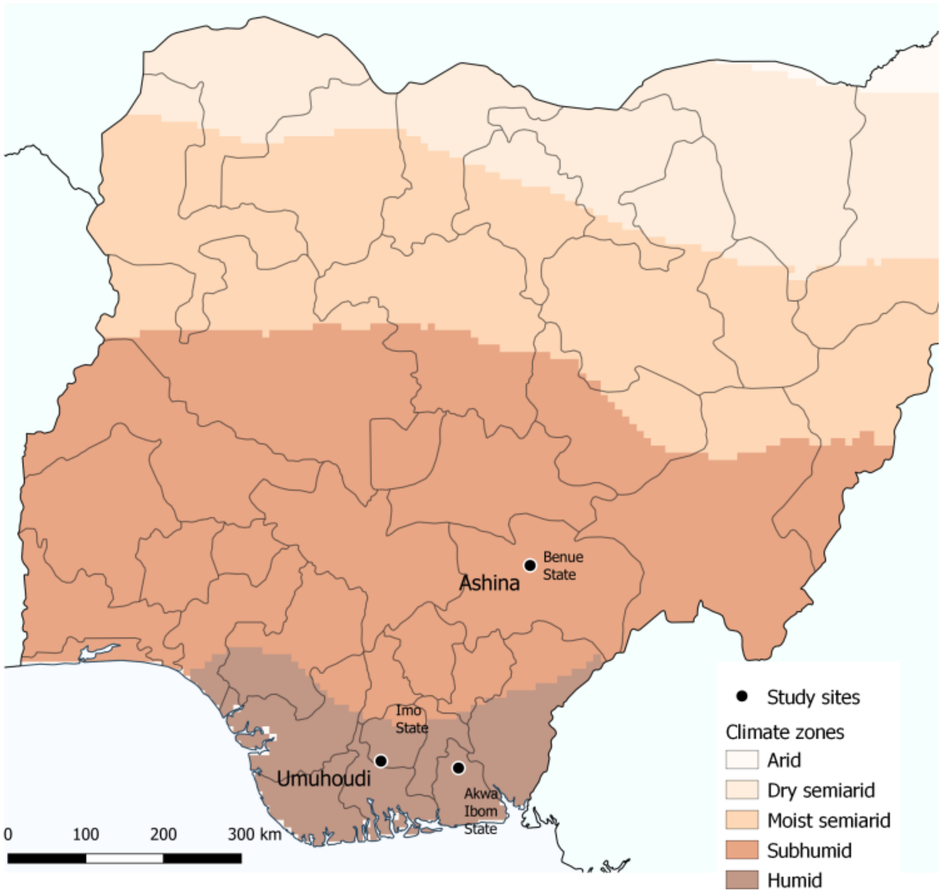

Figure 3.2 Map of Nigeria's agro-ecological zones with three study sites. (Produced with QGIS 3.4 using GIS data from HarvestChoice, 2015.)

Ashina (located in Benue State) is situated in the savannah zone with a considerably shorter growing season (May–October), followed by six months of dry season. The long dry season makes it more difficult for farmers to keep cassava stems in good condition for the next planting period. The farmers in the community own relatively large areas of land (up to 15 ha), which they cultivate with cassava, soybean (*Glycine max*), sorghum (Sorghum bicolor), rice, yam, groundnut (*Arachis hypogaea*), and vegetables like pepper (*Capsicum annuum),* and okra (*Abelmoschus esculentus*), and fruit trees (e.g., *Citrus*). Cassava and soybean are considered main crops. Roots are predominantly processed into *akpu* and *gari* for home consumption and sale on the market. The markets in Ashina and around are more active and better accessible than in the other two study sites.

3.4.2 Methods for data collection and analysis, and sampling

Expert discussions in workshops and meetings provided first insights into the Nigerian cassava seed system as a whole and helped to design an adapted study approach. The next steps of data collection were identifying actors, activities and interactions in performing seed system functions, and understanding the variations and dynamics of demand between and within study sites. A study team, supported by enumerators and translators, collected data for two studies: the first study was on farmers' demand for seed (from August until December 2017) and the second study was on the actors, activities and interactions in the seed system (from May 2018 until June 2018). Both studies applied the principles of a small N/exploratory case study method that has been described as one tool for seed system diagnosis as part of a toolbox for working with RT&B seed systems (Andrade-Piedra *et al.* 2020). Small N/exploratory case studies combine quantitative and qualitative data, and are more oriented toward exploring *real-world* diversity and similarity in a cross-case analysis than toward statistically significant differences and correlations (Mahoney 2000, Ebbinghaus 2005). The explanatory power of this method lies in a cross-case comparison (in combination with within-case studies) of purposefully selected groups of farmers and other seed system actors and the different communities.

The study on farmers' demand for cassava seed (first study) was based on focus group discussions (FGDs) with farmers from three farming communities, individual interviews with farmers in the same study sites, and expert workshop discussions. All farmers were informed about the purpose of the discussions and interviews and were asked if they agreed that the information counld be used for scientific reports. No other personal data were recorded but the name of the farmer, gender, age and community where he or she was living.

To capture the range of different types of farmers in the study area, we held two FGDs with farmers from Imo State and Benue State on how they would differentiate cassava farmers in their communities. Based on these discussions, we defined three categories of cassava farmers: *small* (size of cassava fields < 0.5 ha), *medium* (size of cassava fields 0.5–2 ha), and *large* (size of cassava fields > 2 ha). A preliminary data collection in the three study sites in October 2017 with gender-balanced FGDs served as an entry point to the communities and helped to explore the local context of farming and growing cassava. Subsequently, we carried out a survey based on farming households that reflected all defined farmer categories via purposeful sampling (see Table 3.1). The survey contained questions on a household level and was administered to both women and men (40% and 60%, respectively), who were mobilized by leaders and resource persons in the three study communities. The findings were discussed in a workshop with experts from the National Root Crop Research Institute (NRCRI) and partner organizations of the project "Building an Economically Sustainable, Integrated Seed System for Cassava in Nigeria" (BASICS). The discussions helped to verify the findings and to refine the survey questionnaire. The interviews with farmers, based on the refined questionnaires, took place in the second study phase from November to December 2017.

The study on actors, activities and interactions in the seed system (second study) was based on individual interviews of key experts from formal institutions and informal seed sellers in the cassava seed system, and discussions of a final workshop. We conducted eight interviews with key informants from NRCRI, the Agriculture Development Program (ADP), the National Agricultural Seed Council (NASC), the International Institute of Tropical Agriculture (IITA), the BASICS project, and HarvestPlus on their mandate, strategy and seed distribution channels. These institutions and projects were identified as important actors in the cassava seed system in an earlier workshop (see above). In each of the three study sites, we interviewed seed sellers, which we identified through collaborating cassava farmers

(Akwa Ibom State: 6 women/6 men, Benue State: 6 women/8 men, Imo State: 4 women/8 men). Because markets had been identified as important dissemination channels for cassava stems, we additionally visited six community markets in Ibiaku Ntok Okpo, five in Umuohuodi, and two in Ashina. When seed sellers were not present, we interviewed the market committee and/or other market sellers who also had some knowledge of the sales of cassava stems. The interview questions to the seed sellers addressed their sources of seed, prices, volumes and types of transactions. A final workshop was organized with the NRCRI and Catholic Relief Service (CRS) research teams to discuss and validate the findings of the studies on farmers' demand for seed and the cassava seed system.

Table 3.1. Number of interviewed farmers in individual interviews and number of focus group discussions (FGDs) in the three study sites carried out for the study on farmers' demand

	Respondents of individual interviews			
Study site	***Small farmers***	***Medium farmers***	***Large farmers***	**FGD participants**
Ibiaku Ntok Okpo (South-South Zone); first study phase	5 (1 male/ 4 females)	5 (3 males/ 2 females)	5 (5 males/ 0 female)	23 (10 males/13 females), 12 (7 males/5 females)
Ibiaku Ntok Okpo (South-South Zone); second study phase	5 (1 male/ 4 females)	6 (5 males/ 1 female)	4 (3 males/ 1 female)	10 (9 males/1 female)
Umuohuodi (South East Zone); first study phase	5 (2 males/ 3 females)	8 (5 males/ 3 females)	3 (1 male/ 2 females)	28 (10 males/18 females), 13 (5 males/8 females)
Umuohuodi (South East Zone); second study phase	4 (2 males/ 2 females)	6 (2 males/ 4 females)	4 (2 males/ 2 females)	11 (5 males/6 females)
Ashina (North Central Zone)	9 (7 males/ 2 females)	26 (20 males / 6 females)	12 (6 males/ 6 females)	10 (5 males/5 females), 16 (12 males/4 females)

To relate data from interviews, FGDs and expert meetings to the five seed system functions, aspects of demand, and seed system interactions, as outlined in our theoretical framework, we performed a qualitative content analysis (e.g., Bengtsson 2016). In this analysis, we grouped the most-discussed topics and most-prominent issues that were mentioned by respondents. To analyze the structured questions from surveys in the three farming communities, we collated the data in a spreadsheet and used Microsoft Excel® for descriptive statistics. Resource persons from IITA headquarters in Ibadan, ADP agents in the study regions, and knowledgeable farmers in the study sites supported the identification of cassava varieties via their local names and characteristics.

3.5 Results

3.5.1 Functioning of the seed system at the national level

Key informant interviews indicated that three government organizations in the seed system contributed to providing a legal framework, variety development, seed multiplication and seed dissemination. NASC is responsible for the legal regulation of the seed industry in Nigeria. Following its mandate, NASC assures the quality of all classes of seeds (i.e., breeder, foundation and certified seeds) that are produced by IITA, NRCRI, and other seed growers through certification. The main activity of NASC in the cassava seed system consists of registering seed producers and quality certification of their seed. In that role, NASC controls land preparation during mid-season and upon harvest to assure that cassava stems are true-to-type. Although the seed law restricts the multiplication and sale of non-certified cassava seed, this was not actively implemented at the time of our study. NRCRI has the mandate to conduct research on the genetic improvement, production, processing, marketing and utilization of root and tuber crops and agricultural extension to farmers. As such, NRCRI is the main producer of certified seed and a seed distributor of improved varieties to farmers. If the demand cannot be met by NRCRI by itself, it refers the clients to out-growers. The ADP carries out a nationwide agricultural extension program aimed at increasing the knowledge base and use of improved practices by farmers, including the use of improved varieties. Each state's ADP is a parastatal of the Ministry of Agriculture and all these ADPs fall under the Federal Ministry of Agriculture and Rural Development. ADP has the mandate to disseminate seed through the ADP offices, but this channel was not functional at the time of our study because of financial constraints. NRCRI therefore established alternative dissemination pathways through demonstration plots, non-government organizations (NGOs), state and federal distribution structures, farmer organizations, and farmers directly.

Apart from the government institutions in Nigeria, projects by international institutions support cassava breeding, multiplication and distribution. The BASICS project, implemented by The CGIAR Research Program on Roots, Tubers and Bananas (RTB) and led by the International Potato Center (CIP), for the first time established a certified seed value chain from breeder seed to the sales of certified seed via a decentralized network of village seed entrepreneurs in Nigeria's South-South, Southeast and North Central geopolitical zones. The village seed entrepreneurs have access to early-generation cassava seed from foundation seed producers, which they multiply and sell to farmer-clients in the vicinity. This makes them major distributors of certified cassava seed in Nigeria, next to NRCRI. Since 2010, the program *HarvestPlus,* coordinated by the International Center for Tropical Agriculture (CIAT) and the International Food Policy Research Institute (IFPRI), supports the distribution of biofortified vitamin A cassava varieties. NextGen, a project led by Cornell University, in collaboration with IITA and NRCRI in Nigeria, aims at increasing the rate of genetic improvement in cassava breeding. Breeder seed production is scaled up through GoSeed, part of the business unit of the IITA Business Incubation Platform. Out-growers produce foundation seed by buying breeder seed from and selling foundation seed back to GoSeed.

Different to the actual mandate of ADP, which is the dissemination of certified seed to farmers, the network of ADP agents often act as *brokers* in the system. The ADP extension staff, called agents, facilitate stem sales among farmers, and between farmers and stem sellers by establishing contacts between the potential sellers and buyers. In that role, they contribute to seed dissemination and exchange of seed that is informally multiplied by farmers and other seed sellers. Also, NGOs, churches, and local governments contribute to seed dissemination and exchange. They purchase non-certified cassava seed from different sources and distribute the stems for free to farming communities as a way of support or gaining popularity in rural areas. The link to and between these institutions and farmers, and between farmers is built largely by informal seed sellers. These sellers range from farmers who sell 50–100 bundles (one bundle = 50 cassava stems one meter long) a year to large commercial traders, who sell 2,000 bundles or more a year. During the planting season, stems are traded on village markets or specialized cassava markets. We identified three types of informal seed sellers that commonly exist in Nigeria's cassava seed system:

- Farmer seller: a cassava farmer who sells at least 50 bundles of stems a year from his/her own field as a by-product of root production.
- Stem farmer: a cassava farmer who has a deliberate strategy for stem production and selling (at least part of the cassava fields is planted with the aim to sell stems).
- Stem trader: a trader who does not grow his/her own cassava fields to produce seed, but buys and sells stems, sometimes across long distances.

Farmers make up the largest and most diverse group of actors in the seed system. They continuously source and share cassava stems among themselves and with seed sellers. Besides producing cassava roots for different purposes, some farmers also engage in selling, multiplying and trading stems. As such, the farmers can perform different functions in a seed system.

3.5.2 Functioning of the seed system at the local level

In **Ibiaku Ntok Okpo,** the Akwa Ibom State Agricultural Development Program (AKADEP) used to play an active role in seed dissemination. The ADP agents often facilitate cassava stem sales between sellers and buyers in the community. Four of the 12 seed sellers interviewed in Ibiaku Ntok Okpo indicated that they obtained improved cassava varieties via the ADP in the past years. The seed sellers sold the cassava stems to farmers in the community, which led to the dissemination of improved varieties. Recently, the AKADEP reduced seed brokering, when improved varieties were available among farmers in the community. Only in Ibiaku Ntok Okpo, we identified *stem farmers* who specialized in planting cassava for the sale of stems. They reported to sell significantly more bundles of cassava stems than the interviewed *farmer sellers*. Out of the six interviewed stem farmers, two indicated obtaining new varieties from the market, two from seed sellers in the BASICS project, and four from AKADEP.

The cassava sector in Imo State is characterized by a relatively low intervention of formal actors and low adoption rates of improved varieties as compared to other states. Only 3 of the 12 interviewed cassava seed sellers in **Umuohuodi** reported to have access to new varieties. The others explained to have no contact with ADP, no money to buy stems of new varieties, and no other sources to obtain new varieties. Some farmers in the community reported that they regularly sold stems in relatively large amounts at the cassava stem market to clients from the community and also from other Local Government Areas and neighbouring states. Farmers explained that the stem buyers often came from areas where the soil was infertile and cassava plants did not produce enough cuttings for planting. The farmer sellers also cut stems on demand to sell them from their farm. Their clients know about them through contact with former buyers or through seeing the cassava field of the farmer seller.

The ADP in Benue State, Benue Agricultural and Rural Development Authority (BNARDA), plays a central role in the distribution of cassava seed and new varieties. BNARDA typical sources for stems of improved varieties are HarvestPlus out-growers, IITA, NRCRI, and the Roots and Tubers Extension Program. In addition, seed sellers indicated that BNARDA commonly sourced stems via aggregators from distances of up to 60 km to facilitate seed sales to farmers in the vicinity of their offices. BNARDA has been active for a long time and is well connected to farmers, especially in **Ashina** where a retired ADP extension worker lives. A community leader of Ashina explained that the retired extension worker received improved cassava varieties from BNARDA in 2011 and 2012 to distribute them to farmers for further multiplication as part of the general ADP plan. Some of the farmers, who originally received the improved varieties from BNARDA for multiplication, have become important seed sellers in the community. The local seed sellers in Ashina can be categorized as *farmer sellers*. Some sellers regularly cut stems from their field and advertise the sale by placing a heap of stems along the road. Others sell on-demand on a referral basis, mostly through the ADP and previous clients. The Catholic Church and CRS connect seed sellers and buyers by advertising improved varieties and sales points.

Table 3.2. Presence and role of seed system actors in the three study sites; ADP=Agriculture Development Program

	Ibiaku Ntok Okpo, Akwa Ibom	**Umuohuodi, Imo State**	**Ashina, Benue State**
ADP	Used to actively distribute new cassava varieties, but stopped when farmers had access to new varieties	Low presence and influence in the distribution of quality seed and new varieties	Very active role in distributing new cassava varieties and facilitating seed sale
Farmer seller	Active role, have access to recent varieties	Active role, sell stems mostly on markets and some also on demand from their farm. They have no access to new varieties	Actively selling stems, have access to new varieties and sell on-demand from their farms or ad hoc along the road during planting season
Stem farmers	Deliberately produce seed of recent varieties	Not present	Not present
Stem trader	Not present	Buy stems from seed sellers in the community	Trade with producers and buyers in community, facilitated by BNARDA
Others		Specialized stem markets exist, where clients come from far	Catholic Church / Catholic Relief Service (CRS) create market linkages

3.5.3 Farmers' demand for seed

3.5.3.1 Varietal traits

Farmers at the three study sites indicated to have grown a portfolio of one to six different cassava varieties per household. The use of local names often refers to the characteristics of these varieties. For example, in Ibiaku Ntok Okpo, farmers call a variety, formally known as "TME-419," "Long John" because of its distinctive stem architecture with a non-branching and very straight stem. All varieties in use have traits that farmers like and traits they dislike. For example, farmers in Umuohuodi explained:

> Nwaocha is very good for fufu, as the colour is usually brighter than other varieties. It is the preferred variety for fufu and gari [indicating high starch content. However,] … it is often eaten by rodents because it is sweet unlike other varieties.
>
> Abeokuta matures earlier than other varieties. [However,] … it absorbs plenty of water in the rainy season and retains a small amount of water during the dry season.

In FGDs, farmers described the characteristics of their most popular varieties in the studied communities (Table 3.3). In Ibiaku Ntok Okpo, farmers explained that the variety 6-Months / Give Me Chance is grown in almost every household because it matures within six months and its yields are reasonably high. However, the variety does not store well underground, as it decays relatively early. The farmers did not appreciate the earlier used varieties "Ekauya," "Paya," and "Afiokpo" and gradually stopped planting them.

Farmers indicated that they commonly asked for seed from other farmers or seed sellers to try out new cassava varieties (reported by 7 of 20 farmers in Ibiaku Ntok Okpo, 4 of 15 farmers in Umuohuodi, and 7 of 11 farmers in Ashina). The Akwa Ibom ADP recently introduced the variety "Stainless" (formal name unknown), which is mostly in the hands of medium and large farmers. In FGDs, participants explained that those farmers shared the seed of the variety with other farmers in the community and sometimes asked for money for the stems. Similar patterns of variety diffusion in communities were reported in FGDs in Ashina. In Umuohuodi, farmers recalled the varieties "Nwaocha" and "Agric" to have been in the community for about 10 years. The other varieties had been there for much longer, which farmers were unable to trace back.

FGDs with farmers indicated that in Umuohuodi and Ibiaku Ntok Okpo, decisions on varietal choices, sources for planting material, and marketing of produce were mostly taken together by men and women. In Ashina, these decisions were commonly taken by men. Interviews with key informants and seed sellers showed that men and women both asked for specific varieties when sourcing stems, but they did not have clear differences in variety preferences, i.e., they appreciated the same varieties for similar traits. One female cassava stem seller in Ibiaku Ntok Okpo, however, explained that "new varieties are mostly in the hands of men."

Table 3.3. Most popular cassava varieties (grown by more than 10% of farmers) in the three study communities and distribution among farmers

Study site	Name used by farmers	Formal name	Release date	Farmers who grow variety
Ibiaku Ntok Okpo, Akwa Ibom State (N=30)	6-Months/Give Me Chance	K195 / K29	Not released, IITA field trials in 1976	100%
	Long John/TME 419	TME-419	2005	70%
	Vitamin A/vitamin C/ vitamin E	TMS 011368	2011	43%
	Stainless	*Unknown*	Unknown, recently	17%
	Five-Five	TMS 30572	1984	13%
Umuohuodi, Imo State (N=30)	Abeokuta	*Landrace,* also known as Imo Best/Dabere	*not released*	100%
	Nwaocha	*Landrace*	*not released*	90%
	Ahunna/Vuo Lee	*Landrace*	*not released*	80%
	Akpu Red	*Landrace,* also known as Nwaibibi	*not released*	60%
	Agric	*Landrace*	*not released*	20%
	Egbe nwuri	*Landrace*	*not released*	17%
	Agu Egbu	*Landrace*	*not released*	17%
Ashina, Benue State (N=47)	TMS 1368	TMS 011368	2011	62%
	Akpu Fefa	*Unknown*	Unknown, long time	60%
	TMS 30572	TMS 30572	1984	45%
	TMS 0505	TMS 980505	2005	40%
	Akoyawo	TME 7 (Oko-Iyawo)	*Landrace*, identified in 1971	30%
	Dangbo	TME 2 (Odongbo)	*Landrace* and released as variety in 1986	15%
	TME 419	TME-419	2005	9%

In some cases farmers used different names for the same variety (e.g., “6-Months” and “Give Me Chance”)
Release dates/date of identification were identified from http://my.iita.org/accession2/ and http://seedtracker.org/cassava/index.php/released-cassava-varieties-in-nigeria/

3.5.3.2 Quality of seed

In all three study sites, stem sellers reported on the quality attributes that men and women sought: robust fresh stems, white/cream color of the stem, shorter internodes, free from mechanical damage, diameter (not too small), free of termites, and early maturity. Farmers commonly identify the quality of stems by observing the color of the stem pulp. In this process, they also consider the freshness of the young cassava leaves on the stem. Stems with white powdery substance are considered to be of poor quality. The longer dry season in Ashina, compared to the other two study sites, makes it more difficult to keep the stems in good condition for planting. Some farmers explained that they planted the cassava stems in swampy areas to conserve them until the planting season starts. However, most of the seed was produced from fresh cuttings from farmers’ fields. According to stem sellers in Ashina, their clients considered “disease-free” as an important trait in selecting stems. However, across all study sites, the farmers did not mention disease infestation or other reasons that would indicate degeneration of planting material in the individual interviews nor in the FGDs. They usually sourced seed from other farmers or traders for other quality aspects.

3.5.3.3 Seed sourcing

In the last 12 months, farmers across all three study sites used cassava seed from multiple sources in a single season: their own fields, relatives/friends/neighbours (RFN), the ADP, and traders. The dominant source of stems was farmers' own fields. Off-farm seed sourcing varied between study sites and farmer categories (Table 3.4). In Ibiaku Ntok Okpo, most small and medium farmers sourced stems from their own farms or in a combination of own- and off-farm, whereas the majority of large farmers sourced exclusively from their own farms. In Umuohuodi and Ashina, most farmers sourced planting material exclusively from their own farms. The group of large farmers in Umuohuodi was the exception: many of them sourced their planting material off-farm only (14%) or in combination (43%).

Table 3.4, Mean size of areas planted with cassava per farmer and sources of cassava stems used by the farmers from different categories in three study sites in the last 12 months

Study site	Farmer category	Mean size cassava areas in ha, (standard deviation)	Own-farm only (%)	Off-farm only (%)	Combina-tion (%)
Ibiaku Ntok Okpo	Small (n=10)	0.4 (0.1)	10	30	60
	Medium (n=11)	1.5 (0.4)	18	27	55
	Large (n=9)	3.4 (1.1)	78	0	22
Umuohuodi	Small (n=9)	0.3 (0.1)	67	0	33
	Medium (n=14)	1.4 (0.5)	71	0	29
	Large (n=7)	3.4 (1.2)	43	14	43
Ashina	Small (n=9)	0.4 (0.1)	89	0	11
	Medium (n=26)	1.2 (0.4)	81	4	15
	Large (n=12)	4.1 (2.7)	92	0	8

The major off-farm source for seed across all study sites in the past 12 month was RFN (Table 3.5 and Figure 3.3). According to interviewed farmers, it was normal to share seed without payment within the community. In Ibiaku Ntok Okpo, farmers indicated that in some parts of the community, farmers were traditionally allowed to take cassava stems from fields without prior agreement with the owner as long as the stems were used for planting in one's own fields and not for commercial purposes. In other parts of the community, it required negotiation and possibly payments in cash or in-kind (e.g., seed or labour on other farms). With an increasing commercialization of the cassava sector, cash transactions for sharing seed with RFN have become more common than before. In Ashina, farmers explained that while they shared seed with subsistence farmers in the community for free, they expected commercial farmers to pay for the stems. Next to seed exchange with RFN, farmers across all study sites sourced stems from seed sellers and via ADP-facilitated seed exchange in the last 12 months (see Figure 3.3). In Umuohuodi, the ADP was represented less prominently than in the other study sites, with only one transaction in the study population. Instead, a larger share of cassava stems was sourced from seed sellers (12 transactions in the last 12 months).

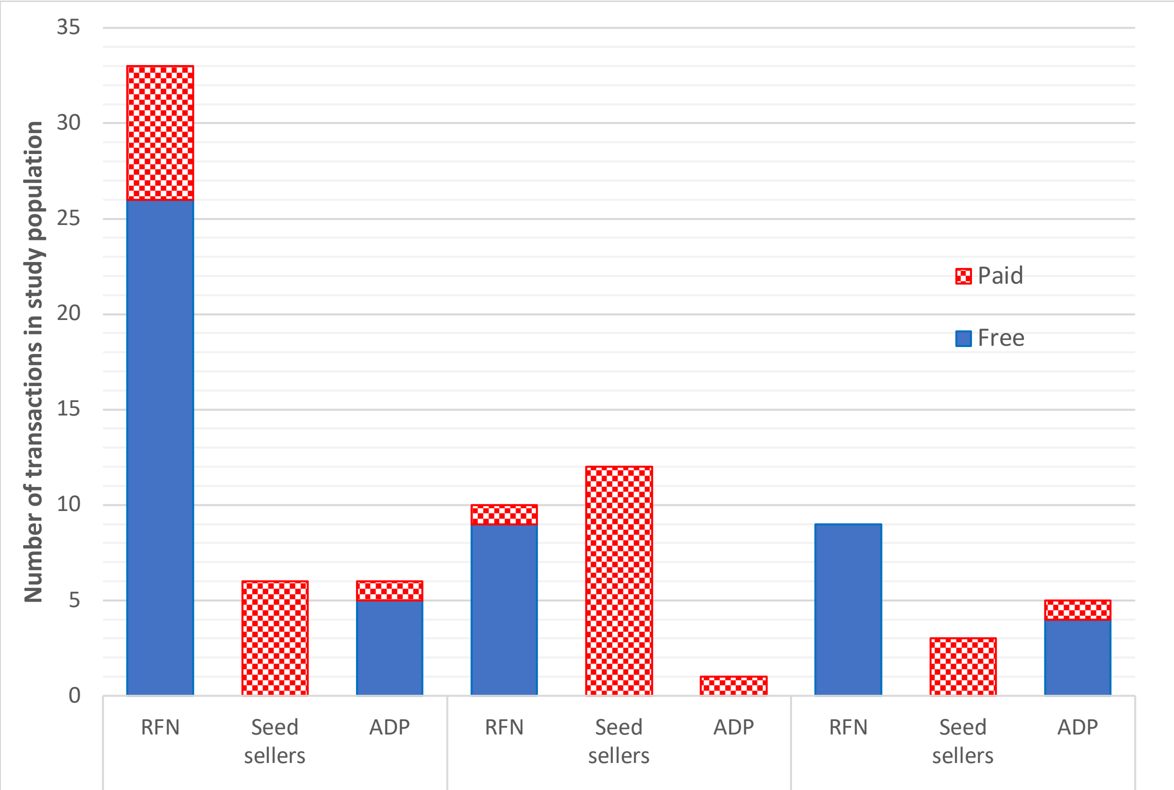

Figure 3.3. Different sources and number of seed transactions in the sample of farmers in the last 12 months. RFN=Relatives, friends or neighbours; ADP=Agriculture Development Program

According to FGDs and individual interviews in Ibiaku Ntok Okpo, most farmers who sourced stems off-farm were men. A female farmer in Ibiaku Ntok Okpo, who regularly sold cassava stems explained:

> It is exceptional for me to source stems from the Ministry of Agriculture. Other women do not have that opportunity; they are afraid to express themselves. They only plant cassava for home consumption and not to sell roots, like I do.

3.5.3.4 Quantity of seed

The data presented in the previous section showed a considerable part of seed transactions from off-farm sources. However, data on the total volumes of cassava stems showed that the majority of stems (more than 80% on each site) were sourced from farmers' own fields in the last 12 months (Table 3.5). Farmers in Ibiaku Ntok Okpo sourced 17% of seed from RFN, and seed from other off-farm sources constituted only a relatively small proportion.

Table 3.5. Volumes of cassava planting material that farmers used from their own field and sourced off-farm in the last 12 months; RFN=Relatives, friends or neighbours; ADP=Agriculture Development Program

Study site	**Mean volumes in bundles (standard deviation)**	**Own field**	**RFN**	**ADP**	**Seed sellers**
Ibiaku Ntok Okpo (N=15)	43.9 (38.2)	81%	17%	0	2%
Umuohuodi (N=15)	145.5 (113.8)	96%	2%	0	2%
Ashina (N=47)	84.8 (63.9)	91%	4%	4%	1%

Note: Figures are based on data from second study phase only. Therefore, not all transactions as presented above are included

A shortage of planting material of farmers from their own fields was reported as the main reason for off-farm seed sourcing (reported by 10 of 20 farmers in Ibiaku Ntok Okpo and by 9 of 15 farmers in Umuohuodi). The farmers indicated a shortage of planting material due to theft, infestation by termites, inadequate availability of their own stems, and the need for more stems to expand farms. In Ashina, only 3 of 11 farmers reported a shortage of planting material from their own fields. These farmers were planning to expand their farms.

Discussions with stem sellers showed a tendency that the larger the average purchase per client, the larger the percentage of male buyers. One seed seller explained that he favoured male clients since they were willing to pay more, resulting in delayed delivery to female clients. During the validation workshop, the participants suggested that women were normally part of a social network in which stem sharing was common, reducing their willingness to pay for stems.

3.6 Discussion

3.6.1 Actors and interactions on the supply side

Our study showed that a wide range of formal and informal actors were involved across all seed system functions. Similar to other RT&B crops, the public sector did not have the capacity and private sector companies were not interested to engage in seed multiplication and dissemination (Gibson 2013, Almekinders *et al.* 2019). The limited capacity of the ADP to disseminate certified seed to farmers already created a gap in the dissemination of new varieties in Umuohuodi and would possibly create a similar gap in Ibiaku Ntok Okpo in the future. The importance of informal seed sellers to provide seed system functions in such situations was emphasized for RT&B crops (Andrade-Piedra *et al.* 2016, Rachkara *et al.* 2017) as well as for other crops (Sperling *et al.,* 2020a). In particular, for vulnerable groups, during stress periods and for seed of specially adapted crops, informal seed traders catered for underserved markets and reached out to farmers in the last mile (Sperling and McGuire 2010, Kansiime and Mastenbroek 2016, Sperling *et al.,* 2020b).

Our findings showed that seed exchange with RFN could enhance farmer's access to seed in case of shortages and the distribution of new varieties once they reached the community, similar to other RT&B crops in Africa (Coomes *et al.* 2015, Tadesse *et al.* 2016, Adam *et al.*

2018, Almekinders *et al.* 2019). All seed that farmers in our study reported on, was non-certified seed produced and sourced from farmers' fields and disseminated via local trade and farmer seed networks. Also a data analysis of six countries and 40 crops showed that farmers accessed 90.2 % of their seed from informal systems (McGuire and Sperling 2016). It is therefore not likely that laws to restrict informal sales of cassava seed, other than certified by NASC, can be enforced in Nigeria.

3.6.2 Demand-side of the seed system

In regard to farmers' demand, access, availability and use of seed varied between the seed systems in the three communities. Farmers across all study sites maintained and gradually replaced a portfolio of varieties. As presented in other studies, the prevailing portfolio of varieties in all study sites reflected varietal choices that are driven by agro-ecological conditions, cultural preferences, and market opportunities for produce, but limited by the access from the supply side (Pircher *et al.* 2013, Tadesse *et al.* 2017). Hence, farmers might use different varieties because they did not have access to a variety that combined their desired traits. Keeping multiple varieties can also be driven by the interest of farmers to have traits for different production uses, e.g., for bitter and sweet cassava varieties (Thiele *et al.* 2020). In either case, this situation indicates a demand for new, better adapted cassava varieties.

Our exploratory study approach revealed that variations in demand not only occurred between different communities, but also within communities and households. In Ibiaku Ntok Okpo, the intensity of off-farm seed sourcing increased from large farmers to small ones. Also Sperling and McGuire (2010) found a significantly higher share of poorer farmers sourcing seed of different crops and in different African countries from informal markets. Their explanation was that poorer farmers often ran out of seed from their own farms, whereas richer farmers bought seed to access new varieties. Social differentiation by gender illustrated variations in demand, in particular that women had less access to new varieties and were not able or willing to pay for larger amounts of cassava seed. We did not explore in-depth gender-specific trait preferences. Different preferences for varietal traits in cassava by men and women in Nigeria were found in other studies (Bentley *et al.* 2017, Wossen *et al.* 2017, Teeken *et al.* 2018).

Our findings on quality criteria for planting material refer to physical condition of the stems, but not to viruses and other pathogens. This can be explained by the absence of pathogens that can cause stem degeneration in Nigeria. The largest threat, cassava brown streak disease, is currently present in east and central Africa but has not yet affected west Africa (Patil *et al.* 2015). If cassava viruses and other diseases reach Nigeria, farmers' demand for seed quality might shift the focus on disease-free planting material.

3.6.3 Supply-demand interactions

The market for cassava seed across the study sties was driven by a combination of three types of demand, i.e., desired varieties, and quantity and quality of seed. Our study indicates that public seed distribution schemes are unlikely to reach farmers with cassava seed that addresses heterogeneous demands. Some scholars argue that farmer-owned seed systems address the variation in demand across social groups, cultural identities and inequalities better (Bezner Kerr 2013). However, without linkages to the formal sector, these seed systems often lack the influx of new varieties and a regular turnover of those (Gibson 2013). In our study, we observed this in Umuohuodi, where the varieties in use had been in the community for 10 years or longer and consisted of landraces only.

Another model to supply quality seed and improved varieties is farmer seed enterprises that are recognized by the legal framework and authorized to produce certified seed (e.g., David 2004). These models have been promoted since the 1980s, but so far they have not reached scale and sustainability to become prominent for seed supply (Almekinders *et al.* 2019). The BASICS project, which is active in the three project areas, builds on such a model. A recent study on the project concluded that decentralized seed multipliers, called village seed entrepreneurs, might be able to satisfy farmers' demand for cassava seed but needed continued programmatic support to do so (Bentley *et al.* 2020).

Both informal seed sellers and village seed entrepreneurs of the BASICS project have the potential to contribute to disseminating quality seed and new varieties on the last mile. However, this can only work when recurrent demand for cassava seed exists or when seed sellers are empowered by the formal system. In this process, the flow of information on various aspects of demand from farmers to early generation seed producers and breeders becomes similarly important. Established village seed enterprises or empowered informal seed sellers know farmers' demand for seed that drives their business. To respond better to farmers' demand, they would need access to a wide array of varieties and influence early-generation seed producers and breeders about which varieties to produce. Such a feedback loop would allow farmers to better articulate their demand for seed toward the supply side in a continuous process.

3.7 Conclusions

We are aware that our exploratory study in the three farming communities is not representative of Nigeria. However, our findings help to explain variations in demand among the study sites, and to a smaller extent also among farmer types and gender. Moreover, our study indicates supply-demand dynamics: (i) farmers maintain an adapted portfolio of varieties, and dynamically source new seed via different channels, (ii) informal seed system actors contribute to the dissemination and exchange of seed where the public sector does not reach out. Seed sellers and village seed entrepreneurs have the potential to deliver seed on the last mile but lack access to new varieties. To close the gap in a process of demand articulation from farmers to breeders and producers of early generation seed, they need continuous support from formal actors.

While arguing for more demand-orientation in seed systems, we recognize the pitfalls of limiting the focus on seed system performance to farmers' demand alone. For example, an evaluation of client-oriented breeding schemes in Nepal showed that the operational seed-producer groups marketed only rice varieties that were already in the hands of farmers, but did not contribute to scaling out new varieties (Witcombe *et al.* 2010). Innovation in seed systems is based on continuous improvement and spread of varieties that also address challenges that farmers might not yet identify, e.g., outbreak of cassava brown streak disease. Making seed systems future-proof, therefore, requires a balance between demand-orientation to make seed attractive to farmers and foresight with other stakeholders to address future challenges and opportunities.

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Chapter 4

Farmer-centred and structural perspectives on innovation and scaling: A study on sustainable agriculture and nutrition in East Africa

Thomas Pircher, Magdalena Nertinger, Luisa Goss, Thomas Hilger, Jeninah Karungi-Tumutegyereize, Lydiah Waswa, and Andrea Knierim

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4 Farmer-centred and structural perspectives on innovation and scaling: A study on sustainable agriculture and nutrition in East Africa

4.1 Abstract

Purpose: We studied innovation processes in agriculture and nutrition to discuss a scaling approach that encompasses the technical, institutional, and behavioural dimensions of change.

Approach: To understand dynamics across these dimensions, we analysed farmers' innovation processes through two analytical lenses: farmer-centred and structural. Focus group discussions in Kapchorwa, Uganda, and Teso South, Kenya looked at farmers' choices of innovations. Individual interviews and stakeholder workshops at both study sites increased understanding of the local innovation system.

Findings: To address local challenges, strive for livelihood aspirations, and fulfil personal taste preferences, farmers selected and adapted practices promoted by a research project. A wide range of additional support providers encouraged farmers to develop innovations in agriculture, marketing, and nutrition.

Practical implications: By promoting innovation as a process rather than an outcome, it is possible to address context-specific needs and enhance farmers' adaptive capacities. Scaling these processes necessitates the involvement of innovation support service providers in order to create an enabling environment for experimentation.

Theoretical implications: Analytical dualism highlights the different roles of human agency and structures in innovation processes needed to design successful scaling strategies.

Originality/value: This paper sets out a novel approach to understanding the increasingly discussed dimensions of scaling by linking them with concepts from innovation studies.

4.2 Introduction

4.2.1 Background and objectives

The 2030 Agenda for Sustainable Development, defined in the 17 Sustainable Development Goals (SDGs), was adopted by all member states of the United Nations in 2015. To achieve the objectives related to agriculture and nutrition, there must be a shift to healthy diets from sustainable food systems (Willett et al. 2019; Caron et al. 2018; Swinburn et al. 2019). New technologies and systemic innovation across food system activities are deemed essential to make our food systems more sustainable and resilient (Herrero et al. 2020; Hall and Dijkman 2019). International agriculture research and development initiatives therefore support the development and spread of innovations and technologies, such as more resilient and nutritious crop varieties, mechanization, digitalization, and sustainable land management practices (e.g. CGIAR 2021). Despite these efforts, the spread of innovations and any associated productivity have lagged behind expectations, especially in Africa (e.g. Mausch et al. 2018; Walker and Alwang 2015).

One reason why many research and development initiatives fail in their efforts to scale innovations successfully is that they do not sufficiently grasp the changing system dynamics around scaling (Woltering et al. 2019; Ika 2012). A new strand of applied research, termed the *Science of Scaling,* acknowledges and embraces the multi-dimensional, multi-level, and multi-stakeholder nature of scaling (Schut, Leeuwis, and Thiele 2020; Hall and Dijkman 2019). Researchers in this field have determined that the key issue in scaling is the lack of understanding of how different dimensions of change (i.e., technical, institutional, behavioural) co-evolve, and how these dimensions can support each other (Schut, Leeuwis, and Thiele 2020). This paper addresses this knowledge gap by studying the dimensions and interactions in scaling processes with concepts from innovation studies.

Underpinning the concept of scaling with an approach from innovation studies takes up the call from researchers to challenge the duality of *innovation versus scaling,* and make scaling an integral part of systemic approaches to innovation (Wigboldus et al. 2016; Foster and Heeks 2013). Rather than a linear process of disseminating technologies and innovations as an outcome from research initiatives, we see scaling as part of a continuous process of refinement and adaptation of innovations across different contexts and scales. This view reflects the new narrative on scaling that Hall & Dijkman (2019: page 46) proposed to international agricultural research. In this narrative, scaling processes are understood as "an interlocking set of adaptations that range from individuals to the entire 'system of use' or socio- technological regime."

Studying innovation processes across scales, including the technical, institutional, and behavioural dimensions of change requires multiple perspectives that differ in their epistemological foundations. While farmers' behaviour in the use of innovations is often explained by actor-centred approaches on a farm or household level, there is a need for systemic approaches to assess the influence of the structures of which these farmers are part (World Bank 2012; Klerkx et al. 2012). Although both types of approaches have been widely applied, an integrative perspective is necessary to successfully study farmers' behaviour in agricultural systems (Feola and Binder 2010). In this study, we aimed to integrate these perspectives for analysing innovation processes by purposefully applying two analytical lenses: farmer-centred and structural. To instantiate the framework, we applied it in the empirical setting of a research and development project on agriculture and nutrition in East Africa. The insights into farmers' behaviour and structural conditions provided starting points for developing scaling strategies for this and other projects.

4.2.2 Study context of the EaTSANE project

The project 'Education and Training for Sustainable Agriculture and Nutrition in East Africa (EaTSANE)' was carried out from 2018 to 2022 in Kapchorwa District, Uganda and Teso South

Sub-County, Kenya. The objectives of the project were (i) to promote farming practices for healthier soils and more diverse produce, (ii) to improve the access of value chain actors to inputs and services, and (iii) to enhance consumers' food culture and diverse nutrition. To achieve these objectives, researchers in the project engaged farmers and rural households in joint research activities, including participatory trials with farmers and students (Fischer et al. 2019), value chain platforms (Dhamankar and Bitzer 2019), and trials of improved practices in nutrition (Kretz et al. 2021) (Table 4.1).

Table 4.1. Project activities of the EaTSANE project to promote innovation in agriculture and nutrition at both project sites

	Farming practices	**Marketing of crops and vegetables**	**Nutrition practices**
Action learning approaches	Farmer-managed field trials, combined with training in compost making, soil fertility management, pest management, and crop diversification	Value chain platforms in which different actors across value chains engaged to develop solutions to their key problems	Trials of improved practices, where farmers experimented together with researchers on the use of inter-connected food conservation, preparation, and nutrition practices
Innovations promoted	Mixed cropping systems and crop rotation to improve soil fertility, reduce soil erosion, and produce specific mix of food crops	Improved management of value chains of nutrient-dense crops across all actors involved	Preservation of fruit and vegetables via solar drying Cooking practices for more diverse and nutritious food Improved child-feeding practices Construction and use of energy-saving cooking stoves
Inputs provided	Seeds of new/underused crop species and improved varieties Rent for experimental plots	Facilitation of meetings	Construction materials for solar dryers and cooking stoves Vegetables and fruit for cooking trials

In the participatory action learning activities, the researchers introduced concepts that combine multiple components or technologies, such as mixed cropping systems (Cheruiyot et al., in preparation) or a set of connected nutrition practices (Kretz et al. 2021). In the value-chain platform activities, farmers identified key problems, formulated their demands, and jointly developed solutions. A cross-cutting activity was to scale the emerging innovations from these processes through communication and education. This required defining what innovations to scale, how to scale them, and with who. To guide this strategy, our study aimed to provide insights into (i) which aspects or components of the promoted innovations farmers actually used, (ii) the individual drivers to use, reject, or adapt the innovations, and (iii) which actors helped farmers to use the innovations.

4.3 Conceptual framework

Although the understanding of scaling processes has been discussed in literature over the past decades, the concept lacks ontological consensus (Frake and Messina 2018). One definition of scaling that sits well with the objectives of our study is ‘strategies and approaches relating to the objective of seeing that the potential of relatively isolated inventions, innovations, and developments benefits people and situations more widely’ (Wigboldus and Brouwers 2016). To refine scaling processes, Schut et al. (2020) conceptualized the evolution of scaling approaches in two ways. The first way referred to concepts such as the adoption or diffusion of innovations (Rogers 1962), where the use of innovations is largely determined by the behaviour of the adopters and the attributes of innovations (i.e. relative advantage, compatibility, complexity, trialability, and observability). This largely corresponds to spreading or replicating an innovation geographically to benefit a higher number of users (out-scaling). The second way, termed ‘scaling of innovations,’ conceptualizes innovations as interdependent practices involving technological, organizational, and institutional change. This implies scaling in the form of systemic change towards a conducive institutional environment for innovation (up-scaling) (Hermans et al. 2013, 2017). We refer to these two interdependent types of scaling by using two complementary lenses for the analysis of innovation processes in agriculture and nutrition.

Our first analytical lens focused on the role of farmers in the uptake, adaptation, and use of innovations on a farm or household level. This perspective pays due attention to human agency, i.e. the capacity of actors to act or react for their own reasons. Actor-centred approaches acknowledge the heterogeneous and complex social realities of which farmers are part (Mausch et al. 2018; Pircher, Almekinders, and Kamanga 2013; Almekinders et al. 2019). In this view, an innovation cannot simply be transferred from one context to another, but requires packaging, unpacking, and a situated reconfiguration to adapt to site-specific conditions (Glover, Jean-Philippe, and Maat 2017; Garb and Friedlander 2014; Glover et al. 2019). Also in Richards (1989; 1993) notion ‘agriculture as a performance’ small-scale farming is conceptualized as a performance, where farmers are adapting to changing agro-ecological and socio-cultural conditions in real-time.

Farmers’ decisions to adopt, adapt and use farming practices have been studied with socio-psychological approaches that explain decision-making through cognitive processes (Dessart, Barreiro-Hurlé, and Van Bavel 2019; Leeuwis and Aarts 2021). Theories like adult learning (Knowles 1980) and transformative learning (Merizow 1991) have been applied to assess the innovation potential of farming technologies (e.g. Probst et al. 2019). While acknowledging the analytical power of these frameworks, the overall design of our study required to identify the motivations of actors in regard to a set of practices in a rapid appraisal. We therefore studied farmer’s innovation behaviour in an approach, guided by a realist evaluation methodology (Pawson and Tilley 1997), of identifying actual practices (outcomes) and finding out about behavioural mechanisms that contributed to change in a specific context.

Our second analytical lens focused on structures, referring to systems which influence the actors at a farm level. Depicting innovation as interacting elements of technological, organizational, and institutional change indicates that innovations are the outcome of complex interactions among diverse actors in Agricultural Innovation Systems (AISs) (Hall et al. 2003; Klerkx et al. 2012; World Bank 2012). The AIS concept can be applied on different levels (local to national) and interpreted in three different ways: structural, functional, and procedural (Klerkx et al. 2012; Leeuwis and Wigboldus 2017). We adopted a procedural view to identify actors of an AIS and understand their interactions and activities. The concept of innovation support services (ISS) (Ndah et al. 2018; Mathe et al. 2016; Faure et al. 2019; Koutsouris and Zarokosta 2020) allowed us to identify driving and hindering mechanisms of innovation on a farm level.

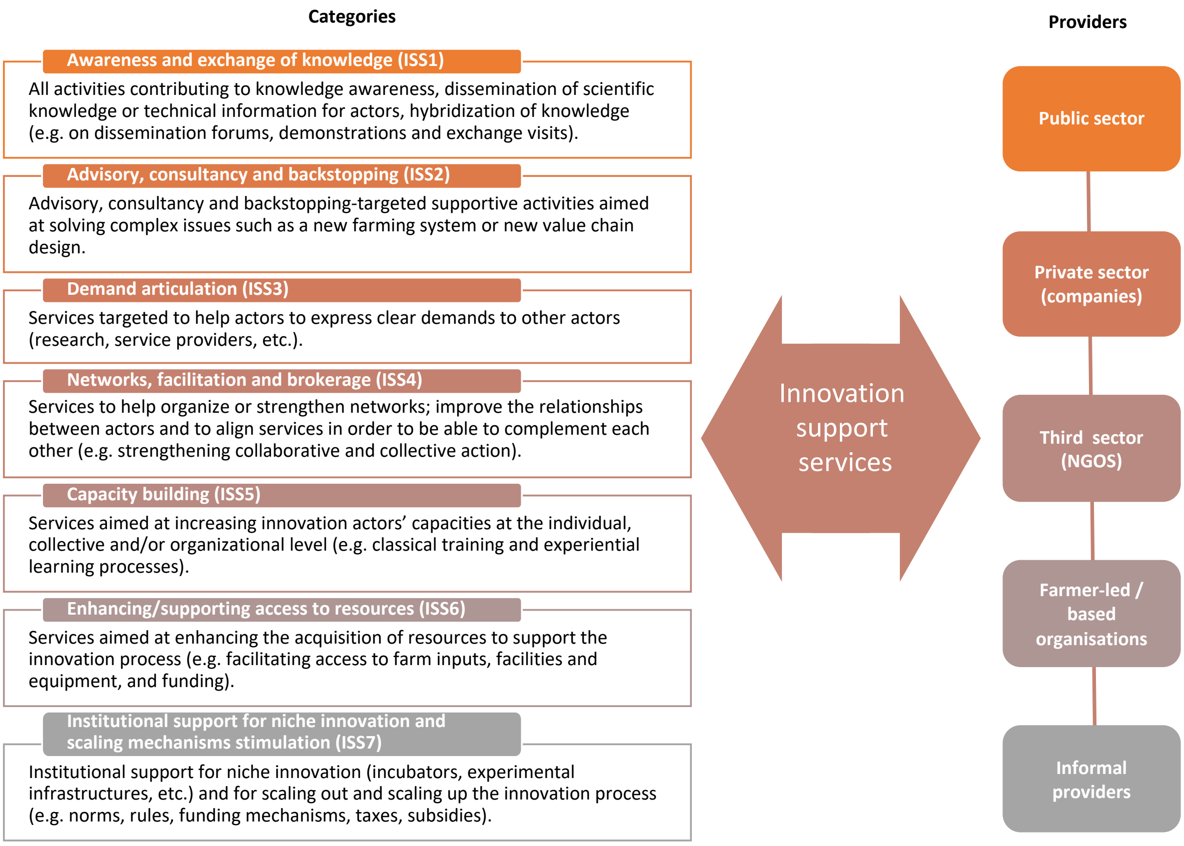

Figure 4.1. Categories and providers of innovation support services (ISS). Adapted from (Mathe et al. 2016; Faure et al. 2019; Ndah et al. 2018)

ISS can be understood as an activity undertaken by an innovation support service provider (ISP) whose constellations and interactions vary across different phases of an innovation (Ndah et al. 2018; Knierim, Ndah, and Gerster-Bentaya 2018) (Figure 4.1). Knierim et al. (2017) distinguish between four organizational types of ISP: public sector, private sector (companies), third sector (NGOs), and farmer-led/based organizations. When applying the framework in the global south, informal providers, i.e. family members or friends, were added as a fifth type (Knierim, Ndah, and Gerster-Bentaya 2018). By mapping ISS, we sought to understand the influence of institutions on innovation processes, which has been identified as a key condition for successfully designing up-scaling strategies (e.g. Hermans et al. 2017; Makate 2019; Struik et al. 2014).

4.4 Materials and methods

4.4.1 Study locations

The study was carried out as part of the EaTSANE project (see 1.2) in several communities of the Kapchorwa District, Uganda, and the Teso South Sub-County, Kenya. Kapchorwa District is located on the slopes of Mount Elgon in the eastern part of Uganda bordering Kenya with altitudes ranging from 1000 to 3000 meters above sea level. Due to the altitude gradient of the study area, temperature and rainfall vary across the district, with a climate that permits two cropping seasons (March to August and September to December). Teso South Sub-County is one of the sub-counties that form Busia County, located along the Kenya-Uganda border. The county has altitudes ranging from 1200 to 1400 meters above sea level with two cropping seasons a year between March and July and September to December.

4.4.2 Data collection

In January and February 2020, we carried out three online key informant interviews with team leaders of the EaTSANE project, and reviewed project documents (articles, reports, BSc./MSc. theses, conference proceedings, etc.) to identify site-specific drivers and constraints to innovation in agriculture and nutrition as well as influencing actors. The findings informed the discussion topics and data collection design of the field studies.

In February and March 2020, the field studies were carried out by a study team of seven researchers with backgrounds in nutrition, agriculture, and economic sciences and two field facilitators. The study team used focus group discussions (FGDs) (Morgan 1997; Krueger and Casey 2015) to efficiently gather information on farmer innovation and the influence of ISS. To capture geographical variations, the team selected four villages for each study site (Olupe, Obekai, Achurut, and Palikite in Teso South Sub-County, Kenya; and Molok, Kiringet, Seron, and Kapndaroi in Kapchorwa District, Uganda), where project activities had taken place over the previous 12 months. The study team mobilized FGD participants in all EaTSANE action learning activities (agronomic trainings, nutrition education activities, and value-chain platforms) in each of the villages. In total, the study team conducted four FGDs in Kapchorwa, Uganda, and four in Teso South, Kenya (see Table 4.2).

In the first part of the FGDs, participants jointly identified innovations in farming, marketing, and nutrition they had developed during the last 12 months. Particular attention was paid to the reasons and motivation for their choices. In the second part, the study team cumulatively summarized the innovations and asked which actors supported or hindered the farmers in developing these innovations. In line with the methodology for stakeholder analysis by Lelea (2014), the study teams and FGD participants co-created Venn diagrams (Theis and Grady 1991) to map influencing actors, and characterize the interactions in each of the villages. As such, the maps described the ISP and ISS from the farmers' perspective.

Table 4.2. Number of focus group discussion (FGD) participants at each study site

Study site	Village	Number of participants
Kapchorwa, Uganda	Molok	13 (9 women, 4 men)
	Kiringet	11 (7 women, 4 men)
	Seron	13 (9 women, 4 men)
	Kapndaroi	11 (9 women, 2 men)
Teso South, Kenya	Olupe	9 (8 women, 1 man)
	Obekai	14 (10 women, 4 men)
	Achurut	14 (10 women, 4 men)
	Palikite	9 (6 women, 3 men)

In addition to the FGDs, the study team carried out open interviews with 10 key ISPs in Kenya and 13 in Uganda to verify the described interactions and to identify other actors who influenced them (second level stakeholders). Finally, the study team held workshops in Kenya and Uganda with representatives of the farmer groups and ISPs to discuss the summarized actor maps from Kapchorwa District, Uganda, and Teso South Sub-County, Kenya (Goss et al. 2020; Nertinger et al. 2020). The participants confirmed or adapted their roles and relationships to consolidate the actor maps, representing ISS and ISPs.

4.4.3 Data analysis

The data collected from the FGDs and the stakeholder interviews were audio-recorded, transcribed, and translated into English where necessary. The data were then structured using qualitative content analysis (Mayring 2014; Bengtsson 2016) and inductively derived categories, subcategories, and interrelated aspects mentioned by the respondents.

The qualitative data from FGDs on how farmers developed innovations were analysed separately to capture differences between farmer groups in the sample villages. The actor maps for Kapchorwa, Uganda, and Teso South, Kenya, were summarized since most identified ISPs operated on a district/sub-county level and the actor maps on a village level overlapped to a large extent. Any variations between actor maps were noted and clarified in the workshop discussions.

4.5 Results

4.5.1 Lens A: Actor-centred analysis on a farm level

When FGD participants reported on their farming, nutrition, and marketing innovations, they mentioned practices that were promoted by the EaTSANE project team (see Table 4.1) as well as other sources. In this section, we describe how the farmers adapted these practices in response to the agro-ecological environment and socio-cultural context of the two study sites.

Kapchorwa District, Uganda

With regard to farming innovations, FGDs in Kapchorwa, Uganda, reported that many farmers selected principles and elements of the promoted cropping systems (Table 4.3). However, they applied these principles separately to address specific contextual challenges and their personal preferences. A major challenge reported in the FGDs was the shortage of agricultural land. The farmers indicated that they increasingly resorted to intercropping (which is a major principle of the promoted cropping system) despite having smaller plots of land. They included potato, pigeon pea, cow pea, and black nightshade as new crops in their cropping patterns. The farmers reported that they preferred the new variety of black nightshade provided by the EaTSANE project because the commonly used, wild variety had a bitter taste. The farmers also mentioned the challenge of erratic rainfall, either too much or too little, leading to problems of soil erosion. This motivated them to plant the newly introduced pumpkin variety that boasts vigorous growth and good soil cover characteristics. Although the farmers did not consume the pumpkin fruit because of its 'watery' taste, they appreciated the leaves and flowers that are commonly eaten in Kapchorwa. Depending on the characteristics of their plots, the farmers applied individual strategies to prevent soil erosion, such as digging trenches or planting border crops and eucalyptus trees.

Table 4.3. Farmer innovations related to EaTSANE project activities in Kapchorwa District, Uganda

	Farming practices	Marketing of crops and vegetables	Nutrition practices
Molok	Used new pumpkin variety as a cover crop to prevent soil erosion and consumption of leaves Improved handling of fertilizer and pesticides	Dried beans on tarpaulin to improve quality Graded and sorted beans to increase the selling price Collective marketing (planned for next season)	Included more vegetables in diets Sun-dried vegetables on grain sack on roof tops Increased thickness of porridge for children Prevented overcooking of vegetables, soaked beans and used less oil Breastfed children up to six month; ate food while breastfeeding
Kiringet	Intercropped egg plants and beans Used crop rotation and fallow periods to free up pasture for animals and increase soil fertility Used pumpkin and field peas to prevent soil erosion and increase soil fertility Intercropped eucalyptus and kales	Used raised surfaces to store farm produce Direct marketing to reach buyers for Sukuma Wiki, maize, tomatoes, and eggplants Collective marketing (planned for next season)	Increased diversity of ingredients for children's food by adding avocado, passion fruit, and milk Used new foods for more nutritious diets (also for child feeding): spinach, carrots, and cowpea. Planned to grow cassava, groundnuts, and sweet potato
Seron	Used field peas, cassava, yams, and lablab as border crops Intercropped pumpkin/maize,	Stored maize, beans, field peas, and potatoes with circulation of fresh air	Served more than one staple food per day Increased the thickness of porridge for children with milk and banana

	beans/maize, amaranth/field peas, and pumpkin/eggplant Started growing potato and pigeon peas	Sold beans of the same color and planted in-demand varieties	Mixed small fishes with porridge Breastfed children up to six month, Dried vegetables on grain sack and on plate stand Started eating pumpkin seeds
Kapndaroi	Dug trenches for erosion control Intercropped groundnuts/maize, maize/sweet potato, field peas/cassava, and carrots/eggplant Started to grow cowpea and a new variety of black nightshade	Direct marketing to larger buyers Preserved beans and maize with eucalyptus leaves Sorted and graded beans and pigeon peas Stored maize, matoke, beans, cassava, and sweet potato on homestead	Dried kales, cabbage, black nightshade, and eggplant Stopped using soda ash to avoid nutrient loss Mixed vegetables for cooking Started eating pumpkin flowers and seeds Breastfed children up to six months Increased thickness of porridge, and used grinded rice, amaranth grain, and soy

With regard to marketing, the farmers tackled the challenges facing them by means of technical and institutional innovations. In response to low prices for commonly grown crops due to oversupply during the seasons and a lack of storage facilities, the farmers welcomed new ideas on post-harvest handling and conservation. They started using *Purdue Improved Crop Storage (PICS)* bags and stored their produce on raised surfaces with more air circulation to avoid moisture and contamination of their produce. The farmers also came to understand that mobile traders with trucks operating in the study area were looking for large quantities, high quality, and uniformity of produce. They established collective marketing arrangements for bush beans and fresh field peas with buyers from inside and outside Kapchorwa District, and graded pigeon peas and beans to comply with the quality requirements of various traders.

While many farmers expressed an interest in healthy diets and improved nutrition, they did not have adequate access to fruit and vegetables, particularly during the off-season. Innovations from training sessions and facilitated experimentation on food preparation in the EaTSANE project helped to address this issue. Farmers in the village Molok set up kitchen gardens to grow a larger variety of vegetables. To access vegetables and fruit outside the season, farmers in three villages used solar dryers that they constructed together with the EaTSANE project team. Farmers who lived far away from solar dryers applied the principles of solar drying with locally available items, such as grain sacks, metallic trays, and drying racks for dishes. To improve the health of their children, the farmers adopted a range of nutrition practices, such as exclusive breastfeeding for six months, serving thick porridge enriched with vegetables, and eating more vegetables and fruit in general. Another innovation was to eat pumpkin seeds and flowers. This had been common practice a long time ago and was reintroduced on hearing about the health benefits.

Teso South Sub-County, Kenya

Farmers in Teso South, Kenya selected specific practices of the proposed cropping systems according to their agro-ecological conditions and access to seed (Table 4.4). Similar to farmers in Kapchorwa, they reported a shortage of agricultural land, which they addressed by intercropping with existing or newly introduced crops. Farmers addressed the issue of decreased soil fertility by incorporating crop residues and growing more legumes. Another challenge in Teso South was the lack and poor quality of millet, nightshade, and cowpea seeds. To contend with this issue, farmers in the village Obekai started producing their own black nightshade seeds.

Table 4.4. Farmer innovations related EaTSANE project activities in four study sites in Teso South Sub-county, Kenya

	Farming practices	Marketing of crops and vegetables	Nutrition practices
Olupe	Used grass as a border crop around kales Intercropped cowpeas, black nightshade, kales, maize and finger millet	Improved management of household finances Diversified production by selling both vegetables and cereals Marketed dried vegetables, in particular cowpea leaves, off season	Offered snacks between meals to their children Introduced more vegetables into household diet Enriched porridge with dried vegetables and oil
Obekai	Produced seeds from black nightshade Incorporated crop residues instead of burning Intercropped multiple crops and vegetables	Diversified marketing of produce by selling a wider range of vegetables	Used solar dryer for cowpea leaves and fruit Diverse diets to improve child nutrition Included preserved fruit in household diet Soaked beans before cooking, stopped using soda ash Constructed and used improved stove
Achut	Planting vegetables seed in line instead of broadcasting Directly planted seeds without pre-cultivating them in seedbeds Intercropped multiple crops and vegetables	Made cassava chips and sold them on markets Increased vegetable production and sold to wider range of buyers	Constructed and used solar dryer and improved stoves Offered fruit to children as snacks Enriched porridge with soybeans, groundnuts, oranges, margarine, and vegetables oil Cooked vegetables together Stopped using soda ash for cooking legumes
Palikite	Intercropped maize / groundnuts and maize / beans / soy Intensified production of beans, kales, cowpeas, and black nightshade Planting vegetables seed in line instead of broadcasting	Sold vegetables in higher quantities Identified new markets to sell vegetable seeds	Conserved cowpea leaves, spider plant, and black nightshade in solar dryer Enriched porridge with soybeans, milk, and groundnuts Increased portions of vegetables in diets Cooked different vegetables together Offered fruit as snacks to their children

There was an increasing market for vegetables in Teso South. However, since the vegetables have different harvest periods, traders did not travel from farm to farm to collect produce in small quantities. The farmers explained that they used three strategies to solve this problem. Firstly, they diversified the production of vegetables, cereals, and cassava to reach more buyers on the local markets. In Palikite, the farmers noted an upcoming market for vegetable seeds in a nearby community and then started selling seed they produced themselves (see above). Secondly, they increased the volume of vegetable production and sold them to buyers outside their community, too. Thirdly, farmers identified and further developed a new market for sun-dried vegetables and cowpea leaves, which they can serve out of season.

Concerning innovations in nutrition practices, the farmers in Teso South were likewise interested in improving their nutrition. Similar to farmers in Kapchorwa, they applied selected practices that were promoted by the EaTSANE project. They used solar dryers or adapted these technologies to their context, such as sun-drying on grain sacks in open spaces. The farmers dried a wide range of crops, such as cowpea leaves, spider plants, black nightshade, and other vegetables. They paid attention to child nutrition by enriching porridge with vegetables, soybeans, groundnuts, milk, or oil and offered fruit as snacks between meals to their children. In terms of food preparation, the farmers reported that they used improved stoves that reduced the use of firewood and produced less smoke, cooked vegetables together to save time and firewood, and stopped using soda ash for cooking legumes to preserve nutrients better.

4.5.2 Lens B: Structural analysis of the AIS

The farm-level innovations described in the previous section can be understood as a selection of options suited to an agro-ecological and socio-cultural environment. In this section, we describe farmer innovation through a structural lens by analyzing the local AIS at both study sites. The farmers who participated in the FGDs identified ISPs, who provided ISS to them. The most frequently mentioned ISP was the EaTSANE project, in which the researchers carried out action learning activities through experimentation with the farmers. As elaborated in section 1.2, the EaTSANE project supported farmers by providing knowledge awareness and exchange (ISS1), advisory, consultancy and backstopping (ISS2), demand articulation (ISS3), capacity building (ISS5), and enhancing/supporting access to resources (ISS6) at both study sites. The influence of other ISS varied between Kapchorwa, Uganda, and Teso South, Kenya, as described in the following.

Kapchorwa, Uganda

In Kapchorwa, Uganda, farmers were influenced by four different actor groups in addition to the EaTSANE project: public sector, private sector (companies), third sector (NGOs), and informal service providers. The interviewed farmers and other stakeholders did not report receiving support from farmer-led organizations. The identified actors encouraged the farmers to innovate in the three fields of action through a range of ISS (see Figure 4.2). In terms of **knowledge awareness and exchange (ISS1)**, the local radio station, the staff member from the national extension program, returning students, the National Agriculture and Food Research Organization (NARO), the Ministry of Agriculture, Animal Industry and Fishery (MAAIF), and the NGO Rikolto shared information on sustainable farming practices with farmers or other stakeholders. The local radio station also shared information on market prices for farm produce to support farmers in securing better prices for stored produce. Visits to markets outside of Kapchorwa district inspired farmers to try new fruit and vegetables. In the Seron community, farmers explained that the village elders had raised awareness about the health benefits of eating pumpkin seeds. Hospitals shared information on child-feeding practices. The district government, a second level stakeholder, provided information on nutrition education to the hospital.

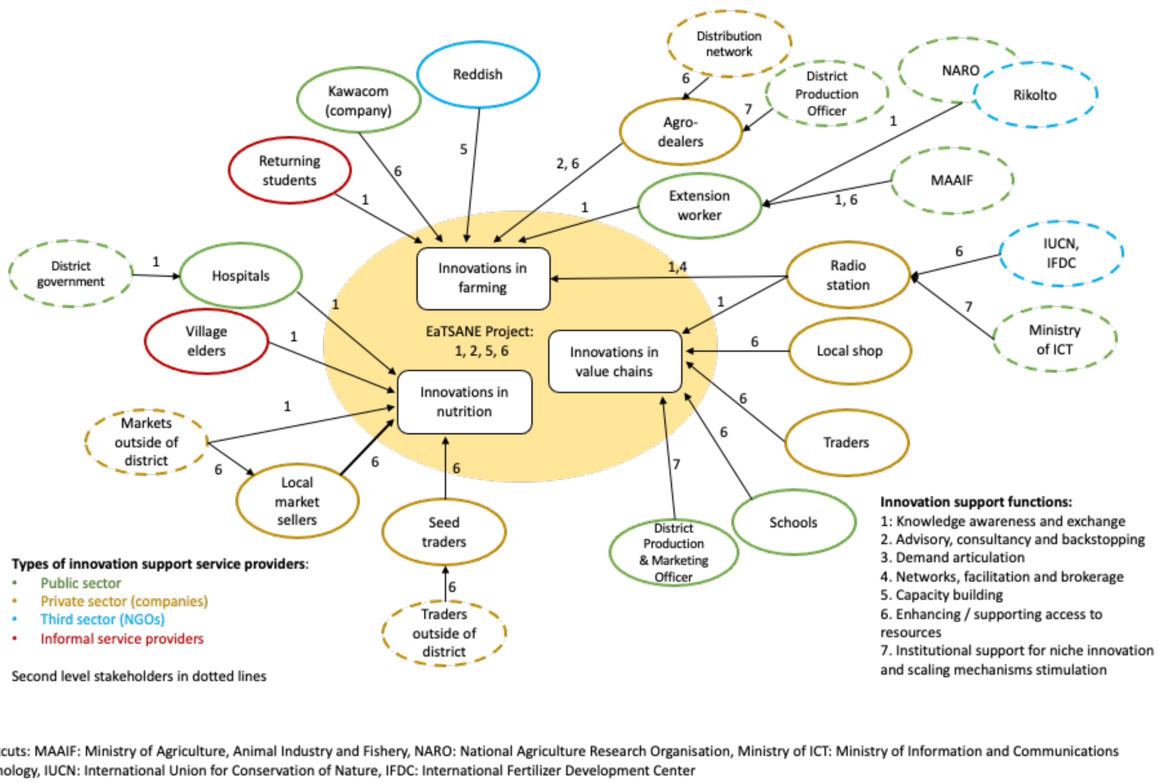

Figure 4.2. Map of AIS actors, including innovation support services and providers in Kapchorwa, Uganda. Abbreviations: MAAIF: Ministry of Agriculture, Animal Industry and Fishery, NARO: National Agriculture Research Organisation, Ministry of ICT: Ministry of Information and Communication

In terms of **advisory, consultancy, and backstopping (ISS2**), farmers reported receiving advice from an agro-dealer in Kapchorwa on how to grow bush beans in intercropping to reduce the need of direct fertilizer application. **Networks, facilitation, and brokerage (ISS4)** was described as the radio station provided a platform on which farmers can discuss and exchange experience with agro-dealers and other experts. Regarding **capacity building (ISS5),** farmers indicated that they received training in the spacing of crops from the NGO Reddish. The most frequently reported ISS was **enhancing/supporting access to resources (ISS6**). Agro-dealers and their distribution networks, seed traders, local shops, and the company Kawacom provided access to farm inputs, such as seed, fertilizer, and tarpaulins for storing produce. Larger traders in the community and schools gave farmers access to markets for selling vegetables and crops collectively at higher prices. Moreover, markets facilitated farmers' access to vegetables for enhanced nutrition practices. The MAAIF funded the national extension program that also reached out to farmers in Kapchorwa. The international NGOs International Union for Conservation of Nature (IUCN) and the International Fertilizer Development Center (IFDC) funded the agricultural program of the radio station. Finally, **institutional support for niche innovation and scaling mechanisms stimulation (ISS7)** played a role as the District Production & Marketing Officer provides regulatory support the collective marketing arrangement of farmer groups. The District Production Officer contributed to regulating the seed market to make seed of better quality (compared to counterfeit seed on the market) available. The Ministry of Information and Communications regulated the content of the radio program, which reached out to farmers in the study area.

Teso South, Kenya

In Busia, Kenya, farmers were similarly influenced by four different ISPs in addition to the EaTSANE project: public sector, private sector (companies), third sector (NGOs), and informal service providers. None of the interviewed farmers or second level stakeholders received support from farmer-led organizations. The identified actors encouraged the farmers to innovate in the three fields of action through a range of ISSs (see Figure 4.3). In terms of **knowledge awareness and exchange (ISS1)**, the international NGO One Acre Fund and the Agricultural Extension Officer shared general knowledge on farming practices. School teachers, hospital staff, and church leaders shared information on more diverse nutrition and child-feeding practices. The farm input shop Agrovet established demonstration plots to present new farming technologies to the community. The village chiefs, known as Barazas, the local radio station, and other community members (neighbours) shared information on both farming practices and nutrition with the community members. We identified community health workers as second-level stakeholders. They informed village members (neighbours) and community health volunteers about improved nutrition practices. Also, Agrovets and the agriculture extension officer acted as second level stakeholders by exchanging information on the latest farming practices with each other.

In terms of **advisory, consultancy, and backstopping (ISS2)**, farmers reported that their neighbours advised them on pest management, and community health volunteers advised them on child feeding, porridge preparation, and balanced diets (i.e. including more fruit and vegetables). We identified **networks, facilitation, and brokerage (ISS4)** as the agriculture extension officer facilitated farm visits where farmers could build networks and exchange knowledge on farming practices. The extension officer organized group meetings (known as *Baraza*), demonstration events, and field days for the same purpose. **Capacity building (ISS5)** was performed by school teachers, hospital staff, and community health volunteers in training sessions on nutrition. These sessions covered aspects of balanced diets, malnutrition and anaemia, and diets for new-borns. The community health volunteers reported that they were trained to run these sessions by the NGOs Red Cross and Ampath. The research organizations Kenya Agricultural and Livestock Research Organization (KALRO) and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) as well as the NGO Once Acre Fund ran training sessions on farming practices. They covered the topics soil fertility and management of biodiversity.

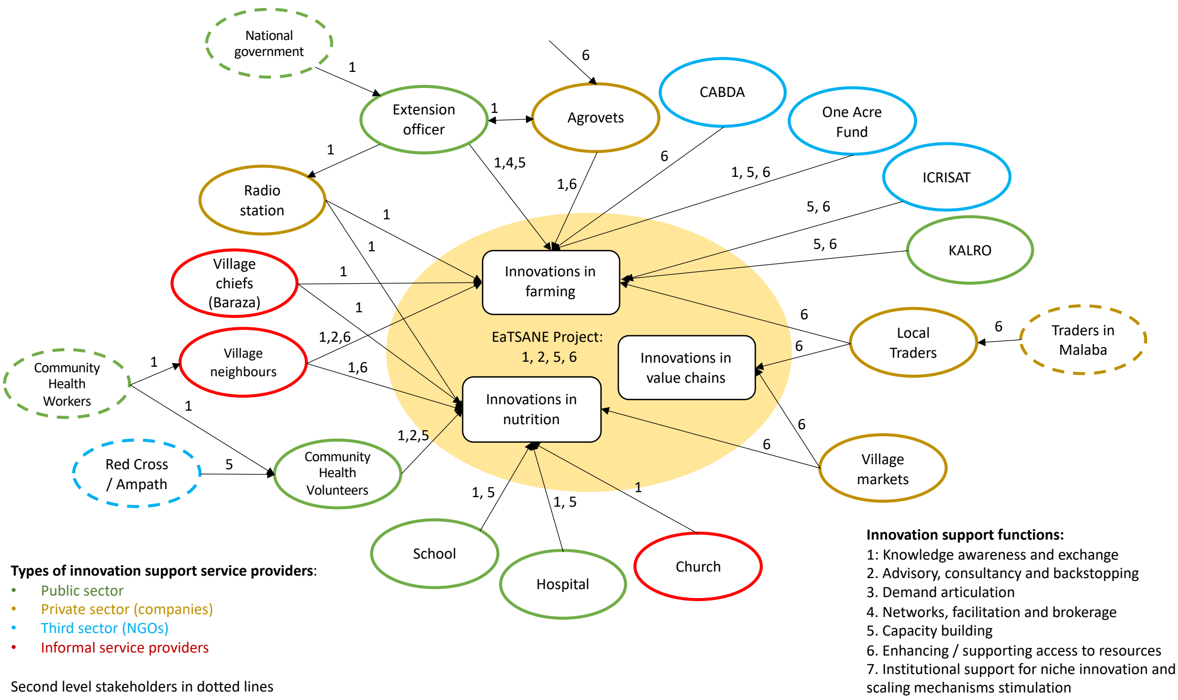

Figure 4.3. Map of AIS actors, including innovation support services and providers in Teso South, Kenya. Abbreviations: KALRO: Kenya Agricultural and Livestock Research Organization, ICRISAT: International Crops Research Institute for the Semi-Arid Tropics

In terms of **enhancing/supporting access to resources (ISS6)**, we identified a wide range of stakeholders: the NGOs One Acre Fund, the program 'Community Area-Based Approach' (CABDA), Agrovets, local traders, KALRO, and ICRISAT provided farmers with access to seeds of different crops that allowed the farmers to grow and combine different crops on their fields (intercropping). Neighbouring farmers exchange seeds within communities. Traders in Busia and the communities sell local seeds of cowpeas, spider plant, amaranth, and black nightshade as grain and seed during the season. They were given the seeds by farmers in the community. The local Agrovet reported selling seeds of amaranth, black nightshade, finger millet, and cowpeas. In an interview, he explained that he produced seeds of amaranth and black nightshade himself and received hybrid seeds of the other crops from a distribution network. He reported that the hybrid seeds were in higher demand as they were not available on the local market. Farmers requested forage seeds from the Agrovet, but there was no supply of these seeds in the community and neither were they available through the distribution network. Besides seeds, the Agrovet also provided access to fertilizers. The traders provided access to markets for selling vegetables. The local trade network for seed and vegetables was supported by traders from Malaba, a nearby border town that was connected to markets of bigger cities and to Uganda. The traders acted as second level stakeholders in the system. Village markets for vegetables provided access to a range of vegetables as a market for selling farm produce as well as a market for buying vegetables to diversify household diets. In our study, we did not identify any institutional support for **niche innovation and scaling mechanism stimulation (ISS7**).

4.6 Discussion

The analysis of farmers' innovation processes, as an interplay between their agency and the influence of ISS, highlighted the relevance of a framework that builds on analytical dualisms. The results from our rapid appraisal directly touched on the specific study objectives related to the EaTSANE project. Although the scope of our combined approach did not allow to study farmers' individual innovation behaviour through more nuanced socio-psychological approaches, the findings provided valuable information on which innovations farmers used, their motivations to do so, and other actors that supported them in this process. The findings at farmer and AIS levels also provided entry points for designing a scaling approach for the EaTSANE and other projects. In the following, we structured our discussion around the questions as to the *what,* the *who,* and the *how* of scaling, which need to be explored for the successful design of scaling strategies (Koerner et al. 2018; Kohl and Linn 2021).

4.6.1 Scaling of what?

Our analysis of innovation seen through a farmer-centred lens indicated that farmers' decisions on innovation in agriculture and nutrition were driven by their aspirations (e.g. better nutrition and income), the challenges they faced (e.g. low prices on markets, decreasing land sizes, soil erosion), and their personal preferences (e.g. taste of vegetable species and varieties). They selected and adapted the promoted practices to fit the specific agro-ecological and socio-cultural context of the two study sites. Although farmers at both study sites used largely similar innovations to address their challenges, Tables 3 and 4 show specific patterns and foci in each village. The heterogeneity in farming has been shown in other studies as variations in farmers' aspirations and motivations (Mausch et al. 2021, 2018; Preissel, Zander, and Knierim 2017). Consequently, disseminating pre-defined technological packages or bundles does not allow farmers to choose and adapt their practices according to their own needs and preferences (Glover, Jean-Philippe, and Maat 2017; Darnhofer, Gibbon, and Dedieu 2012).

Ronner et al. (2021) argue that offering a 'basket of options' builds on the agency of farmers to decide what is most suitable for their specific situations. At the same time, it reduces the burden on research to anticipate which innovations meet farmers' needs. Similarly, the concept of 'modularity' has been applied across disciplines to describe how users combine elements to develop products that fit their own needs (Naik, Fritzsche, and Moeslein 2021; Koerner et al. 2021). The options or modules in our study ranged from specific technologies and practices (e.g. breastfeeding up to the age of 6 months) that were simply adopted or not, to more complex and systemic innovations (e.g. the proposed mixed cropping system, sun-drying, and food preparation) that farmers adapted to their context and preferences. Apart from fitting the current needs of farmers, approaches that facilitate adaptation through innovation can enhance the ability of rural communities to innovate in the face of change, thereby increasing their resilience and sustainability (Douthwaite et al. 2009). We therefore argue that the object of scaling should not be the outcome of innovation processes in a specific context, but an experimental approach that is based on a large set of options.

4.6.2 Mechanisms of innovation and scaling – the how?

Our analysis of the AIS of both study sites showed that farmers accessed a wide range of ISSs. Although boundaries between ISS are not always clear (Koutsouris & Zarokosta, 2020), we did see a tendency that farmers were largely inspired by knowledge, advisory service and capacity building (ISS1, 2 and 5) on new practices that they applied while having access to resources (ISS 6) (e.g. seed of novel crops and varieties). Learning amongst farmers was supported by agricultural extension service and radio via networks (ISS4). We did not identify ISS, aside from the EaTSANE project activities that created niches where farmers could experiment with a wider range of practices (ISS7). This indicated gaps in the AIS of both study sites that limited innovation through experimentation with different options/modules as pointed out above. Creating a widespread impact through innovation would, therefore, be dependent on creating an institutional environment that facilitates farmer experimentation.

Scientific trials on agronomic, nutrition and post-harvest technologies, as carried out in the EaTSANE project, created an intense innovation process that required substantial resources from community members and researchers. Activities in that form would not allow a cost-effective way of institutionalizing experimentation and learning in the study sites. However, components like value chain platforms and community-managed experiments hold potential to continue beyond the lifetime of the project. The community members would need access to a wide array of elements, such as improved crop and vegetable varieties, and materials for storage and conservation technologies, to design their experiments on site specific solutions.

4.6.3 Who to involve in scaling?

Our analysis of the AIS at both study sites revealed a range of potential scaling partners. These included ISPs from private sector, public sector, third sector, and informal service providers. Our results show that farmer-based organizations, another type of ISP, did not influence the interviewed farmers. This group of ISPs could, however, play an important role in creating space for innovation, for instance in collective marketing arrangements (Shiferaw, Hellin, and Muricho 2011). The EaTSANE project established value chain platforms and supported the formation of farmer groups for joint experimentation on agriculture and nutrition practices for the duration of the project. The district and sub-county offices may provide support and facilitate the formal recognition as farmers-based organizations to operate value chain platforms and experimental learning activities in the future. This would be in line with existing learning approaches that were facilitated by the extension officers.

To create access to options/modules for experimentation, agro-dealers, seed traders, local shops in Uganda and Agrovets, local traders, research organizations, and NGOs already play an active role. Although they did react to farmers' demands, access to some elements for experimentation remained limited, e.g. quality seed of forage, legume and vegetable species. These stakeholders might need support from district/sub-county offices in making products in demand available and establishing regulatory frameworks to assure the quality of these (e.g. avoiding counterfeit seeds). To facilitate experimental learning in the communities, the prominently represented ISPs of knowledge, advisory service and capacity building (ISS1, 2 and 5) would need to put more emphasis on farmer-led research in their types of service provision. As argued by Waters-Bayer et al. (2015), third-sector and farmer-led/based organizations would be most promising ISPs for institutionalizing the ideas, principles and spirit of farmer-led research.

The description of AIS actors points out that most ISS targeted agriculture, marketing, and nutrition separately. The EaTSANE project adopted a novel approach by addressing three interrelated topics in an integrated way. Nutrition-sensitive or nutrition-integrated approaches in agricultural extension have the potential to create these important linkages (Keding et al. 2021). ISPs that engage across food system activities are needed to establish these linkages and become key partners in scaling sustainable agriculture and nutrition approaches. This calls for closer collaboration and integration of agriculture, nutrition, and health sectors from a district to a national level.

4.7 Conclusions

This paper highlighted different perspectives on innovation to inform the design of scaling strategies. The *what, how,* and *who* of scaling differ depending on the approaches, topics, and context of research and development projects. Education and training approaches during the implementation of the EaTSANE project have contributed to farmer innovation that addresses context-specific challenges. To address current and future challenges in East African food systems on a large scale, institutional change is needed. The scaling strategy in this paper, which was also reflected in stakeholder workshops (Goss et al. 2020; Nertinger et al. 2020), attempts to initiate such a change process from a district / sub-county level.

From a methodological point of view, we argue that a sound understanding of innovation processes is needed to inform the main questions in scaling strategies. Similar to innovation processes, scaling processes are often not linear but complex and dynamic (Schut, Leeuwis, and Thiele 2020). The dynamic innovation processes in our study are an example to confirm that scaling initiatives should not necessarily target what was initially promoted, but include lessons learned in the field (e.g. community members used some practices for other purposes than the researchers intended). To create a greater and longer-lasting impact, scaling needs to be embedded more in innovation studies and addressed already in the initial stages of research and development projects.

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Chapter 5

General discussion

5 General Discussion

5.1 Introduction

Science and technology can make a major contribution to reaching the Sustainable Development Goals (SDGs) by ending hunger, achieving food security and improved nutrition (UN, 2019). Supporting the development and spread of innovations in agriculture and nutrition, such as crop genetic improvement, mechanization, digitalization, and sustainable land management practices therefore is a main objective of international agricultural research (CGIAR, 2021). Despite decades of research on technological innovation and adoption studies, understanding technological change by small-scale farmers remains a challenge (Glover, Sumberg, Ton, Andersson, & Badstue, 2019). The combined use of structural and actor-centred perspectives, and the interplay between these two, appears promising to provide a nuanced understanding of these processes.

This thesis reviewed and explored the application of study approaches that aim to understand farmer innovation and technological change through the interplay of two analytical lenses: structure and agency. The empirical chapters address this topic by assessing the explanatory power of research methods to understand farmers' demand through a systematic literature review (Chapter 2), and by setting out novel approaches of using analytical dualism to study demand and supply-side interactions in the cassava seed system in Nigeria (Chapter 3) as well as farmers' innovation processes in agriculture and nutrition in relation to agricultural innovation systems in Kenya and Uganda (Chapter 4). This final chapter of the thesis summarizes and discusses the findings from the preceding empirical chapters using the theoretical framework presented in Chapter 1. The discussion of results will highlight contributions to literature as well as practical implications for research and development policies. Finally, limitations regarding data and methodology, and future research needs will be pointed out.

5.2 Summary of main results

The systematic literature review in Chapter 2 provided an overview on how actor-centred and structural perspectives are reflected in methods that have been applied by researchers for studying farmers' choices and demand for seed of roots, tuber and banana (RT&B) crops. The reviewed studies covered a range of scientific disciplines and addressed different aspects and forms of demand. In total, we identified 46 literature sources that describe studies on farmers' demand for RT&B seed encompassing five crops in 18 countries. The qualitative analysis and categorization of the identified studies have led into a classification scheme with three main categories of approaches and respective sub-categories:

(i) Studies that articulate farmers' variety and seed preferences

   a. Articulation of variety trait preferences (n=7)

   b. Means-Ends-Chain analysis of varietal traits and seed (n=3)

c. Assessing willingness to pay (WTP) for varieties or seed (n=7)

(ii) Studies that characterize (non-) adopters and identify determinants of farmers, households or farms

a. Regression analysis of farmers' characteristics (n=11)

(iii) Studies that characterize farmers‘ varietal and seed use and sourcing behaviour

a. Descriptions of variety use and varietal diversity (n=11)

b. Descriptions of seed sourcing behaviour (n=7)

The identified methods all facilitated a process of demand articulation by seed system stakeholders, from which the researchers drew conclusions on farmers preferences for or choices of seed. Whereas the first category in the classification scheme can be considered as an explicit form of demand articulation, the other two represent implicit demand articulation. In an explicit process of demand articulation, farmers were asked by researchers to express their interests in, and preferences for, varieties, varietal traits or types of seed. In an implicit process of demand articulation researchers studied farmers' demand by identifying determinants of adoption, explaining farmers' seed management practices or the functioning of their seed and farming systems.

The study of the cassava seed system in Chapter 3 developed and applied a research approach that recognizes the interplay between farmer's demand for seed (with an actor-centred perspective) and the seed supply functions of the cassava seed system in Nigeria (with a structural perspective). For this purpose, we developed a seed system concept that includes system functions on supply and demand sides. Supply side functions are performed by formal and informal seed system actors, who make adapted seed available and accessible for farmers. These functions include (i) provision of a legal framework, (ii) variety development, (iii) seed multiplication, (iv) seed dissemination and exchange. By placing a focus on farmers as seed users in a demand side function, the model takes into account famers' agency in sourcing seed through multiple channels and expressing their individual demands for seed. The findings show that that a wide range of formal and informal actors were involved across all seed system functions on the supply-side. The national agriculture development program (ADP), which had the mandate to disseminate cassava seed through the local ADP offices, did not have the capacity to supply farmers with sufficient seed of desired varieties. To compensate for limited supply through formal seed channels, the ADP agents facilitated stem sales among farmers, and between farmers and informal stem sellers. Informal seed sellers ranged from farmer sellers, who sell stems as a by-product from their farm to commercial sellers, who produce their own seed and sell across long distances. The presence and role of these seed system actors varied across the three study sites. All farmers maintained and gradually replaced a portfolio of varieties that reflected individual preferences in taste and agronomic traits. Exchanging seed with other farmers and informal seed sellers contributed to the spread of new varieties. Across all three study sites, the farmers used cassava seed from multiple sources in a single season: their own fields, relatives/friends/neighbours, the ADP, and traders. Whereas the dominant source of stems was farmers' own fields, the amounts of seed and varieties sourced off-farm varied between study sites and farmer categories (small, medium and large).

The study on innovation and scaling in Kenya and Uganda in Chapter 4 analysed farmer innovation in the field of agriculture and nutrition through structural and actor-centred perspectives. The international research project "Education and Training for Sustainable Agriculture and Nutrition in East Africa (EaTSANE)" engaged stakeholders in Kenya and Uganda in a participatory action learning approach. The researchers introduced farmers to new agricultural and nutrition practices, such as mixed cropping systems, solar dryers for vegetables and fruits, food preparation practices and the application of a set of connected nutrition practices. Through value-chain platforms, farmers identified key problems and jointly developed solutions for nutrient-dense value chains. The actor-centred analysis showed that the farmers selected and combined soil fertility management practices, newly introduced crops or crop varieties, and strategies to prevent soil erosion according to their individual preferences and demands. The farmers also applied new technologies of post-harvest handling and conservation, made arrangement for direct marketing with nearby traders, and developed new markets for dried vegetables and vegetable seed. To improve their diets, the farmers set up kitchen gardens, used the solar drying technologies and followed selected food preparation and nutrition practices. Our structural analysis of the agricultural innovation systems in both countries showed that – in addition to the EaTSANE project – a wide range of actors influenced the farmers in their innovation processes. These actors included four types of innovation support providers (ISPs), namely private sector, public sector, third sector, and informal service providers. Farmer-based organizations, the fifth type of ISPs, did not influence the interviewed farmers. In terms of innovation support services (ISS), the farmers were largely inspired by knowledge, advisory service and capacity building on new practices, and access to resources (e.g. seed of novel crops and varieties). Learning amongst farmers was supported by the pubic agricultural extension service, radio and via individual networks. Aside from the EaTSANE project activities, we did not identify actors that provided ISS for experimental learning approaches with farmers.

5.3 Discussion of results

The explanatory disbalance between agency and structure has been pointed out in recent innovation and transition concepts (de Haan & Rotmans, 2018; Fischer & Newig, 2016; Markard & Truffer, 2008; Upham, Bögel, & Dütschke, 2020) and agricultural systems research (Engler, Poortvliet, & Klerkx, 2019; Feola & Binder, 2010; Kuntosch & König, 2018; Scoones et al., 2020; Thompson & Scoones, 2009). The authors criticized that current approaches inadequately represent agents and agency, and therefore call for research on integrated concepts that put emphasis on agency-sensitive analysis. As the High Level Panel of Experts on Food Security and Nutrition recently stated "the emerging concept of agency is gaining traction in the international discourse on food security and nutrition" (HLPE, 2019, p. 66). However, to date only few studies explicitly set out a differentiated analysis of structural and actor-centred analysis to understand farmer innovation and technological change (Braun, Rombach, Bitsch, & Häring, 2018; Feola & Binder, 2010; Kuntosch & König, 2018).

This thesis makes a case by analytically separating actor-centred and structural perspectives in three empirical studies that vary in their type (systematic literature review, and field studies), location (Nigeria, Kenya and Uganda), and their main subject of study (RT&B seed systems, and a broader set of agricultural and nutrition practices). The application of the theoretical framework, as presented in Chapter 1, provides an orientation to discuss and interpret findings from the empirical chapters. In particular, Margaret Archer's (1995) morphogenetic approach provides a theoretical and empirical framework to analyse the interplay between structure and agency across the empirical chapters of this thesis. The phases are (1) structural conditioning, (2) social interaction, and (3) structural elaboration.

The systematic literature review in Chapter 2 identified a wide range of methods to study various types of farmers' demand for RT&B seed and varieties. The results contribute to the need of making development of varieties and the delivery of seeds more demand-orientated (Almekinders, Mausch, & Donovan, 2021; Mausch, Almekinders, Hambloch, & McEwan, 2021). In particular, the established classification scheme may guide researchers and development practitioners in reflecting on methods to study specific types and aspects of demand. Making the differences between these methods visible and considering their limitations demonstrates the complexity of understanding farmers' demand. However, as pointed out in the discussion of Chapter 2, a framework is necessary that purposefully combines the existing different methods for demand articulation.

With regard to the structure-agency interplay, the set of methods that were described as implicit demand articulation largely refer to structural aspects. Most of these studies derive farmers' demand for seed either from characteristics of their farming systems or seed systems which the farmers are part of. For instance, researchers concluded on demand by analysing correlations between attributes of the farming systems (farm size, access to extension service, etc.) and the adoption of a particular variety. The methods that were described as explicit demand articulation refer to an actor-centred perspective on farmers as seed users. Researchers identified farmers preferences in and choices of seeds through behavioural approaches. For instance, they assessed farmers' willingness to pay in choice experiments. Whereas the implicit forms of demand articulation could be criticized for being deterministic and neglecting agency, explicit forms of demand articulation tend to be de-contextualized (Almekinders et al., 2019). Combining and integrating these methods may reconcile the explanatory disbalance between agency and structure. In practice, this would imply combining structural-functional analysis of seed systems with behavioural approaches to elucidate farmers seed preferences. The final phase of structural elaboration in the morphogenetic cycle would shed light on how farmers' demand is reacted upon in supply-functions of seed systems, an aspect that was hardly reported on in the literature review.

Chapter 3 addresses the issue of farmers' demand for RT&B seed into the context of the cassava seed system in Nigeria. The concept of seed systems has been developed and applied for decades already (Almekinders, Louwaars, & de Bruijn, 1994). These seed system conceptualizations covered a wide range of aspects, such as the roles of formal and informal actors (e.g. Scoones & Thompson, 2011), interacting sub-systems like project-based seed systems (e.g. Gibson, 2013). Only few of these conceptualizations (e.g. Christinck, Rattunde, Kergna, Mulinge, & Weltzien, 2018) explicitly pointed out the theoretical basis or refer to a specific type of systems thinking. Applying a functionalist system view (Parsons, 1951) to conceptualize seed supply functions helped to define roles and activities of actors in the system in relation to the actors in focus – farmers as seed users. Being key actors in the system, “zooming in” with an actor-centred perspective explained farmers’ demand through social differentiation and individual agency.

The results in that chapter show that functions of the seed system varied across the study sites. Structural conditioning defined access and availability of varieties and different types of cassava seed. Within these boundaries farmers’ seed use behaviour was characterized by dynamic interactions to source seed according to their personal preferences. Social differentiation played a role in how farmers dynamically sourced seed from multiple channels and maintained an adapted a portfolio of cassava varieties. The social interaction reflects the view of social heterogeneity, leading to different social responses to similar contextual conditions (Long, 2001). Finally, the findings refer to a process of structural elaboration, i.e. how farmers influence the supply-side functions of the seed system. Our data indicate a gap between informal seed traders, who dynamically react to farmers demands, and public seed distribution schemes, which does not address farmers heterogeneous demands. Hence, farmers cannot influence early-generation seed producers and breeders about which varieties to produce. Informal seed traders have the potential to fill this gap but need to be empowered.

The study on farmer-centred and structural perspectives on sustainable agriculture and nutrition in Kenya and Uganda (Chapter 4) contributed knowledge on the so far insufficient understanding of how the different dimensions of change (i.e. technical, institutional, behavioural) co-evolve and support each other in a processes of innovation and scaling, as pointed out by Schut, Leeuwis, & Thiele (2020). Our approach addressed interaction between these dimensions by studying the prevailing agricultural innovation systems in combination with the innovation behaviour of farmers. The results of the study highlight the different roles of human agency and structures in innovation processes and draw implications on the design of scaling strategies. While actor-centred perspective informed on the subject of scaling (What to scale), structural perspectives informed on potential roles in the process (Who) and scaling pathways (How to scale). Paying attention to farmers agency in innovation processes brought to attention that promoting innovation as a process rather than an outcome can address context-specific needs and enhance farmers’ adaptive capacities. This supports the call of Waters-Bayer et al. (2015) to scale out approaches of stimulating and supporting farmer experimentation.

With regard to the structure-agency interplay, the results of Chapter 4 indicate that the structural conditions (agro-ecological conditions, food culture, and the presence of ISS) influenced how farmers in the two study sites innovated. This has created a site-specific context that varied across study sites and farmers groups. Whereas farmers on the slopes of Mount Elgon in Kapchorwa District developed innovations to encounter soil erosion in the rainy season, farmers in Teso South experimented incorporating crop residues and growing more legumes to enhance the fertility of their degraded soils. The agency of farmers in adapting to changing structural conditions in real-time explains the individual portfolio of innovations that farmers used. Some of these innovations did not only influence farmers' own technology use in agriculture and nutrition, but also resulted into structural elaboration processes. For example, farmers in Kapchorwa District established collective marketing arrangements with traders and farmers in Teso South developed new value chains for dried vegetables ranging from seed production to new markets for produce. Promoting innovation processes through value chain platforms and experimentation holds potential for structural elaboration but needs more institutional support to continue beyond the EaTSANE project.

The three cases in this thesis point out how structural conditions reflected in seed systems, agricultural innovation systems influence farmers innovation or technological change processes: (1) Researchers concluded on farmers' demand for RT&B seed from analysing prevailing farming systems or seed systems, (2) Seed system functions in Nigeria defined access and availability of different types of cassava seed, and (3) The presence of ISS in Kenya and Uganda influenced how farmers in the two study sites innovated in agriculture and nutrition. The cases also illustrate how farmers react upon these conditions through social interactions. Their reaction was shaped by a reflective process – or an internal conversation between themselves and perceived structures - in which the farmers took action/decisions on their own behalf: (1) Researchers concluded on famers' demand by studying their individual preferences for varieties or types of seed – albeit not in their "real-life context", (2) Farmers in Nigeria maintained an adapted portfolio of varieties supported by individual seed sourcing strategies, and (3) farmers in Kenya and Uganda developed innovations in agriculture and nutrition to pursue their individual goals. However, the data on the final phase of the Archer' morphogenetic cycle – structural elaboration- indicate a limited influence of farmers' agency across the three empirical chapters. The weak representation of this process confirms the need for promoting human agency in our food systems (HLPE, 2019; Scoones et al., 2020) and leads to further discussion in regard to policy implications, limitations and research needs, as presented in the following sections.

5.4 Policy implications

Options for strengthening farmers' agency through more demand-orientation in seed systems as well as in agricultural extension and advisory services have been discussed in recent studies (Almekinders et al., 2021; Cook, Satizábal, & Curnow, 2021). The empirical findings, analysis and discussion led to specific policy recommendations in the respective chapters. From the overall discussion of this thesis and reflection on the applied study approaches, broader policy implications for international agricultural research and development can be derived.

Annexes

1. Frameworks to guide interdisciplinary research on farmer innovation and technological change

Our study of farmers' demand for cassava seed in Nigeria (Chapter 3) and farmer innovation in Kenya and Uganda (Chapter 4) were attempts to address farmers' seed choices and innovation processes with study approaches that cover both farmers' agency and the influence of their seed / innovation systems of which they are part of. These approaches were implemented by study teams that have mixed scientific backgrounds. Whereas all team members engaged in co-creating the overall frameworks, they contributed with their respective expertise on agriculture, nutrition, and social sciences to specific aspects. Reflecting on the study designs confirms that inter-/transdisciplinary research approaches are particularly important when studying complex issues, such as farmers' demand for seed and innovation processes (Knierim, Laschewski, & Boyarintseva, 2018). Agricultural innovation system and seed system concepts provided frameworks to integrate research on multiple aspects of famers' demand and technological change into interdisciplinary dialogue, and synthesis.

Also, the classification scheme in our systematic literature review (Chapter 2) demonstrates that methods to study demand range across multiple research disciplines. Feola et al. (2015) have developed a framework to facilitate interdisciplinary research on farmer behaviour that brings together different streams of research and suggested using their framework for guiding the design and interpretation of studies in the future. Chapter 2 of this thesis follows those lines of thinking by developing an interdisciplinary framework for understanding farmers demand of RT&B seed. As such, the framework can support researchers in acknowledging the explanatory powers and limitations of their methods and exploring combinations that are adapted to the purpose of study. Research programs on demand-oriented seed systems, such as CGIAR research initiatives Seed Equal (CGIAR, 2022b) and Market Intelligence (CGIAR, 2022a), may take this framework as well as the adapted seed system conceptualization in Chapter 3 into account to guide the design of interdisciplinary research on farmers' demand for seed.

2. Institutionalization of demand articulation in seed systems and agricultural innovation systems

Studying the interplay of structure and agency was useful not only to create an understanding of farmers' demands for seed and technological change, but also in terms of seeing entry points for reforming seed systems and agricultural innovation systems. As elaborated in Section 5.3, farmers in Nigeria, Kenya and Uganda had limited scope to change structures through their agency, i.e. by articulating demands toward decision-makers. Also, the review of methods to understand farmers' demand for RT&B seed did not identify information on how the findings of the reviewed studies were acted upon. These findings emphasize the need of institutionalizing the articulation of societal demand for knowledge and technology in an interaction process between the demand and supply sides, as pointed out by other studies (Kilelu, Klerkx, & Leeuwis, 2014; Klerkx & Leeuwis, 2008; Leeuwis, 2022).

To put this into practice, institutional change is required in research and extension systems towards being more responsive to end-user demand (Heemskerk et al., 2003).

In the case of the cassava seed system in Nigeria, informal seed traders and village seed entrepreneurs (VSEs) would need to be empowered to influence early-generation seed producers and breeders. This implies that ADP and supporting programs for seed dissemination offer a set of varieties in demand for affordable prices to informal seed traders and VSEs while influencing early-generation seed producers and breeders about which varieties to produce. In regard to the latter, public breeders and early-generation seed producers would need to adapt breeding objectives and seed production dynamically according to traits and varieties in demand. In the case of the agricultural innovation systems in Kenya and Uganda, the established value chain platforms and action-learning sessions in the communities have created spaces, in which farmers and other value chain actors expressed their demands. After the phasing-out of the EaTSANE project, the district / sub-county offices would need to support the operation of such platforms to strengthen demand-articulation processes towards ISPs) In both cases, the heterogeneity of farmers' demands (resulting from individual aspirations and preferences, styles of farming, etc.) needs to be considered to create an inclusive and iterative process, as described in Leeuwis (2022).

3. **Change of mindsets from linear technology transfer towards technological change as a complex and interactional process**

The implementation of trans- and interdisciplinary work and the institutionalization of demand articulation must go along with a "change of mindset and culture" in regard to technological change. This relates to the notion that sustainable change can only be achieved when people's minds, their values and cultural practices are transformed (Riddell & Moore, 2015). Describing technological change as a complex and interactional process has been emphasized for decades already (Glover et al., 2019; Leeuwis & Aarts, 2021; Thompson & Scoones, 2009). The empirical chapters of this thesis confirmed the thinking that farmer innovation and technological change interact in systemic, and agency-driven dimensions of change. However, the efforts to create a shift of mindset in international agricultural research towards recognizing the complexities of explaining farmer behaviour and innovation have been modestly successful so far. The linear technology transfer thinking, also termed "pipeline model", remains the dominant change narrative for major international funders and agenda-setting institutions for international agricultural research (Douthwaite & Hoffecker, 2017).

Explaining technological change through behavioural approaches has been criticized to neglect real-world conditions and social inter-dependencies (Almekinders et al., 2019; Hall & Dijkman, 2019; Leeuwis & Aarts, 2021). Researchers applying such approaches may need more awareness of structural conditions - and resulting dynamics of agri-food systems and innovation systems - that shape human behaviour. On the other hand, socio-technical sustainability transitions literature neglected to integrate individual actor-focused perspectives (Upham et al., 2020). Researchers in this field may need more awareness of the influence by human agency. This calls for more transdisciplinary collaboration in the framing and implementation of technology-focussed agricultural research. Funding and research organizations need to emphasize on both perspectives and their interplay when designing new research programs. Another entry point for sensitizing on the complexity of technological change processes are curricula of study programs in technological studies that influence the mindsets of future scientists.

5.5 Limitations and future research

This thesis required a diverse mix of methods to address the study objectives in regard to analysing farmers innovation and technological change in a given scope of the respective research projects. The seemingly simple framing of structure-agency interactions has shown considerable analytical power across the empirical chapters. However, the thesis also bears theoretical and methodological limitations, which indicate future research needs.

Data collection activities in field studies presented in Chapter 3 and 4 would have benefited from in-depth individual interactions and the application of behavioural approaches with farmers over a longer time to study their innovation processes and demand for seed as well as their farming, marketing and nutrition practices. Given the conditions of limited budget and time, the studies had an exploratory character: A relatively small sample farmers from the study sites in Nigeria, Kenya and Uganda and key informants from institutions on different levels were purposefully selected. This did not allow statistical representation of the population in the study communities, districts/Sub-counties/zones, or countries. The local variations in units for measurement of land sizes, number of stems in a “bundle” of cassava seed, multiple names for similar varieties, and finally a research bias when researchers from the EaTSANE and BASICS projects engaged in group discussions may have been at the cost of data validity. However, through triangulation of data sources the results coherently explained farmers’ seed use practices and innovation processes, and their underlying motivations.

The systematic literature review (Chapter 2) identified research approaches that drew conclusions on farmers demand from structural influences as well as from farmers agency. When putting the identified studies in a larger context of demand articulation processes, the question arises how these demands are acted upon, i.e. in what regards are these demands addressed by RT&B seed systems? This aspect remained virtually absent in the identified literature sources. The reasons could be that (i) the body of literature with studies on farmers’ demand for RT&B crops is too small to provide information on this aspect, (ii) the operationalization of our literature search did not capture this aspect sufficiently, or (iii) the topic not researched sufficiently.

Drawing from the limitations of this thesis, potential topics for future research areas could be to study structural and actor-centred perspectives, and their interplay, on technological change in more depth, e.g., through multiple complementing studies in the same study context. This would allow applying behavioural methods in combination with comprehensive systems analysis. The broad array of systemic and behavioural study approaches as identified in Chapter 2, as well as overviews on research approaches on the dynamics of agri-food systems (e.g. Thompson & Scoones, 2009) can provide guidance in the selection and combination of methods.

Since structure-agency interactions co-evolve over time, research in this field would benefit from more longitudinal work that goes beyond the timeframe of typical research project funding (e.g. 3-5 years). This could be addressed through research on simulation models that project possible scenarios or through ethnographic observations on the present situation compared with existing ethnographic studies (Feola et al., 2015). Both types of longitudinal research could create a more nuanced understanding by studying multiple morphogenetic cycles.

Finally, this thesis has identified substantial gaps in structural elaboration processes across the three empirical chapters, i.e. actors influencing structures through the outcomes of their actions. Policy implications of empowering informal seed system actors and institutionalizing more demand orientation in seed systems and agricultural innovation systems have been pointed out in Section 5.4. Designing and implementing such policies in an evidence-based manner requires more action research that enhances the understanding processes, mechanisms, and pathways for institutional change better.

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