Analysis of Maize Innovation System: Linking System, Social Network and Scaling Perspectives

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Analysis of Maize Innovation System: Linking System, Social Network and Scaling Perspectives

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DISSERTATION APPROVAL

This is to certify that the thesis prepared by Daniel Nigussie Ashiber, entitled: *"Analysis of Maize Innovation System: Linking System, Social Network and Scaling Perspectives"* and submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy (Development Studies) complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

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DECLARATION

I, Daniel Nigussie, hereby declare that this PhD dissertation is my own original research work. The materials in this research work, neither the whole nor any part of it, were not submitted for the attainment of any academic degree elsewhere. All reference materials form other authors have been fully acknowledged and the reporting procedures do comply with the expected standards and regulation of the university.

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During the Ph.D. studies, the following manuscripts were accepted for publication.

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- ✓ "Analysis of Maize Innovation Processes and Practices: Application of Integrative Innovation System framework and Multi-Level Perspective": The Case of North – Western, Ethiopia in the17 Globelics International Conference:
- ✓ Presented a paper entitled " Exploring the scaling of Agricultural Innovations, AfricaLics PhD Academy , hosted by University of Gondor, Ethiopia
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Daniel Nigussie

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ADPLAC	Agricultural Development Partners Linkage Advisory Council
AIS	Agricultural Innovation System
AKIS	Agricultural Knowledge and Information System
AMSAP	Advanced Maize Seed Adoption Program
ARARI	Amhara Region Agricultural Research Institute
ARI	Agricultural Research Institutes
ATA	Agricultural Transformation Agency
BoAs	Bureau of Agriculture
CASCAPE	Capacity development for scaling Up of best Practices in Ethiopia
CCIC	Canadian Council for International Co-operation
CDAIS	Capacity Development for AIS
CIMMYT	International Wheat and Maize Improvement Center
CGIARs	Consultative Group on International Agricultural Research
COAG	Committee on Agriculture
EIAR	Ethiopian Institute of Agricultural Research
IFPRI	International Food Policy Research Institute
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
FTC	Farmers Training Center
GDP	Growth Domestic Product
ILRI	International Livestock Research Institute
KII	Key Informant Interview

MOANR	Ministry of Agriculture and Natural Resource
NARS	National Agricultural Research System
NGOs	Non-Governmental Organizations
ORDA	Organization for Rehabilitation and Development in Amhara
PADETES	Participatory Demonstration Training and Extension system
PCI	Precise Consult International
PES	Participatory Extension System
PRC	Participatory Radio Campaign
QPM	Quality Protein Maize
R & D	Research and Development
RELC	Research and Extension Linkages Committee
SBN	Sesame Business Network
TIS	Technological Innovation System
TOT	Transfer of Technology

ABSTRACT

In recent decades, innovation generation, dissemination, and utilization have experienced significant paradigm shifts, increasingly incorporating a systems perspective. This research aims to identify the systemic issues and factors related to socio-technical transitions that impede the production, distribution, and adoption of improved maize varieties in Ethiopia. Additionally, it examines the various actors involved and their interactions at different levels within this context. The study also assesses institutional approaches for scaling up and systematically explores the barriers to the adoption and scaling up of improved maize varieties in Ethiopia. To achieve these objectives, primary data were collected through structured and semi-structured interviews and focus group discussions, which were then analyzed thematically. The findings reveal several major obstacles to the system's functioning, including systemic failures such as the absence of key actors, institutional issues, a lack of interaction among actors, and inadequate infrastructure. Three specific functions—entrepreneurship, knowledge development, and establishing legitimacy—were found to be weaker for improved maize varieties released by Pioneer Hi-Bred Seeds Ethiopia Plc., but stronger for those released by public research centers. Conversely, knowledge dissemination and resource mobilization were identified as strengths of Pioneer Hi-Bred Seeds Ethiopia Plc., but as weaknesses for public research centers, agricultural extension service providers, and government seed enterprises. Key actors influencing the system include the Regional Bureau of Agriculture and the Amhara Seed Enterprise, which operate at the regime level and impact the production, distribution, and adoption of improved maize varieties. The study highlights that a public-private partnership has been established to promote the scaling up of improved maize seeds by Pioneer Hi-Bred Seeds Ethiopia Plc. The newly released varieties by Pioneer Hi-Bred Seeds Ethiopia Plc. have a comparative advantage over previous varieties used by farmers, and there is a willingness and readiness among farmers to adopt the new varieties. This presents a promising opportunity for collaboration and the development of a business case. However, the scaling up of improved varieties faces challenges related to knowledge and skills interaction, value chain development, and public governance. In public research centers, there is good interaction in knowledge and skill development, value chain development, and public governance for establishing legitimacy. However, collaboration among actors and financial resource mobilization are poor. To overcome these challenges and ensure the sustainable scaling up of improved maize seed varieties, it is crucial for public and private research institutions, along with other public sectors, to collaborate with development partners and the private sector. Such collaboration will ensure a long-lasting impact on the agricultural sector. In summary, the research underscores the importance of addressing systemic issues and enhancing interactions among key actors to facilitate the successful adoption and scaling up of improved maize varieties in Ethiopia. By leveraging the strengths of both public and private institutions and fostering effective partnerships, it is possible to overcome existing barriers and achieve sustainable agricultural development.

Key words: multi-level perspective; scaling scan; interaction; public-private partnership

CHAPTER ONE

GENERAL INTRODUCTION

1.1. Background of the study

Agriculture is vital for Ethiopia's growth and long-term food security. The sector supports about 85% of the population in terms of employment and livelihood, contributes over 41% of the country's gross domestic product; generate about 90% of export earnings. It is also an important sector in supplying food for the population and raw material for agro-based domestic industries and in generating surplus capital to speed up the country's overall socio-economic development (CSA, 2020).

The Government of Ethiopia is highly committed to sustainably increasing agricultural production to meet the growing demand for food, industrial raw materials, and foreign currency earnings. In order to respond the growing demand of different stakeholders, there is a need for dynamic and proactive research and extension system (MoA, 2017). In recognition of this, the country has made great efforts to transform the agricultural sector, mainly by strengthening its extension services as part of the general agriculture policy reform. Agricultural Extension approaches have changed over time (Norton & Alwang, 2020). Extension approaches prior to 1993 shared some common shortcomings. These include but not limited to inappropriate choice of extension approaches and strategies, lack of extension professionalism and relevant agricultural technologies, low research and extension linkages, and poor participation of farmers in generation and utilization of technologies.

Innovation generation, dissemination and utilization have experienced some major paradigm shifts in the last few decades. All changing paradigms have taken into account the systems perspective. The gradual evolution of the central source model of innovation of the early days, particularly in the 1970s and 1980s, and then the multiple source models in the 1990s and finally the current Innovation System (IS) approach are the three important paradigms. The innovation systems approach emerged as a result of the increasing recognition that the transfer of technology (ToT) model has not fulfilled expectations in terms of developing locally adapted innovative practices. The IS concept puts great emphasis on understanding the nature of relationships and interactions between actors and the knowledge, attitudes, and practices that shape these relationships. Researchers used structural analysis to understand success and failure of the innovation system but structural analysis has proved insufficient for the analysis of IS. Thus, the functional approach emerged to highlight the processes (rather than the structure) that are important for a good performance of innovation systems. The processes are categorized as functions of innovation systems (e.g. entrepreneurial activities, knowledge development, market formation), and they aim to clarify how well an innovation system is functioning. The structural and the functional analyses, as well as the systemic problems and systemic instruments concepts, all have the same systemic–evolutionary foundations but they were developed separately from each other and they are therefore poorly aligned. They are also used rather individually to inform the policy process. This paper aims to address this gap. In particular it shows why structure is so important for explaining systemic problems. Be sides this paper combines coupled structural -functional analysis with the broader theoretical orientation in socio technical system transition, using the Multi Level Perspective to understand the process of generating and scaling innovation.

Since 2010, Ministry of Agriculture adopted a Participatory Extension System as the country's extension system following PADETES (MoA, 2017). This shift in approach was based on ample empirical evidence that pointed to the fact that non-adoption of technologies by farmers emanated from the fact that the technologies in question had been either unresponsive or inappropriate to the needs of the farmers and as a result had not provided directly measurable results or perceived benefits. Participatory approaches are a complement to "large-scale" technology or the establishment of efficient technology transfer systems on a large scale (Leta et al., 2017). Although Ethiopia has invested in agriculture and established extension services, there has been no progress in the provision of advisory services (Debelo et al., 2020). The performance of services and the quality of service providers do not increase, and as a result, the desired results cannot be achieved. Similarly, the maize sector is characterised as experiencing slow rate of technological change and slow emergence of alternative institutional and organizational arrangements to enhance growth and development in the sector. Maize farmers in Ethiopia face serious challenges that limit their overall production and income. The key challenges can be broadly categorized into three groups: (i) lower yields due to limited use of modern inputs; (ii) majority of sales immediately after harvest; and (iii) high post-harvest losses (both on- and off-farm) (MoA, 2017). Furthermore, high input and low output prices, land degradation, climate change, and declining production are other barriers to agricultural development in the country (Leta et al., 2017) As a result, rural poverty and food shortages continue to pose serious problems for the country (Leta et al., 2017).

1.2. Statement of the problem

Maize is one of the most important food crops grown world-wide. It has the highest average yield per hectare and is third after wheat and rice in area and total production in the world. It is grown in most parts of the world over a wide range of environmental conditions (Daly *et al.* 2016).

Maize is the most produced cereal crop in Ethiopia, accounting for 13.4% of the total area harvested, 16.4% of total crop production volume and 14.3% of production value. It is grown by more than half of all farmers, mostly for subsistence. Maize also forms the cheapest source of calorie intake (19% of per capita daily calorie intake nationally) which makes it a top crop in terms of calorie supply (398 kcal/capita/day) (MoA, 2020).

Maize is a key staple food for the majority of smallholder farm families in Ethiopia. But the productivity of this staple crop is constantly called into question due to erratic rainfall, frequent occurrence of drought, declining of soil fertility, poor agronomic practice, and cease/limited use of fertilizer, insufficient technology generation, dissemination and utilization, lack of credit facilities, poor seed quality, disease, insect, pests and weeds. Maize is little used in the food processing industry and continues to have strong export potential. This is because maize supplies from small producers do not meet the quality used in industry for various reasons, among these a one way or linear process in the generation, dissemination and utilization of improve maize varieties (Abate et al., 2015). Therefore, the use of maize as a raw material in agricultural processing is quite low compared to the total production of units, especially compared to industrial use in the country Maize is little used in the food processing industry and continues to have strong export potential (MoA, 2017) . The country developed a five year maize sector development strategy (2013-2017) to address systemic problems. To ensure all components of the maize sector are addressed in a comprehensive and coordinated manner, a value chain approach is being followed. This helps to improve the productivity and competitiveness of the maize industry. The core components identified includes: research and technology development; access to inputs; on-farm production; post-harvest processing & storage like maize Sheller and hermetic bags (PICS bag); trade, marketing and demand sinks (Abate et al., 2015). The maize development strategy, as envisioned in the Agricultural Transformation Agenda, seeks to see maize production contribute to greater food security and increased incomes for smallholder maize farmers by increasing productivity and improving access to sustainable and efficient markets (ATA, 2015).

The review done by Kassa & Alemu (2016) reveals that there is a gradual improvement with increased types and mechanisms of the research-extension linkage in recent years that are related with (i) institutional linkages of actors of the National Agricultural Research System (NARS) with actors of formal agricultural technology delivery systems, (ii) technology demonstration and popularization promoted by the NARS in collaboration with MoA and Regional Bureaus of Agriculture (RBoA), (iii) Farmers' Research Groups (FRGs) approach promoted by the NARS in collaboration with MoA and RBoA, (iv) Technology specific special pre-extension activities promoted by the NARS, (v) Publications made available by the NARS, and (vi) Agricultural Development Partners' Linkage Advisory Councils (ADPLACs) as research-extension linkage platforms. However, there are number of challenges that need policy and development attention to fully exploiting the potentials these approaches offer in strengthening the linkage, which is crucial for the aspired agricultural transformation.

Agricultural research system in Ethiopia is characterized by a top-down, centralized, monolithic and isolated structures. Linkages, interactions and learning mechanisms among the component actors are notably weak and/or often non-existent. Empirical evidence revealed several linkage gaps and missing links among and between the actors in the system (Rashid et.al. 2016). Institutions, for example, universities and research institutes innovate in isolation and although research were taking place at various national and international organizations, the coordination is dysfunctional, and poorly linked to the productive sector. Besides, farmer innovations were not being included in the knowledge system. It was further reported that private sectors involvement are discouragingly weak (Davis et. al. 2010).

The micro innovative strength therefore has remained isolated and encapsulated and many institutions relevant to innovations are weak and possibly non-existent. Undoubtedly the participation of NGOs in research and extension has largely increased but their linkages and interactions are generally weak (Kassa and Alemu, 2016). Hence adopting an interactive, more inclusive and dynamic analytical framework to improve networking and the quality of technological linkages and knowledge flow is an imperative (Spielman *et al* (2007).

The above scenarios point to the need for a relatively new paradigm that incorporates these reforms. Innovation system approach offers a more holistic, multidisciplinary and comprehensive framework for analyzing innovation process, the roles of science and technology actors and their interactions, emphasizing on wider stakeholder participation, linkages and institutional context of innovation and processes.

The concept of innovation systems by Hall *et al* (2008), Spielman *et al* (2007), World Bank (2006a) and Clark (2002) provides an alternative framework to that of the linear technology diffusion model. The latter has been criticized for its failure to understand the source, nature and dynamics of most innovations processes, particularly in the context of developing countries (Edquist, 1997). Wieczorek & Hekkert, (2012b) indicated structural analysis has long been used to evaluate and compare the composition of mostly national innovation systems in an attempt to clarify the determinants of varying rates of innovation. However, structural analysis has proved insufficient for the analysis of technological innovations. Thus, the functional approach emerged to highlight the processes (rather than the structure) that are important for a good performance of technological innovation systems (TISs). The processes are categorized as functions of innovation systems (e.g. entrepreneurial activities, knowledge development, market formation), and they aim to clarify how well an innovation system is functioning(Johnson 2001; Bergek 2002; Hekkert et al. 2007; Bergek et al. 2008). The structural and the functional analyses, as well as the systemic problems and systemic instruments concepts, all have the same systemic–evolutionary foundations but they were developed separately from each other and they are therefore poorly aligned. They are also used rather individually to inform the policy process.

Different research centers releases different technologies of maize. But farmers don't accept the released technology because the farmers-extension-researchers (FER) linkages are weak, fear for newly coming technologies and fear of failure (Gedif, Molla, et al., 2016). The responsible agencies of the government (EIAR and Ministry of Agriculture) do not have databases for the innovations, platforms and the value chains. Although it is known that innovation system can perform better than conventional approaches in linking farmers to markets, encouraging technology adoption, generating income and reducing poverty, the agricultural innovation system of Ethiopia is weak and fragmented(Gedif, Molla, et al., 2016). Since agricultural innovations have no value if they are not taken by the end users, structural and functional analysis of the maize innovation system will help to improve the effectiveness of research and extension services and agricultural policy to increase productivity.

The success of innovations is to a large extent determined by how the innovation system is build up and how it functions (Hekkert et al., 2007,Bergek *et al*., 2008). However, such information is not readily available. There is also a lack of theoretical clarity with regards to the typology of the inducement and blocking mechanisms (Wieczorek & Hekkert, 2012). Despite the central contribution of innovation system in demand-driven and client oriented technology generation, dissemination, utilization and scaling up, there is no comprehensive study conducted on maize innovation system analysis in the study areas.

The purpose of this study is therefore, to apply a compressive innovation system analytical framework, reconciling analyses of systemic structure, functions, failures and merits of innovation system and sustainability transitions to analyse the maize innovation system. The presence of this system failures are often considered to be a new policy rationally. In this study element of structural analysis has been incorporated into a functional analysis of innovation systems and sustainability transitions to better explain the inducement and blocking mechanisms in maize innovation systems, to identify key policy issues. The main questions of this study are therefore how the maize innovation system has functioned to support the development of the maize sector and what have been the major systemic problems?

1.3. Objectives and research questions

1.3.1. Major objective:

This study aims to identify systemic problems in generation, dissemination, utilization and scaling of innovations to improve the functioning of the maize innovation system.

1.3.2. Specific Objectives:

Specifically, in this research the following specific objectives are expected to be conducted:-

- To examine systemic problems in maize innovation system
- To analyze actors interaction in the maize innovation system
- To explore possibility and mechanisms for scalability of maize innovation

1.4. Research Questions

To achieve the above mentioned specific research objectives, primarily the following research questions are crystallised as follow:

1. What takes place inside the maize innovation system in terms of innovation?
2. Who are the key actors, roles they play and interaction in the network, institutional set up and what are the existing infrastructures?
3. What mechanisms exist to integrate actors experience, findings and priorities?
4. How each function is currently filled in the system?
5. What are the influencing factors that will either enable or constrain the scaling process?

1.5. Scope and Delimitation of the Study

A number of different innovation system concepts have been put forward in the literature, including national systems of innovation (Freeman, 1987; Lundvall, 1992a; Nelson, 1992), regional innovation systems (Asheim and Isaksen, 1997; Cooke *et al.,* 1997), sectoral systems of innovation and production (Breschi and Malerba, 1997; Malerba, 2002) and technological systems (Carlsson and Stankiewicz, 1991). There are also other similar socio-technical system concepts (cf. Bijker, 1995; Geels, 2004; Hughes, 1983).

An innovation system requires some unit of study or dimensions of analysis to delineate its boundaries (Metcalfe, 1997; Carlsson *et al.*, 2002). As mentioned above, analysis may focus on the spatial (local, national, and regional economic or geopolitical units), the sectoral (manufacturing, agriculture, or any subsector thereof), or the technological (for example, information and communications technology, agricultural biotechnology, or other distinct technology sets). Further, analysis may focus on the material, such as a particular good or service that forms the focal point of a given commodity value chain.

The study focuses on Sectoral (Agricultural Innovation system) particularly on technological innovation systems (Maize innovation system). As indicated in (Bergek *et al.*, 2007a), i.e. socio-technical systems focused on the development, diffusion and use of a particular technology (in terms of knowledge, product or both). The study does not only focus components exclusively dedicated to the technology in focus, but all components that influence the innovation process for that technology. Intervention efforts were made in various regions of the country using Agricultural Innovation System Approach. However, this study is confined to analyse Maize innovation system in Amhara region particularly West Gojam Zone as per the stated objectives.

1.6. Theoretical and Empirical Literature Review

1.6.1. Major Theories in Innovation System

Technological innovation systems theories are concerned with the identification of regularities and patterns in the full innovation development and implementation process to clarify the conditions under which new technologies develop quickly and become a success or fail (Markard, Hekkert, & Jacobsson, 2015). Hence, it is proposed that technological innovation systems theory can be used to provide useful insights in the systematic analysis and evaluation of technological innovations.

From the technological innovation system theory point of view, innovation is viewed as a competition between a new technology and established technologies and possibly further emerging technologies (Markard & Worch, 2009). For example, if there is an existing technology in the electoral process, new technology can still be developed that would compete with the existing technology.

As noted earlier, conceptually, technological innovation systems can be viewed as a set of networks of actors and institutions that interact and contribute to the development of a novel technology (Carlsson & Jacobsson, 1991; Markard & Truffer, 2008). Technological innovation systems involve collaboration and networking, which enhances trust, capabilities, and cooperation across functions, products, and divisions. Since technological innovation systems are initiated by the interaction of networks of stakeholders and institutions, for innovation to take place, it is important to combine the knowledge of the key actors (stakeholders) (Planko et al., 2017).

Technological innovation may involve many companies, some supplying the materials or partially developed products. Rarely do you find an organisation completely manufacturing everything from the component level up to the final product. Complementary innovations are usually required before a particular technology is suitable for commercial application (Van de Ven, Angle, & Poole, 2000). Adoption may be influenced by the rate of innovation. If the rate of adoption is high, then the level of innovation is also assumed to be high (Borkovich, 2015).

System theory

The agricultural innovation systems (AIS) perspective has caught on rapidly among academics and research organizations. AIS apply complex systems theory to conventional agricultural innovation studies, pioneered by Hall and Clark (1995), Engel (1997) and Hall et al. (2001, 2003). Innovation has since become more widely understood as a social process embedded within complex systems, requiring scholars to study the milieu in which innovation occurs (Spielman et al 2009). The emphasis on the role of Technological Innovation System (TIS) on competence building, i.e. enabling firms and other actors to successfully acquire and assimilate technologies, has been coupled with a major theoretical development in which TISs are related to 'general systems theory' (Hekkert and Negro 2009, 585).

Systems theory fundamentally rests on a relational or interactional view of the world. That is to say that the connections between parts are explicitly given ontological precedence over the parts themselves. In the general sense, a system means a configuration of parts connected by a web of interdependent relationships.

When talking about any system, the emphasis is typically on connections and interdependencies as the defining feature of the organization. The relational paradigm of systems thinking emphasizes how connection, interdependencies, and context shape the component parts of the system and vice versa. The traditional analytical paradigm is fundamentally component-based; analysis is focused on the properties of "things" in isolation and how those things cause change through direct interactions. System thinking helps instead to focus on how the network of connections around the individual parts affect and shape of the system as a whole. This perspective becomes of particular relevance when the system comes to have a high degree of connectivity (Hekkert and Negro 2009).

In innovation systems theory, the importance of investing in S&T is well recognized, but the focus is on the additional insights and types of interventions that can be derived from an innovation systems perspective and that can influence the generation and use of S&T for economic and social development.

For decades, the research development, especially in developing countries, was based on a rather simple TOT model. In order to achieve development, "modem" research results had to be transferred to the "traditional" farmer, and extension seemed to be the appropriate means to do so. The general faith in science and the commitment to modernization led to discrediting indigenous knowledge. This paradigm is extended to general reasoning where people see events as a product of some linear interaction, from A> B> C. Although this view is still held by many administrators, researchers, and extension agents, it is now being seriously questioned (Carayannis et al.2016).

Systems thinking in contrary is focused on nonlinear causality where multiple factors affect an outcome, as they work together synergistically in a networked fashion to generate a combined result that is greater, or less, than the sum of their effects in isolation. A central idea here is that of emergence. With emergence, an event may not have any direct cause, instead within the systems paradigm many events are seen as in fact emergent phenomena, not caused by any one thing but instead emerge out of the interaction between many things interacting in a horizontal, parallel or networked fashion to generate the outcome. Equally, systems thinking looks for circular or mutual causality, how two things affect each other and how every effect feeds back to its source over time (Carayannis et al.2016).

Social Network Theory

The Social Network Theory (SNT) examines different networks of relationships between individuals and the common factors that bring them together. In a scientific form, SNT views relationships between objects, which are labeled as 'nodes'. In terms of utilization and dissemination of agricultural innovation, the analysis of social networks is used to trace the path of innovative information and to understand how the reception of the information flow affects utilization. Finally, the use of the graph makes it possible to correctly visualize all the actors involved in this information transaction. It is in this context that the present work relies on the literature review to understand the SNA and its possible application for the adoption of agricultural innovations (Eriola Marius, 2019).

Sustainability Transition Theory / Socio-technical transition theory

Socio-technical transition literature, particularly the Multi-Level Perspective investigates the fundamental changes in (energy, transport, housing, agro-food) systems that are needed to address persistent sustainability problems (Geels, 2002). Socio-technical transitions research emerged in the early 2000s in the field of innovation studies, was initially tested and refined through several dozen historical case studies of transitions (in mobility, heating, power, agro-food, water, sanitation, music), and has subsequently been widely applied to analyses of unfolding and future sustainability transitions (Geels, 2019)

Changing Approaches for Supporting Agricultural Innovation

The transfer, distribution and use of agricultural knowledge has experienced a major paradigm shift in recent years. Changing paradigms all take the visual system into account. The characteristics of different paradigms can be understood from the perspective of complex and simple systems thinkers. Definitions of the concept of innovation and ways of understanding the goals of the system also offer different features. Gradually, the evolution of innovation focus in the early period, especially in the 1970s and 1980s, followed by the multi-market approach in the

1990s and finally the agricultural innovation approach (AIS) (Anandajayasekeram, 2005) are the three main paradigms affecting agricultural research and development

National Agricultural Research System (NARS)

The National Agricultural Research System (NARS) comprises an institutional system which is responsible for coordinating and implementing scientific research that contributes to the growth of agricultural and natural resources. Development activities based on the National Agricultural Research System (NARS) concept generally aims to strengthen research provision by providing infrastructure, capacity, governance, and policy support at the national level. NARS consists of all institutions responsible for planning, coordinating, or conducting research that plays an important role in the development of agriculture and the conservation of natural resources in a particular country. The NARS framework has been at the center of agricultural development initiatives for the last four decades. The basic idea is linear: agricultural research, through technology transfer, leads to the use of technology and the growth of production. The ability to achieve this goal lies in the comprehensive organization of agricultural research, education and public institutions. Capacity is developed by investing in scientific infrastructure, equipping the workforce with the latest knowledge, generating basic research, and providing operational funding to implement these priorities. This model has proven particularly effective where technological solutions are needed and possible (for example, to overcome the food shortage crisis in South Asia in the 1970s). Prioritizing agricultural products means that small and emerging businesses are often overlooked until they reach the economic core of the economy. Although farmers' adoption of research results in their fields are often stimulated by foreign products and inputs (especially fertilizers), the NARS framework represents the basis for research leading to productive technologies (World Bank, 2006; Rajalahti, 2009).

Agricultural Knowledge and Information System (AKIS)

In the 1990s, the concept of Agricultural Knowledge and Information System (AKIS) gained popularity. AKIS connects people and institutions to promote learning and produce, share, and use agricultural technologies, knowledge, and information. AKIS connects farmers, agronomists, researchers, and extension workers with information and knowledge from various sources to improve their lives. Farmers are at the center of this knowledge triangle (World Bank

2004). The AKIS concept recognizes that research is not the only way to produce or obtain knowledge. Although the AKIS concept focuses on delivering research, it essentially links research, education, and extension and identifies the demands of farmers who need new technologies. The AKIS framework has its origins in the analysis of agricultural extension programs. It is fundamentally about how knowledge and ideas are shared between different rural actors and how this knowledge can be used in rural life. AKIS accepts learning and innovation as a process. The AKIS framework, developed extensively by FAO, addresses many shortcomings of traditional agricultural research and extension, particularly the limited opportunities for collaboration between users and information providers. AKIS acknowledges that there are many sources of information in agricultural innovation and believes that it is important to develop communication channels between them. Focusing on innovation as a social learning activity expands the scope of agricultural research and expands on developing local capacity. The rise of teachers in the industry is clearly visible. AKIS recognizes that education improves farmers' capacity to undertake new activities (World Bank, 2006).

The Evolution of Innovation and Innovation System

Innovation

There are many definitions and categories of innovation, and this is partly because innovation studies encompass many aspects. However, innovation often requires the implementation of new or significantly improved products, processes, or methods (OECD, 2005). Innovations are new products, processes, services, etc. that meet economic and financial objectives. It is defined as the process of creating knowledge and information, making it accessible, and using it to create (Hall et al., 2008). It is generally accepted that innovation in agriculture can come from many sources, including farmers, and this is often referred to as innovation (Biggs and Clay, 1981; Röling, 2009b). Innovation can be viewed as a set of new social and technological processes and practices that represent new forms of interaction in a network of interacting actors (also 'non-human' actors).

Innovation System

The innovation system can be defined as “the set of organizations, institutions, and individuals that demand and provide knowledge and technology and how these different actors work together" (World Bank, 2006). There are many definitions of innovation systems in the literature, and they are all at the same level and stem from one of the first definitions: "...an innovation system is a network of individuals and institutions/organizations, activities and interactions, public or private, that initiate, import, integrate and disseminate new technologies". The concept is used in many areas and agriculture it is often called the Agricultural Innovation System (AIS).

Agricultural innovation systems (AIS)

AIS is a new concept based on two innovations: the National Agricultural Research System (NARS) in the 1980s and the Agricultural Science and Information System (AKIS) in the 1990s (World Bank, 2006; Rajalahti, 2009). AIS can also be defined as a complex network of actors (individuals, organizations, and industries) and supporting institutions and policies that bring existing or new agricultural products, processes, and practices into the social and economic sphere (TAP, 2016). AIS emphasizes agricultural innovation and goes beyond traditional knowledge to include the goals of reform strategies such as decentralization, public-private partnerships, private sector assistance, promoting consensus processes in development, and developing demand-driven services. AIS is concerned with decentralization, formalization and requirements, and increased stakeholder participation in the monitoring, support, and implementation of agricultural technology programs. AIS differs from previous institutions in that it focuses not only on innovation but also on multi-institutional participation in agricultural research and extension. AIS is fundamentally concerned with the interaction of actors and institutions with the environment (infrastructure, policies, and institutions), recognizing that innovation is more than the development of technology, but also the improvement of its components; this can facilitate the development of innovation system innovation itself to enable the integration of useful functions. While there appears to be a common understanding of the innovation enablers of AIS, differences and schools of thought remain. To include all organizations responsible for more than agricultural research and extension systems, according to Hall *et al* (2008), the private sector, the political enabling environment, and other sectors. AKIS recognizes the importance of transferring knowledge to farmers in research systems but prefers to say that most of the technology will flow from researchers to farmers.

According to Groverman et al (2007), AIS theory emphasizes understanding the nature of relationships and relationships between actors and the knowledge, attitudes, and actions that constitute the relationship. In the field of agricultural innovation, the identification of actors and their interactions is considered essential to understanding the success and failure of innovation systems.

Structures and functions in AIS research

Wieczorek & Hekkert (2012b) argue that the four elements that comprise the structural analysis of the framework are actors, interactions, institutions and infrastructure. The framework is based on the premise that the presence or absence of certain structural elements as well as their capacities, are critical to the functioning of the innovation system (Wieczorek & Hekkert, 2012b).

Table 1. Structural Components of Innovation System

Structural element	Sub categories
Actors	Civil society
	Companies: input suppliers, market agents, large firms
	Knowledge institutes: university research labs, technology institutes, research centers
	Government at all levels
	Non-governmental organizations (NGOs)
	Other parties: legal organizations, financial organizations/banks, intermediaries, knowledge brokers, consultant, ICT providers
Institutions	Hard: instructions, regulations, laws and rules
	Soft: customs, common habits, routines, established practices, traditions, ways of conduct, norms, expectations
Interactions	At level of networks
	At level of individual contacts
Infrastructure	Physical: artefacts, instruments, machines, roads, buildings, networks, bridges, harbour.
	Knowledge: knowledge, expertise, know-how, strategic information
	Financial: subsidies, fin programs, grants, among others

System Functions

Hekkert *et al*. (2007) describe seven functions (Entrepreneurial activities, knowledge development, and knowledge diffusion, guidance for search, market formation, resource mobilization and creating legitimacy) that need to be present in innovation systems for successful innovation to occur. The functioning of each of the seven processes is dependent on the four structural components of the AIS: actors, institutions, interactions and infrastructure (Wieczorek & Hekkert, 2012b). (F1-7) that shape an innovation system's performance (and underlying questions associated with each function) are:

F1, Entrepreneurial activities (who are the entrepreneurs, what are the products, are there technological options, are there experimentation, etc...)

F2, Knowledge development (what is the base knowledge, is there enough financial support, are there enough end-users, etc.). .

F3, Knowledge diffusion (are there strong partnerships, can sharing occur, are there commercial implications, etc.). .

F4, Guidance of the search (is there a shared goal, is it specific, what are the technological expectations, is there policy support, etc.). .

F5, Market formation (what does the market look like, what is the size, are there barriers, etc.); F6, Mobilization of resources (are there sufficient resources, what are they used for, can they be accessed, etc.).

F7, The creation of legitimacy (is investment in technology seen as legitimate, is there resistance, where is the resistance coming from, etc.) (Wieczorek & Hekkert, 2012b).

Analysis of Systemic Problems

Systemic failures are known in some literature as systemic problems and can be defined as factors which have a negative influence in the direction and speed of innovation processes and/or block the evolution and functioning of innovation systems. According to OECD such failures include: lack of interaction between actors; mismatch between basic and applied research; malfunctioning of the technology transfer institutions; information and absorptive shortcomings on the part of enterprises. Other authors suggest: failures in infrastructural provision and investment, transition failures; lock-in failures; institutional failures (Wieczorek & Hekkert, 2012b).

Following the structural dimensions identified as actors, institutions, infrastructure and interactions, if one of these aspects does not function well a system cannot function effectively. Therefore the main systemic problems that could arise in an innovation system are (Wieczorek & Hekkert, 2012b):

- The presence or capabilities of the actors
- The presence or quality of the institutional set up
- The presence or quality of the interactions
- The presence or quality of the infrastructure

Those aspects may be considered from positive and negative perspectives senses, for instance by considering their attributes in terms of capacity, quality or intensity (Wieczorek & Hekkert, 2012b).

Analysis of Systemic Instruments

The systemic instruments are the strategies and tools to solve the systemic problems and influence the overall functions of the innovation systems. The main difference between the functional analysis and systemic instrument analysis is the first one is descriptive and provides an analytical tool to evaluate performance of IS, and the second one is prescriptive and support policy design. There are five processes suggested that systemic policies should aim to achieve (Wieczorek & Hekkert, 2012b).

Building and organizing innovation systems regarding to ensure the presence of relevant actors, institutions or infrastructure,

- Providing a platform for learning and experimenting which improve the agents' capabilities related to learn a new innovative process.
- Providing an infrastructure for strategic intelligence and stimulating demand articulation, which enable the capacity aspect of infrastructural problems and the capacity to solve those problems by actors.

- Managing interfaces as a way to stimulate interactions within the IS.
- Developing strategy and vision, regarding to actors' capabilities.

Overview of Agricultural Innovation System in Ethiopia

In Ethiopia, the AIS emerge in a situation where farmers are facing a very diverse agro-ecological situation that is still insufficiently documented and understood. At the same time, farmers also have a diverse range of needs, demands, capabilities and potentials. To create an enabling environment for these farmers, it needs a responsive and reflective system of extension that is providing coaching and facilitation instead of technology transfer (Coote & Rahman, 2016)

The stakeholder mapping study carried out by Coote & Rahman (2016) has clearly shown that the AIS is still quite hierarchic in Ethiopia. Well-functioning AIS is based on a broad dialogue and a bottom-up approach. While certain attempts have been made in this direction by the establishment of the Agricultural Development Partners Linkages Advisory Council (ADPLAC) (and its predecessors); ADPLAC still suffers from limited resources and structural problems that inhibits its functionality. Thus, ADPLAC platforms established at different levels in all regions of the country vary in terms of their level of achievements and successes. In areas where the platforms are strong and vibrant, remarkable success stories have been reported, such as the East Shewa Zone ADPLAC platform. According to the authors, much expertise and contribution to the functioning of the AIS comes from office of agriculture, the farmers themselves and NGOs, but less so from other government offices and the private sector. This implies that Agricultural Innovation System remains strongly dominated by the government and its immediate organizations with weak linkages to the private sector, NGOs, and the education sector.

However, in spite of all constraints, Ethiopia has a lot of opportunities at the moment to change direction in AIS, and the intentions are there and well-articulated, from the government policy papers, bi- and multilateral agreements to the strategies of development organizations and NGOs. One example of a successful initiative is the Sesame Business Network (SBN). SBN is an innovation network in Northwest Ethiopia: It is run by local entrepreneurs and other stakeholders working in the sesame production and trade. The SBN members meet regularly to exchange information, to discuss on possibilities and ways of jointly obtaining various inputs for sesame so that they could benefit from an economy of scale when procuring inputs from suppliers.

The experience of the Nutritious Maize for Ethiopia (NuME) project on the other hand shows how multi-sectoral networks facilitate and speed-up adoption of technologies and strengthen innovation. The NuME project implementation is founded on a network of key implementing partners from different sectors - agriculture, health, education and broadcasting media and private sectors. Such multi-sectoral networking of actors has brought remarkably high rates of adoption of Quality Protein Maize (QPM) by a large number of maize growing farmers throughout the country. High awareness has been created on nutritional and health benefits of QPM among the wider public.

Another prominent example of how AIS can work in Ethiopia is Precise Consult International (PCI). PCI through its dairy agribusiness incubation project shows how market access is an incentive for innovation. For example, consumption habits of dairy products and the individual behavior of consumers in Ethiopia regarding dairy products result in a huge mismatch between demand and supply. Due to this unique consumption behavior, there are serious shortages of dairy products in some seasons leading to a sharp rise in prices. In addition, lack of trust among milk producers, milk collection and marketing cooperatives and processors are among the key institutional problems in the dairy sector. This hampers the exchange of information, knowledge and generally undermines the learning process within the dairy sector AIS (Coote & Rahman, 2016).

1.7. Methodology of the Study

1.7.1. Description of the study area

The study area was the Amhara Region, which is Located in northwestern Ethiopia between 9°20' and 14°20' North latitude and 36°20' and 40°20' East longitude. The Region has an estimated land area of about 170,000 square kilometers. The region borders Tigray in the North, Afar in the East, Oromiya in the South, Benishangul-Gumiz in the Southwest, and the country of Sudan to the West. The study was conducted in the West Gojjam zone, North West of Ethiopia. West Gojjam zone is one of the 11 zones in the Amhara region and lies between 36°30’ to 37°5’ Longitudes East and 10°16’ to 11°54’ Latitudes North. The zone encompasses 10 districts. The total land area of the zone is 13,280 km^2. West Gojjam Zone is one of the top ten maize-producing zones of the country; the others are West Gojjam (5.6 million quintals), East Wellega (4.3 million quintals), Kaffa (3.8 million quintals), East Shewa (3.1 million quintals), West shewa (2.9 million quintals), West Arsi (2.7 million quintals), Illubabor (2.7 million quintals), East Gojjam (2.2 million quintals), West Wellega (2.1 million quintals), and West Harerghe (2.1 million quintals).

Maize is one of the important cereal crops grown in the zone. The total annual production and productivity of maize exceed that of all other cereal crops, though it is surpassed by teff in area coverage. Therefore, considering its importance in terms of wide adaptation, total production, and productivity, maize is one of the top-priority crops to feed the increasing population of the Zone. Nevertheless, the yield of maize remained very low due to many biotic and abiotic constraints (Beyene & Ayalew, 2015).

The study was conducted in the northwestern part of the country, particularly in North Mecha Woreda as it represents the areas where there is high potential for maize production. Mecha Woreda lies within 11°8'−11°39' N latitude and 36°59' 51"−37°20' E longitude covering a total area of 149,119 km^2 (Figure 1), located in the West Gojjam Zone in the Amhara region, about 35 km from Bahir Dar, the capital town of Amhara Regional State of Ethiopia. There are 44 villages including three town administrative villages in the study area. Mecha district is situated at an altitude range of 1,720−2,800m above sea level.

The area is characterized by flat-lying topography with some hilly terrain. This district has different climatic variables in different seasons. The annual rainfall pattern of the study area varies from 1,000 to 2,000 mm.

The temperature varies from 23°C to 27°C. June, July, and August are high-rainfall months, and December, January, and February are low-rainfall months. High temperature is recorded in March, April, and May, and low temperature is recorded in November, December, and January.

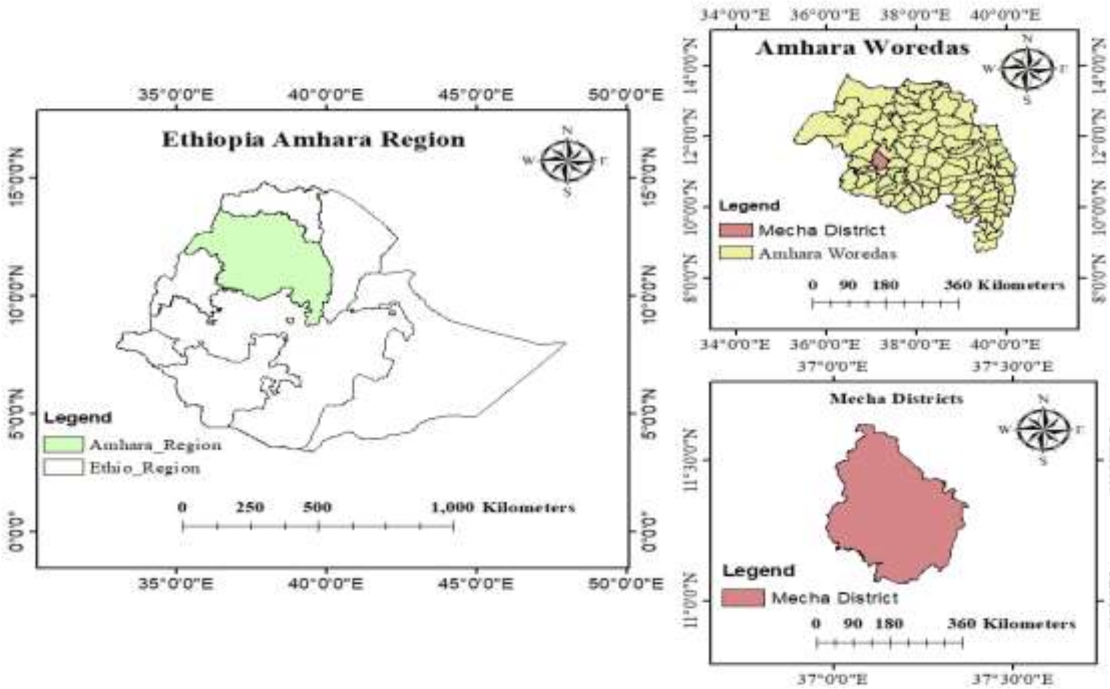

Figure 1: Map of the study areas.
Source: Ethio GIS and CSA (2007)

Research design: mainly a qualitative research was used as research approach to understand in depth enabling environment to the innovation system. Both quantitative and qualitative data were collected particularly to conduct social network analysis. In this study, all sampling procedures followed non-probability sampling, combining purposive and snowball techniques. Purposeful sampling is a technique widely used in qualitative research for the identification and selection of information-rich cases for the most effective use of limited resources. This involves identifying and selecting individuals or groups of individuals that are especially knowledgeable about or experienced with a phenomenon of interest considering specific issue with unique cases. Snowball sampling is used when the population when there is no existing database. Choosing a suitable sample size in qualitative research is an area of conceptual debate and practical uncertainty. The sample size determination for this study is based on data adequacy and saturation.

1.8. Thesis Organization

The dissertation is organized in five chapters. The first chapter is about the general introduction, which consists of background, problem statement, objective, theoretical and empirical literature review, conceptual framework, and finally briefly presents the philosophical and methodological orientation employed in the study. The second chapter focuses on understanding of Ethiopia's maize innovation system from integrated innovation system and sustainability transition perspectives. The third chapter focuses on multi-level analysis of actor's interaction in maize innovation system in Amhara region, Ethiopia. The results of exploring the scaling of maize innovations are presented in the fourth. Finally, chapter five summarizes the key findings and conclusion, and draws important policy implications from the results of the study.

CHAPTER TWO

UNDERSTANDING ETHIOPIA'S MAIZE INNOVATION SYSTEM: APPLICATION OF INTEGRATED INNOVATION SYSTEM AND SUSTAINABILITY TRANSITION PERSPECTIVES

ABSTRACT:

Agricultural innovation is a top priority on the global sustainable development agenda to solve food insecurity, land degradation, climate-change issues, poverty, and unemployment. This paper aims to identify systemic problems and socio-technical transition factors that hinder the development, dissemination, and utilization of improved maize varieties in Ethiopia. Primary data were gathered through structured and semi-structured interview schedules, and analyzed thematically. Results show that systemic failures such as the absence of key actors in entrepreneurial activities, knowledge development and dissemination, institutional problems, lack of interaction between actors, and inadequate infrastructure are the major hindrances to the systems functioning. Three functions, including entrepreneurship, knowledge development, and creating legitimacy, were found to be weaker than others in the case of improved maize varieties released by Pioneer Hi-Bred Seeds Ethiopia Plc. However, these functions were stronger in the case of improved maize seed varieties released by public research centers. Knowledge dissemination and resource mobilization were the stronger functions of Pioneer Hi-Bred Seeds Ethiopia Plc., which were found to be weak in the public research centers. The result also shows that policies and governance affected the sustainable development of improved maize varieties released by Pioneer Hi-Bred Seeds Ethiopia Plc. Promoting knowledge development and resource mobilization within networks of policymakers, the public sector, and local and foreign private sectors, and a regulation on breeders' rights to encourage the involvement of private companies in the sector are recommended to enable the innovation system to function sustainably and to strengthen public –private partnership

Keywords: Innovation system, integrated systemic framework, multi-level perspective

1. INTRODUCTION

Doubling the agricultural productivity and income of small-scale food producers is one of the targets for the achievement of sustainable development goals (FAO, 2018). As a result, developing countries need to dramatically accelerate the innovation process and increase the use of technology by farmers to achieve these goals. Agricultural innovation is a top priority on the global sustainable-development agenda to address issues related to food insecurity, land degradation, climate-change challenges, poverty, and unemployment. Despite Ethiopia's huge investment in agriculture and a shift in approach to a participatory extension system, Substantial change in agricultural extension service delivery has not been achieved (Gerba & Girma, 2017). Investments in small-scale irrigation systems and mechanization, use of improved seeds, fertilizer, and pesticides, and access to finance and credit in rural areas are increasing in the country, but a significant gap remains in the transformation of the agricultural sector.

The purpose of this paper is to understand and evaluate agricultural innovation processes and socio-technical transitions in the context of maize-based farming systems and livelihoods. This study combines data on the innovation system with data on sustainability transitions, using a multi-level perspective. The study also focuses on innovations at various scales, from new individual niches to reconfigurations of the entire systems at the sectoral level. This type of analysis contributes to the generation of empirically grounded and theoretically sound advice on how niche development, socio-technical regime, and landscape factors influence the functions and structures necessary for the generation, dissemination, and utilization of improved maize seed varieties.

Maize yields have doubled from around 1.6 t/ha in 1990 to more than 3.7 t/ha in recent years, the highest level in sub-Saharan Africa after South Africa (FAO, 2019). The adoption of improved maize varieties leads to significant gains in well-being and improves farm productivity (Ahmed et al., 2017). According to (Teressa, 2019), the Ethiopian seed system has undergone tremendous changes. However, the sector still fails to guarantee farmers' access to seeds of improved varieties, in terms of quantity, quality, and timely, especially due to a lack of integration among actors like research centers universities, private companies and seed enterprises; there is a substantial gap between the production and supply of commercial seed and farmers' demand. The seed sector, particularly the development and the performance of improved maize seeds in the country, is characterized as experiencing a slow rate of technological change and variety replacement, inadequate quantity and quality of foundation seed, slow emergence of alternative institutional and organizational arrangements, limited capacity of seed laboratories for the development and improvement quality seeds, seed quality inspection and testing, inadequate infrastructure and equipment, as well as lack of sufficiently trained technical staff, poor market mechanisms, low availability and promotion of improved seeds, inefficient execution of seed law, asymmetry of information, insufficient capital investment and low innovation use. In addition, the conventional top-down and supply-driven approaches are still used to diffuse improved maize varieties (Abate et al., 2015; Abebe & Alemu, 2017; Atilaw et al., 2017; Ayana, 2019; Dawit et al., 2021; Erenstein & Kassie, 2018; Gedif, Tegegn, et al., 2016).

The foregoing scenarios indicate the need for a paradigm shift that incorporates multifaceted reforms and multiple actors. The agricultural innovation system approach offers a more holistic, multidisciplinary, and comprehensive framework for analyzing the innovation process (Klerkx, 2015). Innovation systems can be analyzed at four different levels, namely the national innovation system (Edquist, 2009; Freeman, 1982; Lundvall, 1982; R. R. Nelson, 1993), regional innovation system (Moularet & Farid, 2003), sectoral innovation system (Malerba, 2005), and technology-specific innovation system (Bergekar et al., 2015; Jacobsson et al., 2002). This study adopts a combination of sectoral and technological innovation-system levels of analysis. This is because the dynamics in terms of the structural components of both the sectoral innovation system (SIS) and the technological innovation system (TIS) analysis in terms of functional patterns (as well as functionality) are important for identifying key policy issues and instruments in the structure that either induce (drive) or block a development towards a desirable functional pattern (Bergeki et al., 2005). The present study focused on agriculture as a sector and on improved maize varieties as a technology within the sector. The analysis of the SIS allows us to understand what encourages initiatives and what effect interaction patterns have on the system, while the analysis of the TIS allows us to assess system failures and evaluate the system's performance. Hence the SIS view and the TIS view appear to be complementary, with structural analysis having to precede functional analysis (Markard & Truffer, 2008a; Wieczorek & Hekkert, 2012c).

The Innovation-system approach helps to understand and promote innovation in the agricultural sector. The agricultural innovation-system concept has been adopted and adapted by different scholars and international organizations to provide directions for innovation policies. Several analytical approaches or views have emerged and are currently used to analyze innovation systems, such as structural analysis, functional analysis, integrated structural-functional analysis, and integrated innovation system and sustainability transition using a multi–level perspective. Existing innovation studies, particularly in Ethiopia, have mainly been limited to either structural analysis using social network analysis (Asres et al., 2012; Teklewold et al., 2019a), or functional analysis (Aschalew, 2018; Zelalem et al., 2020), with some using a coupled structural-functional analysis (E. Kebebe et al., 2015b). These studies disregard sustainability-transition perspectives.

Considering this gap, this paper employs a multi-level perspective to combine coupled functional-structural analysis with a broader theoretical orientation in socio-technical system transition. Furthermore, this study stresses the influence of one niche-level technological innovation on another niche innovation and tries to map the role that the transitions have on the development, diffusion, and utilization of innovation. These are innovative approaches that would fill research gaps in understanding agricultural innovation processes and socio-technical transformations. Much more empirical research is required to improve our understanding of this subject and inform policy. Therefore, the objective of the study is to identify systemic problems and socio-technical transition factors that hinder the development, dissemination, and utilization of improved maize varieties. This paper aims to answer two basic research questions: why do improved maize varieties differ in generation, dissemination, and utilization? And can the current paths lead to the sustainable generation, dissemination, and utilization of improved maize seed varieties?

The remainder of this paper is structured into four sections. The second and third sections present a literature review and the methods of the study, respectively. The fourth section presents results and discussions. The last section concludes and suggests policy implications.

2. Literature review

2.1 A brief history of improved maize-seed multiplication and distribution in Ethiopia

The current top-down and centrally designed method for seed multiplication and distribution in Ethiopia may be traced from the imperial regime via the Derg period to the contemporary political setting. In all modern political eras, the formal seed sector was dominated by the government. The government established the Ethiopian seed enterprise (ESE) to supply improved seeds for large and smallholder farmers and to substitute seed imports. In 1990, Pioneer Hi-Bred Seeds Ethiopia Plc. started working in the country in collaboration with ESE. Pioneer Hi-Bred Seeds Ethiopia Plc. ended its partnership with ESE in 1995. However the company remained in Ethiopia and established itself as an independent hybrid maize-seed producer. Today ESE, including its regional seed enterprises such as Amhra, Oromia, Tigray, and SNNP region seed enterprises, remains the most important producer and supplier of hybrid maize seed in the country (Abate et al., 2015; Atilaw et al., 2017).

a. Structural elements of an innovation system

Innovation theories such as the chain model (Kline and Rosenberg 1986) and innovation systems theory (Freeman, 1987; Lundvall, 1982; R. Nelson, 1993; OECD, 1997) emphasize that innovation is not a linear, sequential process, but involves many interactions and feedbacks in the creation and use of knowledge. Moreover, innovation is based on a learning process that relies on various inputs and requires continuous problem-solving. This has made the innovation-system approach central to the modern way of understanding innovation processes.

(Hall & Clark, 2009) argue that the four elements that comprise the structural analysis of an innovation system are actors, interactions, institutions, and infrastructures. The structure of the sectoral systems of innovation draws on (Malerba, 2005) concept of blocks of a sectoral innovation system. The framework is based on the assumption that the presence or absence of certain structural elements as well as skill and competences are important for the innovation system.

Researchers have conducted empirical studies using structural analysis to understand the structure of the innovation system (Asres et al., 2012; Teklewold et al., 2019a). Structural analyses are too static for this purpose, however, because of their attention to structure over process. In addition, other scholars indicate that structural analysis is insufficient for the analysis of technological innovations (Hekkert et al., 2006; Hekkert & Negro, 2009). Thus, the functional approach is necessary to emphasize the processes (rather than the structure) that are important for the proper functioning of technological innovation systems. The processes are categorized as functions of innovation systems.

b. The functional analysis of an innovation system

Researchers have found that to identify the central policy issues in a specific innovation system, a structural focus should be integrated with a process focus. Scholars in the field of innovation studies propose a framework that focuses on seven processes that are highly important for well-performing innovation systems, namely entrepreneurial activities, knowledge development, knowledge diffusion, guidance for search, market formation, resource mobilization, and creating legitimacy (Anna et al., 2008; Esmailzadeh et al., 2020; Hekkert et al., 2006; Hekkert & Negro, 2009; Williams et al., 2020).

The functional approach has been used to identify “blocking mechanisms” and has done so as a framework to identify emerging policy issues (Bergek, 2002) to fill the gap left by structural analysis and identify systemic problems by evaluating their functions (Esmailzadeh et al., 2020; Hekkert et al., 2006; Jacobsson & Anna, 2004). Unlike structural analysis, which focuses on static components (actors, institutions, cooperation networks, and infrastructures), functional analysis is interested in what happens in an innovation system.

Functional analysis has also been criticized for its limitations in providing comprehensive analysis and because it doesn’t allow the identification of problems occurring within a system (Gust-Bardon, 2015). As a result, a coupled functional-structural analysis has emerged as an integrative policy framework (Wieczorek & Hekkert, 2012a), (Lamprinopoulou, Alan, et al., 2014), (Hans-Erik, 2019).

c. Structural–functional analysis/ integrative systemic framework

The integrative systemic framework puts together the structural and functional analysis to provide a holistic analysis of the innovation process and to identify systemic failures in the related sub-processes. Recently researchers used structural–functional analysis to identify systemic problems (Baharloo et al., 2018; Boisier et al., 2021; Gust-Bardon, 2015; E. Kebebe et al., 2015b; Mininberg, 2015). The analysis of the integrative systemic framework allows us to identify systemic failures in the innovation system. The different categories of innovation-system failures are: infrastructural failure, institutional failure, interaction failure, capabilities failure, market-structure failure, directional failure, policy-coordination failure, demand articulation failure, and reflexive failure (Klein-Woolthuis et al., 2005; Klerkx, Mierlo, et al., 2012; van Mierb et al., 2010; Weber & Rohracher, 2012b). For agricultural innovations, few studies have used a combined structural and functional analysis of agricultural innovation (E. Kebebe et al., 2015a; Lamprinopoulou, Renwick, et al., 2014b; Turner et al., 2016).

Critics of the functional structural–functional analysis of the innovation system indicated its limitation in considering pathways of development over time and interactions between actors and processes at different levels, hence black-box the actual things that trigger innovations or how local innovations grow to scale (F. W. Geels, 2019; Köhler et al., 2016; McMeekin et al., 2019). There is a need to complement the structural-functional analysis with a sustainability transition perspective to unravel the complexity of the innovation process and to be able to identify niche innovations or best practices to support innovation (Toillier et al., 2018).

d. Sustainability transitions using multi-level perspectives

Sustainability transitions belong to "long-standing, multi-dimensional, and basic transformational processes through which established socio-technical systems "move to more sustainable patterns of production and consumption". Transitions are multifaceted and long-term processes that consist of multiple actors. Different frameworks have been used to conceptualize, recognize, and endorse the transition toward sustainability (El Bilali, 2019a; Lachman, 2013), one of which is the multi-level perspective (MLP). As indicated in (El Bilali, 2019a), MLP was developed by Arie Rip and René Kemp and further refined by Frank Geels and Johan Schot. MLP is a well-known transition framework and it is a means for analyzing socio-technical transitions (F. W. Geels, 2011). MLP postulates that transitions occur through interrelating processes among the three levels of aggregation (niche, regime and landscape).The general idea of MLP is that innovation does not exist as a separate entity, but rather that it depends on social, technical, and institutional factors. According to this perspective, a transition occurs when these three levels are aligned (F. W. Geels, 2011). Niches are where innovation happens; niches act as incubation rooms away from normal market forces – allows for research and learning through experience; and provides space and time for supporting networks to be established. Niches can be created by landscape developments. Regime refers to the "rule-set or grammar" of processes, governance, technologies, skills, corporate cultures, and artifacts embedded in institutions and infrastructures. Regime can influence landscape change; regime shifts are the result of a cascade of changes over time. Landscape forms the "external structure or context for interactions of actors"; factors such as prices, economic growth, political coalitions, cultural norms, environmental problems, and paradigms slow to change (T. Steward, 2012).

Recently, sustainability-transition studies have been used in agricultural innovation system (AIS) analysis to understand how changes occur and how they may have impacts at the system level, due to the complexity of socio-technical changes. Using Geels's multi-level perspective approach, niches of innovation can be seen as an "innovation system" that is able to transform the dominant socio-technical regimes (F. W. Geels, 2002). This approach emphasizes the role of the institutional environment in influencing rules, norms, and values that support the dominant socio-technical regime or allow the emergence of niche innovations (Toillier et al., 2018).

e. Integrating innovation-system and sustainability-transition perspectives

There have been a few attempts to combine innovation-systems and sustainability-transitions perspectives using the niche-regime-landscape interactions of the MLP (Weber & Rohracher, 2012b) which have then compared the two frameworks and asserted that they are complementary. (Markard & Truffer, 2008b) developed a scheme to combine the two perspectives. An integrated framework for sustainable innovation policy analysis was also developed by (Meelen & Farla, 2013). In this context, sustainability transition using a multi-level view has been integrated into the functions of the innovation system literature. A study conducted by (Hans-Erik, 2019), proposed six landscape factors (LF) to complement the existing TIS function approach in a developing country's context. Based on the study the fulfillment of system functions and the influence of landscape factors can be analyzed using a combination of historical event analysis, literature review, and expert assessments.

Both the theoretical and empirical review indicate the need for hybrid analytical approaches and for a mix of methods and approaches for analyzing innovation systems. The different analytical tools imply different hypotheses and different methods for analyzing innovation systems. Furthermore, there is a need to complement the structural analysis with a functional one, and to complement the structural-functional analysis with a sustainability transition view to unravel the complexity of the innovation process and to be able to identify niche innovations or best practices to support innovation. Due to the complexity involved in understanding the innovation system based on these different views, a large number of methods have been applied and are proposed. To sum up, based on the literature it is recommended to use a hybrid tool to diagnose the innovation system, particularly in seeking to understand the agricultural innovation system.

f. Conceptual framework of the study

This paper reviews both innovation-systems and sustainability-transition concepts; these are closely related concepts for studying large-scale technological change. This study combines structural and functional streams of innovation systems with the multi-level perspective of sustainable transition. The paper assumes socio-technical transitions influence the functionality of the agricultural innovation system.

It is not possible to assess the state of the structural elements of innovation systems without considering the effects of innovation processes or system functions. The functioning of each of the seven processes also depends on the four structural components of the innovation system: actors, institutions, interactions, and infrastructures. To evaluate innovation systems, not only is it necessary to focus on structural-functional analysis, but it must also be integrated with socio-technical transitions to identify what happens in the systems, and the relevant external factors. Considering this gap, this study integrates structural–functional analysis of the innovation system with that of sustainability transitions using a multi-level perspective.

Integrating innovation-system and sustainability-transition perspectives helps in developing a more holistic approach to understanding and evaluating the innovation system and also to gather more inclusive indicators and data. In the previous studies, landscape, regime, and niche factors are studied independently, but this study considers the effects of all these multi-level factors on the innovation system. The study also considers the effect of socio-technical landscape and niche-development factors on the socio-technical regime. Localization of innovations, coordination, and scaling functions are added as system functions, and power relations are considered not only at the niche level as in the previous studies but also at the regime and the landscape levels. The effect of the socio-technical landscape and the niche development on the socio-technical regime is indicated in the framework.

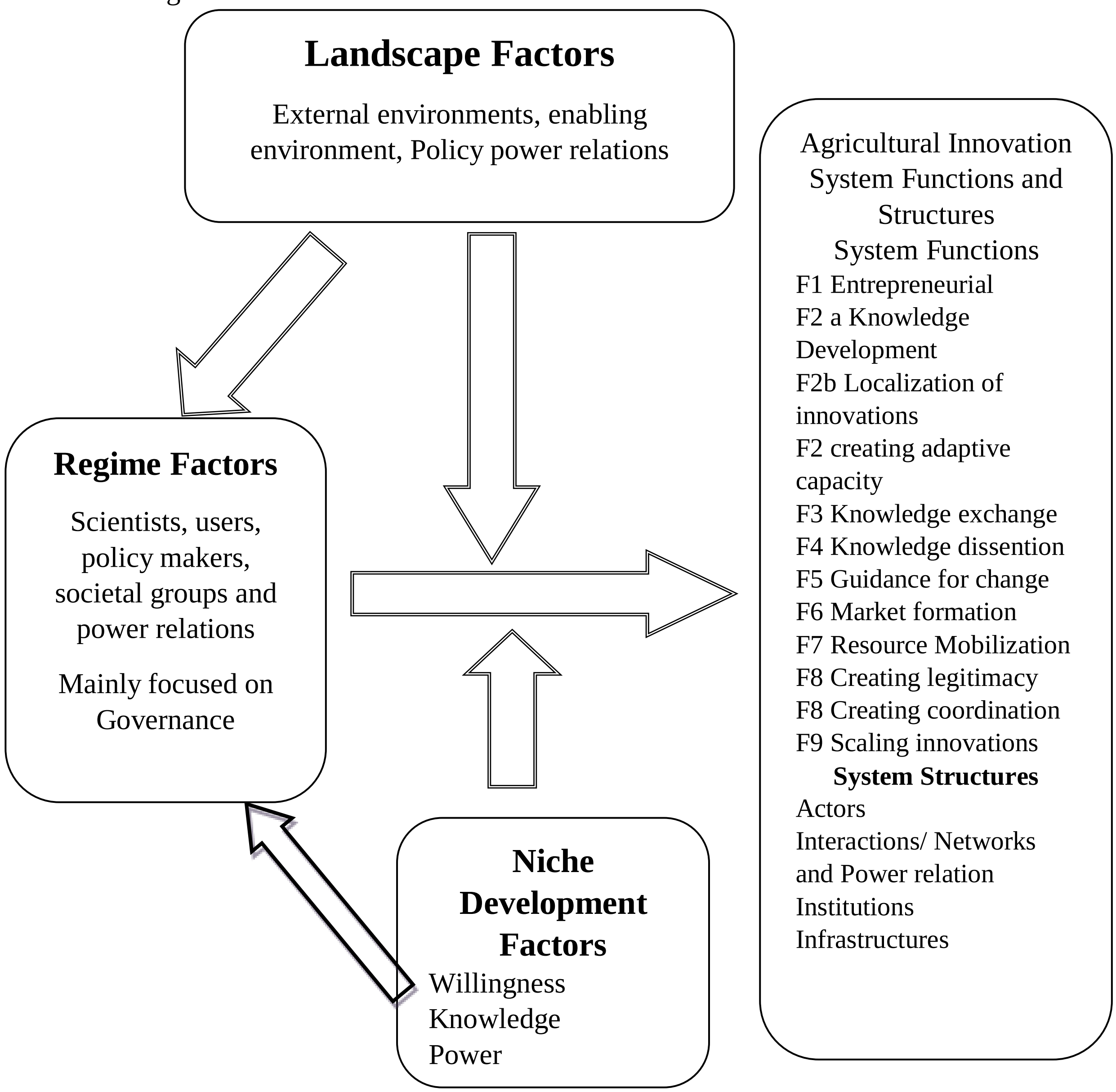

Figure 2: Conceptual Frame work of the study; Source: Source: Adapted from, (Lopolito,Morone and Sito 2011;Hillman et al.2011 ;Hans-Erik 2019: Esmailzadeh et al. 2020).

3. Methods

3.1 Sampling and data collection

In this study, a multi-stage sampling was adopted. In the first phase, the Amhara Region was selected purposively. Then, in the second stage, the West Gojam zone was selected purposively based on the potential for maize production. In the third phase, Mecha Woreda was selected purposively. Finally, key-informant farmers and other actors were selected using the snowball sampling technique. Farmers for focused group discussion (FGD) were selected purposively.

The study made use of primary data sources including smallholder farmers involved in maize production, development agents, the District Office of Agriculture, and other key informants. Moreover, the information gathered from these primary sources has been supported and triangulated from available secondary data sources including regional and district annual reports and research findings. Based on the study objectives, we selected 49 organizations at niche, regime, and landscape level, all actors that were directly involved in the generation, dissemination, and utilization of improved maize varieties. To collect the data FGD with farmers and key-informant interviews with selected organizations was employed. A total of 72 interviews at niche, regime, and landscape levels were conducted with officials and experts from the respective actors involved in the generation and dissemination of improved maize varieties. One of the selection criteria used in this study was to involve only those organizations/institutions that allocate their budget to carrying out activities such as the generation and dissemination of improved maize varieties. Face-to-face interviews were conducted, based on a structured interview guide with closed- and open-ended mixed questions. Given that the interview was an in-person meeting with respondents from all niche, regime, and landscape actors, whenever necessary we discussed the questions further to clarify terminologies. The interview questions consisted of three main parts. The first part was about respondents' information including the type of organization and the activity they are involved in. The second part focused on the activities they performed, including their different functions and the associated structural elements (with whom they work the nature of interactions, the institutions, and the infrastructures they have). The third part consisted of questions about bottlenecks in the process of generation, dissemination, and utilization of improved maize varieties.

Table 1 presents different actors at different levels of aggregation such as niche, regime, and landscape. These actors are both private and public, mostly engaged in the generation and dissemination of improved maize varieties, and located at different levels of aggregation. These actors are located at local, regional, and national levels. Niche actors are those actors around which the implementation of improved maize varieties takes place, like farmers, farmer-based seed multiplications, local seed businesses, private seed enterprises, the kebele office of agriculture, the district office of agriculture, and other district and zonal offices. Regime actors are those actors who are responsible for the regulation of improved seed varieties, like the Amhara Regional Bureau of Agriculture, Amhara Seed Enterprise, and other regional actors. A socio-technical landscape that has an exogenous factor in the development and dissemination of improved maize-seed varieties like the Ministry of Agriculture, Agricultural Transformation Agency, Bako National Agricultural Research Center, Pioneer Hi-Bred Seeds Ethiopia Plc. and other national and international organizations. The following table presents the major actors who are involved in the development and dissemination of improved maize-seed varieties in Ethiopia.

Table 2: Actors at different levels of aggregation

List of actors	Niche level		Regime level		Landscape level	
	Private	Public	Private	Public	Private	Public
Farmers Base Seed Multiplication (FBS)	√					
Farmers(FA)	√					
Kebele office of Agriculture (KoA)		√				
District office of Agriculture (DoA)		√				
District Cooperative Promotion(Dcop)		√				
Merawi Farmers' Cooperative (Mfcop)	√					
Wete Abay Farmers' Cooperative (Wfcop)	√					
Amhara Region seed Quality Direct (Rsq)				√		
Adet Research Center (Adetrc)				√		
Local Seed Bussiness (LSB)	√					
Etho Agri Ceft (Ethioagri)	√					
Private seed dealers (Pseeddel)	√					
Private Seed Multipliers (PSM)	√					
District Communication Office(Dcom)		√				
District Administration (Dadmin)		√				
District Land Administration (Dland)		√				
Zonal office of Agriculture (ZoA)		√				
Zonal Cooperative Promotion(Zcop)		√				
Merkeb Union (Munion)				√		
Zonal Communication office (Zcom)		√				
Zone Administration (Zadmin)		√				
Zonal land administration (Zland)		√				
Amahra Region Bureau of Agricultur.(BoA)				√		
Amahra Seed Enterprise (ASE)				√		
Agent of Pioneer Ethiopia (Apionner)			√			
Advanced Maize Seed Adoption(AMSAP)			√		√	
Pioneer Hi-Bred Seeds Ethiopia Plc.					√	

Regional Cooperative Agency (Rcop)		√		
Regional Communication office (Rcom)		√		
Regional land Administration(Rland)		√		
Agricultural transformation Agency(ATA)	√		√	
Ministry of Agriculture (MoA)				√
Sasakawa Africa Association (SAA)		√	√	
International Maize and Wheat Improvement Center (CIMMYT)			√	
Bahirdar University (BDU)		√		
Integrated Seed Sector Development (ISSD)	√			
National Seed Enterprise (NSE)				√
National Seed Quality Directorate (Nsq)				√
Ethiopian Institute of Agricultural Research				√
Bako National Research center (Bakorc)				√
Amhara Region Agricultural Research Institute (ARARI)		√		
National Media (Nmedia)		√	√	√
Alliance for Green Revolution in Africa		√		√
Ethiopian Biodiversity Institute (IBD)				√
Agro business induced Growth Program	√			
Pioneer HI-Bred International (Pionnerint)				√
National cooperative Agency (Ncop)				√
Ethiopia Seed Association (ESA)			√ Where is seed regulat ory?	

Source: Field survey result, 2020

3.2 Data Analysis Methods

The data collected was analyzed using thematic analyses. Thematic analysis involves analyzing themes within the data set to identify meaning based on research questions. Thematic analysis allows the division and categorization of large amounts of data in a way that makes it far easier to analyze (Braun and Clarke 2006). A deductive approach to thematic analysis was employed in which the theoretical framework gives an idea of what kind of themes to find in the data.

4. Result and Discussions

4.1. Description of the existing maize innovations in the study area

Table 2 presents the identified innovations in the study Woreda. The FGD discussants identified and agreed that the following innovations were utilized by farmers. Among the identified innovations, improved Maize varieties (P3812W, a variety released by Pioneer Hi-Bred Seeds Ethiopia Plc., and BH540 and BH546, varieties released by a public research center) were selected. This is because sustainable generation, dissemination, and utilization of improved maize seeds are critical issues in the study area in particular and in the country in general. According to the focus-group discussants farmers replaced improved maize varieties released by the public with the variety released by Pioneer Hi-Bred Seeds Ethiopia Plc.. This variety was preferred for its seed quality, higher standing power at all sites, pest and disease resistance, high yield, good grain quality, high kernel weight, and market demand. This variety is foreign in origin, but it is well disseminated among farmers.

Table 3: Identified innovations used in the study Woreda

S/N	Identified Maize Innovation	Innovation type
1	Improved Maize Seed Varieties P3812W (locally, Limu) released by Pioneer Hi-Bred Seeds Ethiopia Plc.) , BH540 and/or BH546 released by public research center	Technological Innovation
2	Conservation Agriculture	Technological Innovation
3	Hermetic grain storage bag (PICS bag)	Technological Innovation
4	Application of lime to reduce acidity in the soil	Technological Innovation
5	Maize Sheller	Technological Innovation
6	Manufacturing of processed Animal feed (Grain maize as animal feed)	Technological Innovation
7	Increasing seed rate/ha and row planting	Process innovation
8	Agricultural Commercialization cluster/ Maize commercialization cluster	Institutional Innovation
9	Agricultural Development Partners Linkage Council	Institutional Innovation

Source: Field survey, 2020

4.2. Systemic problems based on integrated functional-structural analysis of an innovation-system and multi-level perspective

As indicated in the diagram below, in the case of improved maize varieties released by foreign private companies, *knowledge dissemination* and *resource mobilization* functions were rated very high as compared to the remaining functions. However, *guidance of search* and *creating legitimacy* functions were rated as very low. For improved maize varieties released by the public research centers, *knowledge development*, *entrepreneurship*, and *creating legitimacy* were rated very high. However, *resource mobilization* and *knowledge dissemination* functions were rated as low. The comparison based on each function is discussed in the following section.

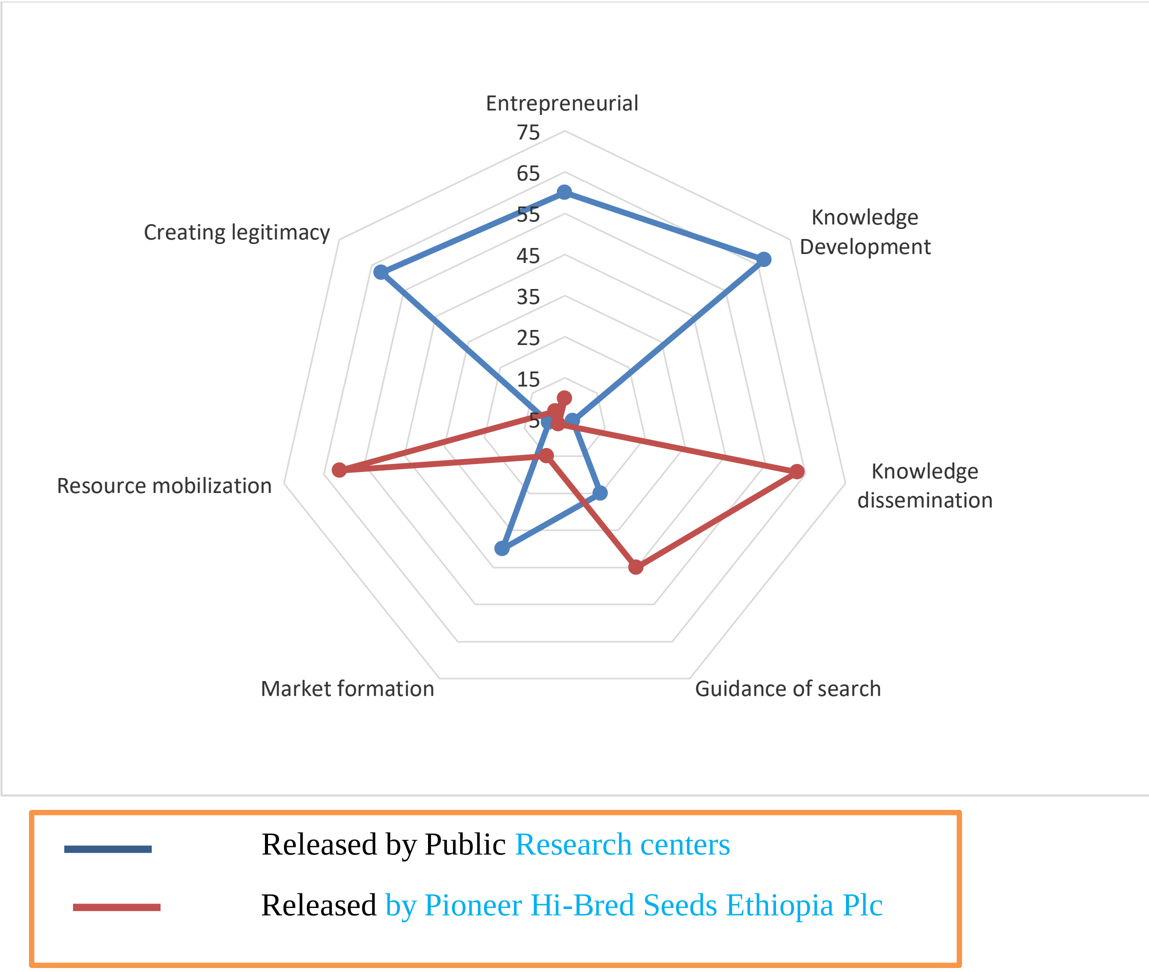

Figure 3. Variety Comparison in terms of different functions

Entrepreneurial Function

Concerning the varieties released by the public research centers, the Amhara seed enterprise has organized private seed multipliers and tried to create a conducive environment for entrepreneurial experimentation. A sufficient number of industrial actors were involved in seed multiplication and also engaged in large-scale production activities. Amhara Seed Enterprise made contractual agreements with the local private sector to multiply the varieties in question and there is strong interaction among different actors. This is in line with the study conducted by (Dawit et al., 2021): the private sector is growing, and under the current set-up, all private seed companies, except the multinational ones, are dependent on the public supply of source seed (basic seed) and also have to align with the public distribution system. Amhara Seed Enterprise supports the seed-producers’ union and cooperatives to address the key bottlenecks in the seed value chain by creating an enabling environment and improving access to a wide variety of crops. With the support of ATA, Amhara seed enterprises continued to build farmers' seed systems in the Amhara region to improve smallholder farmers' access to quality seeds, thereby ensuring food security and improving livelihoods.

However, the case is different for the varieties released by Pioneer Hi-Bred Seeds Ethiopia Plc. There is only one large-scale local private company named Ethio Agri-CEFT engaged in the production and multiplication of P3812W, a variety released by Pioneer Hi-Bred Seeds Ethiopia Plc. There is an agreement between Ethio Agri-CEFT and Pioneer Hi-Bred Seeds Ethiopia Plc. Other local private seed producers were not engaged in the production of P3812W. The entrepreneurial function in Pioneer Hi-Bred Seeds Ethiopia Plc. was limited to interactions between two firms. No multiple actors were involved in entrepreneurial activity and there were no rules and regulations that enforced to engagement of local entrepreneurs in the production of P3812W. This indicates the presence of institutional failure. Those local entrepreneurs who engaged in the production of improved maize varieties released by public research centers faced a challenge in their business.

This is because the improved maize variety released by Pioneer Hi-Bred Seeds Ethiopia Plc. was very competitive and productive. As compared to the public research centers, the number of enterprises involved in the production of Pioneer Hi-Bred Seeds Ethiopia Plc. was very low. Pioneer Hi-Bred Seeds Ethiopia Plc. Itself is responsible for the multiplication of the variety. In general, as compared to BH546, entrepreneurial activities were weak for Pioneer Hi-Bred Seeds Ethiopia Plc. In addition, the results indicate that the number of industrial firms in Pioneer Hi-Bred Seeds Ethiopia Plc. was low as compared to the public research centers, and the level of innovation that was expected to come from these industrial firms was negligible. Entrepreneurship in the multiplication of seeds faced a serious problem, and this implies that it is dominated by foreign private firms. There were no other local private seed producers engaged in the production of P3812W locally called "*Limu*". The owner of the P3812W variety focused exclusively on production. The company did not focus on research and development in the local context. The production scale was very low for BH546 compared to P3812W, indicating a low level of market share. Local private seed companies and cooperatives were kicked out of the market. (Mesfin & Melaku, 2018) recommended that local private seed companies work hard to increase their market share. The rate of abandonment by local entrepreneurs was higher than the rate of entry of new local entrepreneurs into the multiplication of improved varieties. Concerning infrastructure there was limited knowledge and resources, both physical and financial, for the production and multiplication of improved maize seed varieties. Finance and land were also critical problems for local private seed multipliers. They also reported that the supply of hybrid maize seed from by Pioneer Hi-bred Seeds in Ethiopia had steadily increased while that of local private companies was not increasing proportionally. This finding is supported by (E. Kebebe et al., 2015b) since they argued that the low entrepreneurial capacity of smallholder farmers seems to be linked to socio-economic, cultural, and political underpinnings.

A senior agronomist at Pioneer Hi-Bred Seeds Ethiopia highlighted that:

> *"Pioneer Hi-Bred Ethiopia as a private company puts a standard to engage in seed production and multiplication with entrepreneurs. Landownership is one of the criteria. The company made contractual agreements only with large and medium-scale seed producers. This limits the number of actors engaged in seed production and multiplication. The other issue is the quality of production. As a multinational company Pioneer Hi-Bred Seeds Ethiopia Plc. doesn't compromise quality issues. In the Amhara region, only Ethio Agri-CEFT qualifies for the standard set by Pioneer Hi-Bred Seeds Ethiopia Plc."*

Seed companies are classified as small (producing < 1,000 tons); medium (producing 1,000-5,000 tons) and large (producing >5,000 tons) (Atilaw et al., 2017). By this classification, while the four government seed enterprises and Pioneer Hi-Bred Seeds Ethiopia are large-scale producers, the other domestic private seed producers are small-scale. Currently, there is no medium-scale seed producer in the country. Budget limitations and a lack of effective large-scale seed enterprises in the region affected entrepreneurial activities (Ayana, 2019).

Knowledge development

In the case of the variety released by Pioneer Hi-Bred Seeds Ethiopia Plc. the developed knowledge had been used by farmers at a large scale. The varieties meet the needs of farmers in terms of quality and productivity. The variety had a comparative advantage over the varieties released by the public research center. The relevant knowledge was driven by external agencies and it was not developed at a local level. Niche and regime-level actors had no opportunity to participate in the production and multiplication of the variety. Only Pioneer Hi-Bred Seeds Ethiopia Plc., which is a multi-national private company, was responsible for the development, production, and multiplication of the variety. The extent of knowledge development was not sufficient for the supply of innovation in the country, particularly in the Amhara region. The quality of the variety fitted with the knowledge needs within the innovation system but also constituted a barrier for the innovation to move to the next step. There was not enough knowledge exchange between actors and across geographical borders for the development of the variety. According to the respondents there was no “adequate exchange of information between users of technology and Pioneer Hi-Bred Seeds Ethiopia Plc.”. These indicate that knowledge about innovation was not well understood among actors involved in maize production and among the country's entrepreneurs, research institutes, and higher learning institutes. The study conducted by (Mesfin & Melaku, 2018) supports this finding, that failure to produce imported seeds and shortage of foreign currency in the country affects the sustainability of seed import. These form a barrier to sustainable generation, dissemination, and utilization of innovation.

Considering localization of technology as an indicator of knowledge development, the pursuit of technological learning was not undertaken by Pioneer Hi-Bred Seeds Ethiopia Plc. This has led to poor activation of local research and development and the improvement of the relevant variety in Ethiopia. Missing actors in the development of the innovation and lack of rules and regulations that enforce collaboration with local research centers and Universities contributed to the inefficient ability of the system to engage actors in knowledge-development processes.

A deficit in the joint learning process was observed. Reflexive, demand-articulation, interaction, and institutional failures were observed in the knowledge-development function of Pioneer Hi-Bred Seeds Ethiopia Plc. There was a low level of capacity to learn, innovate, modify or multiply, and utilize available innovation by users; and insufficient networking or negotiation skills and a lack of organizational capacity of actors to adapt to and manage the innovation. This finding is supported by the finding of (CtEH, 2021), localization of innovation is important to generate, systematize, and adapt knowledge (both indigenous and imported). The study on people’s seed-supply experiences regarding improved sorghum varieties with a focus on East Africa conducted by (Hambloch et al., 2021), also supports the above scenario. They found that diverse approaches to seed-system development and diverse delivery channels are potentially more promising than private-sector business models. The findings of this study are also supported by a study conducted by (Tekeste & Abebe, 2018). Their findings revealed the participation of private sector expenditure in agricultural research is very low.

However, in the development of improved maize varieties by the public research centers, there was a sufficient number of niche and regime-level actors like the Ethiopian Institute of Agricultural Research, Ministry of Agriculture, Agricultural Transformation Agency, AGRA, CGIAR, Amhara Region Agricultural Research Institute, Adet research center, Bahr Dar University, Amhara region seed enterprise, and local seed producers and cooperatives. There were formalized rules and regulations that forced research institutions to collaborate with universities and seed enterprises. The findings of this study indicate that the Kebele Office of Agriculture, the farmer-based seed multiplication scheme, and the district office of agriculture have more interaction with farmers than other actors. Public research centers employed different participatory approaches to conduct demonstrations on farmers' plots and tried to develop a good relationship with farmers and the Kebele Office of Agriculture. Most of the improved Maize varieties were released by the Bako National Maize Research Center/Public Research Center. By looking at the indicators of knowledge development, it is clear that the following functions were at an acceptable level: adequate projects, documents, and papers; skilled staff in the R&D sector; and a sufficient number of patents. There was the capacity to learn, innovate, modify or multiply, and utilize available improved maize seed varieties by users; and there was good networking among different actors to adapt and manage the varieties. This finding is supported by Abate et al. (2015). They reported that the Ethiopian Agricultural Research Institute introduced a paradigm shift towards an innovation-systems approach which is based on the active participation of farmers in the development and dissemination of technology and on the involvement of partnerships with different actors along the value chain. As indicated in the same study, Ethiopia has a well-organized and nationally coordinated agricultural research and development (AR&D) system with a clearly defined vision and responsibilities. These efforts have demonstrated the importance of local innovations and appropriate technologies.

This phenomenon is also supported by (Ayana, 2019). In collaboration with the Ministry of Agriculture, the Ethiopian Institute of Agricultural Research, and the Regional Bureau of

Agriculture, the Ethiopian seed enterprise and regional seed enterprises are implementing the farmer-based seed-multiplication strategy (FBSM). As a characteristic FBSM are decentralized, locally run, and farmer-based. All relevant public sector institutions (MoARD, EIAR, ESE, and state farms) are mobilized in the multiplication of hybrid maize varieties. According to (Aschalew, 2018), the research-based FBSM models focus on the introduction of new crop varieties into the local seed system, with the involvement of researchers, agricultural extension (development agents and other subject matter specialists), and farmers. The Bako Agricultural Research Center (focused on maize research) is responsible for improving seed production (breeder, pre-basic seed) and strengthening the capacity of improved seed-research centers (to produce breeder, pre-basic, and basic seed).

FGD participants at Kudmie Kebele said that,

> *"There are problems related to the availability of Limu local name of P3812W. We don't know who produced it and from where it comes. But it addresses our needs in terms of quality and productivity. We are suffering to get this variety. Currently, experts from the Woreda Office of Agriculture and extension workers force us to use other varieties distributed by the Amhara region seed enterprise."*

As compared to varieties released by Hi-Bred Seeds Ethiopia Plc., varieties released by the public research centers were not farmers' first choice in terms of quality and productivity. Farmers used the public research center varieties as a secondary option. Due to higher demand from the farmers' side, the variety released by Hi-Bred Seeds Ethiopia Plc. was hampered by the regional government. This is because there is no clear collaboration in the development of the variety. A relatively small number of varieties dominated seed production, and the rates of varietal change as well as seed replacement were low. For example, one of the varieties released by the public research center, BH540, has been utilized by farmers for more than 25 years. The study conducted by (Ayana, 2019) indicates that the domestic private sector had limited infrastructure (knowledge, financial and physical), marketing, seed-brand development, managerial, technical, and operational capacity, and also limited equipment and financial resources.

Knowledge dissemination:

In terms of disseminating P3812W, the system was very effective. The company used the government's extension system to promote the variety and they created demand for the innovation. After two years of releasing P3812W, in 2015 ACDI/VOCA implemented USAID's three-year Feed the Future program and established the Ethiopia Advanced Maize Seed Adoption Program (AMSAP), a public-private partnership among USAID, Pioneer Hi-Bred Seeds Ethiopia Plc., and the Government of Ethiopia to promote and scale up a network for sustainable seed distribution in support of the government of Ethiopia's Agricultural Growth Program (AGP). AMSAP provides increased access to training and improved inputs such as hybrid seed (P3812W), and provides other technical support. There were relevant actors engaged in the dissemination of the innovation, and also the system was capable enough to access adequate finance and other necessary resources for promotion. There existed interaction among all actors and there was well articulated and defined memorandum of understanding between all parties.

Even if there are different actors to disseminate the varieties released by public research centers, there were no well-organized efforts to disseminate the seed varieties. Even farmers were not aware of the competitiveness of the public variety like BH546 against P3812W. As key informants from the research centers and regional seed enterprises replied, BH546 is a competitive variety with regard to P3812W. They argued that P3812W exceeds BH546 in terms of promotion. The public research centers and extension organizations failed to promote the variety. As a result, most maize-growing farmers in the region preferred and used P3812W. The system was very poor in diffusing and disseminating varieties released by the public research centers, particularly BH546. Different actors are involved in the generation and dissemination of the varieties released by public research centers but the interactions among them are weak. Directional, interaction, and institutional failures were observed in the dissemination of varieties released by public research centres. BH546 is a recently released variety as compared to BH540. BH546 is believed to substitute BH540 and compete with P3812W. The study conducted by the (Ethiopian Seed Association, 2019), also confirmed that there is inefficient demonstration and popularization of newly released varieties by the national public system. (Ayana, 2019) also indicates that weak coordination and linkages among actors in the system for seed development, production, multiplication, and distribution affected the utilization of improved varieties released by public research centers. (Riungu et al., 2021) looked at the introduction of new bean and maize varieties in Uganda. They showed that when new seeds are promoted to farmers, many things remain unclear to them and non-adoption may result from limited information and interactions around demonstration trials, limited access to the seed, and uncertainties over the performance of the seed. The public sector in the Amhara region was not strong and had allowed the private sector the opportunity to thrive better. (AGRA, 2019) also indicates that the seed system was below the level required to achieve Ethiopia's ambitions under the agricultural transformation agenda. In particular, the shortage of first-generation seeds and the weak link between research and popularization hinders the promotion of new varieties. This finding goes against the finding of (Abate et al., 2015) who argued that the government support and commitment to agricultural extension in Ethiopia are strong and that there is growing sensitization of farmers to available technologies and strengthening know-how in many major growing regions, especially in major and priority staple crops such as maize, wheat, teff and pulses, which have improved food security across the country.

Experts from the Amhara region seed enterprise highlighted that,

> *"Varieties released by Pioneer hi-breed seeds like P3812W exceed our varieties in terms of promotion, otherwise there is no major difference in yield. In addition, BH546 is a competitive variety towards P3812W. Finance for promotion and dissemination is a key factor for the utilization of improved maize varieties".*

The above finding is supported by a study conducted by (Erenstein & Kassie, 2018) that found that several additional market failures hampered maize seed markets in the sub-region. Although some seed companies have developed their maize varieties or marketed them themselves, most emerging local private seed companies continue to rely on public maize varieties. As these public varieties are public goods, companies have little incentive to invest in their marketing/promotion. This finding is also supported by(Ayana, 2019) in that the promotion of improved seed by ESE has been limited. Better promotion could play an important role in the diffusion of new varieties. For example, a greater effort could be made to advise farmers on the benefits of improved varieties and to differentiate between grain and improved seed. Public support and investment in the promotion of public varieties may thus be needed to help stimulate commercial seed production.

Market formation

Compared to the varieties released by the public research centers there was a large market segment for the varieties released by Pioneer Hi-Bred Seeds Ethiopia Plc. The current and expected future market size is sufficient for P3812W. According to the respondents, accessing the seeds of Pioneer Hi-Bred Seeds Ethiopia Plc. in the market was a big challenge. Farmers were forced to use the black market to obtain P3812W. There existed a state monopoly over the seed market. The results of the market-formation function for Pioneer Hi-Bred Seeds Ethiopia Plc. indicate that the market to sell the produce is large. As compared to the seeds produced by the public research centers, market size within the country and proper prospects for future demand were higher for the seed produced by Pioneer Hi-Bred Seeds Ethiopia Plc. However, the market structure was dominated by the government. Even if Pioneer Hi-Bred Ethiopia made a contractual agreement with dealers to distribute the variety, the company was forced to supply to the regional bureau through the principle of seed allocation.

> *"Most of the time improved maize varieties are supplied by cooperatives. The amount of Limu (P3812W) supplied by cooperatives was very low. As a result, we are forced to use other varieties that are not productive like Limu (P3812W) and also we are forced to buy the variety from the black market with high prices and low quality. The normal price for Limu in cooperatives is around 700 birr for 9kg but we bought around 2,500-3,000 Ethiopian birr in the black market. The problem is not only the price but also the quality. This is due to the shortage of varieties produced by* Pioneer Hi-Bred Seeds Ethiopia Plc. *in the market."*

The above result is supported by a study conducted by (Dawit et al., 2021) in which the government of Ethiopia introduced a novel experiment: direct seed marketing to reduce some of the centralized and state-controlled attributes of the national seed market and to rationalize the use of public resources. It was designed to incentivize private and public seed enterprises to sell seed directly to farmers rather than through the state apparatus. However, currently, private seed producers are authorized to directly market their seeds through regional bureaus of agriculture and then distribute them to cooperatives.

At the time, any incentive for seed companies to invest in marketing their products was even more reduced by the government's attempt to centrally respond to seed demand through farmer cooperatives/unions and centrally distribute seeds accordingly. Central planning of seed markets also can only go so far, with Ethiopia moving from a severe structural shortage of maize seed to a maize seed surplus in the aftermath of a program to stimulate seed production in 2009/10 (Abayechaw & Wulchafo, 2021). Such market failures pose serious constraints to the effective development of the private maize seed sector.

Creating legitimacy

P3812W was introduced in 2013 and there was good advocacy by the government. There was not much resistance towards P3812W and the support for this variety from farmers was positive. In addition, the advocacy for P3812 was done by government extension workers. Currently, the regional seed enterprise agency affects the wide utilization of P3812W. The argument for this is twofold. First, the parental line or the breeder seed of Pioneer Hi-Bred Seeds Ethiopia Plc. was imported, which may affect the sustainable provision of the improved maize seeds. Second, there is a lack of demand for all the seed provided by the regional seed enterprise agency. This is also the biggest concern for local private seed-multiplication enterprises involved in the multiplication of improved maize varieties released by the national and regional research centers. This may also lead to the underutilization of different varieties released by government research institutes. There is much resistance towards the dissemination and utilization of P3812W from the regional government's side. Downscaling of improved varieties developed by Pioneer Hi-Bred Seeds Ethiopia Plc. was observed in the study area.

This is a paradox; there is no resistance from the farmers' side, but there is from the regional government. One point of agreement from this study is the need for the development of varieties and the delivery of seeds to be more demand-oriented. This is also supported by a study conducted by Tracy and Done (2017) that concluded that developing varieties that smallholder farmers want is mandatory. In addition breeders, farmers, and crop buyers must engage in the joint ranking and weighting of the traits that drive farmers' adoption rates.

4.3 Comparison of Varieties using Landscape, Regime and Niche-Level Factors

4.3.1 Socio-technical Landscape-Level Factors

The landscape factors that affect the maize innovation system include customers, competitors, and suppliers; labor, legal, regulatory, and competitive markets and economic conditions, and the provision of technological and other knowledge that values innovation. Landscape factors also exert an influence on measuring the direct and indirect effects of public policies on innovation activities, on social and environmental factors, and on external factors that may impede innovation. Several major aspects of the landscape influence the scope for viable investment in improved maize seed variety-related activities. Accordingly, the Ethiopian seed policy is meant to ensure that farmers get the right seed, at the right time – all this to alleviate food insecurity at various levels of the country and contribute to economic development. However, so far the policies, laws, and regulations developed to support the seed sector have not been very effective. The law of global patents is an important factor. The Ethiopian Plant Breeders' Right Proclamation (No 481/2006), which was later replaced by a new proclamation, No.1068.2017, accepted the intellectual-property protection of new plant varieties (Mesfin & Melaku, 2018). However, the lack of regulation limited the effectiveness of the proclamation as well as the directive. Issues related to regulations on plant breeders' rights, and exclusive rights to new plant varieties, are the major factors affecting the sustainability of improved maize varieties developed by Pioneer Hi-Bred Seeds Ethiopia Plc. This finding agrees with the findings of the study by (Ayana, 2019). He reported that the primary constraint to attracting private investment is the continued existence of the state-led seed system and the lack of regulations on breeders' rights. Although the development of policies is an important step, putting them into practice has been a major challenge to the seed system.

This confirms the findings of the study conducted by (Gobena & Rao, 2019): Ethiopia has not adopted either the WTO-TRIPS agreement or the UPOV convention. It has no obligation to adopt strong plant-variety protection that limits farmers' rights and traditional knowledge. Ethiopian Plant-variety protection should be considered in light of the country's food-security concerns.

(Gobena & Rao, 2019) suggested that Ethiopia, as one of the most food-insecure countries, has to design a plant-variety protection regime that best responds to its specific concerns of eradicating poverty and improving food security. In this line a senior expert from Pioneer Hi-Bred Seeds Ethiopia Plc. argued that

> "Intellectual property rights, foreign currency, infrastructure, and land ownership affect private investment in the country. For example in the Amhara region due to the issue of land size, Pioneer Hi-Breed Seeds Company was forced to make a contractual agreement only with *Ethio Agri-CEFT*. This affects the supply of our product to smallholder farmers. The issue of breeders' rights and the country's infrastructure also affect the development of breeder seeds in the country. Currently, this has become a big issue, particularly from the regional government's side, and in turn affects the performance of our company. All these mentioned are severe constraints to foreign investors in Ethiopia".

This finding is supported by the study by (Mulesa et al., 2021) which recognizes several bottlenecks in the formal seed system, like seed laboratories' capacity for seed-quality inspection and testing, infrastructure, and equipment, as well as technical staff. The study conducted by (Mesfin & Melaku, 2018) confirms that the major issue preventing increased participation of multinationals in the Ethiopian seed system is the financial regulation that limits the repatriation of foreign currency and the lack of regulation of plant breeders' rights. The financial regulation has created a disincentive for most multinationals interested to become involved in the country's seed system. Policies to promote and regulate the production and multiplication of improved seed varieties are still in their infancy.

Currently, the country is dependent on imports of the breeders' seed for the multiplication of P3812W, a product of Pioneer Hi-Bred Seeds Ethiopia Plc., production and multiplication. This influences sustainable technological innovations and creates a heavy burden on maize production in the country, particularly in the study area. The local actors pinpointed this problem as the main current bottleneck in their maize production. (Mesfin & Melaku, 2018) also support this finding that factors that discouraged the private sector were lack of investment incentives, lack of investment guarantees, inadequate market access or tax exemption, and lack of implementation and enforcement of seed regulations, all of which have also been mentioned as constraints. As a result, the private sector in the seed system remains weak.

4.3.2 Socio-technical Regime Factors

Maize-growing farmers who were interviewed for this research reported major bureaucratic problems in accessing improved seed varieties, particularly P3812W. Almost all FGD discussants noted that accessing improved maize varieties developed by Pioneer Hi-Bred Seeds Ethiopia Plc. was a crucial problem for farmers. There were different regime actors that influenced the potential success of commercially improved seed varieties, namely the Amhara Bureau of Agriculture regime (which affected the end product), the Amhara seed-enterprise regime (which affected the production and multiplication of the seed), and the regional research center (which affected the development and dissemination of varieties). Instability in the improved maize seed-multiplication regime was growing under the influence of the landscape factors discussed above.

There was a growth in demand for the varieties developed by Pioneer Hi-Bred Seeds Ethiopia Plc., and their varieties have certain advantages over the existing national varieties. The local technical knowledge required for the multiplication of the varieties was not widespread and there were no learning processes taking place. Farmers' resistance to the varieties developed by Pioneer Hi-Bred Seeds Ethiopia Plc. was low, but it was high for the varieties developed by the public research centers. With the benefit of yield increment and quality product, farmers in the study area now say that "sowing the varieties of Pioneer Hi-Bred Seeds Ethiopia Plc. is the best option among the existing varieties, but a sustainable supply of this innovation needs considerable effort and negotiation". Pioneer Hi-breed Seeds Ethiopia Plc. the owner of P3812W, had no successful relationships with local partners. The absence of such a relationship and lack of trust created major constraints to the sustainable production of P3812W. The supply of P3812W was determined by the Regional Bureau of Agriculture through a quota system or seed allocation. This was one of the major issues that had to be addressed to ensure the sustainable development and dissemination of P3812W. Different regime characteristics and trends affected the wide utilization of P3812W. Among the multinational seed companies operating in Ethiopia, Pioneer Hi-Bred Seed Ethiopia Plc. has its own seed source and distribution network. Tensions therefore exist between the state and the emergent private sector, particularly overseas investors. Although there has been much political attention given to liberalization in the country, the state maintains a strong hold on market players, both through market disincentives (e.g. price fixing) or the limitation of certain transactions (for example distribution networks).

The above finding is supported by the study by (Mesfin & Melaku, 2018) who reported that across each of the elements, the state dominates the seed system. The private sector is encouraged to play a more active role in the system, but in reality, its efforts have been quite limited due to market disincentives or the limitation of certain operations. The study conducted by (Akpo et al., 2020) indicates that the private sector's share in seed production and delivery in sub-Saharan African countries has not been very substantial for decades. This study identified the presence of strong state control, even in notionally privatized but centralized operations. As a result, farmers' access to quality seeds of the recently marketed varieties remains very low.

Table 4: Comparison of varieties released by Pioneer Hi- Bred Seeds Ethiopia Plc. and the public research centers based on Socio-technical regime factors

Pioneer Hi- Bred Seeds Ethiopia Plc	Public research centers
Governed by a profit Private company and only a single actor. Seed distribution is governed by the regional bureau of agriculture /quota system. Efficient management for production and multiplication of quality seed. No private and public actor initiative particularly for knowledge development. The level of governance rests only on national and international levels. Closed or no relationship between different actors in the innovation development processes. There is no niche level and very specific support systems. Different actors engaged in the dissemination of the innovation (Public-private partnership exists). Failed to do the guidance of search and legitimacy functions. This limits the development and diffusion of innovation. There is a political power influence on innovation. Resource mobilization function was done for the adoption of the innovation.	Governed by a public research center and regional seed enterprise and regional bureau of agriculture. Production and multiplication is done by contractual agreement with local private seed producers. There is a quality issue. There are possibilities of actor roles and responsibilities involving various combinations of state and private actors in knowledge development. The level of governance, ranging from global, national and regional and down to local. There is an open relationship between actors, production, and multiplication /development of the innovation. There is niche level of support system Only the regional bureau of agriculture is responsible for the dissemination of the innovations/ limited actors engaged in the promotion of innovations like SAA and AGRA. Through regional seed enterprises the guidance for search and legitimacy was done and this highly affects the wide application of P3812W. The innovation is considered as public good as a result there failed to mobilize resources for wide adoption of the innovation particularly for BH546.

A study conducted by (Erenstein & Kassie, 2018) supported the above finding that fair competition includes the assurance that private seed companies will not have to compete with subsidized state-owned companies, a problem that still hampers the Kenyan, Ethiopian, and, to a lesser extent, Tanzanian seed sectors. Ethiopia also stands out as being more dependent on public seed companies and with an excessively regulated environment that reduces business flexibility and profitability, while raising barriers to entry.

4.3.3. Niche Development Factors

Niche in this study refers to improved maize seed varieties (P3812W, BH540/BH546). Almost all of the farmers who participated in the FGD confirmed that they were using P3812W, a variety developed by Pioneer Hi-Bred Seeds Ethiopia Plc. expecting to make a considerable profit. This mainly happens because they were able to sell their products at a reasonable price. The decline in yield and quality for the existing BH540 acted as an additional push factor for the utilization of the variety released by Pioneer Hi-Bred Seeds Ethiopia Plc.

There are no local learning processes yet concerning the development of P3812W and also no networks of actors. There was high uncertainty in the utilization of P3812W. There was uncertainty in terms of dependency on foreign seeds. The issue of seed sovereignty affected the development of P3812W even if the innovation was the farmers' preference.

Table 5: Comparison of varieties released by Pioneer Hi- Bred Seeds Ethiopia Plc. and public research institute based on niche development factors

Pioneer Hi- Bred Seeds Ethiopia Plc.	Public research institute
There is a demand on the variety. Farmers are willing to utilize the innovation. There is shortage on the supply side. Farmers were forced to search for other means to access it like, the black market. There is no dedicated network of actors as a result lack of power. Limited learning processes, insufficient knowledge for production, and multiplication at a local level.	Lack of a demand Farmers are not willing to use it. There is a network of actors. This hampers the utilization of varieties released by Pioneer Hi-Bred seeds Ethiopia Plc. There is a learning process among actors. There are local private sectors engaged in the production, and multiplication of the variety.

5. Conclusion and policy implications

This study evaluated the innovation process surrounding the improved maize seed varieties in Ethiopia. The result shows that problems concerning the functions and structure and niche, regime, and socio-technical landscape factors affect the improved maize-innovation system.

Three functions, including *entrepreneurship, knowledge development,* and *creating legitimacy*, were weaker than the others in the case of improved maize varieties developed by Pioneer Hi-Bred Seeds Ethiopia Plc, whereas these functions are stronger in the case of improved varieties developed by public centers. Knowledge dissemination and resource mobilization were the stronger functions of Pioneer Hi-Bred Seeds Ethiopia Plc. functions which were found to be weak in the case of the public research centers. One of the main functions that should be considered in the innovation systems of Pioneer Hi-Bred Seeds Ethiopia Plc. is that of entrepreneurial activities and knowledge development. Results also show that institutional problems, lack of interaction between actors, and insufficient infrastructure have prevailed in the generation, dissemination, and use of improved maize seed varieties. To promote P3812W the company and the Ministry of Agriculture at the national level failed to follow the transition paths; rather they used the technology-push approach. Pioneer Hi-Bred Seeds in Ethiopia focused on the transfer of technology to sell competitively on the international market. The result also shows that policies and governance affected the sustainable development of improved varieties developed by Pioneer Hi-Bred Seeds Ethiopia Plc. At niche, there was interaction among different actors in the case of public research centers and demand for P3812W, but the interaction was limited in Pioneer Hi-Bred Seeds Ethiopia Plc. This affected the wide utilization of both varieties. Linkages and the interactions between international actors at all levels were of paramount importance for sustainable innovations. This article concludes by suggesting that the innovation process is much more complex than linear models can describe, and that the process involves a complex interaction between different actors. It is necessary to design policies that stimulate interaction among heterogeneous actors to ensure adequate quality of physical, knowledge, and financial infrastructure to perform the functions of the system effectively.

The integrated framework gives valuable insight into the processes that are important for the successful development and implementation of innovations with the sustainable transition. Based on our findings, we suggest further reconsideration of the integrated framework to enhance its applicability in innovation and transition studies. The findings of this research contribute to the field of innovation-systems literature by providing a stronger foundation for integrating innovation-systems and sustainability-transition perspectives. So far the innovation-system literature has been aimed at studying innovation processes without considering the sustainability-transition perspective. The sustainability-transition perspective focuses on large-scale societal transformation toward sustainability. The insights from this study can contribute to further application and adaptation of the integrated framework by indicating how innovation processes can drive sustainability transitions.

Finally, the paper proposes some policy recommendations to tackle systemic problems regarding improved maize varieties, considering them as innovations. There is a need to integrate all the structures and functions of the innovation system to develop context-appropriate innovations. In improved maize-variety development, particularly when is developed by foreign private companies, the focus should be on the process pathway rather than on the product pathway. The critical aspects of process innovations, such as involving different institutions, partnerships, and strategic engagement, should be considered. The relevant national government bodies should be informed of the agricultural innovation-system perspective in order to be able to provide a pluralistic and demand-driven extension and advisory service. Some of the additional policy recommendations include the promotion of knowledge development and resource mobilization within networks of policy-makers, the public sector, and in both local and foreign private sectors, and also putting the Plant Breeders' Right Proclamation into practice by developing regulations that will grant plant breeders intellectual property rights. Such regulations encourage the involvement of local and foreign private companies in the sector to achieve a sustainable innovation system. The study also suggests new forms of private–public and private–private engagements that are needed for seed systems to have a greater impact on the production needs and priorities of farmers.

CHAPTER THREE

MULTI-LEVEL ANALYSIS OF ACTORS' INTERACTION IN MAIZE INNOVATION SYSTEM IN AMHARA REGION, ETHIOPIA

Abstract *Agriculture is a crucial aspect of Ethiopia's economy, and innovations in the field, especially those related to maize production, are vital for improving smallholder farmers' food security. This study examined actors and their interactions at different levels of aggregation in the generation, dissemination and utilization of improved maize varieties. To achieve this objective, perspectives on sustainability transition have been integrated into the innovation system, social network perspectives, and a multi-level power framework. Approximately 49 actor organizations were selected at niche, regime and landscape levels through* purposive sampling using *the snowball technique. Focus group discussions (FGD) with farmers and key informant interviews with selected organizations were used to collect data. The social network analysis approach was employed to analyze actors' interactions and their influences on the generation, dissemination and utilization of improved maize varieties. The findings reveals that agricultural extension service providers and government seed enterprises such as the Regional Bureau of Agriculture and Amhara Seed Enterprise, a regime level actor that influence the generation, dissemination and utilization of improved maize varieties. Given the priority that the Ethiopian government has placed on achieving food security by strengthening private sectors in the promotion of improved maize varieties, the findings of this study may suggest the need to involve/engage private actors at regime level to foster interaction among governmental and non-governmental actors for a sustainable supply of quality improved maize varieties.*

Key Words: Social Network Analysis, Innovation Processes, niches, regime, landscape

1. INTRODUCTION

Agriculture is considered central to the Ethiopian economy and agricultural innovations in general, and particularly improved maize varieties are fundamental to enhancing food security of smallholder farmers. Despite recent improvements in the development and dissemination of these improved varieties in the country, the adoption level has been slow. Previous studies indicated that limited public and private investment, unaffordable prices, and limited access to credit were among the key constraints to production (van Dijk et al., 2020). From a systems point of view, however, limited interaction, the fragility of synergies and weak coordination among system actors are considered as key constraints (Kelemework et al., 2021; Tarekegn & Mogiso, 2020).

The use of innovations to promote sustainable agriculture requires adjustments in existing system components and their interactions. New approaches are needed to promote close interactions between different actors (Juma, 2015). To unpack the nature of interactions among system actors, the paper used a combination of quantitative and qualitative Social Network Analysis (Froehlich et al., 2020; Gowensmith, 2022; Li et al., 2021; Pantic et al., 2023; Schipper & Spekkink, 2015). The novelty of this paper lies in its use of integrated perspectives from innovation systems, sustainable transition theory and multi-level power frameworks, taking innovation system as a point of departure. The overall maize variety innovation system is framed with the integrated structural –functional analysis of the innovation system to identify its core constraints (Baharloo et al., 2018; Boisier et al., 2021; Gust-Bardon, 2015; E. Kebebe et al., 2015b; Mininberg, 2015). However, innovations are often socio-technical, and innovation system perspectives need to give close attention to contextual factors. To address this, the paper used perspectives from sustainable transition studies, more specifically the Multi-Level Perspective (MLP) in order to capture the contextual issues that affect adoption processes beyond the elements of integrated structural and functional innovation systems (Lauttamäki & Hyysalo, 2019). As indicated in the Multi-Level Perspective literature (Costa et al., 2022; El Bilali, 2019b; Elsner et al., 2023; Gaddis & Jeon, 2022; F. Geels, 2019; Li et al., 2021; Schiller & Radinger-Peer, 2021), transitions come about through interactions within and between three levels: niches (micro level; locus of radical innovations); regimes (meso level; locus of established practices and associated rules); and landscape (macro level; exogenous trends). Critics of MLP point out its failure to provide an insight into the role of power at different levels of aggregation (Avelino, 2017; F. W. Geels & Schot, 2010; Grin et al., 2010). Hence, this paper complements this lacuna with an additional insight from multi-level power framework. By combining these insights, the paper aims at providing a novel understanding of the interaction among maize innovation systems actors in Ethiopia, with a nuanced understanding of the multi-level change drivers and power relation among system actors. The objective of the paper is to unpack the nature of the interaction among system actors of improved maize varieties in Ethiopia to unveil barriers that might hinder their dissemination and enhance the food security of smallholder farmers. The study also addresses the following questions: What does the pattern of interaction look like, and who is the most influential actor in the maize innovation system?

2 Theoretical orientation and conceptual framework

Theoretical orientation

Innovations emerge from the complex interactions among a diverse set of public, private and civil society actors engaged in generating, exchanging and using knowledge (F. Hermans et al., 2017). The agricultural innovation system approach sees innovation as a process of networking, interactive learning, and negotiation among a diverse group of actors. It aims to gain a deeper understanding of the innovation processes and views them as multifaceted and intricate interactions between novel and interrelated practices carried out by various stakeholders (T. D. Hermans et al., 2023; Kamara et al., 2023).

Hence, Wieczorek & Hekkert (2012b) developed a framework that integrates structural elements (actors, interactions, institutions and infrastructure) into the function of innovation system to identify systemic problems. Sustainability transition using a multi-level view has been integrated into the functions of the innovation system literature (El Bilali, 2020; Sutherland et al., 2015). The innovation system and sustainability transition approach provide a space for interaction of actors at different levels of aggregation. Bringing these actors together in the innovation system provides opportunities for actors to exercise power to change or maintain existing functions (El Bilali et al., 2018; Scoones et al., 2015, p. 3; Turner et al., 2020).

According to Avelino, (2017), F. W. Geels & Schot, (2010) and Grin et al., (2010), transition studies overlooked the issues of power in the framework; failed to provide an insight into the dynamics of change. It only provides a descriptive picture of the situations and the socio-technical changes and describes the system in a static situation, without providing insight into the mechanisms of the system's operations. Findings of Cullen et al., (2014) suggest that innovation system may be influenced by forms of power, highlighting the importance of power issues in order to better assess the strengths and limitations of the innovation system.

Network perspective is powerful way of examining the dynamics of interactions and power among actors (Coulon, 2005; F. Hermans et al., 2017; Johnson et al., 2017; Karasek et al., 1996; Kolleck, 2013). In explaining organizational performance network theorists do not only examine the characteristics of actors but also the relationship they have with other organizations (S. Borgatti & Ofem, 2010). The network perspective suggests that the power of individual actors is not an individual attribute but arises from their relations with others. To analyze these network perspectives, the social network analysis framework is used. Social network analysis (SNA) is a process of quantitative and qualitative analysis of a social network. It measures and maps the flow of relationships and relationship changes among actors and considers power as inherently relational. It also allows the generation of in-depth insights into the composition of the network and its effects on the innovation performance related to the structure and functioning of such network. Social network analysis also helps to explore the complexity and multi-dimensionality of innovation processes (F. Hermans et al., 2017). The metrics of social network analysis illustrate power as occupying advantageous positions in networks of relations. Three basic sources of advantage are high degree, high closeness, and high betweenness (Christopherson & Clark, n.d.; Hanneman & Riddle, 2005).

Researchers have also found that social network theory can help explain technology adoption and argued that there is a shift in interest towards a more dynamic analysis of social networks (S. P. Borgatti et al., 2018; Tscherning, 2011). Previous studies (Mapila et al., 2016; Mittal et al., 2018; Onumah et al., 2021; Spielman et al., 2011b; Teklewold et al., 2019b; Tesfaye et al., 2020a; Weyori et al., 2018) used social network analysis to describe actors' interaction and power in the agricultural innovation system. Other studies Caniëls & Romijn (2008); Lopolito et al., (2011); Falcone et al., (2018); F. Hermans et al., (2013), and Giganti & Falcone, (2021) also presented methodological conceptualization of niche and suggested an empirical methodology based on a social network analysis to be applied for investigating the relational network of a niche. The approach introduces a new paradigm for innovation research, making innovation understandable and tractable using tools such as computational network analysis and agent-based simulation. The authors attempted to relate niche development and transition towards sustainability by combining strategic niche management and social network analysis. But all these studies focus only on niche formation and development. Nevertheless, the presence of power at the niche level does not guarantee the prompt of the niche development because it also depends on the distribution of power within the network of multi-level actors. Considering this, Grin et al., (2010) link the multi-level perspective to an existing multi-level power framework, arguing that the three levels of power distinguished correspond to the three levels in transition dynamics: (1) relational power at the level of niches (abilities of agents to draw on institutions), (2) dispositional power at the level of regimes ('embodied in rules, resources, actor configurations and dominant images') and (3) structural power at the level of landscapes. Earlier works failed to examine the interactions and power among the regime and socio-technical landscape actors. Three ways of conceptualizing power were also found in El Bilali et al.'s (2018) work. The first is a conceptualization situated in the multi-level perspective (Geels, 2002), emphasizing power by regime actors over non-incumbent actors (Turnera, et al, 2020).

Conceptual Framework

The dissemination and utilization of improved maize varieties require an understanding of the structural and functional dimensions of the innovation system. To analyze innovation and develop useful policy insights, it is important to approach the issue from systemic, transition and network perspectives. This understanding enables a more useful cross-sectoral learning. Currently, it is understood that the performance of innovation systems depends on the interaction among the different actors and institutions responsible for system functions. Considering this, the current study looks at actors' interactions in disseminating improved maize varieties. This helps to diagnose failures in interactions and power influence in the dissemination and utilization of improved maize varieties, and proposes policies that could address them. The line between understanding the structure of an innovation system and the interaction among its key actors is subtle and these two analyses are closely linked. This paper uses social network analysis integrated with a multi-level power framework. The analysis does not merely focus on the actors but also on their interactions at different levels. To understand these interactions, the analysis takes a network- and systems-level approach, given the interactive, multi-actor and non-linear processes that shape the innovation processes. These give a comprehensive analysis of the dissemination of improved maize varieties in the study area.

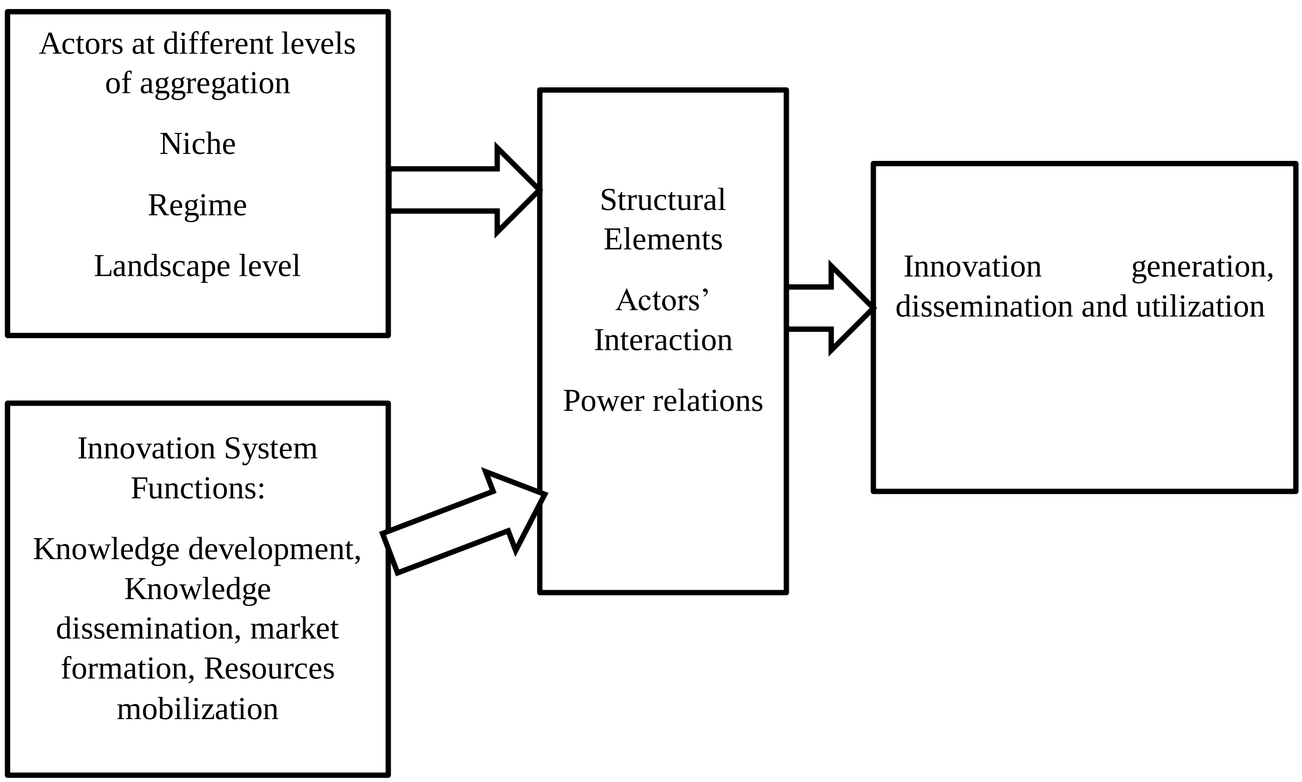

Figure 4: *Conceptual framework* Actor interactions and power relations based on innovation system functions, Source: Adapted from the (Grin et al., 2010; Hillman et al., 2011; Jose, 2014; OECD, 2013).

3. Materials and Methods

3.1 Sampling technique and sample size determination

In this study, all sampling procedures followed non-probability sampling, combining purposive and snowball techniques. Choosing a suitable sample size in qualitative research is an area of conceptual debate and practical uncertainty. The sample size determination for this study is based on data adequacy and saturation.

3.2 Data Type, Sources and Method of Data Collection

Based on the study objectives, the researchers selected 49 organizations at niche, regime and landscape levels that were directly involved in generation, dissemination, and utilization of improved maize varieties. To collect the data, Focus Group Discussion (FGD) with farmers and key informant interviews with selected organizations were conducted. A total of 72 interviews were held at niche, regime and landscape levels with officials and experts from the respective actors involved in generation, dissemination and utilization of improved maize varieties. Face-to-face interviews were conducted based on a structured interview guide with closed and open-ended mixed questions. The interview questions consisted of four main parts. The first part was about respondents' information including type of organization and the activity they are involved in. The second part focused on the activities they performed in different functions and the structural elements (with whom they work, the nature of interactions, the institutions, and infrastructures they have). The third part was about issues related to power. Part four consisted of bottlenecks in the process of generation, dissemination, and utilization of improved maize varieties.

3.3 Data Analysis Methods

In this study, both quantitative and qualitative analytical techniques were employed. Social network analysis was used to examine the patterns, interactions, and power of actors. For this purpose, Gephi software was used as a tool for analysis (Borgatti and Ofem, 2010). Social network analysis characterizes social relationships as networks of nodes, and the ties that describe their relationships and interactions (Jack, 2010). This methodology helps to map and understand the actors' interactions and power relations in a specific social context (Hanneman and Riddle, 2005; Christopherson and Clark, n.d.). In this study, nodes are the individual or institutional actors within the networks, whereas ties are the relationships (commonalities, social relations, interactions or flows) between the actors (Kosorukoff, 2011). In social network analysis, there are many metrics or measurements of networks (Valente et al., 2015). This paper focuses on network centrality measures to analyze the interaction and influence of actors in a network. The results are visualized by network maps and quantified as centrality measures (Degree, Betweenness, Closeness, and Eigen Vector). An evaluation is also done to identify the key or influential actors in the system. The centrality measures are also integrated with thematic analysis.

Table 6: Metrics in the social network analysis

Element	Definition
Network size	Total number of nodes in a network
Network density	Nodes that are actually tied as a proportion of all possible ties in a network. When density is close to 1.0, the network is said to be dense, otherwise it is sparse.
Centrality	Measure of the number of ties that a node has relative to the total number of ties existing in the network as a whole; centrality measures include degree, closeness, and betweenness.
Degree	Total number of ties a node has to other nodes. A node is central when it has the higher number of ties with other nodes.
In-degree centrality	Number of ties received by the node. The in-degree of an actor is an index of prestige /indicate its importance/.
Out-degree centrality	Number of ties initiated by the node. The out-degree is usually a measure of how influential the actor may be.
Closeness	Measure of reciprocal of the geodesic distance (the shortest path connecting two nodes) of node to all other nodes in the network. A node is "close" if it lies at short distance from many other nodes (as in being physically proximate).
Betweenness	Number of times a node occurs along a geodesic path. It is a node that can play the part of a liaison or broker or gatekeeper with a potential for control over others.
Eigenvector Centrality	A measure of the importance of an actor in a network. It also measures how well a given actor is linked to other well-linked actors in the network.

Source: (Spielman et al. 2011a; Zewdie 2012; Valente et al. 2015; Bojovic et al. 2015)

4. Result and Discussion

4.1. Case description

According to Berhanu and Emana (2018), currently, there are twenty-one available maize varieties including sixteen hybrids (BH-660, BH-540, BH-543, BHQPY-545, BH-661, BH-546, BH-547, SPRH-1, AMH760Q, AMH-851(Jibat), AMH-8+53, AMH-854, MH-138Q, OHL HUV, Shone and Limu (P3812W) and five open pollinated varieties (Melkasa-2, Melkasa-4, Melkasa-6Q, Gibe-2 and Morka). The authors collected these data from Bako National Agricultural Research Center. Among these, BH540, BH 546 and P3812W are being utilized in the study area.

BH540, BH546 and BH547 varieties were released by Ethiopian Institute of Agricultural Research, Bako Research Center in collaboration with CYMMIT in 1995 and 2013 respectively. BH540 is a long-aged variety, almost 27 years since its release. Farmers still use this variety. BH546 has a yield advantage of 30% over BH540. Its narrow semi-erect leaves make it desirable for high-density planting and inter-cropping with legumes, a common practice in most maize growing areas of the country. The Ethiopian government, in partnership with Sasakawa Global 2000, played a key role in the popularization and dissemination of BH540. BH546 is a highly stable high-yielding hybrid, tolerant to drought and low nitrogen stresses, as well as major foliar diseases. This variety was developed to substitute BH540 but still farmers are using BH540. BH547 also has a grain yield advantage of 26.4% over BH540 and mean grain yield of 10 tons/ ha. EIAR in collaboration with CIMMYT and the Ministry of Agriculture has begun variety demonstration and popularization to promote the seed delivery system. In terms of its promotion, it is still similar with BH546, not well promoted (Kelemework et al., 2021; Tarekegn & Mogiso, 2020).

One of the FGD discussants confirmed that:

Farmers are utilizing P3812W and BH540. They are not well informed about BH546 and BH547. According to the discussants, they have some information about the existence of varieties that can substitute P3812W but they are not sure about that. As a result they utilize P3812W and BH540. Their first choice is P3812W.

P3812W/ locally called Limu, was released by Pioneer Hybrid Seed Ethiopia in 2012. To disseminate this variety, partnership was created between the Ethiopian governments, Pioneer Hybrids Seeds Ethiopia plc. and USAID. They all together established a project called Advanced Maize Seed Adoption Program/AMSAP/ under Feed the Future or ACDI VOCA. This helped with the wide dissemination of the variety. This variety is solely generated by a foreign private company. The sources of germplasm or inbred lines are managed and controlled by the company. Pioneer Hybrids Seeds Ethiopia plc. a private company made contractual agreement with large scale private farms like Agri -CEFT for the multiplication of seeds. The inbred line comes from abroad and the multiplication is done in Ethiopia. Distribution of the seed is done by the regional bureau of agriculture through allocation based on the demand of districts.

4.2. Actor network- mapping in improved maize seed innovation system

Table 2 indicates actors and their functions. These different functions are performed by different actors, both private and public. Actors can also be categorized based on their functions. In innovation studies, there are different functions like knowledge generation and dissemination, guidance for search, market formation, resource mobilization and creating legitimacy. Based on the findings of this study, the following table indicates the classification of actors based on their function in terms of improved maize seed varieties.

Table 7: Actors based on function

Functions	Public	Private
Knowledge generation	Ethiopian Agricultural Research Institute, Bako National Research Center, Amhra Region Agricultural Research Institute, Adet Research Center, Bahir dar University, CYMMIT,	Pioneer HI-Bred International, Pioneer Hi-Bred Seeds Ethiopia Plc, EthoAgri-CEFT,other local private seed multipliers, Local seed enterprises, Farmers based seed multiplication
Knowledge dissemination	Bureau of Agriculture, Zone Office of Agriculture, District Office of Agriculture, Kebele Agriculture Office, Sasakawa Africa Association, ATA,	Pioneer HI-Bred International, Pioneer Hi-Bred Seeds Ethiopia Plc, other local private seed multipliers, AMSAP, EthoAgriceft
Market formation	Amhara Seed Enterprise, Bureau of Agriculture, Cooperatives Promotion Agency, Zone Cooperative Promotion Offices, District Cooperative Promotion Office,	Pioneer Hybrid International, Pioneer Hibred Seeds Ethiopia Plc, other local private seed multipliers, Etho Agri-CEFT Local seed enterprises, private seed dealers, Merawi farmers cooperatives, Weteabaye farmers' cooperative, Merkebe union
Entrepreneurial	Amhara Seed Enterprise, Bureau of Agriculture, Cooperatives Promotion Agency, Zone Cooperative Promotion Offices, District Cooperative Promotion Office,	local private seed multipliers, EthoAgri-CEFT Local seed enterprises, private seed dealers, Merawi Farmers Cooperatives, Weteabaye Farmers' Cooperative, Merkebe Union
Guidance for search	Ethiopian Agricultural Research Insttute, Bako National Research Center, Amhara Region Agricultural Research Institute, Adet Research Center, Bahir dar University, CYMMIT,	Pioneer HI-Bred International, Pioneer Hi-Bred Seeds Ethiopia Plc, EthoAgri-CEFT,other local private seed
Resource mobilization	Amhara Seed Enterprise , Bureau of Agriculture, ATA ,AgroBig	AMSAP (Advanced Maize Seed Adoption Program)
Creating legitimacy	Ministry of Agriculture, Bureau of Agriculture, Amhara Seed Enterprise, National Seed Quality Directorate, Regional Seed Quality Directorate,	Pioneer Hybrid International, Pioneer Hybrid Seeds Ethiopia Plc, other local private seed multipliers, AGRA, ESA, ISSD,

Source: Own survey results, 2020

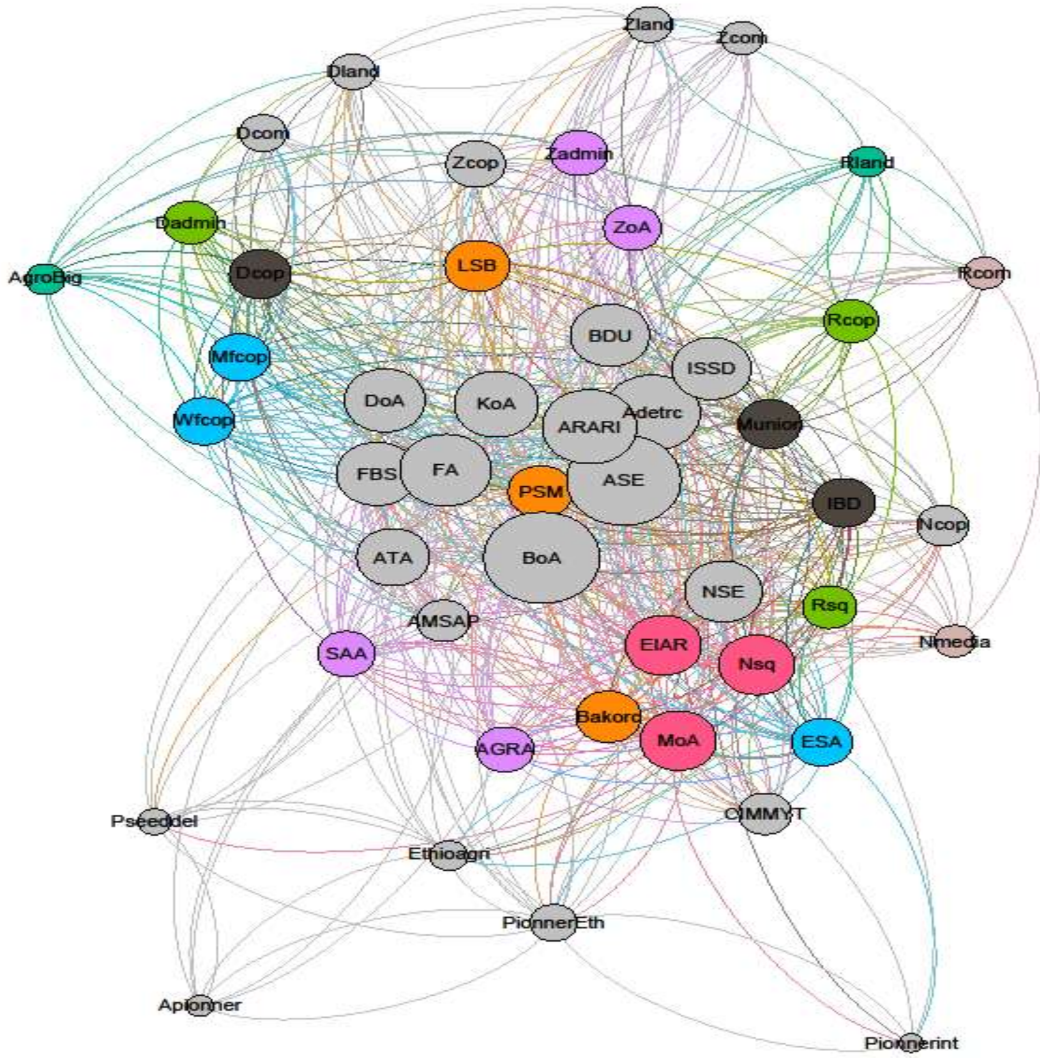

Figure 5: Existing network of actors

Source: Own survey result, 2020

The above network mapping shows the network of actors involved in the generation and dissemination of BH540 BH546 and P3812W. These actors are both public and private organizations and located at different levels of aggregation. The network mapping shows the central and the peripheral actors in the network. As indicated in the network mapping, actors like Kebele Office of Agriculture, District Office of Agriculture, Amhara Regional Bureau of Agriculture, Amhara Seed Enterprise and Adet Agricultural Center are more central in the network whereas actors like Pioneer Hi-Bred Seeds in Ethiopia are peripheral in the network.

In this research, calculating different metrics of the actors' network given in Fig.3 is done and based on these values, the most influential actor is determined. Some of the results are presented in the table below (Table 3 and graphically in Figure 3.

Table 8: Statistical simulated result of the existing network between actors in the maize innovation system

Label	In degree	Out degree	Degree	Eigen centrality	Closeness centrality	Betweenness centrality
FBS	33	11	44	0.88519	0.534091	107.4637
FA	42	9	51	1	0.465347	70.35988
KoA	40	6	46	0.996149	0.431193	18.90408
DoA	33	11	44	0.879844	0.456311	42.14063
Dcop	20	12	32	0.55602	0.474747	21.53374
Mfcop	20	11	31	0.615483	0.566265	39.62222
Wfcop	20	11	31	0.615483	0.566265	39.62222
Rsq	19	8	27	0.47408	0.52809	12.90128
Adetrc	17	37	54	0.436055	0.810345	87.37804
LSB	13	21	34	0.502255	0.643836	93.4909
Ethioagri	11	5	16	0.281474	0.505376	7.22089
Pseeddel	6	7	13	0.202809	0.522222	18.48103
PSM	17	17	34	0.428112	0.602564	40.47015
Dcom	12	10	22	0.284524	0.439252	6.809485
Dadmin	17	10	27	0.43262	0.435185	6.813656
Dland	13	8	21	0.336679	0.412281	4.960185
ZoA	19	10	29	0.452857	0.552941	26.26377
Zcop	17	13	30	0.378014	0.546512	26.57397
Munion	19	13	32	0.445207	0.580247	70.49116
Zcom	11	8	19	0.255659	0.443396	10.48145
Zadmin	20	9	29	0.436755	0.546512	34.28112
Zland	13	8	21	0.311845	0.427273	11.94771
BoA	31	36	67	0.661152	0.810345	341.2903
ASE	26	40	66	0.625045	0.87037	233.262
Api**onner**	4	5	9	0.068203	0.51087	2.394004
AMSAP	4	22	26	0.064231	0.652778	26.38618
PionnerEth	8	14	22	0.143865	0.566265	27.22663
Rcop	14	13	27	0.323035	0.580247	15.41746
Rcom	10	8	18	0.221876	0.52809	9.904793
Rland	9	8	17	0.227062	0.522222	7.931673

ATA	10	29	39	0.233448	0.723077	25.36914
MoA	18	23	41	0.344415	0.661972	59.95956
SAA	12	17	29	0.306001	0.61039	4.104211
CIMMYT	12	14	26	0.308655	0.5875	2.857212
BDU	10	33	43	0.270178	0.770492	18.24424
ISSD	12	31	43	0.316863	0.746032	30.18984
NSE	20	22	42	0.468156	0.652778	29.51602
Nsq	19	22	41	0.439777	0.643836	29.56251
EIAR	17	24	41	0.38875	0.671429	14.02083
Bakorc	18	16	34	0.393717	0.573171	7.332183
ARARI	16	37	53	0.36929	0.824561	45.91115
Nmedia	14	4	18	0.296534	0.376	0.918492
AGRA	11	18	29	0.260692	0.618421	3.605977
IBD	12	20	32	0.312022	0.635135	8.155184
AgroBig	2	15	17	0.055991	0.573171	0.973766
Pionnerint	4	3	7	0.06809	0.451923	0.598214
Ncop	10	15	25	0.218214	0.580247	7.208783
ESA	10	21	31	0.239152	0.643836	28.44829

Source: Own survey result 2020

4.3 Analysis of actors' interactions and power relations in the generation, dissemination and utilization of improved maize varieties based on different SNA metrics measures

Node Degree: In this study, the networking of actors is a directed one and the in-degree and out-degree of each actor is shown in the network using an arrow. The finding of the study indicates farmers and Kebele office of agriculture have highs in-degree which indicates that many of the actors in the network are trying to partner with this part of the industry. Farmers are users of improved maize varieties and Kebele office of agriculture is one of the actors that performs dissemination function. But as it is indicated in the diagram of actor networking (Fig.1), the collaboration of the actors with these organizations is not in an organized way and this is affecting the performance in disseminating improved maize seed varieties. AgroBig, Agents of Pioneer Hi-Bred Seeds Ethiopia Plc, AMSAP, and Pioneer HI-Bred International, have the lowest in-degree. In case of out-degree, Amhara Seed Enterprise, Adet Research Center, Amhara Region Agricultural Research Center and Amhara Region Bureau of Agriculture have the highest out-degree and it indicates that these actors are more central in reaching many actors, and they are powerful. These actors are leveled as regime actors, and this indicates that they affect the governance of the system. Adet Research Center is one of the actors that performs innovation generation functions and located at niche level. The Regional Bureau of Agriculture again performs dissemination function and Amhara Seed Enterprise is a public enterprise engaged in entrepreneurial promotion and market formation functions. All the actors who have high in-degree and high out–degree are public organizations, and this affects the involvement of private actors in the generation, dissemination and market formation function of the system. Therefore, our findings support previous works by (Onumah et al., 2021), which argue that centrality measures revealed that extension actors had the highest out-degree score, with farmer-based organizations having the highest in-degree score. This implies that extension service providers in the cocoa network are the most powerful. Another study conducted by (Tesfaye et al., 2020b) also supported the finding of this study,.The Ethio Wetlands and Natural Resources Association had the greatest out-degree centrality and they leveled this actor as the most influential actor in the network in terms of its ability to communicate climate services directly with other actors across the network. In addition, the authors argued that the National Metrology Agency, Ministry of Agriculture, Agricultural Transformation Agency and Bureau of Agriculture of Amhara region had relatively the maximum in-degree of points. According to the authors, actors who have received information from many sources are powerful. They considered these actors to be key and influential.

As a farmer in Kudmie kebele highlighted:

Farmers have high demand for P3812W, which is developed by Pioneer Hi-Bred Seeds Ethiopia Plc. But farmers are facing serious challenges in accessing this variety. When faced with a challenge of accessing it through formal means, farmers are forced to resort to accessing it through contraband, with a huge risk of adulteration. The Amhara Seed Enterprise wants to sell their seeds to the farmers and as a result the Enterprise limits the dissemination of P3812W.

As indicated in the above findings, it is easy to understand that the public actors influence the dissemination of improved maize varieties developed by the private actors. This affects the interest of private seed companies in the production and supply of high-quality seed to small-scale farmers. The relationship between Amhara Seed Enterprise, Adet Research Center and

Pioneer Hi-Bred Seeds Ethiopia Plc is competitive but not supplementary and is an example of antibiotic rather than symbiotic relationship between the public and private sector. The public and private actors excrete different power. The public extension and seed enterprise restrict and resist the dissemination of improved maize varieties. There is power antagonism between the public and the private actors in the dissemination of improved maize varieties innovation system. They disrupt one another.

In general, as the out-degree result reveals, regime actors are powerful in the study area. Regional Bureau of Agriculture, Amhara Seed Enterprise and Adet Research Center exert a relational dispositional and structural power in the dissemination of improved maize varieties. This means that they are powerful in terms of embodying rules, resources, and actor configurations. They are the dominant images in the system. The power of the regime actors affect the wide dissemination of improved maize varieties generated by the private companies like Pioneer Hi-Bred Seeds Ethiopia Plc.

The board chair of Ethiopian Seed Association highlighted that:

"The association was formed to support the interest of private companies in the production and supply of high-quality seed to small farmers in collaboration with regional, national, and international bodies. However, collaboration is limited, and government seed enterprises and regional agricultural bureau dominate the market formation activity through the principle of seed allocation. Currently, there is no liberal seed marketing scheme in the country and private companies distribute their seeds through the Regional Bureau of Agriculture to farmers' cooperatives. In addition, the issue of land and foreign currency discourages the involvement of private companies in the sector.''

In figure 3 above, it was noted that ATA, AMSAP, MoA and Pioneer Hi-Bred Seeds Ethiopia plc have the highest out-degree. These actors are powerful in the generation and dissemination of P3812W. AMSAP is a public–private-partnership program established for enhancing the dissemination of P3812W. There are missing actors in the generation function like research and higher learning institutes. Localization of this variety is a big challenge for sustainable supply of the innovation. In addition, one of the market formation actors (Amhara Seed Enterprise) considers these actors as a competitor as indicated in the above discussion.

Pioneer Hi-Bred Seeds Ethiopia Plc. is a foreign private company performing good in the dissemination of P3812W. This happens through a project called AMSAP, a partnership created by USAID, ATA, Pioneer Hi-Bred Seeds Ethiopia Plc. and the Ministry of Agriculture. This partnership helps the company to disseminate its innovations to the small holder farmers. Regional Bureau of Agriculture, District Office of Agriculture and Kebele Office of Agriculture also involve in the dissemination of P3812W. But they have poor link in other functions.

The major findings of this study are also consistent with findings from some previous studies (Kelemework et al., 2021; Tarekegn & Mogiso, 2020). These authors indicated the fragility of synergies- weak coordination and integration between systems actors- as the major constraints contributing to the low level of improved variety use in the country.

Closeness Centrality: measures how close a node is to all other nodes and can be calculated as the inverse of the sum of the shortest distance to all other nodes. Closeness centrality indicates the average distance between a given node and all other nodes in the network. Therefore, the more central a node is, the closer it is to all other nodes. Moreover, closeness centrality is a way of detecting nodes/actor that can spread information very efficiently through graph. The findings of this study showed that Amhara Seed Enterprise, the Bureau of Agriculture, and the Adet Research Center have the highest closeness centrality in the network. This implies that these actors are more influential in the network's information flow. They have the shortest distances to all other nodes and they are in a favorable position to monitor and acquire vital information and resources within the system. This indicates that public actors, who perform the generation and dissemination of improved maize variety are closer than the private once. Amhara Seed Enterprise is another public actor engaged in entrepreneurial and market formation function, and it is closer to all other nodes. The closeness centrality measure of private actors like Pioneer Hi-Bred Seeds Ethiopia Plc., Agri-CEFT and other private companies have the lowest closeness centrality measure. This finding is against the work of Juma (2015), which argues institutions, both private and public institutes, with key functions such as research, teaching, extension, and commercialization need to be much more closely integrated. Private seed companies like Pioneer Hi-Bred Seeds Ethiopia Plc. as a knowledge development actor, is placed on the periphery in the network. However, ATA, AMSAP and Pioneer Hi-Bred Seeds Ethiopia Plc. have the highest centrality degree in the dissemination of P3812W as indicated in Table 3 Though it is good to have a good partnership with private and NGOs, the public actors are missed. This affects the sustainable knowledge generation function and dissemination of improved maize varieties.

Betweenness centrality: represents the degree of which nodes stand between each other. It is a way to detect how much influence a node has over the flow of information in a graph/network. Betweenness centrality quantifies the number of times a node acts as a bridge along the shortest path between two other nodes. Nodes that are more frequently on these shorter paths will have a higher centrality score. In the case of improved maize seed varieties, actors' analysis showed that the Bureau of Agriculture, Amhara Seed Enterprise and farmers-based seed multiplication scheme have the highest betweenness centrality and they are considered as the bridge stakeholders in the network.

A development agent in Abyot Fana kebele highlighted that:

''Farmers prefer P3812W as compared to other varieties. But as extension workers, we are not well informed about how this variety was developed and disseminated. We have no linkage with the owner of the variety. We send our request to the district office of agriculture and the office sent to regional bureau and then the regional bureau allocates to farmers' cooperatives. It would be better if the owner of the variety has a linkage with us to supply this variety as per farmers' demand.''

The public actors control the communication between different actors in improved maize varieties dissemination. This shows that these actors are 'bridges' between nodes in the network. The finding of this study is also supported by (Onumah et al., 2021) who reported extension (bridging domain) and research actors (supply domain) also formed the core of the cocoa innovation system. Similarly, (Teklewold et al., 2019c) identified the regional livestock agencies/bureaus, research centers and the regional animal health laboratories to have higher values serving as a bridge to connect other actors. Interdependent nodes/players tend to be social media innovators and brokers.

As indicated in Figure 3 and Table 3, the Bureau of Agriculture and AMSAP have the highest betweenness centrality. These two actors are serving as a bridge to the dissemination of P3812W.

They combine different perspectives, transfer ideas between groups, and derive power from their ability to present and pull strings. But betweenness centrality assumes that all communication between nodes happens along the shortest path and with the same frequency, which is not the case practically. Therefore, it does not give us a perfect view of the most influential nodes in a graph, but rather a good representation.

Eigenvector centrality: In graph theory, eigenvector centrality (also called self-centrality) is a measure of the influence of a node in a network. It assigns scores to all nodes in the network based on the concept it connects to high-scoring nodes contribute more to that node's score than equal connections to low-scoring nodes. It is one method of computing approximate importance of each node/actor in a social network. This measure helps to find the most central actors, that is, those actors with the smallest farness from others in the network. Higher eigenvector scores indicate that actors are more central to the main pattern of distances among all the actors. Lower values indicate that actors are more peripheral than others in the network. The finding of this study indicates, Kebele office of agriculture, farmers-based seed multiplication scheme and district office of agriculture have the highest eigenvector centrality than the other actors in the network. The result of Eigenvector centrality measure in table 3 revealed that niche level actors are more important or influential for sustainable generation, dissemination, and utilization of improved maize varieties. As a result, both public and private actors need to work closely with these actors. In addition, these actors have relational power at the level of niches (abilities of agents to draw on institutions). The finding of (Tesfaye et al., 2020b) also indicated actors with the strongest link having highest Eigen value are most central actors with the smallest farness from others in the network. In the present study, agents such as Pioneer Hi-Bred Seeds Ethiopia Plc and other private companies have the lowest Eigen values indicating these actors are more peripheral in the network. This also has an implication on their relational and power exercise for the generation and other functions of improved maize varieties.

5. Conclusion

This paper analyzed the functions, interactions, and power relations of actors in generating, disseminating and utilizing improved maize varieties. Understanding network relations and the power and characteristics of the different actors is needed to understand the functions of the system. Most of the functions in improved maize varieties were largely performed by the public organizations, which offered few opportunities for private actors. The conventional top-down and supply-driven approaches to extension are still used to disseminate improved maize varieties in the country. With respect to maize varieties developed by a private company, Pioneer Hi-Bred Seeds Ethiopia Plc has made a significant progress with the development of several varieties that are appropriate to farmers' needs. However, the ultimate availability of these varieties remains limited due to asymmetric power relation between the private and the public actors involved in the functioning of the system.

Evidence suggests that private sector involvement in technology development in Ethiopia is on the rise, particularly with respect to the production and distribution of improved maize varieties. However, this limits the participation of the public sector like research institutes and universities in collaborative seed multiplication process. Promoting greater private investment in the production of improved maize varieties and in the establishment of independent distribution and marketing channels to farmers is one of the major recommendations of pervious research works (Kelemework et al., 2021; Tarekegn & Mogiso, 2020). In this study, the dominant supply of innovation by the public sector was noted. This implies that public actors are more influential in the network's information flow, which affects the sustainable generation of improved maize varieties. Kebele and District offices of agriculture are the closest actors to each other in the sense that they share membership in all three cliques. However, innovation source actors (private actors) do not share any membership with these actors, indicating that private innovation generators are relatively unconnected to other network actors. The implications of the findings to improved maize variety innovations in the study area are (1) public service providers particularly regime actors are key nodes with respect to the function of improved maize varieties, and (2) private improved maize variety generators are largely peripheral. The findings suggest that the network may be insufficiently configured to provide farmers with ties to the innovation generators or knowledge developers. As a result, farmers operate with little access to the innovation developed by the private sector.

The findings of the paper suggest that despite the changing dynamics of the maize sector, innovation tends to follow a linear path of supply-driven technology dissemination through the public or private sector without full engagement of relevant actors involved in the functions of improved maize varieties. These are some of the challenges limiting maize production and its potential towards ensuring food security of smallholder farm families in Ethiopia. Hence, the paper suggests the need to further explore policies that create more space for interaction between private and public actors for the sustainable supply of quality improved maize varieties.

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CHAPTER FOUR

EXPLORING THE SCABILITY OF MAIZE INNOVATIONS IN ETHIOPIA: USING INTEGRATED INNOVATION SYSTEM PERSPECTIVE AND SCALING SCAN FRAMEWORK

Abstract Both *public and private sectors engaged to improve the productivity of maize through research and extension. However, with limited participation of private sector, translating research outputs into outcomes and, ultimately, impact at scale has been an enduring challenge for the government. The objective of this paper is therefore to assess the scaling processes of public agricultural research centers and private companies and systematically explore factors that hinder the uptake and scaling up of improved maize varieties in Ethiopia. Very few research outputs have been systematically assessed with innovation system and scaling scan perspectives. Efforts to understand how public and private research centers operate to scale improved maize varieties are scarce. Such knowledge is essential to improving scaling processes. The study compares the scaling processes of improved maize varieties, considering it as a technological innovation. The comparison was made with varieties released by Pioneer Hi-Bred Seeds Ethiopia Plc. and varieties released by public agricultural research centers using integrated innovation system and scaling scan framework. The finding shows that the varieties released by Pioneer Hi-Bred Seeds Ethiopia Plc. have a comparative advantage over the previous varieties that farmers used. There is a wish and readiness for the farmers to use the variety released by Pioneer Hi-Bred Seeds Ethiopia plc. In the case of Pioneer Hi-bred seeds Ethiopia Plc., a public-private partnership was created to support the scaling up of improved maize seeds. There is good opportunity in creating collaboration and the development of a business case. However, poor interaction in knowledge and skills, value chain development and public governance which affects the scaling-up of improved varieties released by Pioneer Hi-Bred Seeds Ethiopia Plc. In the case of public agricultural research centers, there is good interaction in knowledge and skill and in public governance for creating legitimacy, but the activity of actor's collaboration, searching finance to mobilize resource and value chain development is poor. To address this challenge and to scale these for long-lasting impact on the sector, both public agricultural research centers and private companies engaged in scaling of improved maize varieties need to work in partnership through establishing stakeholder platforms with development partners, the private and public sector to bring sustainable scaling up of improved maize seed.*

Key words: Innovation; scaling ingredients; scaling scan; Partnership

1. Introduction

The scaling of agricultural innovations is central to Ethiopian agricultural extension and advisory service, with particular emphasis on the development and scaling of improved varieties. The country dedicated significant effort and budget to the pre-extension and pre-scaling up of improved maize varieties through agricultural research centers and full scaling –up of agricultural technologies through Ministry of Agriculture and Regional Bureau of Agriculture (Abdirazak & Bereket, 2018; Basha et al., 2021; Louhichi et al., 2019). Agricultural production has increased since 2000 (FAO, 2018). This is due to the expansion of land and labor use, as well as the increased use of improved varieties (Cheru et al., 2019). Despite rapid growth in the use of improved maize varieties, current adoption rates remain quite low (Dercon & Gollin, 2019). For many decades, agricultural research has developed technologies aimed at increasing agricultural productivity, but many technologies have failed to do so. In countries where agriculture is predominantly practiced by smallholder farmers, uptake of these technologies has been especially poor. In addition, translating research outputs into outcomes and, ultimately, impact at scale has been an enduring challenge for the sector (source). As indicated in Ampadu-Ameyaw et al. (2017), capacity building, characteristics of innovation, and the establishment of partnership and collaboration strategies are among the key factors determining the scaling up of innovations.

Achieving scaling up of improved maize varieties is one of the greatest challenges facing in research centers in the country (Hall & Dijkman, 2019). As a result, research outputs do not reach farmers and remain shelved in research centers and improved variety did not reach many farmers (Yigezu Wendimu, 2021). This is due to the lack of an innovation platform that allowed the participation of interested and relevant stakeholders with their specific roles along crop value chain development, lack of integration among stakeholders, and political insatiability of access to newly released improved maize varieties. Both farmers and development agents have less awareness about newly released technologies and their production systems. Lack of well-organized institutional support, inadequate transport, and communication facilities, unavailability of seed or planting material specifically for high-value crops, a large number of actors in a fragmented and underdeveloped innovation system, very low national and regional innovation capacities, and considering farmers as passive recipients of technology and limited technical backstopping and supplying of early-generation seeds, financial services, insufficient funds for supporting scaling up, and disorganized structures resulting in poor infrastructure for attracting businesses remain a critical issue in the Particularly, government research centers focuses on pre-extension and pre-scaling demonstrations, but this doesn't guarantee for scaling up. Sustainable scaling up of improved maize varieties is a major concern for the sector. (Tilaye tekelewold 2016, Tewodros Tefera, 2014, Adane 2016; Feyissa Desiso 2018; Abdirazak Abdala1 and Bereket Tufo2 2; Aman Kiniso 2018; Gebissa Yigezu Wendimu 2021) Benyam Tadesse 2021 Korji Dembi 2021; Mbo'o and Colverson, 2014; Elias et al, 2015).

Previous studies on scaling are based on (Linn et al., 2010), a scaling model which considers scaling function as a linear function with the theoretical background of diffusion model. The model considers scaling activity as a linear process and focus on a single innovation (Lennart Woltering, 2024). Yet, despite intentions to "change systems" and "transform food systems", approaches to scaling in research for development are stuck in the past, and remain largely focused on linear adoption pathways and do not sufficiently draw from systems thinking (Hall and Dijkman, 2019; Leeuwis et al., 2021; McGuire et al., 2022). However, scaling-up is complex and requires systematic thinking. Recently the narratives around scaling are shaped around the idea that scaling innovations should contribute to systems transformation (Lennart Woltering, 2024). Scaling thus conceptualized as an integral part of a systemic approach to innovation and change (Klerkx et al., 2012; Sartas et al., 2020; Wigboldus et al., 2016). The absence of systems thinking makes policy vulnerable to being ineffective and inefficient (Hopkins et al., 2012). Scaling not only requires changes at the individual or household level; rather, it aims to make the entire system work differently (Wigboldus et al., 2016). From a system and transition perspectives a realistic scenario is that scaling of an innovation contributes to changes in its sector and scaling with innovation system perspective helps to achieve the aspiration of pursuing sustainable development goals (Wigboldus et al., 2016).

There is a need to study beyond single innovations towards (complementary and competing) interactions between multiple innovations like between two different improved maize varieties (Sandén & Hillman, 2011) or niches (Köhler et al., 2019; Markard & Hoffmann, 2016). And the repercussions these dynamics have for the 'functioning' of the larger system. In line with this (Jacobs et al., 2018) developed a scaling scan framework which leads to a sustainable system change in which the impact remains, or even accelerates, without further special project or donor interventions. According to the authors successful scaling of innovations requires the complementary non-technological requirements. These non-technical requirements form the basis for the scaling scan, which is built around 10 “scaling ingredients” that each require attention to reach a scaling ambition. The scaling scan frame work developed by (Jacobs et al., 2018) was designed to systematically deal with the complexities of scaling and tailor scaling approaches to specific contexts. There is a need alternative approach to scaling that better reflect the complexity involved in sustainable development draw on systems thinking theory. The scaling scan tool facilitates the integration of a systems approach to scaling to a broad public (Lennart Woltering, 2024). In order to understand the ingredients of scaling scan, it is necessary to understand its structure (Jan Ubels et al., 2024). The above argument indicates that to understand scaling of innovations, analysts must take a systems-level approach, given the iterative, multi-actor and non-linear process that shapes the scaling processes.

Very few innovations particularly improved maize varieties have been systematically assessed with innovation system and scaling scan lens. Efforts to understand how scaling of improved maize varieties differ from one another and what scaling action a selected improved maize variety would require in order to generate sustained impacts is insufficient. Such knowledge is critical for improving the design of scaling up of improved maize varieties to support the transformation of the agricultural sector. This paper investigates the scaling processes of public agricultural research centers and private companies engaged in scaling up improved maize varieties in the country. The purpose of the study is therefore to understand the factors behind the differences in the scaling potentials of improved maize varieties and to investigate bottlenecks and leverage points throughout the scaling process.

2. Theoretical perspectives and empirical findings

2.1 Concepts of scaling

Scaling refers to the adaptation, adoption, and use of innovations, such as processes, technologies, and markets or political systems, across a wide range of actors and geographies (Eastwood et al., 2017; Glover et al., 2017). According to Hartmann & Linn (2008), “Scaling up means expanding, integrating and supporting successful policies, programs, and projects in different areas to reach more people.” Definitions can and should be adapted to specific circumstances. According to Smith et al. (2015) scaling-up is “deliberate efforts to increase the impact of innovative, well-tested pilot or research projects to benefit large population groups and promote sustainable development of policies and programs. Dunn-Rankin et al. (2014) identified four scale dimensions: approach, outcome, sustainability, and balance. Sustainability means achieving beneficial results even after the life of the project.

2.2. Basic elements of innovation system theory

The innovation system is composed of farmers and public and private institutions and uses systems thinking to improve innovation in the agricultural sector (Hall et al., 2006). Innovation systems perspectives imply the use of innovation lens in the design, implementation and evaluation of the activities of the various actors involved in the innovation process.

In order to analyze innovation and develop useful policy insights, it is important to approach the issue from a systemic perspective. There are many actors involved in the innovation process, including researchers, financiers, manufacturers, government, and consumers. Collectively and through their interactions, they constitute an “innovation system”. At the highest level, this system must perform certain functions in order to support successful innovative activity. Therefore, the analysis should not merely focus on the single actors but also on their interactions and how these contribute to the functioning of the system as a whole.

An innovation system is the group of organizations and individuals involved in the generation, diffusion, adaptation and use of new knowledge and the context that governs the way these interactions and processes take place. In its simplest, an innovation system has three elements: the organization and individuals involved in generating, diffusing, adapting and using new knowledge; the interactive learning that occurs when organizations engage in these processes and the way this leads to new products and processes (innovation); and the institutions (rules, norms and conventions, both formal and informal) that govern how these interactions and processes takes place (Horton 1990). People working on similar issues, be it in a specific commodity sector, at a particular location or in any problem area tend to form a chain or network that can be described as innovation system. (Hall & Clark, 2009) argue that the four elements that comprise the structural analysis of an innovation system are actors, interactions, institutions, and infrastructures. The structure of the sectoral systems of innovation draws on (Malerba, 2005) concept of blocks of a sectoral innovation system. The framework is based on the assumption that the presence or absence of certain structural elements as well as their capacities is critical to the functioning of the innovation system.

2.3. Scaling scan framework

Jacobs et al., (2018) argue scaling aims to increase the use of innovations (new technologies or practices) to impact many people. Abi Teka, (2019) used a conceptual framework adapted from IIRR (2000) and (Gündel et al., 2001) for studying the enabling environment for the horizontal and vertical scaling-up of Sustainable land management considering three institutional levels (National level, Regional and local levels) in Ethiopia. De Roo et al., (2019) employed a techno graphic approach to study the scaling up of mallet barely in Southern Ethiopia. A techno graphic approach implies technology to contain both material and social components. Their finding provides evidence that the socio-political dynamics of access to technology can have an important influence on its wide spread application and may complicate efforts to scale the uptake of technology. Gebreyes et al., (2021) used the notion of scaling as a social construct and overcoming of scaling constraints as a spatial strategy to unpack the social constituents of scaling, scaling practices and ways of overcoming scaling constraints in Africa RISING project. Van Loon et al., (2020) used scaling scan framework to assess the scaling agricultural mechanization services in smallholder farming systems. (Kang'ethe et al., 2021) applied scaling scan framework to assess the scaling of African chicken genetic gains;

The decision and capacity for scaling up adoption, whether at the individual farmer level or organizational level, have been shown to be influenced by the 10 scaling ingredients advanced by Jacobs, Ubels, and Woltering (2018, 10–14).

These ingredients enable the examination of the completeness of ambition-achieving components in the system or institutions.

1. Technology/practice. The innovator leverages this ingredient to provide an effective and efficient solution to the issues at stake or the issue that the innovator is trying to solve for the target clients.

2. Awareness and demand. This combination of ingredients allows for innovation that factors in the wishes and readiness of the end-user to use the solution.

3. Business case. This ingredient facilitates the assessment of whether the innovator has attractive financial or economic propositions for the user and other actors to respond to the demand.

4. Supply chain. This ingredient scrutinizes the goodness, effectiveness, and business conduciveness of the partnerships in the system.

5. Finance. This ingredient surfaces the financing options available to the users and other actors and if the options are effective.

6. Knowledge and skills. This ingredient reveals the current capacities at the individual and institutional levels that can be banked on to take off in promoting an innovation.

7. Strategic collaboration. This is focused on examining organizational tasks, advocacy, and policy processes.

8. Evidence and learning. This is a data driven ingredient that can be relied on to achieve impact and is backed up by facts and credible research.

9. Leadership and management. This enhances the collaboration ingredient by integrating internal and external processes through navigating opportunities with power brokers and influential organizations.

10. Public sector governance. This ingredient examines the conduciveness of local and national strategies, policies, and regulations in scaling the technology.

Using the scaling ingredients, the framework can show the weak and strong aspects scaling processes. The guide questions provided by German et al. (2006) reinforce the notion that technology users interact with the technology; hence, this study focused on adaptation as opposed to wholesale adoption. The combined insights from the work of German et al. (2006) and Jacobs, Ubels, and Woltering (2018) make this framework robust in that it provides both theoretical and pragmatic guidance on how to optimize uptake of certain innovations. The scaling scan framework focuses on the well-functioning of the 10 ingredients but ignores the analysis of structural components (actor's interactions, institutions and infrastructure) which very crucial for the full understanding how the scaling process works. In addition to the simple scoring of the ingredients it is equally important to analyze the structural components in each ingredient which allows identification of Problems occurring within a system and this leads to identification and evaluation of main actors, institutions, cooperation networks, and infrastructure supporting innovative activities. This provides us a holistic understanding about the scaling processes. The current study tried to fill this gap.

3. Conceptual framework of the study

The innovation system analysis framework is a useful tool for understanding how the process of innovation is working (or not working) in a country, and distilling recommendations for how to improve its performance. While the specifics of which actors are relevant and which functions they perform will vary from economy to economy, the functions necessary for a robust and healthy innovation system are consistent across many levels of development. By focusing on these functions, and the degree to which they are successfully performed by system actors, the analyst can arrive at important insights and make useful recommendations for policy actions. Innovation system perspective suggests the analysis of three elements: the components of the system, principally its actors; the relationships and interactions between these components and the competencies, functions, process and results such components generate (IPMS2009)

Scaling up cannot be implemented in a business as usual mind-set model. It demands new way of organizing things, an innovative institutional setup, communication and knowledge generation and a platform for sharing. Scaling is designed to stimulate a wider scale change not only to the target clients but also in the government policy, operational modalities and institutional set up and structure. Scaling up is not an end in itself but an instrument to achieve the goal of improved livelihoods for the greatest number of people and reach wider geographical settings. In this regard the scaling scan tool helps as an assessment tool for individuals and groups to explore what is required to scale an innovation in a specific context.

In this study we first identify the structural components of the scaling processes (actors, interaction/ networks, institutions, and infrastructure) and describe the activities and dynamics of the scaling processes in terms of scaling ingredients, and develop recommendations for mechanisms to improve those ingredients.

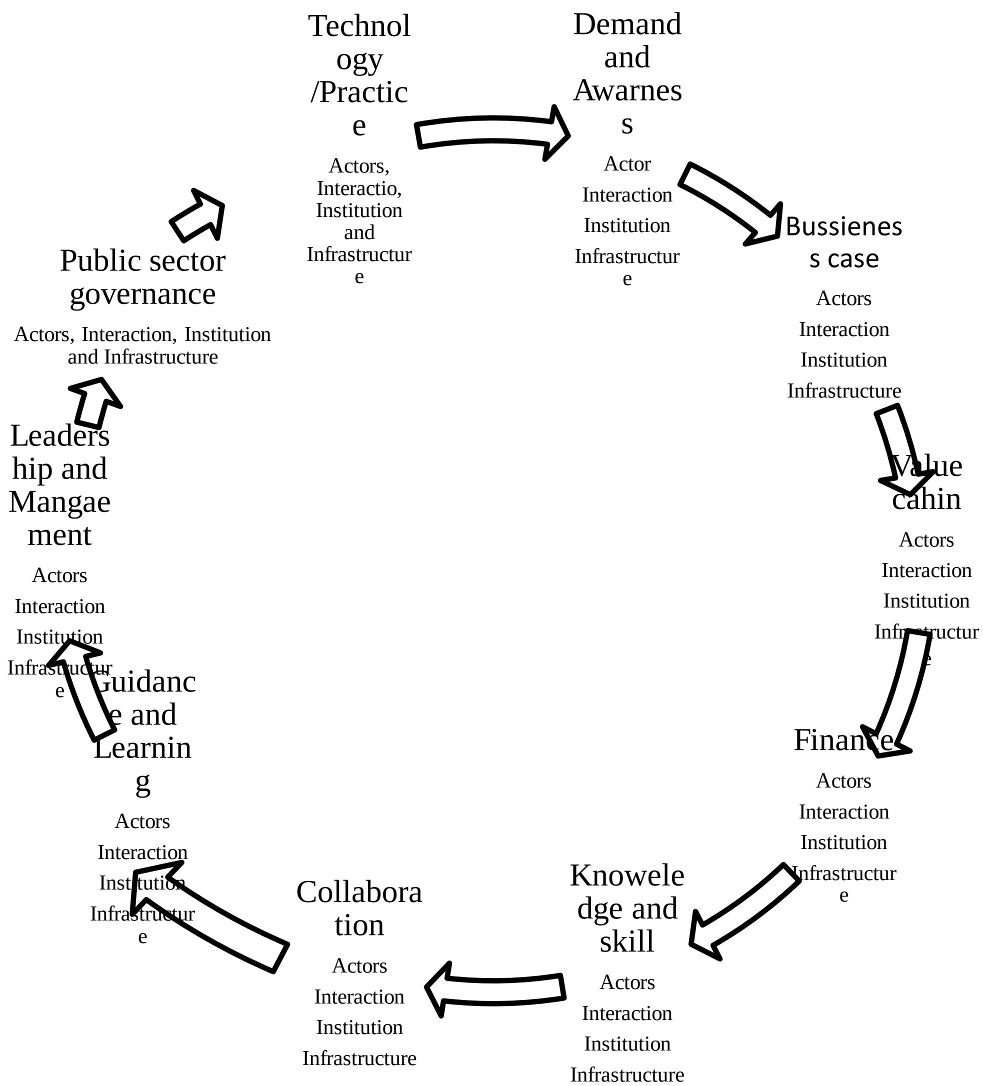

Figure 6. Conceptual Framework

Source: (Jacobs et al., 2018)

4 Methodology

4.1 Research approach and process

Qualitative research was used as research approach to understand in depth enabling environment to scale maize innovation. As a tool, integrated innovation system and scaling scan framework was used to identify the potential challenges and opportunity in scaling improved maize varieties in the study area.

The study used two sampling techniques to select the farmer participants: criterion and snowball (Marshall and Rossmann 2011). In criterion sampling, research participants are selected based on a set of criteria. Our study had two criteria for the farmer participants: (1) have tried using the improved maize varieties and (2) have been farming in the area for at least 10 years. From the resulting pool of farmers, we used snowball sampling to identify the farmer participants. We contacted prospective key informants from niche, regime and landscape actors through snowball sampling. Four FGD from each *Kebele* with farmers and one FGD from each kebele with development agents and from *Woreda experst* were established.

4.2 Data analysis and presentation

The data was analyzed with qualitative analysis. In this study we made an expert judgment to score the scaling ingredients based on the qualitative analysis, we qualitatively apprise them (Manalo et al., 2022, Kangethe et al., 2021a). In depth analyzing and interpreting was made to understand and narrate the each ingredient of scaling scan of improved maize varieties released by both public agricultural research centers and Pioneer Hi-Bred Seeds Ethiopia Plc. The data was also analyzed with simple descriptive methods. The levels of scaling ingredients importance were determined by analyzing the scoring of the Likert scales. The result was presented in table, spider web graph and bar graphs.

5. Result and discussion

5.1 Constructing scaling ambition

According to the results of the key informant interview and FGD, Public research centers and private companies like Pioneer Hi-Bred Seed Ethiopia Plc. had different priorities to scale. Public research centers in Amhara Region gave priority to different improved maize varieties for scaling. Pioneer Hi- bred seed Ethiopia Plc. in Amhara region, priority was given to P3812W (locally "Limu"). Pioneer Hi Bred Seeds Ethiopia Plc. the scaling followed some procedures to set the scaling ambition. They made Program which is called Advanced Maize Seed Adoption Program (AMSAP)- a USAID funding and finally, present the scaling ambition to stakeholders for further inputs and validation. Establish the program with the ambition to leverage the private sector investment of Pioneer Hi bred Seed Ethiopia Plc. and to enhance the incomes of 100,000 smallholder maize farmers in four regions of the country. However, Public research centers in collaboration with AGP-II and other actors focused on pre-scale up activities.

5.2. Analysis of the scaling processes of improved maize varieties based the scaling indigents.

In this section, we look more closely at the scaling ingredients outlined by Jacobs, Ubels, and Woltering (2018) to better understand the lessons in scaling processes of improved maize varieties. According to the results of the interview and FGD, Public research centers and private companies like Pioneer Hi-bred Seed Ethiopia Plc. had different priorities to scale. Public research centers in Amhara Region gave priority to different improved maize varieties for scaling. Pioneer Hi- bred seed Ethiopia Plc. in Amhara region, priority was given to P3812W (locally "Limu"). Pioneer Hi Bred Seeds Ethiopia Plc. the scaling followed some procedures to set the scaling ambition. They made Program which is called Advanced Maize Seed Adoption Program (AMSAP) and finally, present the scaling ambition to stakeholders for further inputs and validation. Establish the program with the ambition to leverage the private sector investment of Pioneer Hi -Bred Seed Ethiopia Plc. and to enhance the incomes of 100,000 smallholder maize farmers in four regions of the country. However, Public agricultural research centers in collaboration with AGP-II and other actors focused on pre-scale up activities.

Technology/Practice - An effective and efficient solution for the issue at stake

The workshop participants strongly argued the technology improved seed variety released by Pioneer Hi-Bred Seed Ethiopia Plc. fits and compatible with the local circumstance and it is relevant to them. They say the variety address their problem and boost up their productivity. As compared to the varieties released by the public agricultural research centers the new variety has a great advantage. Both key informants and FDG participants explain the variety has a significant and observable advantage over the other the existing varieties. The institutional key informant interview also supports the variety released by Pioneer Hi-Bred Ethiopia Plc. has sound benefit for the farmers in terms of different parameters. The majority of the farmers were convinced in using the innovation. The innovation is not adequately available to the farmers and it is not accessible and affordable for smallholder farmers. It is difficult to multiply the variety with farmers' context. The varieties are highly relevant, a better advantage as compared to varieties released by public agricultural research centers, comparative advantage exists, and farmers can easily adopt them.

Awareness and Demand - A wish and readiness for the consumer or producer to use the solution

. This helps to create awareness and demand. Information about the variety was easily available. In this regard, Kebele Extension workers play a great role. The variety gets social credibility because the project uses the government structure to create awareness about the innovation, and it is also by far better in terms of productivity and quality. Most actors recognize the importance of the variety to the farmers. Some actors like Research Institutes and Seed Enterprises have a fear on the sustainable provision of the varieties. Their argument is since the parent stock of the variety was not produced in Ethiopia, this may create a dependency on the will of the suppliers. This threat arises because all actors do not have the necessary information and knowledge about the innovation. Local opinion leaders are willing to support and promote the innovation but this highly constrained by the Regional Bureau of Agriculture and Seed Enterprises. The demand for the innovation is real. This can be evidenced by farmers and local leaders. Farmers are willing to pay for the innovation. The innovation addresses farmers' priority problem.

Business Cases - Attractive financial/economic propositions for users and other actors to respond to the demand

The AMSAP exists to support developing business cases. AMSAP Tried to link farmers with cooperatives and then unions to the World Food Program to sell their produces. The product is marketable. Currently, demand for the variety is higher than supply. There exists a mismatch between demand for variety and supply. The link between farmers, cooperatives, unions, and the World Food Program was good. The link at the ministerial and kebele levels was also good, but at the regional and zonal levels, it was poor. There was no existing link between other actors like public agricultural research centers and higher learning institutes; the link between all the value chain actors was weak and had poor interaction.

Initially, AMSAP arranged financing options for users. they tried to link microfinance institutions, and they were provided with different financial options The innovation is distributed through cooperatives, and as a result, it is affordable for farmers. The problem is its accessibility. Farmers were forced to purchase in the black market as a result, farmers took risks.

There are no viable business cases for the innovation. Farmers, service providers and seed multipliers are not engaged in the business. The innovation is dominantly owned by private company. Limited information about the innovation to fully engaged as a business. Most actors are interested in to the innovation but the opportunity to continue in the business is very limited. The supply of the innovation is limited but the utilization of the innovation is high. According to the institutional survey actors have no any role in improving and intensifying the supply of the innovation. No one invest in the development of the innovation. Government research institutes, universities and private seed multipliers are not allowed to replicate the innovation. In general the business climate was not conducive.

In case of BH 546 Amhara Seed Enterprise organize private seed multipliers and tries to create conducive environment for entrepreneurial experimentation. Sufficient number of industrial actors involved in seed multiplication and also engaged in large scale production. However, the case is different in P3812W. There are no any other local private seed producers engaged in the production of P3812W. The entrepreneurial function P3812W variety is very weak. Since P3812W is a very competitive and productive, local private seed companies and cooperatives are kicked out of the market. Those entrepreneurs engaged in the production of BH546 face a challenge in their business. As compared to BH546 the number of industrial actors in the production of P3812W is very low. Only DuPont Pioneer is responsible for multiplication of P3812W.

Value Chain - Effective links between actors to pursue their business cases

The business to business relations and transactions among actors is very limited. There is power imbalance among actors. The overall performance of different actors was not conducive for scaling the innovation. Farmers and other actors were not adequately organized and poor coordination of actors

Knowledge and Skills - Capacities at individual and institutional level to use, adapt and promote the innovation.

The innovation is developed in the USA. The only thing that they do in Ethiopia is multiplication. The company rents lands in the Amhara and Oromia regions and distributes them to farmers. The capacity to multiply the seed is good and of high quality. They keep the standard. through the AMSAP project, they promote and scale the innovation. The company does have the capacity to promote and scale the innovation. Organize different field days at Kebele, district, Zonal, regional, and National Levels. No interaction to develop the innovation together. No participatory research for the development of knowledge no platforms exist. Good coordination between actors to promote and scale the innovation. Good networks and platforms to promote innovation. Local private actors are motivated to multiply the innovation but they lack the source

Farmers have the necessary knowledge and skill to use the innovation. Extension workers in collaboration with the company they train farmers on practical application of the variety and they also conduct large scale demonstrations and knowledge transfer, however it is difficult to multiply the variety. The parental stocks of the variety were not produced in the country. Seed producer cooperatives' are not allowed to multiply the seed. Knowledge institutes like research institutes, Universities were not participated in the knowledge development and skill transfer activities. These constraints the sustainable provision of the technology and their by the scaling processes. There are no appropriate institutional set up like rules and regulations or polices available to allow farmers and other actors to adopt and promote the innovation. The right actors were not engaged to provide and improve the knowledge necessary for sustainable adoption of the innovation. In general the institutional environment in which actors (such as knowledge institutes) to develop and improve the technology/practice within the national and local system was missed.

In case of Limu, the developed knowledge is being used by farmers' at large scale. The variety meets the felt needs of farmers in terms of quality and productivity. Limu has comparative advantage over other varieties. The knowledge is driven by external agencies and it is not developed at local level. Niche and regime level actors have no the opportunity to participate in the production and multiplication of the variety. Only DuPont Pioneer which is an international private company is responsible for development of the knowledge, production and multiplication of Limu variety. The knowledge producers located at national level. The extent of knowledge development is not sufficient for the development of the innovation system. The quality of the variety fits with the knowledge needs within the innovation system but the quantity of the variety produced form a barrier for the innovation to move to the next step. There was no enough knowledge exchange between actors and across geographical borders for the development of the knowledge/ variety/. This is the problematic parts of the innovation in terms of knowledge development as a result this forms a barrier for sustainable generation, dissemination, utilization and scaling of the innovation.

However, in the development of BH546, there are sufficient number of niche and regime level actors like Regional Research Centers, Regional Seed enterprises (Amhara Region Seed Enterprise), Bahirdar University and local seed companies and cooperatives. As compared to Limu, BH546 was not farmers' first choice in terms of quality and productivity. Farmers used this variety as a secondary option. The variety is released by Bako national Maize research center/ Public research center/.

Collaboration - Strategic collaboration within and beyond the sector to scale the innovation

The only actors identified to scale the innovation are Ministry of Agriculture, DuPont pioneer and USAID. A project called AMSAP/Advanced Maize Seed Adoption Program/ was established by ACDIVOCA/Feed the Future program. This project was responsible to the scaling of the innovations. All relevant actors were not engaged. Regional Research institutes, regional seed enterprises and Universities were not included. The scaling plan would need to be worked out with different stakeholders.

The roles and responsibility of key actors were not properly identified and cleared. The performances of actors were not complementary. For example regional seed enterprises, regional bureau of agriculture and regional research institutes are not willing to scale the innovation rather they are doing for they are limiting the scaling of the innovation. There are no linkage and or networks among actors for joint strategic direction setting and advocacy. Ineffective links with parallel initiatives or policy processes that could serve to scale the innovation. Parallel linkages are essential to scale the innovation.

In terms of diffusion or disseminating Limu, the system was very effective. The company used the government extension system to promote the variety and they create demand for the innovation. After two years of release Limu varitey, in 2015 ACDI/VOCA implements USAID's three –year Feed the Future Ethiopia Advanced Maize Sees Adoption Program (AMSAP), a Public-private partnership among USAID, DUPont (Corteva Adriscience) and the Government of Ethiopia to promote the variety. The program's goal is to leverage the private sector investment of DuPont Pioneer to enhance the income of 100,000 smallholder maize farmers in the four regions of Oromia,Amhara Tigray and Southern Nations ,Nationalities, and Peoples. And also to scale up a network for sustainable seed distribution in support of the government of Ethiopia's Agricultural Growth Program (AGPP). AMSAP provides increase access to training, improved inputs such as hybrid seed (Limu) and provides other technical support.

There were no any organized efforts to disseminate BH546. Even farmers were not aware the competitiveness of the variety. As Key informants from research center and regional seed enterprise replied, BH546 is a competitive variety towards Limu. They argued Limu exceeds BH546 in terms of promotion. The public research centers and Extension organizations failed to promote the variety. As a result most Maize grower farmers in the region preferred and used Limu. The system was very poor to diffuse and disseminate BH546.

AMSAP plays a critical role in the effective coordination of the scaling process. Good leadership with integrating with the national, regional zonal, and kebele levels for scaling. AMSAP uses national and level structures for lobbying and advocacy. The program used Development Agents as an instrument for change. The company used the existing extension system of the government..

Evidence and learning - Evidence and facts underpin and help gain support for the scaling ambition

There is no useful and credible data available on the impact and other parameters, which could help in understanding the scaling process. I have observed many farmers use the innovation but the impacts of scaling needs to be assessed. Ineffective use of modern data and IT tools to support, analyze, share, and promote the innovation and to drive the change process. The data and monitoring (including bottom-up/field data) were not effectively used to steer the scaling process. Data and monitoring was not adequate. There was no enabling institutional learning. The scaling process may not be sustainable.

Leadership and Management - Effective coordination and navigation of the scaling process

The day-to-day leadership of the scaling process was not adequately established, recognized, and connected to the relevant actors. The role and responsibilities of different actors have not been considered and formalized. The scaling strategies were not formulated by identifying potential leaders. All the potential actors and stakeholders were engaged in decision-making to facilitate the scaling processes. There are no adequate, influential and compelling spokespersons, messengers, conveners and power brokers for the innovation; however the innovation by itself is highly demanded by the farmers. The leadership doesn't support internal and external change management processes to achieve organizational/institutional changes required.

Public Sector Governance – Government support to reach the scaling ambition

The role of the regional government in reaching scaling ambition was very limited. This is because the regional government believes this innovation may create impact on the local hybrid varieties developed by the regional and national research centers. Currently the extension service was discouraging the scaling of the innovation. This needs discussion with regional and federal government. Local and national strategies, policies and regulations should be conducive to scaling the technology/ practice. Innovation policy required for the sustainable supply of the innovation. Because of the aforementioned reasons, government agencies are not actively supporting scaling the innovation. There was no any financing mechanisms (such as subsidies or tariffs) applied to benefit scaling the innovation. Farmers and suppliers themselves cover the cost for the innovation.

With respect to P3812W ("*Limu")*variety, There is no a clear vision on how the knowledge should develop specially in terms of seed multiplication. There are no clear policy goals regarding this innovation. The visions and expectations of actors involved insufficiently aligned to reduce uncertainties. Lack of shared vision block the development of the maize innovation system. The alignment of expectations of relevant actors is poor. Within BH546 the guidance for search was done by the regional Seed Enterprise, Bureau of Agriculture and Regional research Institutes.

Currently, the government especially the regional government hinders the scalability of the innovation. The government sees this innovation as a competitor to the country's agricultural research centers. The regional Seed enterprise, research institutes, and the Bureau of Agriculture perceive this innovation may kick other local hybrid varieties from the market and then the country may fail under dependency on seed from America. No Conducive rules and Regulations for scaling the innovation and high frustration towards the government side. This calls for policy options

5.3. Scoring results of Scaling ingredients based on the qualitative analysis

Table 9 Scoring results of scaling ingredients for varieties released by public agricultural research centers

Scaling ingredients	Overall score	Question 1	Question 2	Question 3	Question 4
1. Technology/ practice	**5.0**	5.0	5.0	5.0	5.0
2. Awareness and demand	**3.0**	4.0	3.0	4.0	1.0
3. Business cases	**2.5**	1.0	5.0	1.0	3.0
4. Value chain	**1.0**	1.0	1.0	1.0	1.0
5. Finance	**3.3**	4.0	3.0	3.0	3.0
6. Knowledge and skills	**4.5**	3.0	5.0	5.0	5.0
7. Collaboration	**1.8**	4.0	1.0	1.0	1.0
8. Evidence and learning	**3.3**	5.0	2.0	2.0	4.0
9. Leadership and management	**1.5**	3.0	1.0	1.0	1.0
10. Public sector governance	**4.0**	5.0	5.0	5.0	1.0

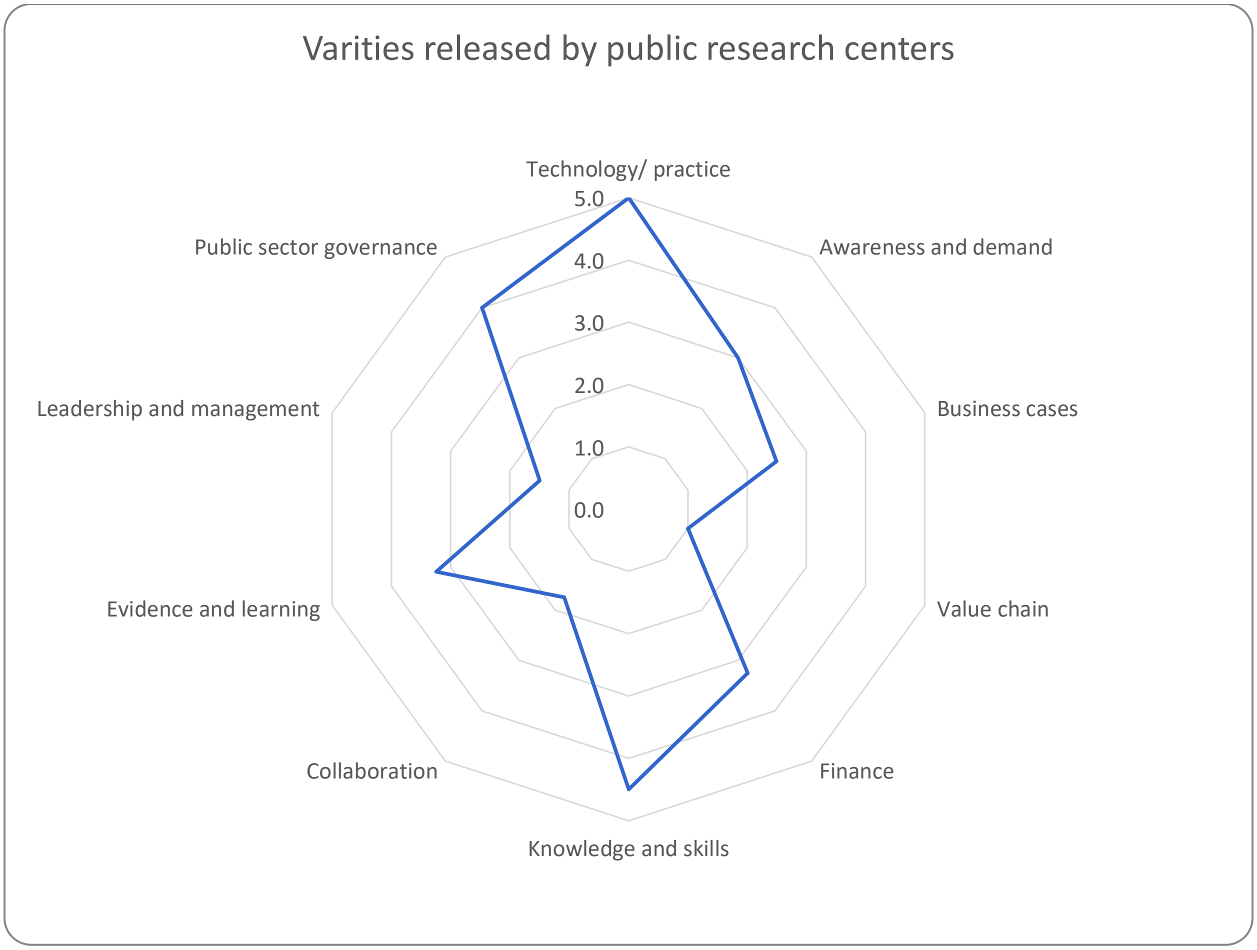

Figure 7. Scoring results of scaling ingredients for public research centers

Table 10 Scoring results of scaling ingredients for varieties released by Pioneer Hi- Bred Seeds Ethiopia Plc.

Scaling ingredients	Overall score	Question 1	Question 2	Question 3	Question 4
1. Technology/ practice	**4.8**	5.0	5.0	4.0	5.0
2. Awareness and demand	**4.3**	5.0	3.0	5.0	4.0
3. Business cases	**4.0**	4.0	4.0	4.0	4.0
4. Value chain	**2.0**	2.0	2.0	2.0	2.0
5. Finance	**3.0**	4.0	2.0	3.0	3.0
6. Knowledge and skills	**2.8**	3.0	3.0	3.0	2.0
7. Collaboration	**3.5**	5.0	4.0	3.0	2.0
8. Evidence and learning	**3.3**	4.0	3.0	3.0	3.0
9. Leadership and management	**4.3**	5.0	5.0	4.0	3.0
10. Public sector governance	**2.0**	2.0	2.0	2.0	2.0

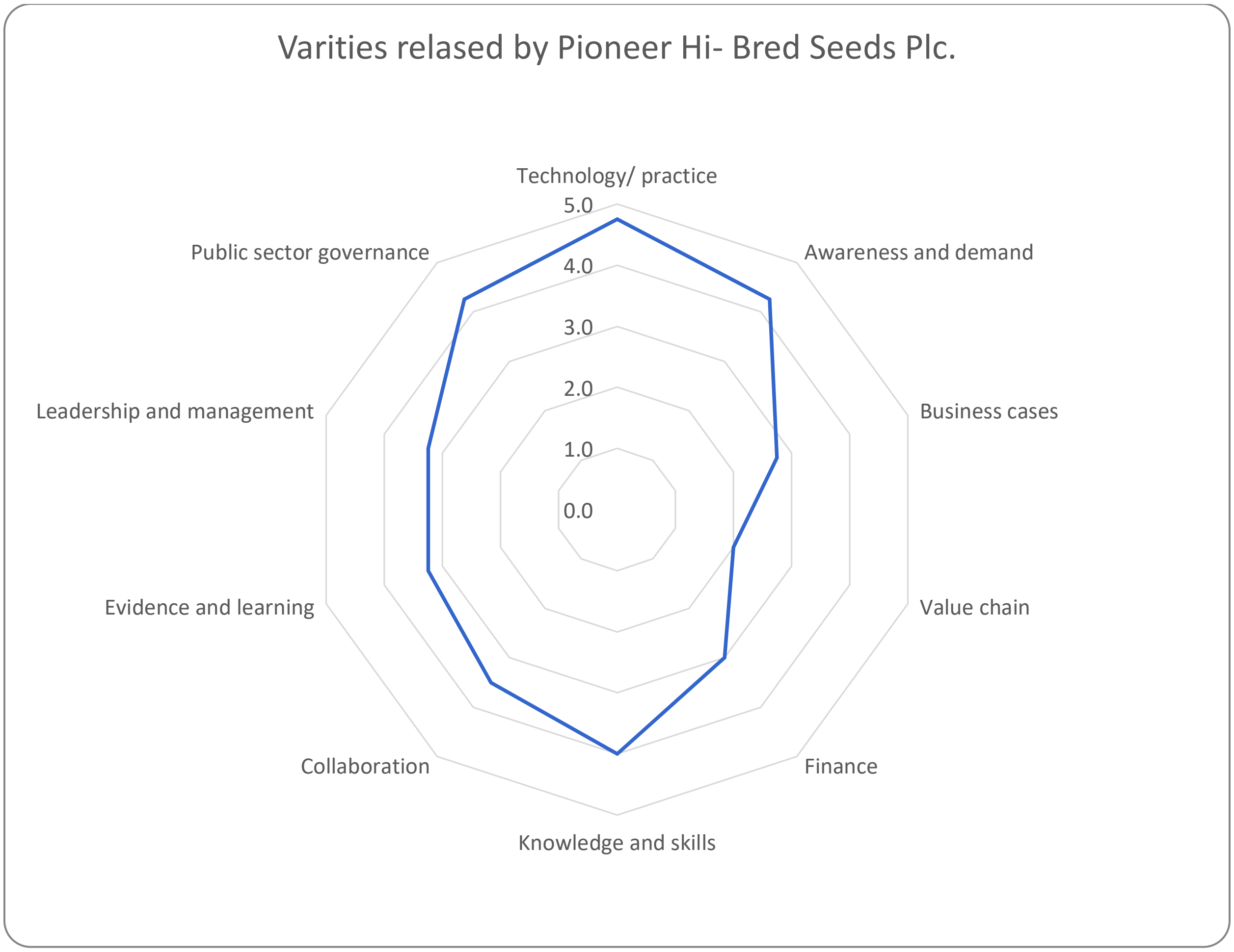

Figure 8. Scoring results of scaling ingredients for varieties released by Pioneer Hi-Bred Seeds Plc.

6. Conclusions and Recommendations

The paper analyzed the scaling processes of improved maize varieties released by both public agricultural research centers and private company, Pioneer Hi-Bred Seed Ethiopia Plc. Based on the study, it is concluded that improved maize varieties are the prior innovations to scale in West Gojam. Based on the results of the scaling ingredient assessment, availability of technology, adequate knowledge and skills, and public sector governance support are some of the opportunities to scale for the varieties released by public research centers. High incentive business cases, strong collaboration and partnership, better awareness and demand for innovations are the potential opportunities in the varieties released by pioneer Hi-Bred Seed Ethiopia Plc. As a potential constraint for improved varieties released by public research centers scaling includes less organized value chains, poor leadership and management, financial constraints, weak collaboration, less structured value chains, a lack of evidence and learning, and fewer incentive business cases. For varieties released by Pioneer Hi-Bred Seeds Ethiopia Plc., limited availability of the technology, a lack public sector governance support, and no organized value chain, weak collaboration among stakeholders are the potential constraint to scaling processes. Information gap among actors and finical constraints are also the major cause of fewer business cases in maize production.

To overcome the above constraints, efforts should be made through the following strategies: In scaling varieties released by public research centers, the regional Bureau of Agriculture and Seed Enterprises needs to establish a functional value chain to deliver quality seed at the right time and place. It can also create and strengthen the linkage using the platform. It can collaborate with the Adet Agricultural Research Center, Merkebe Unions, and Bahir Dar University to supply improved seeds, as well as with non-governmental organizations, agricultural cooperatives, and agro-dealers to supply maize-improved seeds. In addition, the mechanism should also be designed to monitor and regulate seed pricing in collaboration with Zonal cooperatives, agriculture, and trade offices. Efforts should be made to overcome the financial problems of farmers and value chain actors. The Zone Agricultural Office, in collaboration with the Bureau of Agriculture, should lobby microfinance and other financial institutions to reconsider their lending mechanisms. They should simplify their lending procedure and lower their interest rate for smallholder farmers. Risk sharing mechanisms (i.e., agricultural insurance) should also be designed between farmers and credit provider institutions for agricultural commodities since agriculture is a very risky sector in the country. In addition, the Zone Agriculture Office should give attention, allocate an adequate budget to the sector, and scale the variety for the wider community. To overcome the existing weak leadership and collaboration on scaling varieties released by public research centers, the Zonal and Woreda offices of agriculture need to make scaling of improved maize seeds a prior agenda item for regional higher officials. To do so, the zone agricultural office should write and document the experiences and then reach out to politicians through various mechanisms. A series of workshops should be organized to raise their awareness and level of knowledge about modern, improved maize varieties. It could be organized in collaboration with Bahir Dar University, the Adet agricultural research center, and seed enterprises to share the cost of the workshop. Efforts should be made to create a strong and functional value chain for scaling improved maize varieties released by public research centers. To do so, the Zone Agriculture Office should take the lead, map the existing relevant actors, and organize workshops for the actors. In the workshop, they could discuss their problems, find solutions for their problems, and share roles and responsibilities among themselves to scale improved maize variety innovation. The value chain could be strengthened by establishing a functional stakeholder platform. Actors could have a good opportunity to do joint planning, monitoring, and evaluation of their activities and progress.

In scaling varieties released by Pioneer Hi-Bred Seeds Ethiopia Plc., there is limited availability of the technology, a lack public sector governance support, and no organized value chain in West Gojam Zone. Therefore, Pioneer Hi-Bred Seeds Ethiopia Plc. should make an effort to establish effective value chain to scale the varieties in the area. The company needs to analyze and identify relevant actors in improved maize seeds through research and promotion activities and organize workshops to them. It should facilitate the establishment of platforms among the actors and regular meeting, monitoring and evaluation. Weak collaboration among stakeholders should be solved to scale improved varieties released by the company in West Gojam Zone. To address this, company should design a strategy, bring all stakeholders together, and share the necessary knowledge and skills.

The information gap among actors is the major cause of fewer business cases in maize production. Hence, developing a trustworthy information-delivery mechanism is crucial to establishing genuine relationships among actors. Pioneer Hi-Bred Seeds Ethiopia Plc. and other collaborators need to work together to create a viable information communication system and deliver relevant information to the farmers and concerned actors. They need to identify important information on production, marketing, and disease incidences through assessment. This could be done by the university and research center. In addition, the information should be delivered through modern and trustworthy mechanisms. Financial constraints are a serious problem for the farmers to purchase seed and chemicals; unions must purchase maize seed from the farmers. Hence, accessing affordable credit is essential for smallholder farmers to address their financial constraints and use the required inputs. This can be done in collaboration with the Regional Bureau of Agriculture and microfinance institutions in the region.

CHAPTER FIVE

SYNTHESIS OF MAIN FINDINGS, CONCLUSIONS AND IMPLICATIONS

5.1 Synthesis of the main findings

Introduction and Context

The dissertation titled "Analysis of Maize Innovation System: Linking System, Social Network, and Scaling Perspectives in Ethiopia" investigates the intricate dynamics of the maize innovation system within Ethiopia. It seeks to understand the factors influencing the effectiveness of improved maize varieties, exploring systemic, socio-technical, and interaction-related barriers that affect the production and dissemination of these varieties. By integrating system-level analysis, social network perspectives, and scaling issues, the study provides a holistic view of the challenges and opportunities within the maize innovation system.

Research Objectives and Methodological Approach

The study focuses on three primary objectives:

1. Identifying Systemic and Socio-Technical Constraints:

   To pinpoint barriers within the maize innovation system that hinder the development, dissemination, and utilization of improved maize varieties.

2. Analyzing Actor Interactions:

   To assess how interactions among various stakeholders influence the performance and effectiveness of the maize innovation system.

3. Exploring Scaling Opportunities and Constraints:

   To examine factors affecting the scaling of improved maize varieties and identify constraints that limit their widespread adoption.

Employing a pragmatist paradigm, the research integrates both quantitative and qualitative methods. Key informant interviews, focus group discussions, and social network analysis were used for data collection. Qualitative data were analyzed using transcription, categorization, and interpretation techniques, while quantitative data provided supplementary insights. This approach ensures a comprehensive understanding of the maize innovation system.

Key Findings

1. **Systemic Failures and Structural Weaknesses**:
    - **Systemic Failures**: The maize innovation system is impeded by failures in critical areas such as knowledge development, dissemination, and market formation. These issues are rooted in structural weaknesses, including inadequate infrastructure, insufficient financial resources, and outdated research facilities.
    - **Impact on Smallholders**: These structural deficiencies create bottlenecks that limit the system's ability to effectively support smallholder farmers, thereby constraining agricultural productivity and technology adoption.
2. **Socio-Technical Constraints**:
    - **Barriers**: Socio-technical constraints, such as weak enforcement of property rights, restrictive procurement rules, and limited law enforcement, exacerbate the challenges within the innovation system. These factors contribute to higher transaction costs and reduce the economic benefits of adopting improved technologies.
    - **Recommendations**: Addressing these constraints is essential for fostering a more supportive environment for innovation and technology diffusion. Effective solutions should consider local contextual factors to enhance relevance and impact.
3. **Interactions Among Actors**:
    - **Challenges**: The study identifies gaps in interactions among stakeholders, including public institutions, private companies, farmers, and NGOs. Effective collaboration and partnerships are necessary for improving knowledge sharing, resource mobilization, and innovation diffusion.
    - **Enhancement Strategies**: Strengthening interactions and building synergies among actors can significantly improve the performance of the maize innovation system and facilitate better technology dissemination.

4. **Scaling Opportunities and Constraints**:
   - **Opportunities**: Factors such as the availability of robust technologies, adequate knowledge and skills, and supportive public sector governance present opportunities for scaling improved maize varieties.
   - **Constraints**: Scaling is hindered by fragmented value chains, financial limitations, weak institutional support, and poor leadership. Addressing these constraints is crucial for realizing the potential of maize innovations and ensuring their widespread adoption.

5.2 Conclusion

The research investigated the constraints within the maize innovation system and analyzed the interactions among various actors' influencing it. It also examined the scaling of maize innovations to identify opportunities and constraints for scaling, particularly improved maize varieties. The study employed integrated innovation systems and sustainability transition perspectives, social network analysis, and a scaling scan framework to achieve these objectives.

The findings revealed that structural analysis failures, along with weaknesses in the innovation system's functions and socio-technical factors, have impeded the development and utilization of improved maize varieties. The first paper identified the systemic and socio-technical constraints of the maize innovation system in the studied area. Despite the critical role of innovation in transforming the agricultural sector, the maize innovation system and sector development face several challenges. These constraints, including deficiencies in innovation functions and socio-technical factors, have adversely impacted the overall functioning of the innovation system, thereby affecting agricultural productivity and household food security.

To address the core objective, the study examined the systemic and socio-technical transition constraints of the maize innovation system, analyzing actor interactions and their influence on the system. This was followed by assessing the scaling of maize innovations to pinpoint opportunities and constraints for scaling, especially improved maize varieties. Guided by integrated innovation systems and sustainability transition perspectives, social network analysis, and a scaling scan framework, the study reached several conclusions.

The research concluded that structural analysis failures, coupled with weaknesses in innovation system functions and socio-technical factors, have hampered the development of the maize innovation system and the generation, dissemination, and utilization of improved maize varieties. The first paper identified the systemic and socio-technical constraints of the maize innovation system in the studied woreda. Despite the importance of innovation in transforming the agricultural sector, the maize innovation system and sector development are hindered by multiple factors. These include failures in structural elements, weaknesses in innovation functions, and socio-technical factors, all of which contribute to the underdevelopment of the maize innovation system and the sector overall. Weak structural elements negatively impact the well-functioning of the innovation system. A failure in one function can trigger a cascade of dysfunctions, leading to an overall ineffective innovation system.

In summary, the maize innovation system's failure to effectively develop and disseminate improved maize varieties is due to systemic and socio-technical constraints. Weaknesses in structural and functional elements, such as inadequate infrastructure and poor knowledge dissemination, have hindered progress. Public and private institutions face challenges in generating and distributing varieties that meet smallholder farmers' needs. To address these issues, it is essential to strengthen public-private partnerships and improve interactions among actors within the maize innovation system

To overcome these constraints, the study suggests several strategies. Strengthening public-private partnerships can enhance collaboration and resource sharing, leading to better innovation outcomes. Improving interactions among actors within the maize innovation system can foster knowledge exchange and coordination, facilitating the development and dissemination of improved maize varieties. Additionally, addressing structural weaknesses, such as infrastructure and knowledge dissemination, can create a more conducive environment for innovation. By implementing these strategies, the maize innovation system can become more effective in developing and scaling improved maize varieties, ultimately enhancing agricultural productivity and household food security

5.3 Implications for Policy and Practice

1. **Policy Reforms and Institutional Strengthening**:
   - **Policy Changes**: There is a need for policy reforms that promote innovation, streamline bureaucratic processes, and provide financial incentives. Such reforms can help address systemic failures and structural weaknesses within the innovation system.
   - **Institutional Support**: Strengthening public institutions through better resource allocation, training programs, and improved governance structures is crucial for enhancing the overall effectiveness of the maize innovation system.
2. **Enhancing Actor Interactions and Partnerships**:
   - **Collaborative Efforts**: Building stronger partnerships among stakeholders is essential for improving knowledge sharing, resource mobilization, and technology dissemination. Public-private partnerships can play a significant role in scaling up innovations and ensuring their broader adoption.
   - **Network Building**: Establishing and enhancing networks among actors can facilitate better coordination and collaboration, leading to more effective innovation and technology diffusion.
3. **Addressing Socio-Technical Constraints**:
   - **Policy and Practice**: Interventions should focus on overcoming socio-technical constraints to create a more favorable environment for innovation. Policies should be designed to address local contextual factors and enhance their relevance and effectiveness.

5.5 Implications for future research

1. **Expanding Scope**:
   - **Broader Studies**: Future research should explore other regions and commodities to generalize findings and understand systemic barriers in different contexts. Comparative studies across regions can provide insights into common challenges and effective solutions.

- **Diverse Contexts**: Investigating other agricultural systems and commodities will help in identifying universal and context-specific barriers and opportunities.

2. **Policy-Oriented Research**:
   - **Focus on Coordination Problems**: Research should identify conditions under which systemic and coordination problems are most severe and develop effective policy interventions to address these issues. Engaging with policymakers will ensure that research findings inform actionable solutions.
   - **Evidence-Based Policy**: Developing evidence-based policies will help in crafting interventions that are both effective and sustainable.
3. **Longitudinal Impact Assessments**:
   - **Evaluation of Interventions**: Conducting long-term studies to evaluate the sustainability and effectiveness of interventions will provide valuable insights for guiding future policy and program development. These assessments can help in understanding the long-term impact of implemented strategies.
4. **Technological and Socio-Economic Impact Studies**:
   - **Impact Analysis**: Future research should assess the technological and socio-economic impacts of improved maize varieties. This includes evaluating their effects on productivity, income, and food security.

Overall Contribution

The dissertation provides a comprehensive and integrated analysis of the maize innovation system in Ethiopia. It highlights systemic barriers, socio-technical factors, and actor interactions that impact the effectiveness of improved maize varieties. By offering insights into these challenges and opportunities, the study contributes significantly to the understanding and enhancement of the maize innovation system. The recommendations for policy and practice, along with suggestions for future research, offer a robust foundation for addressing the challenges within the maize sector and improving food security and agricultural productivity in Ethiopia. The study's comprehensive approach ensures that the findings are relevant and actionable, paving the way for more effective interventions and strategies to support smallholder farmers and enhance the overall performance of the maize innovation system.

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APPENDICES

Appendix: Report on Plagiarism Assessment

Addis Ababa University
College of Development Studies
Office of the Associate Dean for Research and Technology Transfer
Template for Reporting Plagiarism Assessment

Name of the Center: Center for Rural Development Program of study: Regular Program level (Masters/PhD): PhD please, check one: Regular/Continuing

Name of the Adviser/s: Dr. Getnet Alemu and Dr. Million Getnet

Topic of the dissertation/thesis: **Analysis of Maize Innovation System in Ethiopia: Linking Systems, Social Network and Scaling Perspectives.**

S/N	Name and ID.NO. of the student/candidate	Percentage of plagiarism confirmed	Comments given and improvements made by the student/candidate
1	Daniel Nigussie Ashiber (ID:GSR3224/GSR/09	**5%**	Matched texts are changed as attached shown in Plagiarism correction format

Remark by adviser/s
____
____
____

Name of the center head/coordinator ___________ Signature ___________ Date___________

1. Name of the adviser/sGetnet Alemu (PhD) Signature ___________ Date _________
2. Name of the adviser Million Getnet (PhD) Signature ___________Date __________

Note that:

1. All Centers and their faculty members should carefully read, understand and brief students/candidates working under their supervision about the plagiarism policy and the checker software.
2. By adopting the use of the software, it is assumed faculty members have read and shared the key provisions in the guidelines with students/candidates working with them.
3. Thesis/dissertation advisors shall first run and report the level of plagiarism on the submission of the thesis/dissertations of their respective students/candidate
4. The anti-plagiarism policy of the university allows for a maximum of 20% report (green color) and, with further qualitative analysis and interpretation over this 20% report itself by the advisor/s. Please refer to the anti-plagiarism guideline for assessment results more than 20%.

5. Center heads/ coordinators shall further verify the plagiarism assessment results reported by the adviser/s
6. A thesis/dissertation not assessed through the university software and not signed by the adviser/s will not be endorsed by the head /coordinator to proceed for defense.
7. The final plagiarism assessment report will be attached with the thesis/dissertation for the consumption of examiners.

No	Matched Text	Changed Text	Page
1	Significant change in the provision of advisory service has not been achieved	Substantial change in agricultural extension service delivery	20
2	Seed laboratories for seed quality inspection and testing	To ensure the success of the innovation system, it is essential to invest in the development and improvement of seed laboratories,	21
3	Improved maize varieties	Not changed because the words are standardized words	21
4	Sectorial innovation system , technological innovation system	Not changed because the words are standardized words	21
5	Maize seed production and distribution	Maize seed multiplication and distribution	23
6	As well as their capabilities is critical for the innovation system	Skill and competences are important for the innovation system	23
7	Through interacting process within and between three analytical niche socio-technical regime and	Interrelating processes among the three levels of aggregation(niche, regime and landscape)	26
8	Factors such as price economic growth, political coalition cultural norms	Not changed because the words are standardized words	26
9	The number of industrial actors in the production of	The number of enterprises	35
10	Organizational capacity of actors to adapt to manage	Not changed because the words are standardized words	37
11	Innovation is an endogenous processes that cannot rely on spin off foreign research but needs local capacities to generate ,synthesize and adapt knowledge (both indigenous and imported	Localization of innovation in generation and utilization	37
12	Private sector actors have minimal involvement in agricultural research; total private sector spending accounts for less than half of one percent of the total agricultural expenditure	The participation of private sector in agricultural research is very low	38

13	Private sectors had limited knowledge and skill in business planning skill marketing seed brand development managerial technical and operational capacity and also limited equipment and financial resource	Limited infrastructure(knowledge, financial and physical)	39
14	Below the level required to achieve Ethiopia's ambition under the agricultural transformation agenda in particular	Below the standard to achieve agricultural transformation	
15	The framework gives valuable insight in to the processes that are important for the successful development and implementation of	The framework provides a clear understanding on the application	50
16	Within and between three levels niche(Micro level focus on radical innovations ,regime (meso level (established practice and associated rules	Among the three levels niche, regime and landscape	53
17	Emerge from the complex interaction among diverse sets of public ,private and civil society actors engaged in generating , exchanging and using knowledge	emphasizes interaction among different actors involved in production , dissemination and utilization	54
18	Allow the generation of in depth insight in to the composition the networks and its effect on the innovation performance	Helps for the understanding of the effects of interaction and networks on the functioning of the innovation system	55
19	The complex and multi dimensionality of innovation processes	The holistic nature of the innovation processes	55
20	By combining strategic niche management and social network analysis	Integrating niche and social network analysis	56
21	Not guarantee the prompt of niche development because it also dependence on the distribution of power within the network of actors	Not only Niche development but also power within the network of actors is equally important	56
22	The structural and functional dimension of the innovation system	Not changed because the words are standardized words	56
23	of innovation system depends on the interaction among the different actors	Interaction among different actors affects the performance of innovation system	56
24	Network of actors involved in generation	Network of stakeholder involved in production	63
25	The dissemination of improved maize varieties	The diffusion of improved maize varieties	66
26	The interest of private companies in the production and supply of	The interest of private enterprises in the multiplication and distribution	66
27	In the production and supply of high quality seeds to	In the multiplication and distribution of	66

28	Gives us perfect view the most influential actor nodes in a graph but rather good representation	Indicates Powerful actor in the network	70
29	Eigenvector centrality: In graph theory Eigen vector centrality also called is a measure of the influence of a node in a network.	Not changed because the words are standardized words	70
30	It assign scores to all nodes in the network based on the concept	Not changed because the words are standardized words	70
31	The need to further explore policies that create more space for	Polices that enhances partnership and collaboration	72
32	Despite rapid growth in the use of improved maize varieties	Regardless of improvement in the utilization of improved maize varieties	74
33	Current adoption rate remains quit low	The utilization rate is low	74
34	Formation of partnership are collaboration strategies are among the key factors determining the scaling up of innovations	One of the key determine factor for scaling of innovation is formation of linkage among different actors	74
35	Innovation platforms that allowed the participation of interested and relevant stakeholders with their specific roles along the value chain development	Multi-stakeholder platforms with assigned roles and responsibilities	74
36	There is a need to study beyond single innovation towards (complementary and competing) interaction between	The focus of the study should be more than one innovation	75
37	Collaboration strategic collaboration within and beyond the sector to scale	Partnership with multi-stakeholders	89
38	Underpin and help gain support for the scaling ambition	Strengthen the scaling ambition	91
39	Effective coordination and navigation of the scaling process	Actual collaboration and partnership in the scaling processes	91
40	That have influenced the development of maize innovation system	That have affected the advancement of maize innovation system	96

Appendix: Checklist for Key Informants (KIIs)

General Instruction

1. Please answer all the questions
2. Your answer will be kept confidential
3. If necessary, please feel free to use Amharic language

Thank you for your cooperation and take your time to fill this questionnaire!

Part I: **General Information**

1. Name of your organization: ____
2. Current position_ ____
1. Sex (a) Male (b) Female

3. In which category does fall your age?
   a) Less than 25 years b) 26 - 30 years
   c) 31 - 35 years d) 36 – 40
   e) Greater than 40 years
4. What is your highest level of education?
   a. Certificate b. Diploma
   c. Advanced Diploma
   d. First Degree/DVM
   e. Master's Degree
   f. Philosophy of Doctorate (PhD)

5. How long have you been working totally in this organization______ year?

Part II Structural Dimensions and System functions

F1 - Entrepreneurial Experimentation and production

1. Are these the most relevant actors?
2. Are there sufficient industrial actors in the innovation system?
3. Do the industrial actors innovate sufficiently?
4. Do the industrial actors focus sufficiently on large scale production?
5. Does the experimentation and production by entrepreneurs form a barrier for the Innovation System?
6. Structural components within the function :- Actors , institutions, interactions and infrastructure
7. Who are the actors? (Presence, Capabilities), what are their roles?

8. What institution exists? (Presence, Capacity/quality) What are the Bye-Laws and norms of the system are there other rules? (How important are they in practice of innovation? Is there community ownership of Bye-Laws? What was the impact of NGOs, Gov in formulation of them? What are typical issues where norms are broken? What are possible sanctions? Which ones have been taken already? What happens if someone violates rules? Which outside actors are involved in sanctioning?)
9. How was the interaction? (Presence, Intensity/quality), How do actors interact in the activities? What are mechanisms for interactions?
10. What infrastructure exists? (Presence, capacity /quality)

    Physical: ___________________

    Knowledge:____________________

    and Financial: _____________________

F2 - Knowledge Development

11. Describe the state of the knowledge system?
12. Which parties develop knowledge?
13. Where is the knowledge producers located?
14. How much knowledge is developed?
15. What are the types of organizations involved in knowledge production?
16. Is the amount of knowledge development sufficient for the development of the innovation system?
17. Is the quality of knowledge development sufficient for the development of the innovation system?
18. Does the type of knowledge developed fit with the knowledge needs within the innovation system
19. Does the quality and/or quantity of knowledge development form a barrier for the TIS to move to the next
20. Structural components within the function :- Actors, institutions, interaction and infrastructure
21. Who are the actors? (Presence, Capabilities), what are their roles?
22. What institution exists? (Presence, Capacity/quality) What are the Bye-Laws and norms of the system are there other rules? (How important are they in practice of innovation? Is there community ownership of Bye-Laws? What was the impact of NGOs, Gov in formulation of them? What are typical issues where norms are broken? What are possible

sanctions? Which ones have been taken already? What happens if someone violates rules? Which outside actors are involved in sanctioning?)

23. How was the interaction? (Presence, Intensity/quality), How do actors interact in the activities? What are mechanisms for interactions?
24. What infrastructure exists? (Presence, capacity /quality)

    Physical: ___________________

    Knowledge:_____________________

    and Financial: ______________________

F3 - Knowledge dissemination

25. Is there enough knowledge exchange between actors?
26. Is there sufficient knowledge exchange across geographical borders?
27. Are there problematic parts of the innovation system in terms of knowledge exchange?
28. Is knowledge exchange forming a barrier for the innovation?
29. Structural components within the function:- Actors, institutions, interactions and infrastructure
30. Who are the actors? (Presence, Capabilities), what are their roles?
31. What institution exists? (Presence, Capacity/quality) What are the Bye-Laws and norms of the system are there other rules? (How important are they in practice of innovation? Is there community ownership of Bye-Laws? What was the impact of NGOs, Gov in formulation of them? What are typical issues where norms are broken? What are possible sanctions? Which ones have been taken already? What happens if someone violates rules? Which outside actors are involved in sanctioning?)
32. How was the interaction? (Presence, Intensity/quality), How do actors interact in the activities? What are mechanisms for interactions?
33. What infrastructure exists? (Presence, capacity /quality)

    Physical: ___________________

    Knowledge:_____________________

    and Financial: ______________________

F4 - Guidance of the Search

34. Is there a clear vision on how the industry and market should develop?
35. In terms of growth - In terms of technological design
36. What are the expectations regarding the technological field?
37. Are there clear policy goals regarding this technological field?

38. Are these goals regarded as reliable?
39. Are the visions and expectations of actors involved sufficiently aligned to reduce uncertainties?
40. Does this (lack of) shared vision block the development of the maize innovation system?
41. Structural components within the function:- Actors, institutions, interactions and infrastructure
42. Who are the actors? (Presence, Capabilities), what are their roles?
43. What institution exists? (Presence, Capacity/quality) What are the Bye-Laws and norms of the system are there other rules? (How important are they in practice of innovation? Is there community ownership of Bye-Laws? What was the impact of NGOs, Gov in formulation of them? What are typical issues where norms are broken? What are possible sanctions? Which ones have been taken already? What happens if someone violates rules? Which outside actors are involved in sanctioning?)
44. How was the interaction? (Presence, Intensity/quality), How do actors interact in the activities? What are mechanisms for interactions?
45. What infrastructure exists? (Presence, capacity /quality)

    Physical: ___________________

    Knowledge:____________________

    and Financial: ______________________

F5 - Market Formation

46. Is the current and expected future market size sufficient?
47. Does market size form a barrier for the development of the innovation system?
48. Structural components within the function:- Actors, institutions, interactions and infrastructure
49. Who are the actors? (Presence, Capabilities), what are their roles?
50. What institution exists? (Presence, Capacity/quality) What are the Bye-Laws and norms of the system are there other rules? (How important are they in practice of innovation? Is there community ownership of Bye-Laws? What was the impact of NGOs, Gov in formulation of them? What are typical issues where norms are broken? What are possible sanctions? Which ones have been taken already? What happens if someone violates rules? Which outside actors are involved in sanctioning?)
51. How was the interaction? (Presence, Intensity/quality), How do actors interact in the activities? What are mechanisms for interactions?

52. What infrastructure exists? (Presence, capacity /quality)

    Physical: ___________________

    Knowledge:____________________

    and Financial: _____________________

F6 - Resource Mobilization

53. Are there sufficient human resources? If not, does that form a barrier?
54. Are there sufficient financial resources? If not, does that form a barrier?
55. Are there expected physical resource constraints that may hamper technology diffusion?
56. Is the physical infrastructure developed well enough to support the diffusion of technology?
57. Structural components within the function: Actors, institutions, interactions and infrastructure
58. Who are the actors? (Presence, Capabilities), what are their roles?
59. What institution exists? (Presence, Capacity/quality) What are the Bye-Laws and norms of the system are there other rules? (How important are they in practice of innovation? Is there community ownership of Bye-Laws? What was the impact of NGOs, Gov in formulation of them? What are typical issues where norms are broken? What are possible sanctions? Which ones have been taken already? What happens if someone violates rules? Which outside actors are involved in sanctioning?)
60. How was the interaction? (Presence, Intensity/quality), How do actors interact in the activities? What are mechanisms for interactions?
61. What infrastructure exists? (Presence, capacity /quality)

    Physical: _________________

    Knowledge:____________________

    and Financial: _____________________

F7 - Counteract resistance to change/legitimacy creation

62. What is the average length of the innovation?
63. Is there a lot of resistance towards the new technology, the set up of projects/permit procedure? If yes, does it form a barrier?
64. Structural components within the function:- Actors, institutions, interactions and infrastructure

65. Who are the actors? (Presence, Capabilities), what are their roles?
66. What institution exists? (Presence, Capacity/quality) What are the Bye-Laws and norms of the system are there other rules? (How important are they in practice of innovation? Is there community ownership of Bye-Laws? What was the impact of NGOs, Gov in formulation of them? What are typical issues where norms are broken? What are possible sanctions? Which ones have been taken already? What happens if someone violates rules? Which outside actors are involved in sanctioning?)
67. How was the interaction? (Presence, Intensity/quality), How do actors interact in the activities? What are mechanisms for interactions?
68. What infrastructure exists? (Presence, capacity /quality)

    Physical: ___________________

    Knowledge:______________________

    and Financial: _______________________

69. Please rate from very weak to very strong with each of the following system functions
70. Who exercise power at different level of aggregation (Niche, regime and landscape)
71. Who is empowered by and with whom?
72. Describe the process for scaling of maize innovation in relation to scaling scan ingredients?
73. Who is responsible at different levels? (Niches, regime and Landscape)

Appendix FGD check list for farmers:

The participants should be included from men and women household heads:

- Those who use maize innovation

Name of facilitator: ________________________________

Name of conductor: ________________________________

Venue: ____

Date: _______________ Time: ________________________

Participants list

S.No	Name	Sex	Age	Education
1				
2				
3				
4.				
.5				
6				
7				
8				
9				
10				
11				
12				
13				

1. Would you tell us what you generally know about the innovation that you use?(its activities, contribution)
2. When were you started using the innovation?
3. What were your main reasons for using the innovation?

F1Enterpruneral activities:

- Are these the most relevant actors?
- Are there sufficient industrial actors in the innovation system?
- Do the industrial actors innovate sufficiently?
- Do the industrial actors focus sufficiently on large scale production?
- Does the experimentation and production by entrepreneurs form a barrier for the Innovation System?

  - Who are the actors? (Presence, Capabilities), what are their roles?
  - What institution exists? (Presence, Capacity/quality) What are the Bye-Laws and norms of the system are there other rules? (How important are they in practice of innovation? Is there community ownership of Bye-Laws? What was the impact of NGOs, Gov in formulation of them? What are typical issues where norms are broken? What are possible sanctions? Which ones have been taken already? What happens if someone violates rules? Which outside actors are involved in sanctioning?)
  - How was the interaction? (Presence, Intensity/quality), How do actors interact in the activities? What are mechanisms for interactions?
  - What infrastructure exists? (Presence, capacity /quality)

    Physical: ___________________

    Knowledge:_____________________

    and Financial: ______________________

F2 Knowledge development

- Describe the state of the knowledge system?
- Which parties develop knowledge?
- Where is the knowledge producers located?
- How much knowledge is developed?
- What are the types of organizations involved in knowledge production?
- Is the amount of knowledge development sufficient for the development of the innovation system?
- Is the quality of knowledge development sufficient for the development of the innovation system?
- Does the type of knowledge developed fit with the knowledge needs within the innovation system

- Does the quality and/or quantity of knowledge development form a barrier for the TIS to move to the next
- Structural components within the function :- Actors, institutions, interaction and infrastructure
  - Who are the actors? (Presence, Capabilities), what are their roles?
  - What institution exists? (Presence, Capacity/quality) What are the Bye-Laws and norms of the system are there other rules? (How important are they in practice of innovation? Is there community ownership of Bye-Laws? What was the impact of NGOs, Gov in formulation of them? What are typical issues where norms are broken? What are possible sanctions? Which ones have been taken already? What happens if someone violates rules? Which outside actors are involved in sanctioning?)
  - How was the interaction? (Presence, Intensity/quality), How do actors interact in the activities? What are mechanisms for interactions?
  - What infrastructure exists? (Presence, capacity /quality)

    Physical: ___________________

    Knowledge:____________________

    and Financial: ______________________

F3 Knowledge dissemination

- Is there enough knowledge exchange between actors?
- Is there sufficient knowledge exchange across geographical borders?
- Are there problematic parts of the innovation system in terms of knowledge exchange?
- Is knowledge exchange forming a barrier for the innovation?
- Structural components within the function:- Actors, institutions, interactions and infrastructure
  - Who are the actors? (Presence, Capabilities), what are their roles?
  - What institution exists? (Presence, Capacity/quality) What are the Bye-Laws and norms of the system are there other rules? (How important are they in practice of innovation? Is there community ownership of Bye-Laws? What was the impact of NGOs, Gov in formulation of them? What are typical issues where norms are broken? What are possible sanctions? Which ones have been taken already? What happens if someone violates rules? Which outside actors are involved in sanctioning?)

- How was the interaction? (Presence, Intensity/quality), How do actors interact in the activities? What are mechanisms for interactions?
- What infrastructure exists? (Presence, capacity /quality)

  Physical: ___________________

  Knowledge:____________________

  and Financial: _____________________

F4 **Guidance of search**

- Is there a clear vision on how the industry and market should develop?
- In terms of growth - In terms of technological design
- What are the expectations regarding the technological field?
- Are there clear policy goals regarding this technological field?
- Are these goals regarded as reliable?
- Are the visions and expectations of actors involved sufficiently aligned to reduce uncertainties?
- Does this (lack of) shared vision block the development of the maize innovation system?
- Structural components within the function:- Actors, institutions, interactions and infrastructure
  - Who are the actors? (Presence, Capabilities), what are their roles?
  - What institution exists? (Presence, Capacity/quality) What are the Bye-Laws and norms of the system are there other rules? (How important are they in practice of innovation? Is there community ownership of Bye-Laws? What was the impact of NGOs, Gov in formulation of them? What are typical issues where norms are broken? What are possible sanctions? Which ones have been taken already? What happens if someone violates rules? Which outside actors are involved in sanctioning?)
  - How was the interaction? (Presence, Intensity/quality), How do actors interact in the activities? What are mechanisms for interactions?
  - What infrastructure exists? (Presence, capacity /quality)

    Physical: _________________

    Knowledge:____________________

    and Financial: _____________________

F5 Market formation

- What does the existing market look like
- Is the current and expected future market size sufficient?
- Does market size form a barrier for the development of the innovation system?
- Structural components within the function:- Actors, institutions, interactions and infrastructure
  - Who are the actors? (Presence, Capabilities), what are their roles?
  - What institution exists? (Presence, Capacity/quality) What are the Bye-Laws and norms of the system are there other rules? (How important are they in practice of innovation? Is there community ownership of Bye-Laws? What was the impact of NGOs, Gov in formulation of them? What are typical issues where norms are broken? What are possible sanctions? Which ones have been taken already? What happens if someone violates rules? Which outside actors are involved in sanctioning?)
  - How was the interaction? (Presence, Intensity/quality), How do actors interact in the activities? What are mechanisms for interactions?
  - What infrastructure exists? (Presence, capacity /quality)

    Physical: ___________________

    Knowledge:_____________________

    and Financial: ___________________

F6 Resource Mobilization

- Are there sufficient human resources? If not, does that form a barrier?
- Are there sufficient financial resources? If not, does that form a barrier?
- Are there expected physical resource constraints that may hamper technology diffusion?
- Is the physical infrastructure developed well enough to support the diffusion of technology?
- Structural components within the function: Actors, institutions, interactions and infrastructure
  - Who are the actors? (Presence, Capabilities), what are their roles?
  - What institution exists? (Presence, Capacity/quality) What are the Bye-Laws and norms of the system are there other rules? (How important are they in practice of innovation? Is there community ownership of Bye-Laws? What was the impact of NGOs, Gov in formulation of them? What are typical issues where norms are

broken? What are possible sanctions? Which ones have been taken already? What happens if someone violates rules? Which outside actors are involved in sanctioning?)

- How was the interaction? (Presence, Intensity/quality), How do actors interact in the activities? What are mechanisms for interactions?
- What infrastructure exists? (Presence, capacity /quality)

  Physical: ___________________

  Knowledge:______________________

  and Financial: ______________________

F7 Creating legitimacy

- What is the average length of the innovation?
- Is there a lot of resistance towards the new technology, the set up of system/permit procedure? If yes, does it form a barrier?
- Structural components within the function:- Actors, institutions, interactions and infrastructure
  - Who are the actors? (Presence, Capabilities), what are their roles?
  - What institution exists? (Presence, Capacity/quality) What are the Bye-Laws and norms of the system are there other rules? (How important are they in practice of innovation? Is there community ownership of Bye-Laws? What was the impact of NGOs, Gov in formulation of them? What are typical issues where norms are broken? What are possible sanctions? Which ones have been taken already? What happens if someone violates rules? Which outside actors are involved in sanctioning?)
  - How was the interaction? (Presence, Intensity/quality), How do actors interact in the activities? What are mechanisms for interactions?
  - What infrastructure exists? (Presence, capacity /quality)

    Physical: ___________________

    Knowledge:______________________

    and Financial: _______________________

4. Who exercise power at different level of aggregation (Niche, regime and landscape)
5. Who is empowered by and with whom?
6. Describe the process for scaling of maize innovation in relation to scaling scan ingredients?
7. Who is responsible at different levels? (Niches, regime and Landscape)
8. What are the characteristics of the innovation for scaling?
9. What are the influencing factors that will either enable or constrain the scaling process?
10. Suggestions or comments about weakness and strength, for the improvement of the maize innovation system? In relation to structure, function, power relation and scaling of the innovation